Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

# South Africa Geothermal Country Update (2005-2009)

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**Keywords:** geothermal resources, South Africa, geology, energy resources, policies, thermal springs.

## ABSTRACT

South Africa is located in a geologically stable zone. Despite this, the country is relatively well endowed with thermal springs. Eighty seven thermal springs, with temperatures ranging from $25^0$C to $67,5^0$C have been documented to date. These springs are all of meteoric origin and are associated with crustal faulting. 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.

Of the 87 thermal springs, 29 have been developed for direct use - mainly as family leisure and recreational resorts. Very few utilize the water for health or spa purposes. Since coal is abundant and relatively cheap, coal burning power stations are the major suppliers of South Africa's energy requirements. Until recently, very little attention was devoted to research on renewable energy resources. In view of the low temperatures of thermal springs, no effort was made to develop geothermal resources. A recently launched research project is aimed at investigating the feasibility of generating power using a thermal spring binary system as well as from hot granites. This paper gives an overview of energy production in South Africa, the state of local renewable energy projects, and the latest research endeavours on the geology, distribution, chemical and biological properties of geothermal resources.

## 1. INTRODUCTION

South Africa occupies the southernmost part of the African continent, stretching from $22^0$ to $35^0$ S and 17 to $33^0$ E. Its surface areas is 1 219 090 km$^2$. To the west, south and east it is bordered by the Atlantic and southern Indian Oceans, and to the north, by Namibia, Botswana, Zimbabwe and Mozambique (South African Yearbook 2000/01).

### 1.1 South Africa's Energy Resources

The South African economy can be considered as energy intensive and is based on primary extraction and the processing of coal and uranium. Coal is plentiful and can be extracted cheaply and consequently a large coal mining industry has developed.

<u>1.1.1 Coal</u>

Coal meets about 88% of South Africa's primary energy needs while the remainder is exported. At present about 109 Mt is used for electricity generation, 44 Mt for petrochemical industries (such as SASOL), 10.4 Mt for general industrial sector use, and 5.7 Mt for the metallurgical industry. Coal merchants buy 8.4 Mt to sell locally and abroad (South African Yearbook, 2008/09).

Eskom (the Electricity Supply Commission) has also commissioned an underground coal-gasification pilot plant next to the Majuba Power Station. This process uses a matrix of well drilled into the coal bed. Air is injected and the coal is ignited underground, thus producing a synthetic gas. This is harvested and used for fuel for boilers or turbines (South African Yearbook, 2008/09).

<u>1.1.2 Nuclear Energy</u>

South Africa has one nuclear power station, located at Koeberg in the Western Cape. It is owned by Eskom. Eskom is investigating the development of an additional 20 000 MW by 2025. The expanded nuclear program is expected to result in the development of a nuclear energy industrial complex centering on uranium beneficiation and power-plant manufacturing infrastructure (South African Yearbook, 2008/09).

<u>1.1.3 Oil and gas</u>

South Africa has very limited oil reserves and about 95% of its crude oil requirements are met by imports from the Middle East and Africa. Refined petroleum products such as petrol, diesel, paraffin etc. are produced by the refining of imported crude oil; the conversion of coal to liquid fuel by Sasol and gas to liquid fuel by PetroSA (South African Yearbook, 2008/09).

Very few natural gas deposits occur within the country. At present, PetroSA is exploiting the reserves off the coast of Mossel Bay, where the Mossgas plant converts the gas into liquid fuels.

Sasol produces both petrol and gas from coal. The Department of Minerals and Energy aims to increase the availability of liquid petroleum gas (LPG) as well liquid natural gas (LNG) to the population for thermal applications of energy.

<u>1.1.4 Electricity production</u>

Eskom generates about 95% of electricity in South Africa and about 45% in Africa. Most of this is generated from the burning of coal, with a small percentage originating from nuclear energy sources (see Table A).

Despite the relatively large amount of electricity that is generated by Eskom power stations, there is still a significant proportion of the population that does not have access to electricity – either because they live in deep rural areas or because they cannot afford it. Raw coal, candles, paraffin, wood and dung are the main energy sources of heat for these people.

Eskom is facing a number of problems regarding the future supply of electricity to the nation. It is becoming increasingly expensive to mine the coal reserves, the power stations are ageing and demand is increasing at an unprecedented rate. At present, Eskom's net generating reserve margin is only 8%, and during 2008, the country suffered major supply interruption as load shedding had to be implemented to manage the energy shortage.

To counter these problems, additional coal-fired power stations will be built. It is envisaged that by 2026, Eskom will double its capacity to 80 000 MW. The government and Eskom have also embarked on a strategy to develop its renewable energy resources (South African Yearbook, 2008/09).

**Table A. The percentage of total primary energy supply in South Africa, 2004**

| Energy source | % Energy supply |
|---|---|
| Coal | 68.2 |
| Crude Oil | 19.4 |
| Renewables | 8 |
| Nuclear | 2.8 |
| Gas | 1.6 |
| Hydro | 0.1 |

Source: Department of Mineral and Energy (2006:2)

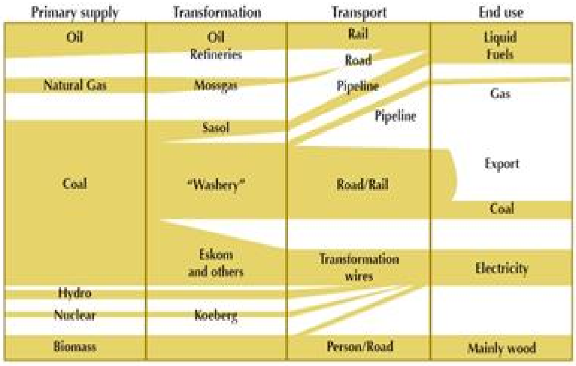


**Figure 1 .Energy flows through the South African economy, (Department of Environment and Tourism, 2007).**

Figure 1 shows the energy flows through the South African energy economy, from supply to the end use of energy. The flow of energy from its source, through transformation, transport to final use has a number of conversion losses as determined by the laws of physics. As a result of its high reliance on fossil fuels, a substantial quantity of carbon (0.9 tones) is released per unit (1 ton of oil equivalent) of energy consumed. The transformation and consumption of energy accounts for 75% of South Africa's greenhouse gas emissions.

### 1.2 Renewable Energy Policy and Interests

Renewable energy sources have not yet been exploited optimally in South Africa. The Department of Mineral and Energy (DME) strengthened international relationships in this area through the support offered to partnerships established during the World Summit on Sustainable Development in 2002. These include the Global Village Energy Partnership and the Renewable Energy and Energy Efficiency Partnership.

Cabinet approved the White Paper on Renewable Energy in November 2003. The following targets are stipulated: A 10000-GWh renewable energy contribution to final energy consumption by 2013 to be produced mainly from biomass, wind, solar and small-scale hydro. The renewable energy is to be used for power generation and non-electric technologies such as solar water-heating and biofuels, and could add about 1 667 MW new renewable energy capacity per year.

Solar energy is abundantly available in South Africa. Most areas receive more than 2500 hours of sunshine per year, and average daily solar radiation levels range between 4.5 and 6.5 kWh/m$^2$/d. A study is underway to determine the feasibility of a large-scale concentrated solar radiation (CSR) project. If economically and environmentally viable, Eskom will establish a 100-MW pilot CSR plant in the Northern Cape during 2009.

The first public-private partnership aimed at establishing alternative electricity was developed by the Darling Independent Power Producer, the Development Bank of South Africa and the Central Energy Fund. Four wind turbines were erected at Darling (W Cape), generating around 5.2 MW. All the electricity generated at the plant will be sold to the City of Cape Town.

Eskom has established a pilot wind-turbine facility at Klipheuwel in the Western Cape. The plant generated more than 12 GWh during the 2002 – 2005 test- phase. Eskom intends investing in a 100-MW wind facility, also in the Western Cape.

In theory, vast amounts of energy could be derived from the ocean tides, waves and currents. A number of experiments are underway to test such systems.

### 1.3 Lead Agencies in Energy Development

The following stakeholders are involved in energy development (Department of Mineral and Energy, 2003):

- Department of Mineral and Energy (DME) develops policy, strategy, action plans, legislation, regulations and enforcement, coordination, dissemination of information, monitoring, auditing and review, monitoring of publicly funded research development, and promote capacity and development.

- The National Electricity Regulator (NER) regulates all electricity utilities in South Africa. It also advises the Minister of Mineral and Energy on all matters related to the electricity supply industry.

- The Electricity Supply Commission (ESKOM) is the main producer and supplier of electricity in South Africa and, as such, holds the monopoly for these activities.

- The National Energy Regulator of South Africa (Nersa) is the regulatory authority established in terms of the National Energy Regulator (NER) Act, 2004 (Act 20 of 2004), with the mandate to undertake the functions of the gas regulator as set out in the Gas Act, 2001; the Petroleum Pipelines Regulator Authority, as set out in the Petroleum Pipelines Act, 2003 (Act 60 of 2003); and the NER as set out in the Electricity Act, 1987 (Act 41 of 1987 as amended.

- The Nuclear Energy Corporation for South Africa (Necsa) undertakes and promotes R & D in the field of nuclear energy and radiation sciences and technology.

- The National Nuclear Regulator (NNR) oversees safety regulation of nuclear installation and activities involving radioactive material.

- The Central Energy Fund (CEF) is mandated to engage in the acquisition, exploitation, generation, manufacture, marketing and distribution of energy and to engage in research relating to the energy sector.

- The South African National Energy Research Institute (Saneri) is a subsidiary of CEF. It facilitates skills development and undertakes research and technology development.

## 2. GEOLOGICAL SETTING OF SOUTH AFRICA

According to McCarthy and Rubidge (2005) the formation 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 granites (granitites) and greenstone belts (Visser, 1998). The Kaapvaal Craton stabilized approximately 3100 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 Super group were deposited, and very importantly, the Limpopo Belt had formed. The Limpopo Belt separates the Kaapvaal Craton and the Zimbabwe Craton (Visser, 1998) (Fig.2), comprising mainly gneisses (Johnson *et al*, 2006). The Limpopo Belt is further divided into the Southern Marginal Zone, the Central Zone and the Northern Marginal Zone (Johnson *et al*, 2006).

From 2700 million years ago up until 1000 million years ago, a sequence of deposition, intrusion (such as the Bushveld Igneous Complex, and metamorphism occurred to form the Ventersdorp-, Transvaal- and Olifantshoek Super groups, 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 Paleozoic (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 Super groups have 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).

## 3. GEOTHERMAL RESOURCE AND POTENTIAL

The known geothermal resource for South Africa comprises approximately 87 hot springs spread almost over the whole country (Figure 3). There has been no recent volcanic activity in South Africa, and therefore all thermal springs are considered to be meteoric of origin. The aquifers are considered to be secondary, and the heating of the water is due to deep circulation along mainly fault zones (Kent, 1969). The thermal springs are not confined to any specific type of geology. They are mainly located in the parts of the country receiving high rainfall and where deep crustal faulting, occurs.

No exploration boreholes have been drilled (as far as is known), but geothermal heat flow measurements have been taken in boreholes drilled for other purposes. With the current hottest temperature measured at surface of 67.5°C, the potential of electricity generation on large scale is very low. However, research is currently underway to determine the potential in terms of other alternative uses such as aquaculture and direct space heating of thermal springs.

A large percentage of hot springs seem to coincide with metamorphic provinces on the margins of the Kaapvaal Craton, such as the Cape Fold Belt and the Limpopo Belt, while other hot springs are associated with basins and granite terrains within the Kaapvaal Craton.

Studies on specific areas of interest, such as the Table Mountain Group aquifer, have calculated heat flows for that area. Hartnady and Jones (2007) used the following equation to determine the heat flow:

$$Q = -K_t \left(\frac{dT}{dz}\right) \quad (1)$$

Where $Q$ is heat flow,

$dT/dz$ is the thermal gradient, and

$K_t$ is the thermal conductivity.

Geothermal energy associated with hot dry rock has not been investigated in detail in South Africa. Andreoli *et al* (2006) described the relationship between the uranium and thorium content of rocks of the Namaquan metamorphic complex and their metamorphic grade. An image of the total count gamma-ray exposure map (Andreoli *et al*, 2006) of South Africa shows that the Namaqualand may have potential for the so-called dry heat geothermal energy. However, this must be studied further.

The geothermal resource potential is not known for the country as a whole.

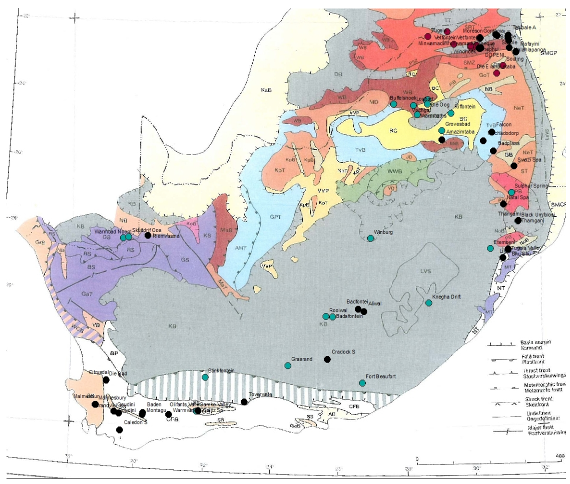

**Figure 2: Locations of thermal springs in South Africa.**

## 4. GEOTHERMAL UTILIZATION

Currently, geothermal energy utilization is confined to the use of thermal springs for leisure and recreation. However, there is some evidence that the thermal springs in the far north-eastern parts of the Limpopo Province were used as sources of salt hundreds of years ago (Kent 1942). The southern springs were used traditionally by the Khoi peoples for medicinal purposes. White settlers developed some of these springs such as those at Caledon, Montegu, Clan William and Aliwal North in the south and Warm baths in the north as health spas. Initially, mud was used for healing, but later pools were built in which patients suffering from rheumatism and related diseases, could be 'cured'. In 1916, Rindl documented around 70 medicinal springs in South Africa. These included both warm and cold springs. At present, approximately 32 of the 90-odd thermal springs have been developed as family holiday resorts, providing a variety of accommodation varying from hotel to self catering chalets and caravan parks. A list of these resorts together with information on the type of development and some physical and mineralogical characteristics of the springs, are provided in Table C. Limpopo Province boasts the most of these, followed by the Western Cape. Most resorts do not offer any form of specific medicinal or therapeutic regimes (Boekstein, 1998; Hoole 2001, 48).

The current use and type of development at thermal springs is thus limited and very little research has been done to determine the potential uses at the various thermal springs. A research project was launched in 2007 to determine optimal uses. Researchers from the University of South Africa (UNISA) (4 staff and 3 students) and the Council of Geoscience (2 researchers) are involved in this project. Researchers from other universities (Durban University of Technology, NW University) and the Council of Geoscience, have expressed an interest in participating in the near future.

A preliminary study focussing on the physical and chemical characteristics of thermal springs in Limpopo Province has been undertaken (Olivier *et al.,* 2008). The results of this study are documented elsewhere in the International Geothermal Conference proceedings 2010 (Paper No. 1482) and indicate that waters from the springs are contaminated with fluorine and bromine, making them unfit for human consumption. Some springs also have high levels of other toxic and potentially toxic elements such as mercury, arsenic and selenium. This research will be extended to include all the thermal springs in southern Africa. It is envisaged that detailed studies will be undertaken to assess the health risk posed by current uses of the springs. The economic viability of various agricultural practices, aquaculture, direct heating and possibly small-scale geothermal energy production and mineral extraction will be investigated as part of the project. No research has ever been conducted on thermophilic organisms in South African thermal springs and their potential for use in industry. This aspect will receive urgent attention in this project.

## 5. DISCUSSION (TABLES)

### Table 1

The major role played by coal is evident. Some 72% of South African energy supply in 2006 was provided for by coal, followed by oil (12,5%), renewables (10%), gas (3) nuclear (2,5%) and hydro (0,25%) (Climate Answers and Stephen Tindale, 2009).

### Table 2

Currently there is no geothermal energy plant that is generating electric power.

### Table 3

Table 3 gives the location of thermal spring resorts with bathing and swimming facilities. However, their utilization of geothermal energy is currently unknown.

### Table 4

Geothermal (ground source) heat pumps: none.

### Table 5

Currently information on installed capacity, annual energy use and capacity factor for bathing and swimming is unknown.

### Table 6

Wells drilled for electrical or direct use: unknown.

### Table 7

In the period 2008-2009, four staff members from the University of South Africa (Unisa) have been involved in the research activities in the field of geothermal resources. Professor Olivier is leading the team and is currently supervising three students, two for Masters and one for PhD. Two researchers from the Council for Geosciences are included in the geothermal research team. However, the interest for research in the geothermal field is growing.

### Table 8

Total investment in geothermal is unknown.

## 6. FUTURE DEVELOPMENT AND INSTALLATIONS

Nothing is planned at present, but efforts are being made to convince government of the importance of exploring the possibility of geothermal energy production and other development.

## 7. ACKNOWLEDGEMENTS

The authors thank Noma, Director for Renewable Energy: South Africa Department of Mineral and Energy (DME) for assisting with documents; Thembakazi: South African National Energy Research Institute (SANERI), for clarifying the functions of SANERI; the National Research Foundation (NRF) and the Council for Geoscience, for funding the research; Magda Roos (GIS), and the Council for Geoscience, for assistance with maps.

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**TABLE A**

| NAME | NEAREST TOWN/ PROVINCE | ACCOMODATION | SOURCE TEMP. ($^{0}C$) | pH | MINERALS IN SPRINGS (ACCORDING TO KENT 1916) |
|---|---|---|---|---|---|
| The Overberger | Caledon, W. Cape | Hotel | 49 | 7.2 | Fe, Ca, Mn, Na, K, Cl, $SO_4$, $HCO_3$, Si |
| Goudini Spa | Worcester, W Cape | Chalets, flats, camping sites | 40 | 5.7 | Na,Mg, K, Cl, $SO_4$ |
| Brandvlei | Rawsonville, W Cape | Picnics facilities only | 64 | 6.6 | Mg, K, Ca, Si, Cl, $SO_4$ |
| Avalon Springs | Montagu, W Cape | Hotel, self-catering flats | 43 | 6.1 | Na, Mg, K, Li, Cl, Ca, $SO_4$, $HCO_3$, Si |
| Warmwaterberg | Ladismith W Cape | Flats, log cabins, caravans, caravan sites | 43 | 6.4 | Na, Mg, K, Ca, Fe, Mn, Cl, $SO_4$, $HCO_3$, Si |
| Calitzdorp spa | Calitzdorp, W Cape | Self-catering chalets, flats, caravan sites | 43 | 4.9 | Na, Mg, K, Ca, Fe, Mn, Cl, $SO_4$, $HCO_3$, Si |
| The Baths | Citrusdal, W Cape | Chalets, flats, caravan sites | 51 | 4.9 | Na, Mg, K, Ca, Cl, $SO_4$, Si |
| Aliwal Spa | Aliwal North, E cape | Chalets | 43 | 4.9 | Na, Mg, K, Li, Ca, Al, F, Cl, Br, Si, I, $SO_4$, $HCO_3$, $H_2S$ |
| Badfontein Guest Farm | Aliwal North, E Cape | Cottage | 30 | 9.1 | Na, Ca, K, Si, Cl, F, $SO_4$, $PO_4$ |
| Cradock Spa | Cradock, E Cape | Chalets, caravan sites | 31 | 9.6 | Na, Mg, K, Ca, F, Cl, $SO_4$, Si, $HCO_3$, $CO_3$, $H_2S$ |
| Riemvasmaak | Kakamaas, N Cape | Camping site | 39 | 7.5 | Na, Ca, Mg, K, Si, Cl, $SO_4$, $NO_3$, F |
| Forever Vaal Spa | Christiana, N W Province | Chalets, hotel, caravan sites | 36 | 7.6 | Na, Li, F, Cl, $SO_4$, $NO_3$ |
| Florisbad | Bloemfontein Free State | Picnic sites | 29 | n.a. | $NH_4$, Li, Na, Mg, Ca, Ba, Al, Fe, Cl, $SO_4$, $CO_3$, Si |
| Thangami Safari Spa | Vryheid, KwaZulu-Natal | Chalets, caravan sites, guest houses | 41 | 8.4 | Na, K, Ca, Fe, Cl, F, $SO_4$ |
| Natal Spa | Vryheid, KwaZulu-Natal | Hotel, caravan sites | 44 | n.a. | Na, Mg, Ca, Cl, $SO_4$, $CO_3$, Si |
| Shu Shu Hot Springs | Kranskop, KwaZulu-Natal | On island in Tugela river. Caravan and camping sites, | 52 | 7.4 | Na, K, Ca, F, Cl, $SO_4$, $HCO_3$, Si |
| Lilani | Greytown, KwaZulu-Natal | chalets | 40 | 9.3 | Na, K, Fe, Cl, $SO_4$, F |
| Mabalingwe Spa | Pretoria, Gauteng | Chalets | 36 | 7.8 | Na, K, Ca, F, Cl, $SO_4$ |
| Forever Spa Badplaas | Carolina Mpumalanga | Hotel, chalets, caravan park | 50 | 8.9 | Na, K, Mg, Ca, Si, F, Cl, $SO_4$, $HCO_3$, $CO_3$ |
| Zimthabi | Thabazimbi Limpopo Province | Chalets caravan sites | 32 | n.a | Na, Mg, K, Ca, F, Cl, $SO_4$, $HCO_3$, Si |
| Die Oog | Mookgophong, Limpopo | Chalets, caravan sites | 40 | n.a. | Na, Mg, Ca, F, Cl, $SO_4$, $HCO_3$, Si |
| Rhemardo | Mookgophong, Limpopo | Chalets, caravan sites | 38 | 7.2 | Na, Mg, K, Ca, F, Cl, $SO_4$, $HCO_3$, Si |
| Mphephu | Louis Trichardt Limpopo | Chalets | 43 | n.a | n.a. |
| Sagole Spa | Sagole Limpopo | Chalets, dormitories | 49 | 9.6 | Na, Mg, K, Ca, Cl, $SO_4$, $CO_3$, $HCO_3$, Si |
| Forever Eco Tshipise | Musina, Limpopo | Chalets, hotel, guest house, caravan sites | 58 | 8.9 | Na, Mg, F, K, Ca, Cl, $SO_4$, $CO_3$, $HCO_3$, Si |
| Forever Eco Eiland | Tzaneen, Limpopo | Chalets caravan sites | 43 | 8.1 | Na, K, Ca, F, Cl, $SO_4$, $CO_3$, $HCO_3$, Si |
| Makutsi Safari Farm | Tzaneen, Limpopo | Chalets | 35 | 7.4 | Na, Mg, K, Ca, F,, $SO_4$, $HCO_3$, Si |
| Libertas (Borehole) | Mookgophong, Limpopo | Chalets, log cabins, gaboose (train coach) caravan sites | 52 | 7.0 | Ca, Na, Cl, F, $SO_4$, K, Mg |
| Lekkerrus (borehole) | Mookgophong, Limpopo | Chalets, log cabins, caravan sites | 46 | 7.9 | Ca, Na, Cl, F, $SO_4$, K, Mg |
| Môreson | Musina, Limpopo | Private, houses, caravans | 38 | 8.6 | Na, Ca, Mg, Cl, $HCO_3$,$SO_4$ $NO_3$ |
| Vischgat | Mookgophong, Limpopo | Guesthouse | 40 | 7.1 | Na, Ca, K, Mg, $HCO_3$, $SO_4$,F, Cl |

**TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY**

| | Geothermal | | Fossil Fuels | | Hydro | | Nuclear | | Other Renewables (gas, bagasse, pumped storage) | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cap (MWe) | Gross prod. GWh/yr | Cap (MWe) | Gross prod. GWh/yr | Cap (MWe) | Gross prod. GWh/yr | Cap (MWe) | Gross prod. GWh/yr | Cap (MWe) | Gross prod. GWh/yr | Cap (MWe) | Gross prod. GWh/yr |
| In operation in December 2009 | 0 | 0 | 32202 | | 1580 | | 1840 | | 2347 | | 37056 | |
| Under construction in December 2009 | 0 | 0 | | | | | | | | | | |
| Funds committed, but not yet under construction in December 2009 | 0 | 0 | | | | | | | | | | |
| Total projected use by 2015 | 0 | 0 | | | | | | | | | | |

**TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2009**

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
H = Hybrid
2F = Double Flash (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Data for 2009 if available, otherwise for 2008. Please specify which.

| Locality | Power Plant Name | Year Com missioned | No. of Units | Status[1)] | Type of Unit[2)] | Total Installed Capacity MWe | Annual Energy Produced 2009[3)] GWh/yr | Total Under Constr. or Planned MWe |
|---|---|---|---|---|---|---|---|---|
| None | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | | | | | | | |

**TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2009 (other than heat pumps)**

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

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

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. ($^oC$) - outlet temp. ($^oC$)] 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. ($^oC$) - outlet temp. ($^oC$)] 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 | | | | | Capacity[3)] | Annual Utilization | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Flow Rate (kg/s) | Temperature ($^oC$) Inlet | Temperature ($^oC$) Outlet | Enthalpy[2)] (kJ/kg) Inlet | Enthalpy[2)] (kJ/kg) Outlet | (MWt) | Ave. Flow (kg/s) | Energy[4)] (TJ/yr) | Capacity Factor[5)] |
| Caledon.W .Cape | B | Unknown | unknown | unknown | unknown | unknown | unknown | unknown | unknown | unknown |
| Worcester. W. Cape | B | | | | | | | | | |
| Rawsonville. W. Cape | B | | | | | | | | | |
| Montagu. W. Cape | B | | | | | | | | | |
| Ladismith. W.Cape | B | | | | | | | | | |
| Calitzdorp. W. Cape | B | | | | | | | | | |
| Citrusdal. W.Cape | B | | | | | | | | | |
| Aliwal North. E. Cape | B | | | | | | | | | |
| Cradock. E Cape | B | | | | | | | | | |
| Kakamas. N. Cape | B | | | | | | | | | |
| Christiana. NW Provin | B | | | | | | | | | |
| Bloemfontein. Free Sta | B | | | | | | | | | |
| Vryheid. Kwazulu-Nata | B | | | | | | | | | |
| Kranskop. Kwazulu-Na | B | | | | | | | | | |
| Greytown. Kwazulu-Na | B | | | | | | | | | |
| Pretoria. Gauteng | B | | | | | | | | | |
| Carolina. Mpumalanga | B | | | | | | | | | |
| Thabazimbi. Limpopo | B | | | | | | | | | |
| Mookgophong. Limpop | B | | | | | | | | | |
| Louis Trichard.Limpop | B | | | | | | | | | |
| Sagole. Limpopo | B | | | | | | | | | |
| Musina. Limpopo | B | | | | | | | | | |
| Tzaneen. Limpopo | B | | | | | | | | | |
| **TOTAL** | | | | | | | | | | |

**TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009**

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = $10^{12}$ J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. ($^{o}$C) - outlet temp. ($^{o}$C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

**Note:** please report all numbers to three significant figures

| Locality | Ground or water temp. ($^{o}$C)[1] | Typical Heat Pump Rating or Capacity (kW) | Number of Units | Type[2] | COP[3] | Heating Equivalent Full Load Hr/Year[4] | Thermal Energy Used (TJ/yr) | Cooling Energy (TJ/yr) |
|---|---|---|---|---|---|---|---|---|
| None | none | none | none | none | none | none | none | none |
| **TOTAL** | | | | | | | | |

**TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009**

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. ($^oC$) - outlet temp. ($^oC$)] 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. ($^oC$) - outlet temp. ($^oC$)] 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)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
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] | unknown | unknown | unknown |
| Other Uses (specify) | | | |
| **Subtotal** | | | |
| Geothermal Heat Pumps | | | |
| **TOTAL** | | | |

[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, 2005 TO DECEMBER 31, 2009 (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) | none | | | | |
| Production | >150° C | none | | | | |
| | 150-100° C | none | | | | |
| | <100° C | none | | | | |
| Injection | (all) | | | | | |
| Total | | 0 | | | | |

**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 Programs
(6) Private Industry

| Year | Professional Person-Years of Effort | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2008 | 0 | 1 | 4 | 0 | 0 | 0 |
| 2009 | 0 | 1 | 4 | 0 | 0 | 0 |
| Total | 0 | 2 | 8 | 0 | 0 | 0 |

**TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$**

| Period | Research & Development Incl. Surface Explor. & Exploration Drilling | Field Development Including Production Drilling & Surface Equipment | Utilization | | Funding Type | |
|---|---|---|---|---|---|---|
| | | | Direct | Electrical | Private | Public |
| | Million US$ | Million US$ | Million US$ | Million US$ | % | % |
| 1995-1999 | none | none | none | none | none | none |
| 2000-2004 | none | none | none | none | none | none |
| 2005-2009 | unknown | unknown | unknown | none | unknown | unknown |