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South Africa Geothermal Country Update (2020)

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ABSTRACT

Coal is abundant and relatively cheap in South Africa and thus coal burning power stations are the major 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. 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 the African continent. It occupies an area of 1 219 090 km^2 and is bordered by the Indian Ocean to the east, the Atlantic Ocean to the west and Namibia, Botswana, and Zimbabwe Mozambique and Swaziland to the north and northeast. Lesotho is an enclave surrounded by South African territory. South Africa is the 9th largest country in Africa and the 24th largest country in the world by area. In 2018, its population was 57.7 million (South African Yearbook, 2017/18, 8.1).

1.1 South Africa's energy resources

Since 2011, South Africa has consistently produced around 230 000 Gigawatt-hours electricity per annum (Fig.1) (Statsa, 2019). Most is consumed domestically, but around 12 000 gigawatt-hours are exported to other Southern African Development Community (SADC) countries (Enerdata 2015). Approximately 82% of South Africa's electricity generating capacity comes from fossil fuels (coal, oil and gas) with coal being the most important of these (77%). This is because coal reserves are plentiful and are generally found near the surface and hence can be mined relatively cheaply. Currently there are no oil reserves in the country although large parts of the Karoo are underlain with reserves of oil/shale. However, the aridity of the area and fragility of the ecosystem restrict the use of fracking to utilize this resource. Recent exploration projects off the east and south coasts have shown promising results. South Africa also has considerable uranium reserves. This has enabled the country to build the only nuclear power station (Koeberg) in Africa. In 2018 it contributed about 4% to the national energy grid (South African Yearbook 2017/18, 8.11)

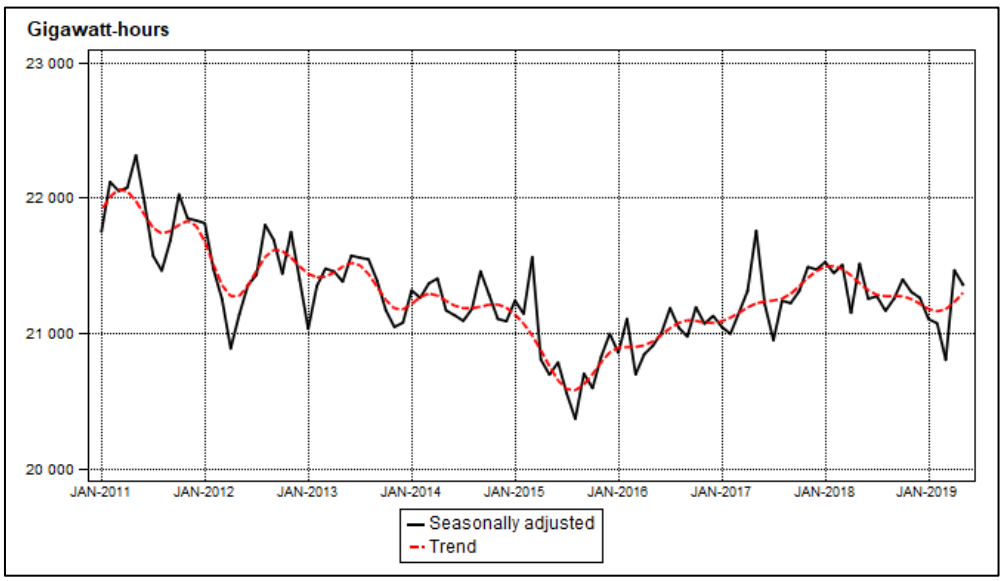

Figure 1: Monthly generation of electricity in South Africa (Statsa, 2019)

The predominance of coal-fired power stations has serious environmental consequences resulting in the country being one of the leading carbon emitters in Africa. Moreover, many of these power stations are reaching the end of their life-cycle and the lack of maintenance over the last 25 years has resulted in frequent load-shedding. This reached a maximum of level-4 early in 2019 and 2020

with 4 000MW of demand dropped from the grid to save the system from collapse. However, the air-cooled Madupi power station came on-line in 2019 and should alleviate some of the shortages during peak demand periods. This situation also prompted the government to intensify the development and use of renewables. In 2018, 91% or 46776 MW came from thermal power station (coal, oil and gas) while 4533 MW (8.8%) was generated from renewable energy sources (Power Africa Fact Sheet, 2018).

The most feasible renewable resource is solar energy since the country receives an average of more than 2 500 hours of sunshine per year, and average solar-radiation levels range between 4.5 and 6.5kWh/m^2 in one day. Sunshine is abundant all year round. The annual 24-hour global solar radiation average is about 220 W/m^2 for South Africa making South Africa's local resource one of the highest in the world (South African Yearbook 2017/18, 8.10). The largest solar power generator in South Africa is the 96 MW photovoltaic Jasper Solar Power Project located in a solar park in the Northern Cape. The 75MW Lesedi solar project is also located in this park. In addition, South Africa has an excellent wind resource and numerous small wind farms are dotted around the country (South African Yearbook 2017/18, 8.10). The Jeffrey's Bay wind farm is one of the largest. The government aims to add 3 725 MW of wind and solar voltaic and concentrating solar power to the energy mix in the next few years. South Africa has a mix of small hydroelectricity stations and pumped-water storage schemes. However, hydroelectricity is imported from Cahora Bassa scheme in Mozambique and Mpanda Nkuwa (Zambia) (South African Yearbook 2017/18, 8.10). Plans are underway to develop the Grand Inga rapids site (in the Democratic Republic of the Congo) to supply electricity to the whole of the SADC region. In the short term, the Lesotho Highlands Water Project could supply 72 MW of hydroelectric power to South Africa. The first pilot wave-power energy project was launched in 2019. Results from this project are not yet available. The geological stability of the subcontinent precludes the occurrence of very high temperature geothermal energy resources (Dhansay, de Wit and Patt, 2014).

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

Table A. Percentage of electricity generating facilities in South Africa (SA Yearbook 2017/18; Enerdata 2018)

Energy source	% Energy supply
Coal	77%
Gas	6
Nuclear	3
Hydro	7
Wind	4
Solar	3

Source: Enerdata, 2018, 11

1.2 South African government setting (South African Yearbook 2017/18, 8.3)

The South African government has established a number of institutions to develop and manage energy used in the country. The most important to these are the Department of Energy (DoE) –- which is mandated to ensure the secure and sustainable provision of energy for socio-economic development – and the National Energy Regulator of South Africa (NERSA) which regulates the energy sector, controls the prices and is responsible for grid management. The Department of Mineral Resources (DMR) is responsible for developing mining policy. Other role-players include the National Nuclear Regulator (NNR), Nuclear Energy Corporation of South Africa (Necsa), the Central Energy Fund (CEF). The SFF is in charge research, finance, development and exploitation of appropriate energy solutions.

1.3 Government policy and interest (South African Yearbook 2017/18, 8.2)

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* (2017/18, 8.2), the following legislation regulates the energy sector for the post-2005 period:

- 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 Radioactive Waste Disposal Act, 2008 (Act 53 of 2008).

These Acts supplement older Acts such as the Petroleum Products Act, 1977 (Act 120 of 1977); The Central Energy Fund (CEF) Act, 1977 (Act 38 of 1977); The National Nuclear Regulator (NNR) Act 47 0f 1999; the National Energy Regulator Act, 2004 (Act 40 of

2004) the National Environmental Management Act, 1999 (Act 107 of 1999), the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002). Numerous amendments to existing legislation have been submitted to Parliament for consideration.

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 90% of electricity consumed in the country and distributes electricity to about 5.6 million customers in the industrial, mining, commercial, agricultural and residential sectors (*South Africa Yearbook* 2017/18, 8.5). Eskom has a net capacity of 41 GW. It owns 13 coal power plants with a net capacity of 35GW (Enerdata, 2018, 9). Eskom also buys and sells electricity to the SADC countries.

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, 199).

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 granites (granitoids) and greenstone belts (Visser, 1998). The Kaapvaal Craton stabilised 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 Supergroup were deposited, and very importantly, the Limpopo Belt had formed. The Limpopo Belt separates the Kaapvaal Craton and the Zimbabwe Craton (Visser, 1998), comprising mainly 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 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 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 were formed, and the Cape Fold Belt had formed. Gondwana then fragmented to form the current coastline of southern Africa (McCarthy and Rubidge, 2005).

Small areas with the potential for hot dry-rock are located south of Upington in the Namaqualand region of the Northern Cape and in young tectonic basin northern part of Kwazulu-Natal. The heat generated in these areas mainly results from radioactive decay of the rock. Radioactive granites are usually the preferred target for hot dry rock technology. South Africa is rich in granites and gneisses of various ages and chemical compositions. Most of these granites are radioactive and some possess a thermal gradient above average. The granites in the Limpopo Province still have to be investigated in terms of radioactivity and heat flow, but represent a very large volume of rock with potential for geothermal anomaly. Deep fractured aquifers have been identified in the Limpopo belt and Cape folded belt where temperatures of 100°C to 150°C could be found at depths of 3000 to 5000 m. (Chevalier et al. 2014). Figure 2 shows geothermal resources of South Africa and their associated geological systems divided into hot rocks and hydrothermal fractured aquifers.

2.2 Hydrothermal systems and hot springs

Hydrothermal systems correspond to deep aquifers in high permeability zones acting as reservoirs of hot water that can be extracted for geothermal energy generation (electricity or heat transfer network). Hot springs are very good indicators of deep water circulation and active hydrothermal systems linked to specific geological structure. Although South Africa is located in a geologically stable zone, it has a number of thermal springs (springs with a temperature above 25ºC). Initial research by Rindle (1916) and Kent (1949) identified more than 90 thermal springs. However, increased aridity and extraction of groundwater for agricultural purposes has caused many to dry up and currently more than 70 are still active (Figure 3). 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. Siloam in Limpopo Province is the hottest with temperatures ranging between 67 and 71ºC. 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. Only seven have temperatures exceeding 50ºC. Except for Siloam, the hottest spring also have the highest flow rate. Isotope studies by Saeze (2013 (in Nyabezi et al., 2013) and Durowoju et al. (2019) confirm that the thermal springs are all of meteoric origin and are associated with crustal faulting.

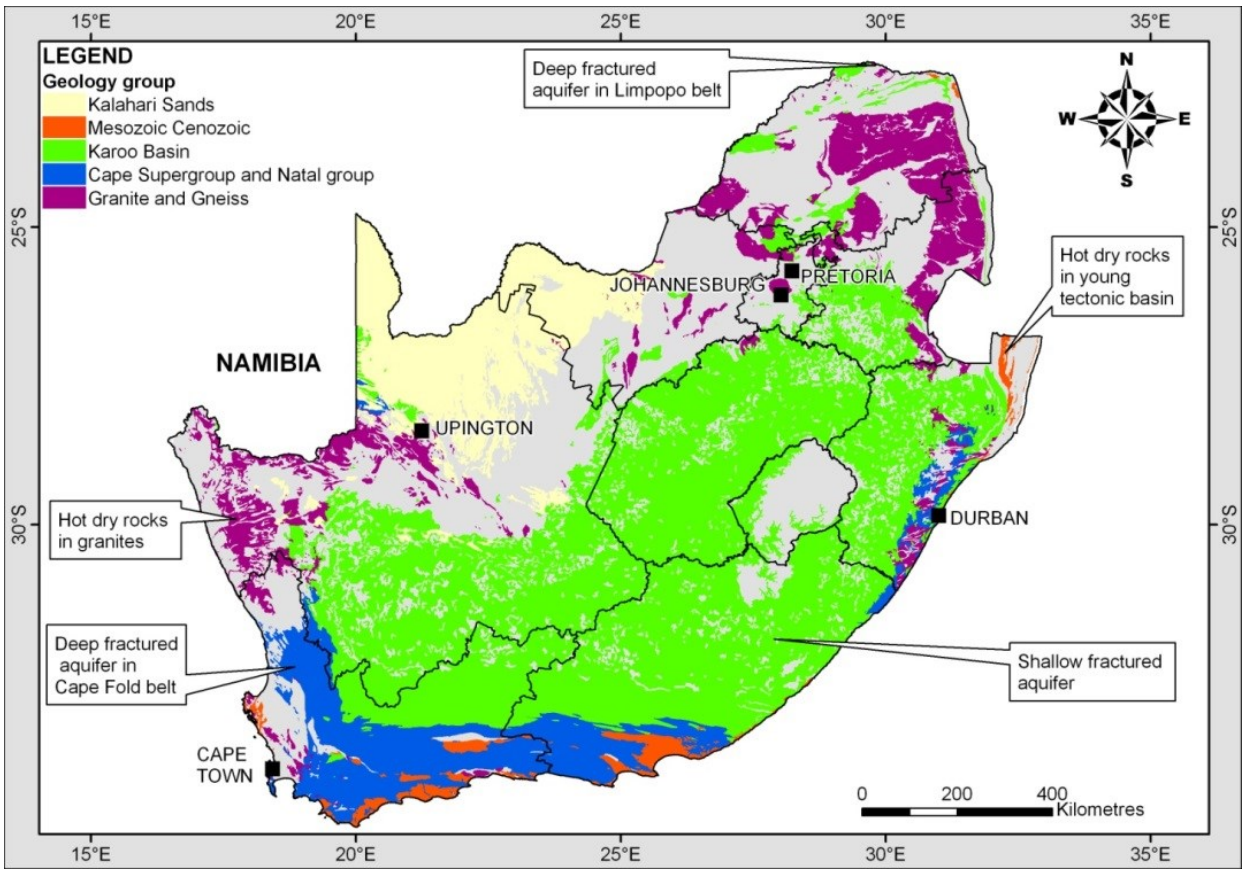

Figure 2: Geothermal resources of South Africa and their associated geological systems divided into hot dry rocks and hydrothermal fractured aquifers (Chevallier et al. 2014).

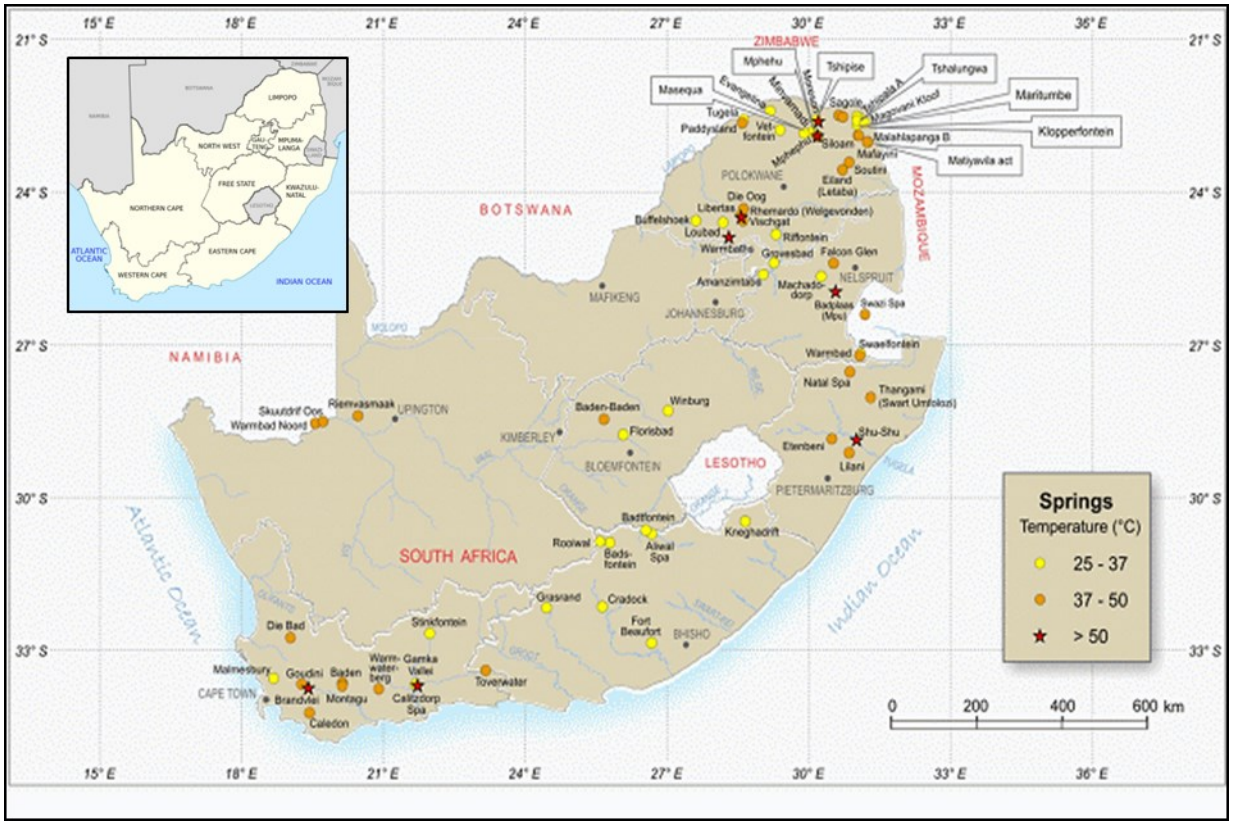

Figure 3: Distribution of thermal springs in South Africa (Olivier & Jonker, 2013).

3. 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 their use 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. Figure 4 shows how the local communities use indigenous knowledge in the salt-making process.

Figure 4: 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 waned over time, and currently the most popular use is leisure and recreation. A list of these is given in Table B. 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 are 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. 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). 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.

In a recent study by Jonker (2017), thermal springs were classified for their balneological (bath therapy) potential using international standards. Factors such as water temperature, total dissolved solids, chemical and gaseous composition and climate were used. It was found that most waters can be classified as either Na and K-rich sodic waters; Ca and Mg-rich sodic waters, saline (Na-Cl) and Na-rich sulphate waters. These are believed to be beneficial for the treatment of a range of diseases such as nervous disorders, including depression, skin ailments, specific cancers, cardiac disease, respiratory disease such as TB, neuralgia, sciatica, lumbago, fevers and infections. Results of potential uses of the 50 active springs are presented in Table C below.

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.

Table B: South African thermal spring resorts (Source: Boekstein, 1998, modified).

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, retirement cottages
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

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.

The WRC 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 (Tekere et al 2011, 2012). Most of the microbes found in these springs also occur under mesophilic conditions and are not true thermophiles, nevertheless they are highly distinct from bacteria occurring in deep mine-water (Magnobosco et al, 2014). 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.

Table C: Suitability assessment of springs in South Africa (Olivier & Jonker 2013), modified

USE			AGRICULTURE			AQUACULTURE				MINING						
	Bottling	Cosmetics	Greenhouse	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																
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																
Natal Spa																
Lilani																
Thangami																
Shu-Shu																
Warmbaths																
Birlanyoni																
Badplaas																
Grovesbad																
Machadodorp																
Falcon Glen																
Amanzimtaba																
Sulphur Spring																

H = HEAT; W = WATER

Red = not suitable; pale blue = suitable; dark blue – very suitable (>R10 000 000/month for extraction of minerals at Dec 2012 mineral prices and an exchange rate of R8/$: assuming 100% extraction). #Use for Balneology updated 2019 following Jonker 2017
Springs with the same colour in column 1 are located in the same province: in order: Limpopo; W Cape; E cape; Free State, N Cape; KwaZulu Natal; Mpumalanga.

4. DISCUSSION

Table 1. Present and Planned Production of Electricity

Table 1 shows that coal is still the major source of energy in South Africa. Other fossils include gas and diesel. Sources of energy at lower levels include hydro and nuclear. Other renewable sources reflected in the table include wind, pumped storage, solar, biomass, biogas, and bagasse. New coal-fired power stations, the Kusile in Mpumalanga and the Medupi at Lephalale in Limpopo Province, were operational in September 2017. Both plants, collectively, have 2,388MW of capacity (EIA, 2017).

Table 3. Utilization of Geothermal Energy for Direct Heat As of 31 December 2019

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

Table 7. Allocation of Professional Personnel to Geothermal Activities

There are three researchers from the University of South Africa, one from the University of Fort Hare,and three from the University of Venda conducting research in the Geothermal field. There is one Masters student studying at the University of Venda. A PhD from UNISA was obtained in 2016. There are five researchers at the Council for Geosciences.

Table 8. Total Investment in Geothermal in (2019) US$

The Water Research Commission (WRC) in Pretoria invested R650 000 to the researchers at the University of Venda. The Council for Geoscience estimated R2million was spent on research in the country. The total spent in research amount to R2650 000 million (186,504.7 USD).

5. FUTURE DEVELOPMENT AND INSTALLATIONS

South Africa has introduced the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) to address energy challenge in the country. By 2018, the REIPPPP attracted investment to the value of R201.8 billion (USD14.6 billion) (IPPPP, An Overview 2017). The programme is yielding fruit. By the end of December 2018, the REIPPPP had made the following impacts on energy supply capacity:

a. 6422MW of electricity has been procured from 112 Renewable Energy Power Producers in seven bid rounds.
b. 3876MW of electricity generation capacity from 63 IPP projects have been connected to the national grid.
c. 32700GWh of electricity has been generated by renewable energy sources procured under the REIPPP (IPPPP, An Overview, 2018)

The new capacity determinations included 1475MW of renewable energy comprising of the following sources: solar PV (6225MW), wind (6360MW), CSP (1200MW), hydro (195MW, landfill gas (25MW) biomass (2010MW), biogas (110MW), and small-scale renewable energy programmes (400MW). The total cumulative foreign investment amounted to R209.4 billion (USD16,1 Billion).

The future energy budget summary for 2019-2021 is shown in Table D.

Table D: Future Energy Budget for 2019-2021 (modified from

http://www.treasury.gov.za/documents/National%20Budget/2018/ene/Vote%2026%20Energy.pdf)

Item	2019/2020 R Million	2019/2020 USD Million	2020/2021 R Million	2020/2021 USD Million
Administration	299.1	20.92	314.8	22.02
Energy Policy and Planning	56.2	3.931	60.3	4.218
Petroleum and Petroleum Products	92.7	6.48	99.3	6.946
Electrification and Energy Programmes & Project Management	5845.4	408.9	6168.4	431.54
Nuclear Energy	870.3	60.88	912.1	63.81
Clean Energy	409.9	28.67	442.7	30.97
Total	**7573.6**	**529.84**	**7997.6**	**559.51**

In 2019, the South African government published The Integrated Resource Plan 2019 indicating that it aims to reduce the country's reliance on coal while increasing the renewable energy mix. Table E provides a detailed map of the proposed energy mix until for the period 2019 to 2030.

Table E: Proposed energy mix 2019 to 2030 (modified from The Integrated Resource Plan 2019 (Dept. Mineral Resources and Energy, 2019).	**Coal**	**Coal decom-missioned**	**Nuclear**	**Hydro**	**Storage**	**Solar**	**Wind**	**CSP**	**Gas**	**Other (e.g. bio)**
Current base	**37 149**		**1860**	**2 100**	**2 912**	**1 474**	**1 980**	**300**	**3 830**	**499**
2019	**2 155**	**-2 373**					**244**	**300**		**Allocation to the extent of the short term capacity and energy gap**
2020	**1 433**	**-557**				**114**	**300**			
2021	**1 433**	**-1 403**				**300**	**818**			
2022	**711**	**-844**			**513**	**400** **1 000**	**1 000**			
2023	**750**	**-555**				**1 000**	**1 600**			**500**
2024			**1860**				**1 600**		**1 000**	**500**
2025						**1 000**	**1 600**			**500**
2026		**-1 219**					**1 600**			**500**
2027	**750**	**-847**					**1 600**		**2 000**	**500**
2028		**-475**				**1 000**	**1 600**			**500**
2029		**-1 694**			**1 575**	**1 000**	**1 600**			**500**
2030		**-1 050**		**2 500**		**1 000**	**1 600**			**500**
TOTAL INSTALLED CAPACITY by 2030 (MW)	**33 364**		**1 860**	**4 600**	**5 000**	**8 288**	**17 742**	**600**	**6 380**	
% Total capacity MW	**43**		**2 36**	**5 84**	**6.35**	**10 52**	**22.53**	**0.76**	**8. 1**	
% Annual Energy Contribution (% of MWh)	**58.8**		**4.5**	**8.4**	**1.2***	**6.3**	**17.8**	**0.6**	**1.3**	

	Installed capacity
	Committed/already contracted
	Capacity decommissioned
	New additional capacity
	Extension of Koeberg Plant Design Life

	Includes distributed Generation Capacity for own use

This implies that by 2030, new additional capacity will reach 1500 MW from coal; 2 500 MW from hydro; 6 000 MW from solar; 14 400 MW from wind; 1 860 MW from nuclear; 2 088 MW from storage; 3 000 MW from gas and 4 000 MW from other distributed generation such as biomass, landfills etc. Unfortunately Geothermal energy is not part of this mix.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Coal plus gas &diesel		Hydro		Nuclear		(wind,solar,biomass,bio gas,bagasse		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 2019			48,925	225,661	692,18	1,220	1,870	11090,47	4844,2	16672,03	56,320	255,665
Under construction in December 2019												
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020												

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (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					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	
Rawnsonville		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						0.1		3.7	
Aliwal Nort	E.Cape	B						0.1		3.7	
Cradock	E.Cape	B						0.1		3.7	
Kakamas	N.Cape	B						0.1		3.7	
Christiana	NW. Provir	B						0.1		3.7	
Bloemfonte	Free State	B						0.1		3.7	
Vryheid	KZN	B						0.1		3.7	
Kranskop	KZN	B						0.1		3.7	
Greytown	KZN	B						0.1		3.7	
Pretoria	Gauteng	B						0.1		3.7	
Carolina	Mpumalan	B						0.1		3.7	
Thabazimb	Limpopo	B						0.1		3.7	
Mokgopho	Limpopo	B						0.1		3.7	
Makhado	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											
23								2.3		85.1	

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

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015		2	4			
2016		2	3			
2017		2	6			
2018		5	6			
2019		5	6			
Total		5	7			

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) 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						
2015-2019	186504.7					