FLORENCE SCHOOL OF REGULATION:

REGULATION FOR SUSTAINABLE FOR SUSTAINABILITY DEVELOPMENT GOAL 7 (2021)

THE SOUTH AFRICAN POWER SECTOR

COUNTRY REPORT

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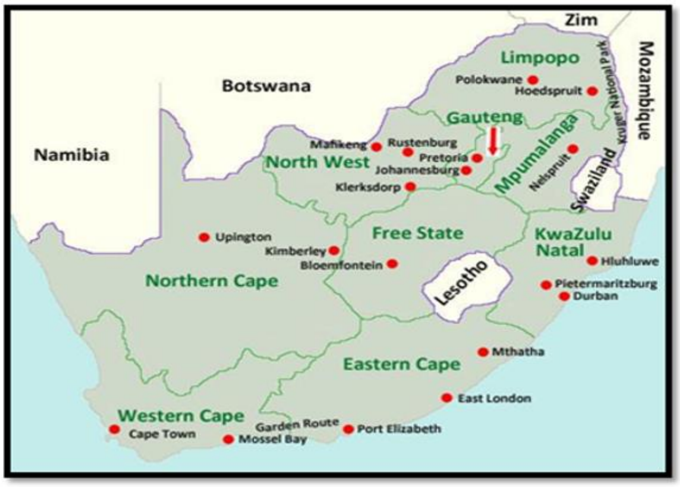
1. SOUTH AFRICA – COUNTRY OVERVIEW

1.1. GEOGRAPHY

South Africa is a country situated at the southernmost tip of the African continent, and is bordered by Botswana, Mozambique, Namibia and Zimbabwe, while completely surrounding the Kingdoms of Lesotho and Eswatini (Swaziland). As the 25th largest country in the world, it covers an area of about 1.21 million square meters (Vacorps, 2021). South Africa has 11 official languages, including English, and 9 provinces. There are 3 capital cities: Pretoria (the administrative capital, in the Gauteng Province); Bloemfontein (the judicial capital, in the Free State Province) and Cape Town (the legislative capital, in the Western Cape Province) (Mandy, 2021). South Africa has a coastline of 2,798 km (1,739 mi) – which is bordered on the West by the Atlantic Ocean and on the South and South East by the Indian Ocean.

Figure 1.1: Map of South Africa



Source: Vacorps, 2021

1.2. DEMOGRAPHICS

According to June 2020 projections, South Africa is Africa's 6th most populous country and the 10th slowest growing nation (United Nations World Population Prospects, 2019). Despite being lower than the continental average, South Africa's population growth is predicted to follow that of the continent. The effects of population expansion on the South African economy will be determined by birth, death, and net migration dynamics[1].

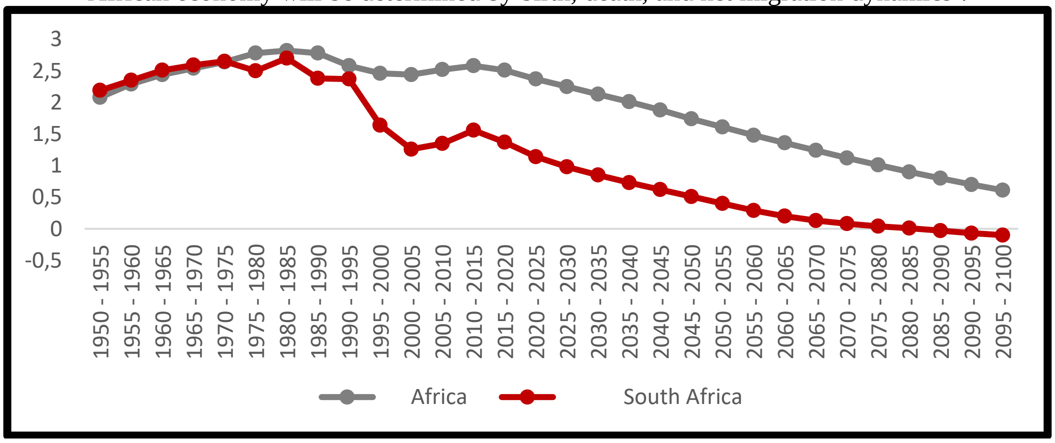


Figure 1.2: Population growth rate (Africa vs South Africa)

Source: Graph constructed from UN Population Prospects data

Births, declining fertility, and death have all contributed to South Africa's population increase. For the past six decades, birth and fertility rates have been declining, owing to greater education and literacy among women, which has transformed their reproductive behaviour. The mortality rate has also decreased According to Stats SA, the population is aging. The median has risen from 23 to 27 between 2002 and 2020, and is anticipated to reach 31 by 2030. (United Nations World Population Prospects, 2019).

Due to the above-mentioned changes in women's reproductive behaviour, Post-apartheid SA's youth (aged 15-24) witnessed a decline in growth between 2003 and 2017. Nonetheless, the UN estimates that South Africa's population will remain young in 30 years (Figure 1.2). Between the years 2030 and 2050, this demographic group is predicted to expand at an average of 7.6% over the next ten years before dropping to -0.4%. The most unequal society on the planet is South Africa (Webster, 2019). Only three billionaires in South Africa have more fortune than the poorest half of the population. In sum, 10% of the population owns 93% of the wealth in South Africa. In terms of income, the bottom 90% only earn 35% of the income (Webster, 2019). South Africa’s racial composition consists of 80.8% black Africans, 8.8% coloured people, 7.8% white and 2.6% Indians and Asians (Statistics South Africa, 2020). Due to its political history, the black population remains disadvantaged when it comes to income, employment, and education. In 2020, white people are still more likely to find work and earn better than any other population group, and women earn 30% less than men.

[1] In this document, migration refers to internal and cross-border migration unless otherwise specified.

1.3. ECONOMY

South Africa is categorized as a middle income, emerging market (Mandy, 2021). As with many other African countries, it is rich with an abundant supply of natural resources – in particular: gold, platinum, diamond, and coal. According to consultancy firm PWC, the country's financial and legal institutional framework are well developed – a trait that aided in limiting the effects of the Global Financial Crisis. Compared to its African counterparts, SA's energy, communication and transport infrastructure is modern enough to support economic trade within the country and in the region (Organisation for Economic Co-operation and Development, 2021).

Table 1.1: Economic indicators for different regions

GDP Growth (%)				Gross Debt as % of GDP		
Region	**2008**	**2009**	**2021**	**2008**	**2009**	**2021**
Global	2.7	-0.4	6			
Advanced economies	0.1	-3.4	5.1	79.8	93	121.65
Emerging Economies	5.8	3.1	6.9	32.4	35.4	65.99
Developing Asia	7.3	7.7	8.6	30.8	31.2	71.95
Sub-Saharan Africa	5.7	2.6	3.4	29.1	32.2	56.16
South Africa	3.7	-1.5	3.1	27.8	31.3	80.78

Source: IMF World Economic Outlook, 2021

Between 2000 and 2008, the economy was growing at an average rate of 4.2% per annum, and the financial crisis found the country at the tail end of its economic boom (Mataboge, 2020). Subsequent mismanagement of public funds, caused by (inter alia) a high public sector wage bill, corruption, and general inefficiencies, was value destructive. Consequently, SA is now faced with low or negative economic growth, high unemployment, lingering inequality, insolvent state-owned entities, and a large infrastructural gap. Unfortunately, fiscal policy is no longer in a position to boost the economy, due to the high debt-to-GDP ratio; resulting, the three major sovereign rating agencies (Fitch, Moody's, and Standard & Poor's) to have placed the country's credit status below investment grade.

The government, rating agencies and several sovereign rating institutions have acknowledged the importance of implementing structural reforms that were important, even pre-pandemic, in placing the country back on the path of economic growth. These include: fiscal consolidation and spending efficiency; shrinking the public sector wage bill; limiting political and board interference in the day to day running of SOE's; ensuring financial stability and efficiency of SOE's (which includes bringing in private sector participation); reforms in energy, transport, and telecoms policies to improve infrastructure provision and investments (Organisation for Economic Co-operation and Development, 2021).

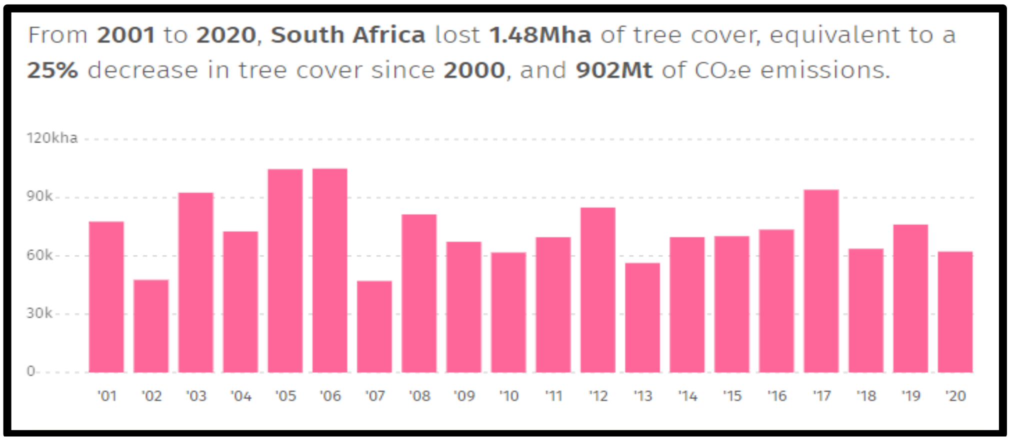
1.4. POLITICAL STABILITY

Twenty seven (27) years have passed since the African National Congress (ANC) has been in power post democratic elections. The ANC is the governing party both nationally, and in 8 of the 9 provinces and most of the local municipalities (Abedian, 2021). While still the ruling party, ongoing corruption by party officials and in government has posed challenges to governance, service delivery and financial management. In July 2021, the country saw mass protests after the jailing of Former President Jacob Zuma for contempt of court. Under the banner, "Free Jacob Zuma " protestors looted shops, burnt buildings, barricaded roads – resulting in disruptions in the economy and damage estimated at over $1 Billion (Sishi, 2021). It is widely believed among analysts that the protest was not necessarily rooted in the firm belief of freeing Jacob Zuma, but rather the deep seeded poverty and inequality of the South African society, which can easily be manipulated for political purposes thereby highlighting the country's political instability.

1.5. ENVIRONMENT

South Africa faces three (3) core environmental problems: pollution, lack of energy and deforestation (Woo, Undated) as shown in figure 1.3. According to Robyn Hugo, a climate change expert, SA is the 12th largest global greenhouse emitter and has per capita emissions higher than China, India, and the global average (Phillips, 2021). A major contributor to the aforementioned is the heavy reliance on coal for energy production. The country's power producer, ESKOM, has had challenges decarbonizing due to the abundant coal supply in the country and a lack of suitable renewable alternatives. SA's large coal reserves places it as the 7th and 5th largest global coal producers and exporters respectively (Statista 2021). . It is estimated that SA has over 53 billion tonnes of coal reserves, which is enough to sustain the current production rate for the next 200 years (Eskom, 2021).

Figure 1.3: Tree cover loss in South Africa



Source: Global Forest Watch, 2021

1.6. SA AND THE WORLD

SA's economy is one of the most sophisticated and largest on the continent. It played an essential role in the actualization of the African Continental Free Trade Area (AfCFTA), which is meant to increase intra-African trade. SA is one of the largest exporters to other African countries. Globally, SA is one of the countries viewed as the "gateway to Africa". However, recent political events (which also contributed to the country's rating downgrade) have placed it on shaky grounds with international investors. SA is part of the BRICS (consisting of Brazil, Russia, India, China, and SA).

2. EVOLUTION AND PRESENT SITUATION OF THE POWER SYSTEM

The power system is defined as "a network which consists of generation, distribution and transmission system. It uses the form of energy (like coal and diesel) and converts into electrical energy. (Circuitglobe.com). In S.A, most of the physical (engineering), economic (management) and regulatory activities are controlled by the national power utility (Eskom) and the government. This section explores how it evolved.

From an economic (management) perspective, Eskom became the largest electricity producer in Africa, expanding from the 1960's to around 1994. As a company with a non-profit objective, Eskom received extensive support from a pricing, investment, and regulatory perspective from the state. However, in the 1970s to 1980s, Eskom transitioned to a profit-making organisation to continue its expansion.

Attempts to privatise Eskom in the 1990s didn't materialized. With its role as a state owned entity, having monopoly over an essential commodity, Eskom was and still is highly susceptible to political interference. The refusal for funding in the 2000's and subsequent corruption, high debt levels that rendered the utility insolvent led to non-maintenance and non-renewal of infrastructure, inability to meet demand, scheduled power cuts and over 500% increase in tariffs since 2000. This explains the current state of the SA power system: a system with insufficient power infrastructure capacity, unreliable electricity supply, and unequal electricity access and high electricity prices.

3. THE POWER SYSTEM: PHYSICAL AND FUNCTIONAL DESCRIPTION, INCLUDING REGULATORY ASPECTS CORRESPONDING TO EACH ACTIVITY.

A. ELECTRICITY ACCESS

The economy of South Africa is heavily dependent on its state-owned utility, Eskom, to generate electricity. During the 2019 state of the nation address, President Cyril Ramaphosa, announced that the national utility is struggling; and if changes are not rapidly implemented, the default on its R 419 billion debt could cripple the economy (Joffe, 2011; Cronje, 2019). This served as the precursor to the executive order of the President to unbundle Eskom into three separate entities which are: generation, transmission, and distribution of energy. During (and even after) such time, certain remote communities in South Africa would have to wait to be connected to the electricity grid. This announcement has initiated a process that could take many years, despite the 14% of national population lacking electricity (Cronje, 2019). Globally, off-grid solutions have become the most suitable form of aid for the electricity generation to such remote communities and municipalities.

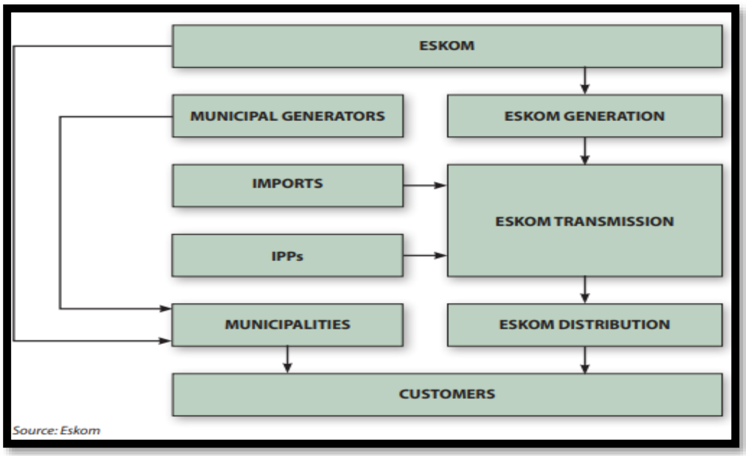


Figure 3.1 ESKOM Power Structure (Eskom & the Energy Sector Report 2019)

B. INSTALLED GENERATION CAPACITY AND ELECTRICITY GENERATION MIX

I. Main sources

SA's main energy source is coal, although renewable energy is slowly being added to the mix. Renewable energy is the inexhaustible, infinite energy that is derived from the earth's resources, such as wind and sunlight (Black, 2018). It is often referred to as clean energy, unlike the use of fossil fuels, which emit greenhouse gases, resulting in contaminated and polluted air, which harms the environment and affects climate change (Nunez, 2019) (Shinn, 2018). Figure 3.2 shows a breakdown of installed capacity by energy source.

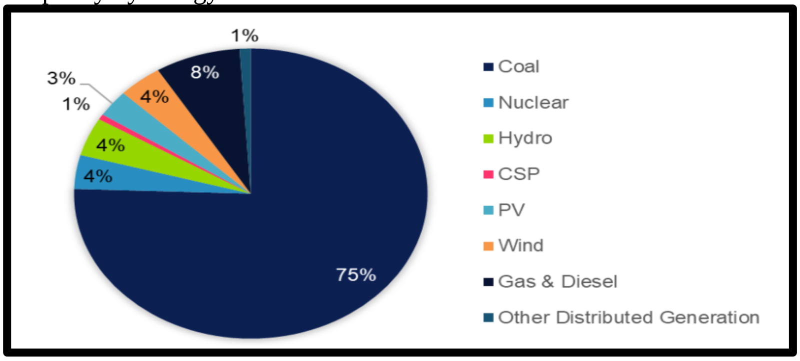


Figure 3.2: Breakdown of SA's total generation capacity by source (Dyson, 2020)

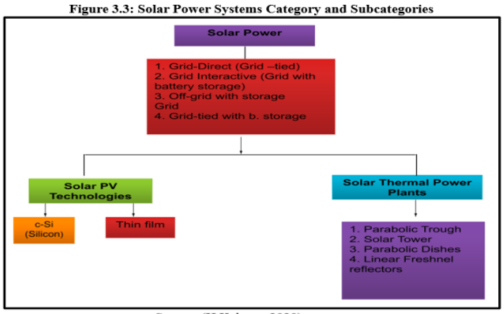
II. Renewable energy

1. Solar

There are four main energy transfer methods under solar renewable energy systems available in South Africa, namely: PV-direct system, Off-grid system, Grid-tied system with battery, and Grid-tied system without battery. The other subcategories are illustrated in Figure 3.3.

Some functional Solar power plant in South Africa include Karoshoek Solar One (100MW), Kathu Solar Park CSP (100MW), Kaxu Solar One (100MW), Xina Solar One (100MW) and Droogfontein 2 Solar Park (75MW).

Figure 3.3: Solar Power Systems Category and Subcategories



Source: (H.Kekana, 2020)

2. Hydro

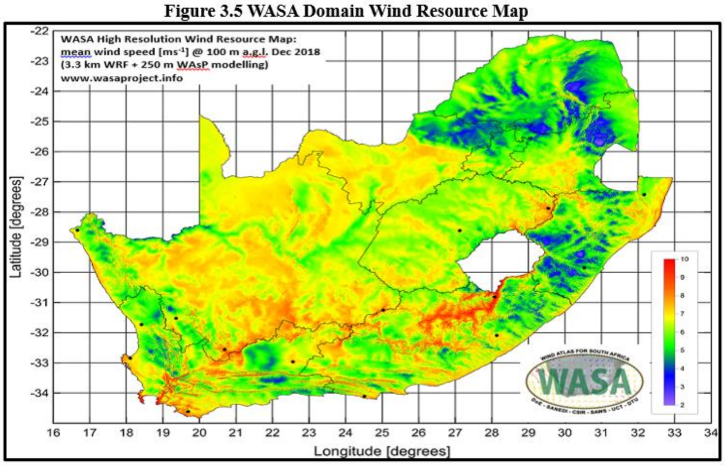
Hydroelectric power refers to the generation of electric power through the extraction of energy from moving water streams. In South Africa we have two such systems in operation: at Palmiet (400 MW) and Drakensberg (1 000 MW), whilst Ingula (1 332 MW) is still under construction (Centre for renewable & sustainable energy studies, 2018). The two largest hydroelectric power dams in SA are shown in **Figure 3.4**.

Figure 3.4 South Africa's Hydroelectric Power Plants (a) Palmiet (b) Ingula (Source: Eskom)

3. Wind

SA is a unique country gifted with both an excellent wind profile in the southernmost parts of the country as well as good solar resources in the North Western part of the country. There is an estimated 410 000 km^2 of land exposed to wind speeds greater than 6.5 m/s; but only 1174 km^2 would be available for wind farms (https://energypedia.info, n.d.). The Wind Atlas of South Africa (WASA) (see Figure 3.5) has at least two applications: assisting in the establishment of massive grid-connected wind farms and providing more detailed wind resource data to identify possible off -grid electrification prospects. Some of the installed wind farms in South Africa include Roggeveld (147MW), Oyster Bay (140MW), Karusa (140MW), Nxuba (140MW), Cookhouse (139MW) etc.

Figure 3.5 WASA Domain Wind Resource Map



Source: www.wasaproject.info (2018)

4. Biomass

As a sector which most benefits the Waste and Environmental care department, biomass-to-energy has great potential in South Africa to become a reliable and sustainable source of energy and power generation. The renewable energy industry can benefit from harnessing energy from agricultural and forest-based industrial growth and biomass waste. If sufficient biomass is available, bio-power then combined heat power (CHP) plants can be established as clean and reliable power sources, suitable for base-load service. The Howick wood pellet plant in KZN produces 5 MW electrical capacity, while in Tsitsikama (Western Cape) there is a diversified forest operations biomass electricity plant of 6 MW which was operated by (AES) Associated Energy Service.

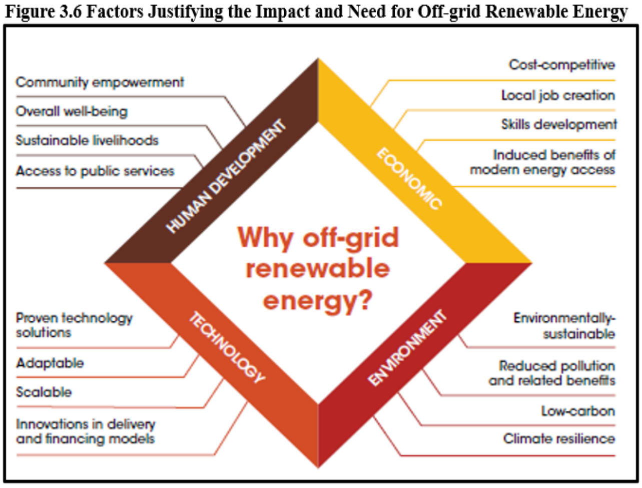
5. Geothermal

South Africa does not have large scale geothermal resources to generate electricity or use for direct heat. Only heat pump technology can be viably used depending on location and demand for heating and cooling. Currently, ground water heat pumps are very rare in the country. In most parts of South Africa, the demand for space heating is much lower than for cooling because winters are short and mild. Hotel Verde in Cape Town has about 12000 m² usable surface area and the plant has a capacity of 304kW in cooling, 364kW of heating only or 182kW for heating plus 167kW for hot water generation. The system saves around 50% of the electrical energy that a conventional HVAC system would require. The expected payback period is 5 to 7 years

III. Off-grid

Although most commonly used in remote locations and regions without utility service, off-grid solar systems can work anywhere to meet the desired energy demand. Off-grid

Figure 3.6 Factors Justifying the Impact and Need for Off-grid Renewable Energy



Source: (www.impactamplifier.co.za, 2018) renewable energy system is the decentralization of power generation. The growth of fossil-based power stations without renewable energy sources is deemed inefficient and costly, thus the need for off-grid solutions and decentralized power-generation systems becomes a priority (www.impactamplifier.co.za, 2018). While off-grid solutions were previously too expensive, currently they are feasible. According to the IEA estimates, mini-grids will be the most suitable and financially viable solution for over 45% of the global non-connected population, while standalone systems could contribute a further 25% (ESCoBox, Practical Action Consulting, 2017). These factors (**Figure 3.6**) dive into the multi-layered impact that off-grid systems have on communities.

C. Generation (the physical, functional, and regulatory aspects)

According to Eskom, South Africa's total generation capacity was 214,968GWh in 2020. The capacity and generation from all sources in 2020 are shown below (**Table 3.1**).

Table 3.1 South Africa Energy Capacity and Generation

		Capacity	Generation
Base-load stations	Coal-fired	37 424MW	194 357GWh
	Nuclear	1 860MW	13 252GWh
Mid-merit/peaking ıtions	Pumped storage	2 724MW	5 060GWh
	Hydro	600MW	688GWh
	OCGT	2 409MW	1 328GWh
Self-dispatching	Wind	100MW	283GWh

Source: Eskom

Coal is the major energy source for South Africa, comprising around 70% of the country's installed generation capacity. Under its 2019 Integrated Resource Plan (IRP), South Africa intends to decommission 24,100 MW of its conventional thermal power sources, specifically coal, within the next 10-30 years. The share of coal in the country's generation mix is likely to decrease as more renewable generation comes online in the coming years under the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). Since 2005, Eskom has been expanding South Africa's generation capacity to meet the country's growing demand for energy under the new build programme developed by DEMR in conjunction with NERSA. The programme's target is to increase the country's generation capacity by 17 384MW. In 2020, Eskom managed to deliver 12 388MW of the target. Eskom operates 90% of the base-load and peaking generation stations in the country while the rest are operated by municipals and independent power producers (IPPs). Eskom is a vertically integrated utility as such, there is no electricity trading market currently in South Africa. The price of electricity is regulated by NERSA and the conditions of sale are on standard supply arrangements when a load (industrial and domestic) is connected to the relevant grid. NERSA is also charged with issuing generation licenses, setting and approving power tariffs and charges as well as and determining Eskom's revenue requirement in accordance with the requirements of the Electricity Pricing Policy (EPP).

D. Transmission network

I. The physical aspect (technology, amount, cost, etc.)

There is a total of 27 770 km (as of March 2007) high voltage transmission lines and 325 000 km of distribution lines, a formidable distance to inspect and maintain. All overhead lines are vulnerable to natural phenomena such as lightning, flooding, veld fires, strong winds, including man-made disturbances such as cane fires lit under the lines and cable theft. All of these cause technical problems that must be addressed for power restoration. All the high voltage lines plus the big transformers and related equipment form the transmission system, also known as the National Grid are within the domain of Eskom's National Control Centre.

II. The functional aspects (how is that activity performed, who makes operation and capacity expansion decisions)

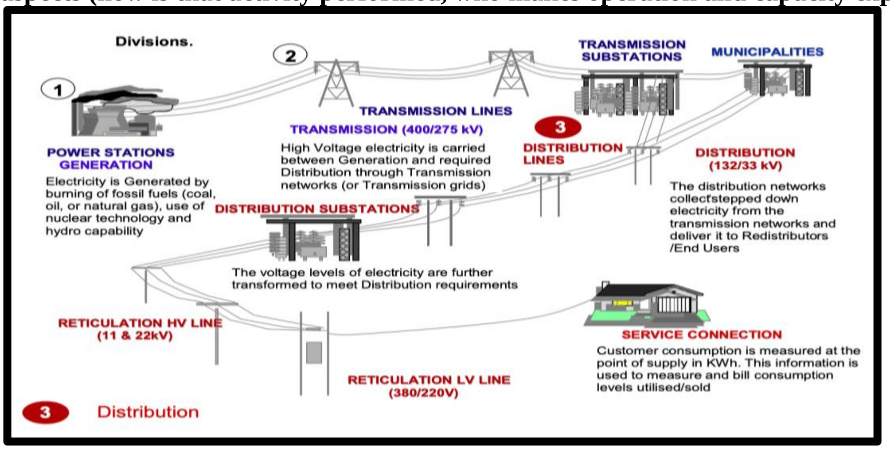


Figure 3.7 Functional Aspects of Energy Transmission

III. The regulatory aspects plus business model of this activity

Table 3.2 South Africa's Energy Regulation and Business Model

Document	Year	Provisions/function
NDP 2030	2012	Sets goals for energy investing to ensure reliable, efficient, and affordable electricity delivery for economic growth and social equity. Notes the need to reduce energy-related pollution and greenhouse gas emissions to mitigate climate change impacts, in line with Nationally Determined Contributions (NDC) to the United Nations Framework. Creates an independent transmission system operator, endowed with power planning, procurement, and contracting functions.
IRP 2010-2030	2011	Detailed vision of the electricity sector, drafted through expert and public consultation, laying out a 20-year plan to allocate future power generation needs and priority sources. Offers a legal basis for generation procurement for Eskom and the IPP Office, guiding investments across the power sector and defining the overall generation mix. Updates to the IRP often face uphill battles due to the politically-charged nature of the sector.
IRP 2019	2019	Generation capacity additions of 39.7 GW from 2019 to 2030. Ease the impact of decommissioning coal plants to protect the security and stability of the future power grid (recognizing promise of new generation). Prioritize private generation investments (except in nuclear power). Add 7.2 GW new coal sources, 1.9 GW of nuclear power (extending life of Koeberg Power Station), and 3 GW of gas/diesel turbines. Add 25.4 GW from renewable generation, including 2.5 GW from hydropower (through interconnection with the Democratic Republic of Congo), 22.9 GW from wind, solar PV, and concentrated solar power. Add 2 GW of storage capacity and 500 MW/year other capacity additions, e.g., distributed generation (from retail, commercial, and industrial customers), co-generation, biomass, and landfill (waste-to- energy).
RERESI, DPE	2019	Sets out steps for long-term sector sustainability, including restructuring Eskom. Sets out an incremental process to separate Eskom's core functions of generation, transmission, and distribution into distinct subsidiary entities. Created a separate transmission operator in March 2020 to fulfil the role of purchasing, system operation, and grid management. Legally separated generation, transmission, and distribution entities by 2021. Offers a much-needed package of fiscal injections amounting to 105 billion South African Rand (ZAR) (US$ conversion) to service debt obligations, determined by National Treasury and DPE and according to Eskom's performance, restructuring, and cost reduction.
Electricity Regulation Act	2006	Defines NERSA's powers and functions of tariff-setting, licensing, and setting technical standards. Empowers ministers responsible for energy to determine how much energy may be procured in a certain timeframe, and the authorized parties to the transaction. Electricity Pricing Policy (2008) outlines tariff-setting and pricing methodologies. Only awards generation licenses to new plants according to the capacity allocation defined by the IRP's planned generation mix. SSEGs of up to 1 MW are exempt from licensing requirements, reducing obstacles for third parties to connect small renewable generation facilities to the grid.

E. Distribution network

Table 3.3 South Africa's Energy Distribution Network

Power System	Physical aspect	Functional aspects (As depicted in Figure 3.6)	Regulatory aspect	Business model

Distribution network	Consists of approx. 379,000 km of low voltage lines; Eskom owns 288,000 km of distribution lines (1 to 132 kV), with the remaining 91,000 km of low voltage lines (mostly below 1 kV) being owned by the municipalities (National Electricity Regulator, 2003). Electric power distribution is characterized by significant economies of scale e.g., average distribution costs ranged from 23.9 cents per kWh for distributors of less than 1 GWh in annual sales to only 13.4 cents per kWh for distributors of less than 1000 GWh Approximately 60% of generated power is distributed to approx.4000 energy-intensive large businesses and 4.9 million households mainly in rural areas (Eskom, 2014)	Distribution segment has been highly fragmented; Municipalities have constitutional right to supply electricity within their local boundaries (Ioannis et al., 2007); Eskom has legislative rights to supply electricity throughout South Africa where municipalities are not supplying (Ioannis et al., 2007); the municipal segment of the distributor sector is characterized by a large variance in size – a small number of very large and a large number of very small distributors.	National Electricity Regulator (NER) issues licenses and regulates all aspects of distribution (Ioannis et al., 2007; Marquard, 2006); Mostly, under control of the municipalities (Ioannis et al., 2007)	Municipal utility business model e.g., PV prosumer business model (Jan Ole Voss et al., 2018)

F. Retail

Table 3.4 South Africa's Energy Retail

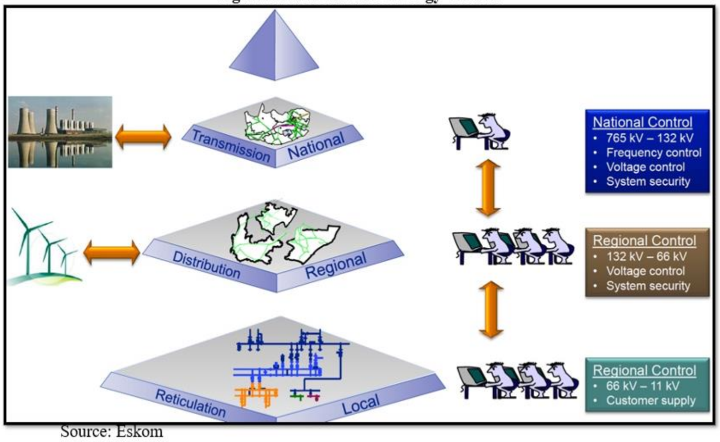
Retail	The remaining 40% of Eskom's generated power is sold to municipalities for redistribution to urban residential and small business consumers (Eskom, 2014). Of the approx.280 municipalities, 177 distribute electricity which contributes approx.30% of total municipal revenues (Stats SA, 2015); Average electricity tariffs for both domestic and industrial customers are very low by international standards (Ioannis et al., 2007) Poor households obtain low priced electricity through substantial electricity cross-subsidies (Kelly et al., 2018); Business organizations consume approximately 70% of all electricity in the country (EGI, 2013), with over half consumed by 32 extremely energy intensive companies (EIUG, 2014).	Eskom sells most of its electricity as bulk power to its large mining and industrial customers and municipalities. These three customer categories account for 82 percent of its revenue and 89 percent of its electricity sales. In addition to the 3.4 million customers serviced by 177 municipal distributors, Eskom itself operates retail distribution services for 3.1 million customers. The average selling price in 2003 to industrial customers was about 2 US cents/kWh and for residential customers was 5.5 US cents/kWh (Anton, 2007).	National Electricity Regulator (NER) issues licenses and regulates all aspects of retail/consumption such as tariff (Ioannis et al., 2007; Marquard, 2006);	Net metering, net-billing and energy savings performance contract (ESCO) (Stephanie et al., 2016)

G. System Operation

Eskom is a vertically integrated utility that owns, operates, and maintains the high voltage transmission lines carrying electricity across the country, and the distribution systems that deliver lower voltage electricity directly to customers. Eskom operates 391 784km of high-, medium and low-voltage lines and underground cables as well as 306 949MVA of transformer capacity. Eskom's hierarchical control responsibility as system operator is shown in Figure 3.8

Eskom receives energy offers day-ahead from generators. A unit commitment application determines which units to commit. The day ahead application consists of an hourly-based security constrained dispatch application to also determine and potentially relieve transmission constraints under normal and contingency conditions. The reschedule facility is designed to re-optimize day-ahead schedules when there are significant "on the day" changes. The real-time dispatch is performed cyclically every 5 minutes for 15 min ahead. Security constraints are determined by the real-time contingency analysis application. The real time dispatch uses the latest state-estimator solution to determine current generation and network conditions and a neural network to determine the load forecast for the next 15 min.

Figure 3.8 South Africa Energy Control



Source: Eskom

Automatic generation control (AGC) operates every 4 seconds, matching supply to demand. When there is insufficient generation available, customer demand is reduced to ensure system stability is maintained. Generator base points are computed and sent to the Supervisory Control and Data Acquisition (SCADA) or Energy Management System (EMS) from day ahead or real time dispatch tools to ensure an improved real time dispatch performance.

In 2019 President Cyril Ramaphosa announced that Eskom will be unbundled. Part of the unbundling includes the establishment of an independent system and market operator (ISMO) as a state-owned entity. On 15 February 2021, the CEO of Eskom revealed that the ISMO will be in place by 2022. The main functions of the ISMO will include:

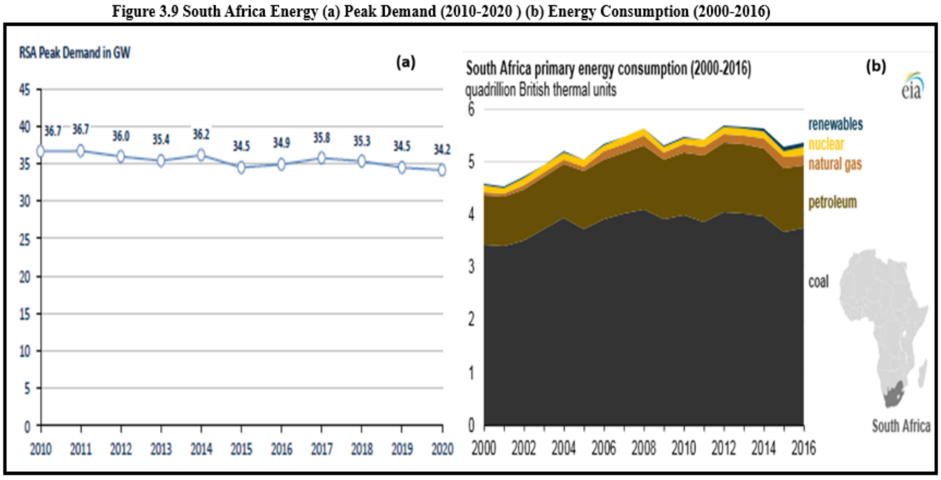
- Purchase power from the generators, including IPPs through power purchase agreements. ISMO will then sell this power to distributors and large customers at a wholesale tariff;
- Include in the wholesale tariff its operational cost in accordance with the approval of the Regulator. The Regulator will regulate the wholesale tariff in terms of the Electricity Regulation Act, 2006 (Act No. 4 of 2006) (ERA);
- Be responsible for the system operation functions through dispatch. ISMO will dispatch all the generation plants into the national grid except for self-dispatched plants, including but not limited to, wind- and solar plants.

H. Electricity demand

I. Peak demand, annual energy consumption, and estimated future demand

Figure 3.9 displays the South African peak energy demand over the past decade, ranging from a low of 34.5GW to a maximum of 36.7GW. The forecasted growth projection suggests the country experience reduced energy demand, which comes largely from the rolling load-shedding. South Africa's energy demand vs energy supplied highlights that energy demand is growing and will continue to grow. The current IRP2019 seeks to include more RE power generation over the next decade to meet the growing demand, while reducing the dependency on coal-fired power-stations.

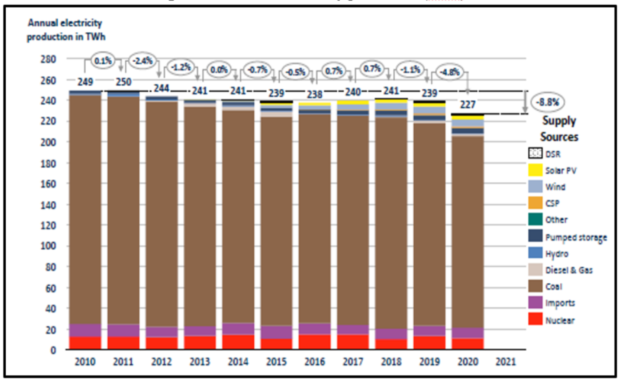
Figure 3.9 South Africa Energy (a) Peak Demand (2010-2020) (b) Energy Consumption (2000-2016)



Source: (https://www.eia.gov/todayinenergy/images/2018.01.31/main.png)

II. Demand curve

Figure 3.10 Annual electricity production (TWh)



Source: Wright & Calitz, (2021)

Figure 3.10 displays the annual electricity production from various energy sources over the last decade. The demand curve is superimposed on the annual production line. This displays the declining energy demand, which is affected by a few factors; firstly the impact of new domestic technology is less energy intensive i.e(lights, stoves and kettles), these have all adapted to using less energy to achieve the same energy output. Furthermore, there are more companies, residentials and individuals going off-grid, hybrid and using alternative energy.

Currently the energy demand curve displays a decline in energy demand; however the graph also shows the decline in the coal-fired generation reducing without adequate compensation for the energy lost, through the increased growth of embedded generation of RE.

As the fourth industrial revolution beckons upon the Africa continent, South Africa will have to grow its production to meet the forecasted energy demand over the next decade. Growth is inevitable and the recent announcement by the President to unlock the small embedded generation from a maximum of 10 MW to 100 MW, could potentially change the supply-demand dynamics of energy over the next decade; thereby allowing more IPPs to generate under 100 MW without passing through lengthy bidding process. This will also influence how Eskom closes the gap on its 11,3GW target by the end of 2030.

III. Consumer categories and tariff for each one

There are different categories that have various tariff prices based also on the power supply, whether in bulk or to residentials. From the rural tariffs, the energy charge lies between 105.78 -228.47 c/kWh. At this tariff, access to electricity becomes unlikely and even more so in remote communities, which adds to the difficulty of electrifying remote and rural villages. Table 3.5 displays the consumer categories and the tariffs for each one.

Table 3.5 Consumer categories and tariff for each one

Eskom's residential net tariffs in c/kWh [ZAR VAT.incl]	
RESIDENTIAL TARIFFS	
Block 1 [< 600kWh]	124.59
Block 2 [> 600kWh]	196.72 – 200.34
Network capacity charge [ZAR/POD/day]	5.34 – 20.65
Local authority's residential tariffs [VAT incl.]	
Block 1 [< 600kWh]	124.59
Block 2 [> 600kWh]	196.73 – 200.36
Network capacity charge [ZAR/POD/day]	5.34 – 20.65
Eskom's residential tariffs (bulk) [VAT incl.]	
Energy charge [c/kWh]	163.57
Network capacity charge [ZAR/kVA]	33.85

Source:(http://www.eskom.co.za, 2015/2016)

IV. Reliability of supply and quality of service

The reliability of the supply and quality of service in South Africa has had challenges regarding the rolling stages of load-shedding which made it difficult for SMEs and further deteriorated the economic growth of the country. Load-shedding has occurred for various reasons, amongst which is the break-down of turbines and coal-loading conveyor belts. However, these intermediary challenges have only further stressed the necessity of transitioning to renewable energy. Figure 3.10 displays the average daily electricity generation, with system load/load demand. It displays that peak load demand occurs between 05:00-10:00 and 16:00-20:00, and the supply supersedes the demand between 00:00-05:00 and 21:00-00:00.

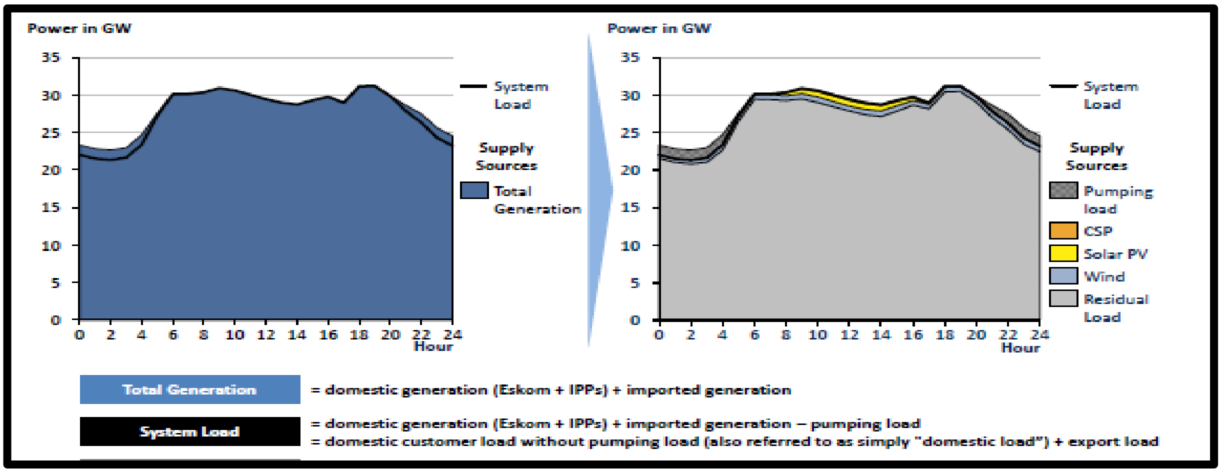


Figure 3.11 Power produced over 24hours - Source: (Wright & Calitz, March 2021)

V. Historical major power outages and system failures

Major power outages in the country have been due to poor long-term planning and the delay in empowering the IPP process to support the embedded generation over the past decade. South Africa has some of the best wind and solar resources in the world, however the IPP program has shown limitations in its implementation in recent times including the delay in the onboarding of the Medupi power station. Figure 3.11 displays the growing energy being load-shed year-on-year by Eskom, which indirectly speaks to the amount of energy demand still not being met.

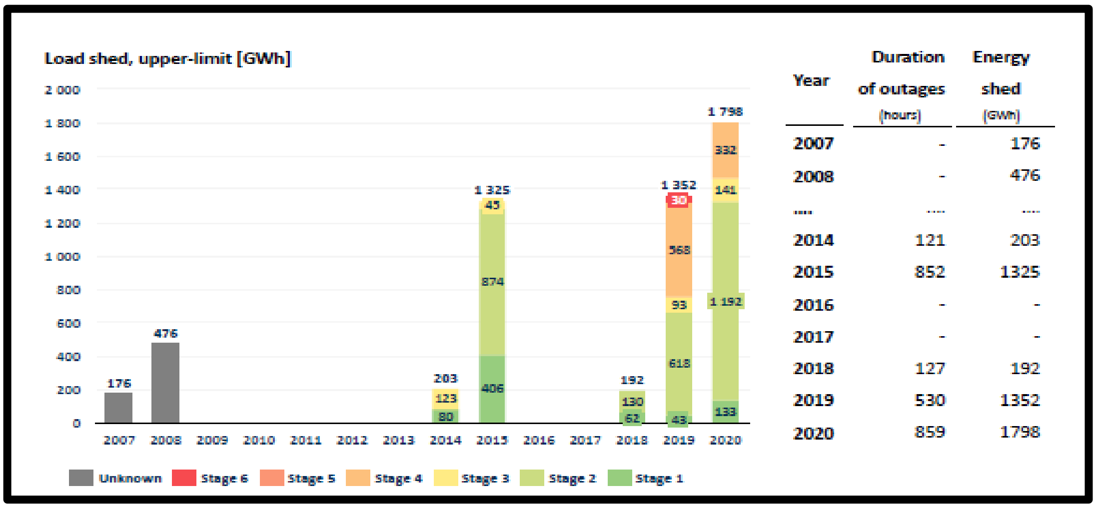


Figure 3.11 demonstrates the two largest hydroelectric power plants Source (Wright & Calitz, March 2021)

4. INSTITUTIONAL SET UP

A. MINISTRY OF ENERGY

On 29 May 2019, President Cyril Ramaphosa announced the appointment of the Minister of Mineral Resources and Energy pursuant to Chapter 5 (The President and National Executive), Section 91(2) and 93(1) of the South African Constitution. The appointment of the Minister of Mineral Resources and Energy necessitated the re-configuration of the Department of Mineral Resources and the Department of Energy into the new merged Department of Mineral Resources and Energy (DMRE).Under the National Energy Act,[2] DEMR's mandate is spelled out as ensuring that diverse energy resources are available in sustainable quantities and at affordable prices in the South African economy to support economic growth and poverty alleviation, while also taking into account environmental considerations. The Act also tasks DEMR with energy planning - for the increased generation and consumption of renewable energy; contingency energy supply; the holding of strategic energy feedstock and carriers; adequate investment in appropriate upkeep and access to energy infrastructure; measures for the furnishing of certain data and information regarding energy demand, supply and generation; the establishment of an institution to be responsible for the promotion of efficient generation and consumption of energy; and energy research and all matters connected therewith. Whereas, under the Electricity Regulation Act[3]DMRE makes determinations for the establishment of Independent Power Producers (IPP) for the purpose of greater competition in the electricity generation sector so as to increase the supply of electricity.

[2] Act No. 34 of 2008
[3] Act No. 4 of 2006

DMRE is also mandated with:

- developing and publishing the country's Integrated Energy Plan (IEP) which is a roadmap of the future energy landscape for South Africa that guides future energy infrastructure investments and policy development; and
- Regularly revising the country's Integrated Resource Plan (IRP) which is an electricity infrastructure development plan based on least-cost electricity supply and demand balance, taking into account security of supply and the environment. (IRP 2019)

According to DMRE's Strategic Plan 2020 -2025, the following are its immediate objectives:

- initiate a medium-term power purchase programme to assist with creating reserve capacity;
- extend Koeberg nuclear power plant's design life by another 20 years;
- support Eskom (South African electricity public utility) financially and legally to comply with Minimum Emission Standards (MES) over time, taking into account the energy security imperative and the risk of adverse economic impacts;
- put together a 'just transition' plan in consultation with all social partners to help avoid job losses, guide the modernization of the energy sector, and appropriately exploit current resources;
- retain the current annual build limits on renewables (wind and photovoltaic), pending the report on a just transition;
- hold off sterilizing the development of coal resources for purposes of power generation and instead prepare a framework for energy and environment planning that supports a just transition;
- support the development of gas infrastructure with all diesel-fired power plants (peakers) being converted to gas;
- commence the nuclear build programme to add 2 500 MW at a pace and scale that the country can afford; and
- support strategic power projects in neighbouring countries, thus supporting regional electricity interconnection. These include the INGA Hydropower Project in the Democratic Republic of Congo (DRC) and gas projects in Mozambique and enable the development of cross-border transmission infrastructure needed for the regional power pool.

DMRE works with and also oversees several institutions in South Africa's electricity sector listed below:

- Eskom Holdings State-Owned-Company (SOC) Limited: 100% state-owned vertically integrated electricity utility responsible for generation, transmission, distribution, and sale of electricity to South Africa and the Southern African Development Community (SADC) region.
- iGas: As per the Ministerial Directive of 2 October 2000, iGAS is mandated to act as the official State agency for the development of the hydrocarbon gas industry in South Africa.
- Nuclear Energy Corporation SOC Limited (NECSA): NECSA is established in terms of Section 3(1) of the Nuclear Energy Act[4], and is charged with the implementation and execution of national safeguards and other international obligations.
- National Radioactive Waste Disposal Institute (NRWDI): Is dedicated to professional nuclear waste management and disposal services under the National Radioactive Waste Disposal Institute Act[5].

B. POWER SECTOR REGULATORY BODIES

(i) National Energy Regulator of South Africa

National Energy Regulator of South Africa (NERSA) is the regulatory authority established under the National Energy Regulator Act.[6] Under Section 4 of the National Energy Regulator Act, NERSA is mandated with undertaking the functions of the:

a. National Electricity Regulator as set out in the Electricity Regulation Act (Act No. 4 of 2006);
b. Gas Regulator as set out in the Gas Act, 2001 (Act No. 48 of 2001); and
c. Petroleum Pipelines Regulatory Authority as set out in the Petroleum Pipelines Act, 2003 (Act No. 60 of 2003)

As well as perform any other functions assigned to it by statute or published government policies and regulations developed by the Minister of Mineral Resources and Energy including licensing, setting, and approving prices and tariffs; monitoring and enforcing compliance; and resolving disputes in the electricity, piped-gas and petroleum pipelines industries. NERSA is listed as a public entity under Schedule 3A of the Public Finance Management Act.[7] It derives its revenue by, *inter alia*, imposing prescribed levies on the regulated industries, following a prescribed transparent procedure.

The regulator states its missions as '*to regulate the energy industry in accordance with government laws and policies, standards and international best practices in support of sustainable development*' and has chosen to adopt the internationally accepted regulatory principles of transparency, neutrality, consistency, and predictability; independence, accountability, integrity, efficiency, and public interest to underpin its regulatory approach.

- NERSA's five strategic outcome-oriented goals as outlined in its Strategic Plan for 2015/16 – 2019/20) were:
- to facilitate security of supply in order to support sustainable socio-economic development in South Africa;

[4] Act No. 46 of 1999
[5] Act No. 53 of 2008
[6] Act No. 4 of 2004
[7] Act No. 1 of 1999

- to facilitate investment in and access to infrastructure in the energy industry in support of sustainable socio-economic development in South Africa;
- to promote competitive and efficient functioning as well as the orderly development of the energy industry in order to sustain socio-economic development in South Africa;
- to facilitate affordability of and accessibility to the energy industry to balance the socio-economic interests of all stakeholders in support of economic development of South Africa and a better life for all; and
- to position and establish NERSA as a credible and reliable regulator in order to create regulatory certainty.

In March 2021, NERSA sought stakeholder input into the strategic plan of its electricity division to inform and guide the activities across all departments within the Electricity Division (NERSA 2021). NERSA' organizational structure is composed of Full-Time Regulator Members (FTRMs), Part-Time Regulator Members (PTRMs), the Chief Executive Officer (CEO) as well as the Executive Managers and Senior Managers reporting to the CEO, with their link to the programmes being implemented by NERSA. NERSA also has a dual reporting system whereby the Internal Audit Unit (IAU) reports to the CEO and to the Audit and Risk Committee (ARC), while the ARC reports to the Energy Regulator. (See NERSA's regulatory structure outlined below)

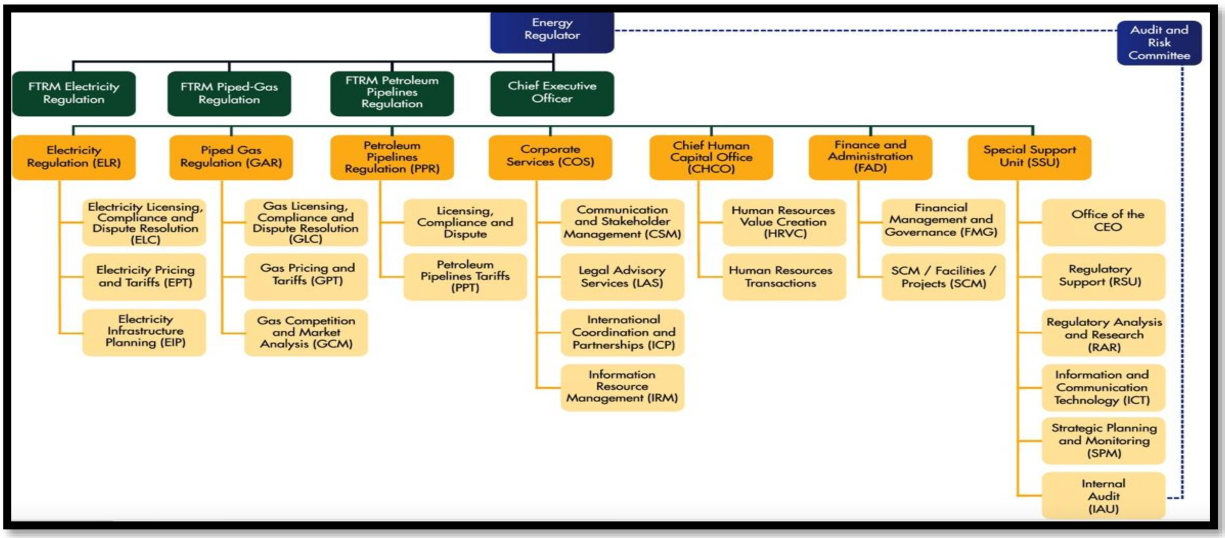


Figure 4.1 NERSA's Organizational Structure (Source: NESRA)

(ii) National Nuclear Regulator

National Nuclear Regulator (NNR) is the regulatory authority established under Section 3 of the National Nuclear Regulatory Act.[8] Under the National Nuclear Regulatory Act, NNR is tasked with:

- providing for the protection of persons, property, and the environment against nuclear damage through the establishment of Safety Standards and Regulatory Practices (SSRP);
- Exercising regulatory control related to safety over:
- the siting, design, construction, operation, manufacture of component parts and the decontamination, decommissioning and closure of nuclear installations; and
- Vessels propelled by nuclear power or having radioactive materials on board which are capable of causing nuclear damage (this, through the granting of nuclear authorizations).
- exercising regulatory control over other actions to which the Act applies, through the granting of nuclear authorizations;
- providing assurance of compliance with the conditions of nuclear authorizations through the implementation of a system of compliance inspections;
- fulfilling national obligations in respect of international legal instruments concerning nuclear safety; and
- ensuring that provisions for nuclear emergency planning are in place.

The NNR is listed as a national public entity in Schedule 3 Part A of the Public Finance Management Act (PFMA). Under Sections 8 (1) and (2) of the PFMA, the NNR is governed and controlled by its Board in accordance with the National Nuclear Regulatory Act to ensure that the objects of the Act are carried out, and to exercise general control over the performance of the NNR's functions. NNR's Board and CEO are appointed by the Minister of Mineral Resources and Energy in line with the Act.

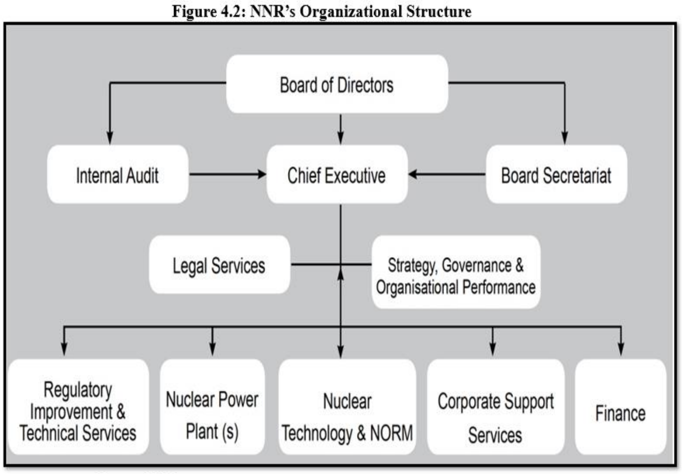
NNR's five strategic goals as outlined in its Strategic Plan 2019-2024 are:

- to provide efficient and effective nuclear regulatory services;

[8] Act No. 47 of 1999

- to operationalize the Centre for Nuclear Safety and Security (CNSS);
- to ensure financial viability and sustainability of the organization;
- to provide robust internal business processes; and
- to optimize strategic people management practices.

Figure 4.2: NNR's Organizational Structure



Source: NNR

The NNR structure defines the major categorization of roles in the organization. NNR is led by its Board which carries out its functions through the following board committees: the Transformation and Development Committee, the Audit and Risk Management Committee and the Technical Committee. The CEO, in consultation with the Board appoints the Executives. Currently the NNR has five Executives in the areas of Finance; Nuclear Power Plants; Nuclear Technology and Naturally Occurring Radioactive Material (NORM); Regulatory Improvement and Technical Services as well as Corporate Support Services, which includes Communications and Stakeholder Management. There are also strategic units placed under the ambit of the CEO and/ or the Board. These are the Internal Audit which services the Board and reports to the Chairman of the Audit and Risk Management Committee functionally and administratively to the CEO and the Board Secretariat which services the Board and reports to the Chairman of the Board, including the Legal Services and Risk Management as well as the Strategy and Organizational Performance. (See NNR's regulatory structure outlined in Figure 4.2)

C. RURAL ELECTRIFICATION BODIES

It is worth noting that the country does not have an authority solely mandated with rural electrification. The Energy Policy White Paper of 1998 required the integration of grid and non-grid technologies in a single National Electrification Programme. The South African Government encourages private-sector participation in rural energy service provision. The approach pursued was the award of geographical concessions to provide non-grid electricity supplies (primarily solar home systems) in remote areas. The process began in 1998 with a joint venture between ESKOM and Shell International in the Eastern Cape Province. This venture started with the objective of supplying solar energy to 50,000 low-cost housing units. Other concessionaires were granted similar agreements between 1998 and 2002, in the Provinces of KwaZulu Natal, the Eastern Cape, and The Northern Province (WB 2015). Shell Renewables later initiated two isolated renewable mini-grid systems in the Eastern Cape: one at Hluleka Nature reserve and one nearby at Lucingweni village. From 2002, the Integrated National Electrification Programme (INEP) the programme was set up to assist municipalities with funding for implementation of electrification projects and from 2005 the planning, funding and coordination of the INEP was permanently established in the Department of Energy and Minerals (now DMRE). Through INEP, South Africa achieved 90% electricity access in 2016 and is on course to delivering universal access by 2025(INEP 2019).

During the implementation of the INEP, it became apparent that a vast number of poor households could not afford grid-based electricity, resultantly; the government introduced the 2004 Free Basic Electricity (FBE) policy. The FBE policy provides households connected to the national grid with 50 kWh of free electricity a month. This helps the poorest households, which have a relatively low electricity demand, to meet basic energy needs (SEA 2014).Owing to the fact that the INEP is unable to ensure grid electrification of all remote rural areas in the short or medium-term, the government put in place the Non-Grid Electrification Programme which is designed to temporarily give deep rural communities access to limited electricity until such time that grid connections are possible DMRE (2020).

5. POLICY, LEGAL AND REGULATORY FRAMEWORK

A. STRUCTURE AND OWNERSHIP OF THE SOUTH AFRICAN POWER SECTOR

(i) The power sector and electricity market

The power sector is narrowly defined as "a sector engaging in the production, processing, distribution and sales of electric power in forms suitable for feeding industrial processes and household equipment, and involved in the processing, distribution and sale of electric power from sustainable sources. (Baryla, et al., 2013). The term "power sector" includes the production, transmission, and trade of not just electricity, but also gaseous fuels, steam-extracted heat energy, hot water, or wind. In relation to electricity – power sector refers to the production and trade of electricity (i.e.: generation, transmission, and distribution), further subdivided into the professional and industrial segments. The professional industry/segment consists of companies whose primary activity is the production and distribution of power and the industrial segment generates power for their own use and surplus power may be delivered to the grid. A new area of the power sector that is gaining popularity and relevance is "presumption". Thus, refers to entities that produce and consume their own electricity of smaller capacity than the industrial segment (e.g.: households, small farms).

Power/electricity is a commodity. Therefore, there exists an exchange that enables purchases through different mechanisms termed as an electricity market.

(ii) The case of South Africa

Note worthily, S.A has started to recognize the importance of renewable power sources. Although IPP's, who mainly uses renewable sources of energy, only provide 5%-10% of electricity generation. There is potential for the renewable energy IPP's to play a bigger role, with SA's Renewable Energy Independent Power Producer Programme (REIPPP) being lauded for its procurement design and private sector participation. The programme commenced in 2011 (known as "Round 1") and in 2021 at "Round 5". Furthermore, the president has relaxed licensing requirements for embedded generation, which is believed to induce more "prosumer" based renewable energy options.

The power sector is structured as a combination of a natural monopoly and an single buyer model – the latter means that IPP's can generate electricity which is to be sold to Eskom's grid and distributed as Eskom's supply (Dyson, 2020). Recent amendments to regulations involving embedded generation (discussed in section 5) show slight movements away from this model. Currently, 173 municipal-owned producers and 13 private distributors are licensed to distribute and sell power to consumers. From a market perspective, Eskom uses its monopolistic position to supply power to other utilities, large industrial customers, commercial and residential customers, and also exports to the Southern African Power Pool (SAPP).

B. THE REGULATORY ENVIRONMENT – ELECTRICITY ACT, POLICIES AND SECONDARY REGULATION

Three key pieces of regulation govern the planning around electricity delivery. These are: the National Electricity Act No 34 of 2008 (NEA); National Regulator Act No 40 of 2004 and Electricity Regulation Act No 4 of 2006. Some of these were detailed in the preceding section. This section discusses each act as part of the overall regulatory environment for the sector.

(i) The Electricity Regulation Act No 4 of 2006 (ERA)

The ERA has a primary objective of establishing a framework for the supply of electricity. It also empowers National Energy Regulator of South Africa (NERSA) to be a custodian and enforcer of this framework. Additionally, it empowers the Minister of Minerals and Energy to, amongst other things, (1) determine the current amount of new energy to be generated as well as from which sources (2) state the requirement for new generation capacity, including procurement through a competitive and fair tender process and the extent of private sector involvement.

From a NERSA perspective, the ERA defines the powers and the functions of the regulator, especially as it regards tariff setting and setting minimum technical standards for the process. Tariff setting and methodologies themselves are outlined in the Electricity Pricing Policy (2008).

Table 5.1 Documents defining the policy and regulatory framework in the SA power sector

Document	Year	Provisions/function
NDP 2030	2012	Sets goals for energy investing to ensure reliable, efficient, and affordable electricity delivery for economic growth and social equity. Notes the need to reduce energy-related pollution and greenhouse gas emissions to mitigate climate change impacts, in line with Nationally Determined Contributions (NDC) to the United Nations Framework. Creates an independent transmission system operator, endowed with power planning, procurement, and contracting functions.
IRP 2010-2030	2011	Detailed vision of the electricity sector, drafted through expert and public consultation, laying out a 20-year plan to allocate future power generation needs and priority sources. Offers a legal basis for generation procurement for Eskom and the IPP Office, guiding investments across the power sector and defining the overall generation mix. Updates to the IRP often face uphill battles due to the politically-charged nature of the sector.
IRP 2019	2019	Generation capacity additions of 39.7 GW from 2019 to 2030. Ease the impact of decommissioning coal plants to protect the security and stability of the future power grid (recognizing promise of new generation). Prioritize private generation investments (except in nuclear power). Add 7.2 GW new coal sources, 1.9 GW of nuclear (extending life of Koeberg Power Station), and 3 GW of gas/diesel turbines. Add 25.4 GW from renewable generation, including 2.5 GW from hydropower (through interconnection with the Democratic Republic of Congo), 22.9 GW from wind, solar PV, and concentrated solar power. Add 2 GW of storage capacity and 500 MW/year other capacity additions, e.g., distributed generation (from retail, commercial, and industrial customers), co-generation, biomass, and landfill (waste-to- energy).
RERESI, DPE	2019	Sets out steps for long-term sector sustainability, including restructuring Eskom. Sets out an incremental process to separate Eskom's core functions of generation, transmission, and distribution into distinct subsidiary entities. Created a separate transmission operator in March 2020 to fulfil the role of purchasing, system operation, and grid management. Legally separated generation, transmission, and distribution entities by 2021. Offers a much-needed package of fiscal injections amounting to 105 billion South African Rand (ZAR) (US$ conversion) to service debt obligations, determined by National Treasury and DPE and according to Eskom's performance, restructuring, and cost reduction.

Electricity Regulation Act	2006	Defines NERSA's powers and functions of tariff-setting, licensing, and setting technical standards. Empowers ministers responsible for energy to determine how much energy may be procured in a certain timeframe, and the authorized parties to the transaction. Electricity Pricing Policy (2008) outlines tariff-setting and pricing methodologies. Only awards generation licenses to new plants according to the capacity allocation defined by the IRP's planned generation mix. SSEGs of up to 1 MW are exempt from licensing requirements, reducing obstacles for third parties to connect small renewable generation facilities to the grid.

Source: Dyson (2020)

Finally, **Table 5.2** summarizes the stakeholders that influence policy and regulation in the sector

Table 5.2: Stakeholders that influence the policy and regulatory framework of SA's power sector

Institution	Role/mandate in the electricity sector
Policy-setting and planning bodies	
National Treasury	Manages public spending and approves departmental budgets.
Department of Mineral Resources and Energy	Drafts power sector legislation, policies, and plans, including pricing policy for National Energy Regulator of South Africa (NERSA) to regulate tariffs, to secure sustainable energy and mineral resources.
Oversees: IPP Office	Conducts competitive procurement for new generation from IPPs.
Department of Public Enterprises (DPE)	Sole shareholder of Eskom; oversees efficiency and financial sustainability of all state-owned enterprises.
Dept. of Cooperative Governance and Traditional Affairs	Supports municipalities to deliver core services of electricity supply.
Department of Environmental Affairs	Drafts legislation on air quality standards, and promotes clean, efficient energy in line with international obligations.
Department of Trade and Industry	Drafts commercial and industrial policy to promote inclusive and equitable economic development.
National Planning Commission	Expert advisory body to draft, promote, and monitor implementation of the NDP. Consults public on pathways for a just transition in line with the NDP.
State-owned enterprise	
Eskom	Vertically-integrated state-owned electricity generation, transmission, distribution, and retail company.
Statutory regulatory agencies	
NERSA	Regulates and determines electricity tariffs following Electricity Pricing Policy. Grants licences for generation, transmission, and distribution operators according to the IRP. Sets and monitors technical supply and service standards.
Private sector, civil society, unions	
Renewable energy industry and IPP associations	Various IPP associations advocate for IPPs' interests in the country, e.g., to improve the policy environment for private participation, run transparent auctions, and increase renewable energy share in the IRP.
Energy-Intensive Users Group	Represents large industrial and mining customers of Eskom, which collectively make up 40% of Eskom sales. Lobbies for favourable prices for large industrial customers, and now backs regulatory reforms for competition from IPPs.
Trade unions	Advocate for electricity sector workers' interests and on the affordability of power. Oppose Eskom restructuring and decommissioning of coal generation due to expected job losses.
Community, social & environmental groups	Various community groups and non-governmental organizations voice civil society concerns, including for social and environmental justice in realizing a just transition, e.g., the Centre for Environmental Rights, Earthlife Africa, Greenpeace, Project 90 by 2030.

Source: Dyson (2020)

C. ELECTRIFICATION PLANS

According to the University of Cape Town's Energy Research Centre, SA's electrification programme was largely successful between 1990 and 2011. Access to electricity increased from 35% in 1990 to 84% in 2011 (Prasad, 2014). After a political transition, the electrification programme achieved success due to a number of key enablers: (1) Eskom had access to capital, infrastructure and skills and capacity- the economy at the time was also very energy intensive. This helped it fund the electrification programme from 1991. For example, Eskom paid R300 000 as a grant to local authorities, in support of their electrification programme (2) The fiscus was also in a position to fund this transition with the formation of the Integrated Electrification Programme (INEP), which was vested in the DMRE. In addition, Free

Basic Electricity (FBE) was introduced in 2004 for poor households (who were given the first 50kWh to use for free) (3) the electrification plan had supportive policies.

The electrification rate and progress were threatened by lack of power infrastructure maintenance, Eskom’s deteriorating financial state, corruption indecisive policy action (detailed in section 2) The country’s electrification aspirations were set out in Chapter 5 of the National Development Plan (National Planning Commission, 2012). The plan aimed to achieve at least 90% grid connection by 2030 (with off-grid connections an option where grid connection is impractical). This, after the electrification rates became half of those a decade ago, which highlighted the infeasibility of universal access by 2014 (National Planning Commission, 2012). The solution to this included, at a high level, the diversification of power sources and ownership of the electricity sectors while balancing affordability, security, and climate change obligations. Central to this was widening participation and accelerating investments in the private sector, which spoke to procurement processes for IPP’s and removing uncertainties around whether the IPP’s can sell electricity directly to customers or through Eskom.

(i) Capacity Plan
In 2019, the long-awaited Integrated Resource Plan (IRP) was released. The IRP is “an electricity capacity plan which aims to provide an indication of the country’s electricity demand, how this demand will be supplied and what it will cost” (Dempster, 2019). Much of this detailed what was included in the NDP – i.e.: an increased focus on renewable energy sources and gradual decommissioning of some of Eskom’s coal fired power plants. Table 5.3 provides a snapshot of this plan.

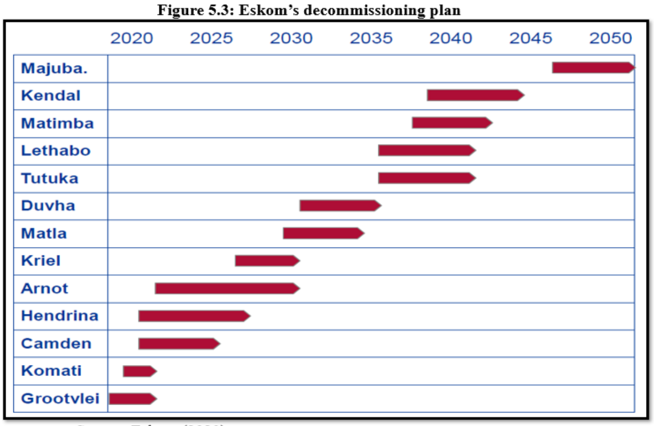
	Coal	Coal (Decommis-sioning)	Nuclear	Hydro	Storage	PV	Wind	CSP	Gas & Diesel	Other (Distributed Generation, CoGen, Biomass, Landfill)
Current Base	37,149		1 860	2,100	2 912	1 474	1 980	300	3 830	499
2019	2,155	-2,373					244	300		Allocation to the extent of the short term capacity and energy gap.
2020	1,433	-557				114	300			
2021	1,433	-1403				300	818			
2022	711	-844			513	400 1,000	1,600			
2023	750	-555				1000	1,600			500
2024			1,860				1,600		1000	500
2025						1000	1,600			500
2026		-1,219					1,600			500
2027	750	-847					1,600		2000	500
2028		-475				1000	1,600			500
2029		-1,694			1575	1000	1,600			500
2030		-1,050		2,500		1000	1,600			500
TOTAL INSTALLED CAPACITY by 2030 (MW)	33,364		1,860	4,600	5,000	8,288	17,742	600	6,380	

Installed Capacity
Committed/Already Contracted Capacity
Capacity Decommissioned
New Additional Capacity
Extension of Koeberg Plant Design Life
Includes Distributed Generation Capacity for own use

Table 5.3: The updated energy mix Source: IRP, 2019

Eskom’s exact plan to decommission coal fired plants is detailed in the Just Energy Transition (JET) Plan. The formation of the JET office was announced in late 2020, and the resulting plan confirmed in the second half of 2021. The plan is estimated to cost approximately USD10 Billion, and aims to see the majority of the coal fired plants shut down by 2050. During this period of transition, Eskom aims to move towards cleaner energy sources, while creating job opportunities for those displaced by the replacement of coal. This is also done so that Eskom is also a “direct” supplier of renewable energy, ensuring that renewable energy is not a private sector monopoly.

Figure 5.3: Eskom’s decommissioning plan



Source: Eskom (2020)

The IRP2019 also noted plans to extend the life of the Koeberg nuclear plant beyond its design life by a further 20 years, even though it will revert to its installed capacity of 1926MW. In total, additional generated capacity of 18 000MW has been committed to since IRP2010, and the coal’s contribution to the energy mix will be significantly reduced as shown in figure 5.4. This shows very clearly the commitment to increase the role of solar PV and wind technology sources by 2030. The immediate, short-term priority though, was the filling of the 2000MW capacity gap.

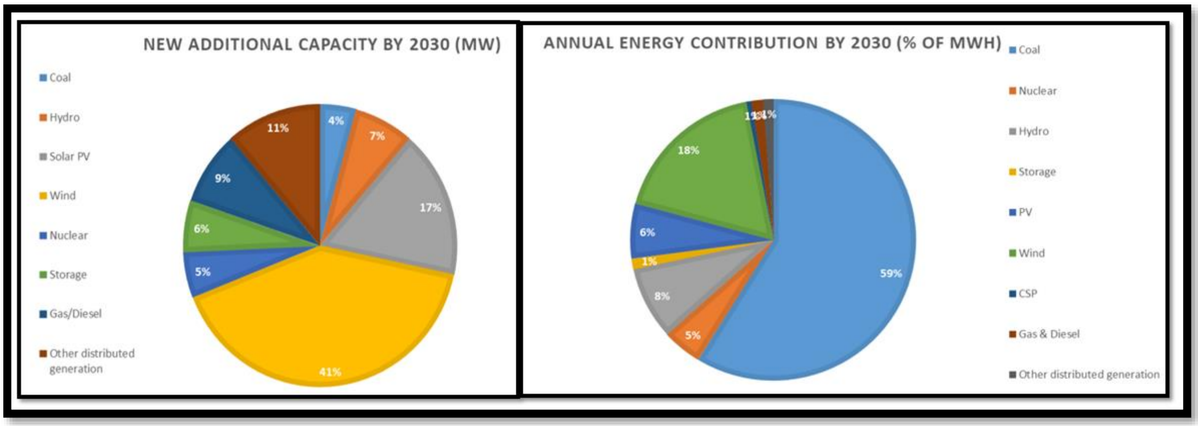


Figure 5.4: Capacity in 2030, by energy source (Source: Dempster, 2019)

The economic impact of the COVID-19 pandemic acted as an accelerant to implementing the IRP2019, specifically with regards to closing the 2000MW gap. What with Eskom's power cuts already putting strain on the economy, lockdowns imposed by efforts to reduce COVID-19 infections, securing electricity supply was seen as much needed infrastructure to kick start the ailing economy (Presidency, 2021). Therefore, in August 2020, the Minister of MRE issued a request for proposals to bridge this gap, with power procured under the Risk Mitigation Independent Power Procurement Program (RMIPPP) to be operational by the end of June 2020. Additionally, early 2021 saw the announcement to procure 2600MW of renewable energy being fast tracked (under REIPPPP round 5). Furthermore, the President amended Schedule 2 of the ERA – this sought to exempt generation projects up to 100MW from licensing requirements from NERSA, irrespective of whether are connected to the grid (The Presidency, 2021). However, a grid connection permit and environmental impact assessments would still need to be done to ensure compliance and reduce the possibility of compromising the integrity of the energy system. What stands out in all these efforts to secure capacity, is that renewable energy sources are playing a much bigger role in the energy mix.

(ii) Implementation plans

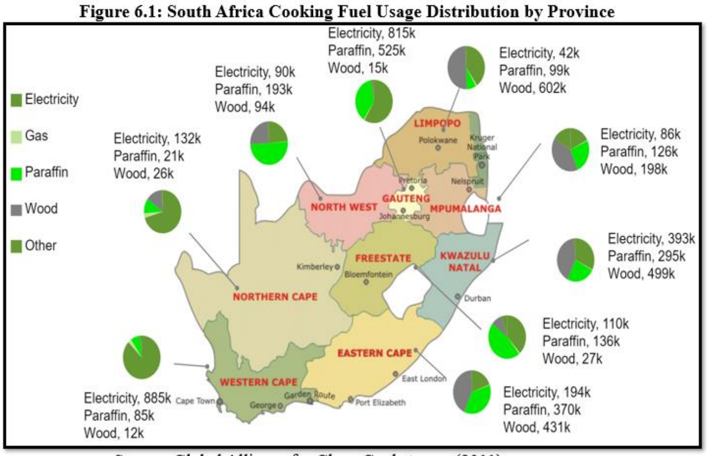
SA acted decisively in determining where generation capacity will come from – most of which is currently done by Eskom. Eskom currently also carries the bulk of the transmission load. Currently, Eskom has electrification plans, but so do municipalities. None of this is coordinated and there is very little predictability about what will or won't happen – if and where the plans are "visible" (Kruger, 2021). Municipalities responsible for electricity reticulation. Although IPP's have a bit more regulatory certainty than a decade ago, it is not advisable to construct for example, a mini-grid, without knowing whether this clashes with Eskom's or municipality's electrification plan.

6. CLEAN COOKING

A. OVERVIEW OF CLEAN COOKING

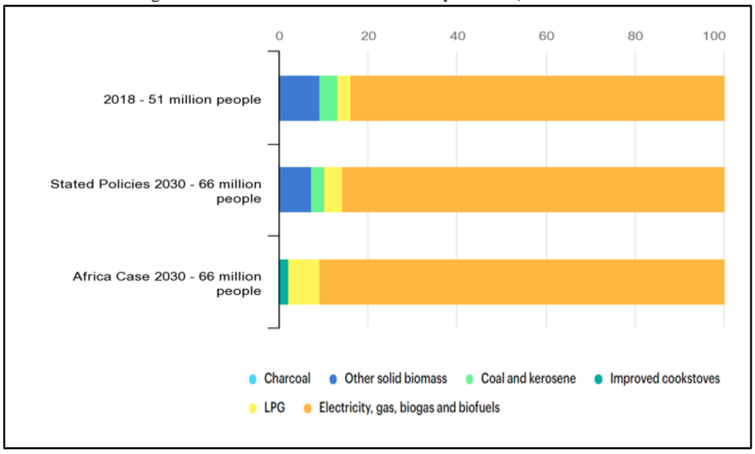
Cooking is a necessary and energy-intensive activity that brings families together and has cultural and social significance across the world (The World Bank Group, 2019; Wright *et al.*, 2020). So lid fuels such as wood, coal, crop residues, charcoal etc. are often utilized in traditional stoves in various low- and middle-income nations including South Africa (Pope *et al.*, 2018; Wright *et al.*, 2020). As at 2011, the setbacks related to cooking fuels in South Africa are unique to different regions (see Figure 6.1) and require unique interventions (Global Alliance for Clean Cookstoves, 2011). As of 2014, 81% of the population of Sub-Saharan Africa relies on biomass for their culinary needs (Casteleyn, 2017). This condition poses serious health, environmental, and development risks, costing the United States $58.2 billion per year (Casteleyn, 2017). As international organizations and national governments specify actions to improve the current situation, concern over access to clean cooking technology (CCT) is growing.

Figure 6.1: South Africa Cooking Fuel Usage Distribution by Province



Source: Global Alliance for Clean Cookstoves, (2011) Residential solid fuel combustion contributes up to 58% of global black carbon emissions and a gigaton of CO_2 per year, or around 2% of global emissions (The World Bank Group, 2019). The usage of such harmful fuels and technologies can lead to indoor air pollution, which can lead to respiratory ailments, heart problems, and even death (The World Bank Group, 2019). In fact, indoor air pollution caused by these solid fuels causes approximately 4 million premature deaths each year, with children under the age of five accounting for half of them (WHO, 2018; Wright *et al.*, 2020). In some areas, solid fuel cooking has environmental consequences, such as forest degradation (Wright *et al.*, 2020).

Figure 6.2: South Africa fuels and CCTs by scenario, 2018-2030



Source: IEA, (2019)

In South Africa, as at 2018, 87% of the entire population have access to clean cooking technology (as shown in Figure 6.2) and this figure is expected to get to 93% by 2040 ((IEA, 2019)). Clean cooking energy is critical for achieving climate mitigation goals and a variety of development goals, particularly for enhancing women's and children's well-being. CCT is crucial for economic, social, and long-term development (Paudel *et al.*, 2021).

WHO's Household Energy Database is used to track global progress in the transition to cleaner fuels and stove combinations in homes. Any rating better than 87, according to the University of Iowa rating system, is deemed safe technology, and the thermal efficiency must also be greater than 34% (AFR EA, 2014). For improved cooking and CCT, the ISO/IWA tier classification standards are presented in Table 6.1. In 2011, the health, social hazard, and impact of pollution from all cooking fuels were investigated as shown in **Figure 6.3.** It was observed that cooking with Paraffin and biomass (wood) had the highest impact while ethanol, electricity, gas, and coal had the lowest even though these four also have their setbacks (Global Alliance for Clean Cookstoves, 2011).

Figure 6.3: Health, Social Hazard, and Impact of Cooking Fuels

Stove and Fuel Type	Health and Social Hazards	Impact
Wood	• Deforestation • Loss of productive time spent collecting wood • Environmental pollution	Moderate High
Coal	• Prolonged indoor use can cause CO poisoning • Environmental pollution	Low
Paraffin	• Shack fires • Fumes	Moderate High
Ethanol	• Poisonous if consumed	
Gas	• Risk of gas explosion	Low
Electricity	• Electrocution from makeshift wire connections • Criminal activity with illegal connections	Low

Key
Low; Moderate Low; Moderate High; High

Source: Global Alliance for Clean Cookstoves, (2011)

B. CHALLENGES AFFECTING ADOPTION

The number of people with access to clean cooking in low- and middle-income countries has increased by 60% since 2000, but this progress has been stifled by rapid population expansion, leaving at least 400 million more people without clean cooking today than in 2000 (IEA, 2017; WHO, 2016). Cleaner cooking fuels such as gas and electricity are becoming more widely available, but the greater prices and logistical problems of such systems are limiting their use (Wright *et al.*, 2020). Despite over thirty years of efforts, the adoption of CCTs has continuously become an issue with severe gender, health, economic, environmental, and climate impacts (United Nations, 2020). Only Sub-Saharan Africa is experiencing a considerable increase in the number of people without access to CCTs, stressing the urgent need for action (IEA, 2020). Asides the aforementioned, rural dwellers also believe CCTs cannot cook all types of local foods. South Africa has all the capabilities to develop an effective cookstoves value chain, however, there are few organizations focused on raising awareness (Matinga *et al.*, 2011).

C. APPROACHES FOR ADOPTION

In Sub-Saharan Africa, the lack of access to clean cooking remains severe, with availability growing only marginally from 15% in 2015 to 17% in 2018. Clean Cooking is a household-focused project that encourages the use of renewable energy. It must be a political, economic, and environmental priority, backed by policies, investments, and cross-sector collaboration. The level of commitment and the size of the investment are important factors in making such a transition (The World Bank Group, 2019). Initially, improved cookstoves advocated in Sub-Saharan Africa, notably in SADC, were almost exclusively those made by micro-enterprise stove manufacturers. Because of the dispersed character of these local craftspeople and their performance, these have been favoured for their low cost and local job possibilities.. It is critical to develop advocacy groups that can connect market players and raise awareness among informal households in South Africa in order to achieve the 93% 2040 CCT adoption. To realize the Sustainable Development Goal on energy (SDG7), it is necessary to accelerate the shift to clean cooking fuels and CCT, which demands initiatives such as results-based financing and wide public and private sector participation.

7. SPECIFIC REGULATION AND BUSINESS MODELS FOR ELECTRIFICATION MODE, COOKING AND OTHER ENERGY ACCESS RELATED ACTIVITIES

Table 7.1

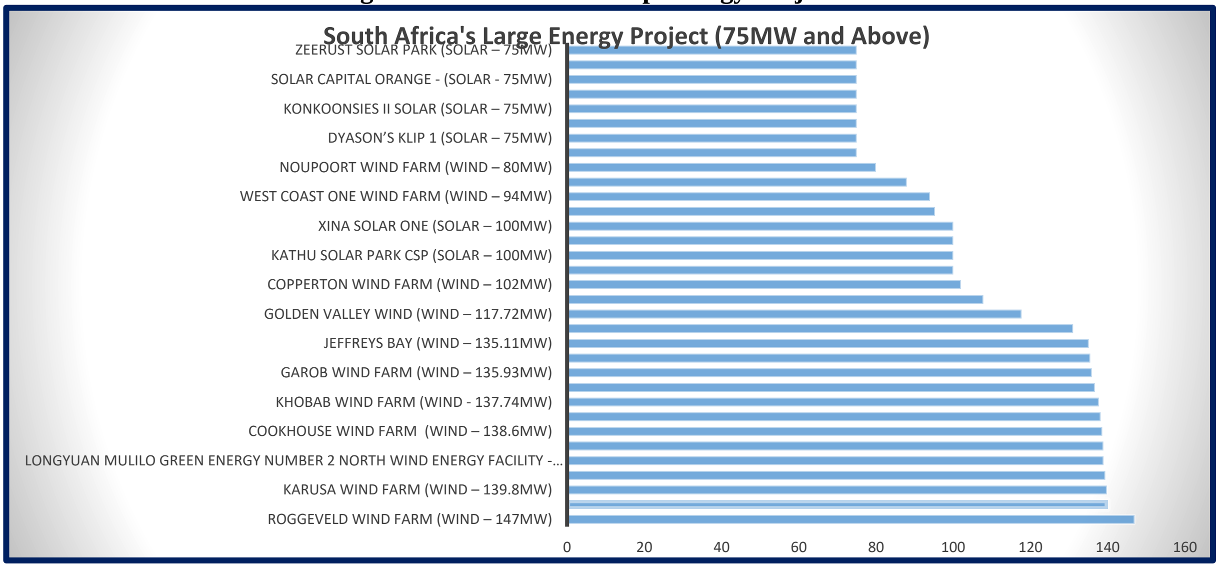
Electrification mode	Regulation	Model	Success (es)	Shortcoming (s)
Grid extension	National Energy Regulator of South Africa (NERSA)	Public - largely dominated by ESKOM – large centralized government owned utility.	Provides electricity for almost any application with the highest quality of service available; network extension, where there is enough generation capacity (Energy Sector Management Assistance Programme (ESMAP), 2000) a village (or community of houses) connected to the network, all the habitants (even those who cannot afford the connection at their homes) get benefits from the grid supply such as street lighting, pumped or irrigation water, education or health applications, agricultural and productive uses.	low electrification rates in most rural areas; low population density (spatial heterogeneity), remoteness of small villages, high costs of electricity production, transmission, and distribution, including losses, low energy demand, low level of industrialization, limited funding support and low return-on-investment (Longe *et al.*, 2017).
Micro grids (or mini-grids since they describe the same system, thus used interchangeably)	Licensing quality and safety PPA, tariff and consumer disputes grants and subsidy scheme	Four different business models from an ownership perspective (Utility/private/ community/hybrids)	Optimizes power quality, reliability, efficiency, and sustainability with accompanying economic benefits (cheaper cost of energy, local employment generation and economic development) and environmental benefits (if renewable energy sources are used).	Refer *
Stand-alone systems	Primary unregulated market Mobile payment (for lease or PAYG/lease) Quality standards	Three established business models (customer financed-bases PAYG, lease systems and cash) (Pitteloud et al., 2017)	For example, the solar home system (SHS) concessional model resulted in the installation of around 100,000 solar home systems Bring opportunity for technological innovation.	This SHS concession failed due to: lack of initial planning from the public sector side; competition from the grid and unwillingness of local populations to pay and lack of regulatory preparedness (Ignatio *et al.*, 2019).
Renewables	National Energy Regulator (NERSA)	Public-Private Partnership (South African Institute of International Affairs (SAIIA), 2019).	Attracted investment (equity and debt) to the value of R209.7 billion, of which R41.8 billion (20%) is foreign investment (Republic of South Africa, 2019). This programme has received international acclaim for fairness, transparency, and certainty. There has been a rapid increase in SMEs focusing on renewable energy in the country. Enabled the allocation of specific risks to those parties best able to manage them.	Extremely complex as it involves high transaction costs-costly to the public if risks are misallocated (SAIIA, 2019).
Energy efficiency	Regulated by National Electricity Regulator (NER) and implemented by Eskom and utilities - National Regulator for Compulsory Specifications (NR CS) - a well-developed system of standards and codes of practice derived from the South African Constitution, The White Paper on Energy Policy, the Draft Energy Bill and the Standards Act (Department of Minerals and Energy, 2005)	Service-based business model – Energy Service Company (ESCO), can be a private or public utility, a cooperative, a Non-Governmental Organization (NGO) or a private company (Republic of South Africa, 2013; webpage, n.d) Energy Resource Optimizers (ERO) undertakes full energy audits (Republic of South Africa, 2013)	allow potential clients to overcome high upfront costs effectively turns capital expense into an operational expense for clients Creates sustainable long-term revenue streams.	

8. EXISTING MAJOR ENERGY PROJECTS

A. LARGE ENERGY PROJECTS

The largest energy projects recently completed as well as those in progress are from wind and solar sources. Of the 95 fully operational renewable energy projects, 45 projects are solar PV and of those 45, 39 projects generate 10 MW or more. From the 95 projects a further 8 projects are CSP and are separated into two strict power outputs, either 50 MW or 100 MW. On the other hand, Wind energy projects are 36 in total, ranging from 5MW to 140 MW, which is the maximum. There is 1 landfill gas to electricity project which is fully operational, 2 biomass projects but unfortunately 1 is halted and the other is under construction. 3 small hydro projects, 2 of which are fully operational and 1 under construction.

Figure 8.1 South Africa Top Energy Projects



Data Source: Mybroadband, (2021); USAID, (2019).

B. RURAL ELECTRIFICATION PROJECTS

South Africa is responsible for over 40% of Africa's electricity. The national utility Eskom, a key electrical supplier, dominates the electricity sector in South Africa, generating over 90% of the country's electricity (Ratshomo & Nembahe, 2019). Due to historical considerations, South Africa's electrification program is still grid-based. Eskom began grid electrification efforts in the late 1980s. Between 1994 and 2011, about 5.2 million houses were linked to the grid (Barnard, 2011). As of 2011, 84 percent of the population have access to the internet (Stat SA, 2012). The iShack (improved Shack) project is one of South Africa's rural electricity projects. The iShack Project's goal is to provide incremental in-situ electricity access in informal settlements. It is a social enterprise that has provided off-grid electricity while the informal settlements await grid electrification. The project has tested a model that delivers basic electricity to rural and urban informal areas through a pay-for-use solar home system (SHS). iShack kicked off operation 2013 commenced with a trial-and-error approach and have been able to deliver electricity to over 1500 households so far. The project is expected to exceed 2500 households in the next couple of years (iShack, 2021). This project was partnered by Greenfund, Sustainable Energy Africa, Green Cape and the Sustainable institute.

D. CASE EXAMPLE OF THE PROVISION OF MODERN ENERGY ACCESS

Currently, several municipalities are exploring alternative solutions for providing energy services to families in a financially and environmentally sustainable manner in the long run. The cities of Johannesburg, Cape Town, and Polokwane Municipality, for example, are all considering alternative energy solutions to complement power. The section examines modern energy availability in the Polokwane Municipality. Polokwane has developed an Energy and Climate Change Strategy with five goals that address the municipality's primary energy concerns. The third Goal of the strategy is to reduce energy poverty by meeting the energy needs of residents with safe, clean, affordable, and reliable energy services. The municipality, in collaboration with Sustainable Energy Africa and the University of Limpopo, began to investigate an alternative energy services model approach in which the municipality purchases energy from small-scale community-based energy services enterprises to address energy poverty.

9. KEY CHALLENGES IN THE ENERGY SECTOR

A. INADEQUATE ENERGY SUPPLY

South Africa has been plagued by scheduled and controlled electricity shutdowns (load shedding) since 2005 but during December 2019 and the beginning of January 2020, it became a daily occurrence. According to the Council for Scientific and Industrial Research (CSIR), South Africa had the worst year of load shedding on record in 2019, with blackouts persisting for a total of 530 hours, and Stage 6 load shedding being implemented for the first time (where over a third of Eskom's total capacity was offline). The CSIR forecasts that the load shedding will continue for two to three years, depending on government decisions and actions. Load shedding is a consequence of several factors, of which insufficient generating capacity is primary. South Africa produces around 47,000 MW against an installed generation capacity of 52,000 MW. In 2021, President Ramaphosa announced that Schedule Two of the Electricity Regulation Act would be amended to allow private investors to build their own power plants with up to 100 megawatts of generating capacity without requiring a license, in a bid to address the nation's failing electricity supply.

B. HIGH ELECTRICITY PRICES

By December 2020, the price of electricity in South Africa was 0.151 USD/kWh for households and 0.073 USD/kWh for businesses which includes all components of the electricity bill such as the cost of power, distribution, and taxes. For comparison, the average price of electricity in the world for that period was 0.138 USD/kWh for households and 0.123 USD/kWh for businesses. In February 2021, the North Gauteng High Court ordered that an amount of R10 billion be added to Eskom's allowable revenue to be recovered from tariff customers in the 2021/22 financial year. NESRA also approved that Eskom's Regulatory Clearing Account (RCA) applications for year 2 (2014/15), year 3 (2015/16) and year 4 (2016/17) of the third Multi-Year Price Determination (MYPD3) period and Eskom's supplementary tariff application for the 2018/19 financial year of R4 749m and R1 288m respectively, be recovered in the 2021/22 financial year. This will result in an average tariff percentage increase of 15.63% in the 2021/22 financial year. The ever-increasing prices of Eskom electricity have brought electricity consumers under immense pressure as well as increased levels of non-payment and theft as result of the lack of affordability. The price hikes have also led to a loss of investor confidence and a decline in country competitiveness.

C. COAL AS A SOURCE OF PRIMARY ENERGY

The Department of Energy's 2019 Integrated Resource Plan stated that South Africa, whose energy generation capacity is dominated by fossil fuels (91.2%), is expected to keep using coal as its main electricity source. In 2019, South Africa's energy sector contributed to roughly 80% of the country's greenhouse gas emissions, of which half were derived from fuel production and electricity generation alone.

D. VERTICALLY INTEGRATED ELECTRICITY UTILITY

Eskom's vertically integrated monopoly has resulted in ballooning operational and capital expenditure costs for the utility. It has also blocked the entry of new players in the sector thereby inhibiting competition and lowest cost of power production. Further, the low transparency and accountability associated with monopolies has created an environment where corruption and maladministration flourishes At the 2019 State of the Nation Address, the President announced that Eskom Holdings SOC Ltd would be unbundled into three wholly owned entities: Generation, Transmission and Distribution. The legal separation of the transmission unit is expected to be completed by December 312021 and that of generation and distribution, by the end of December 2022.

E. ESKOM FINANCIAL INSTABILITY

Eskom has been experiencing a depletion of its cash reserves, reduction in funding streams, and higher operating costs. The country's slow economic growth has weighed heavily on most SOEs resulting in a reduction in funding from the fiscus. In 2020, Eskom's debt was upwards of USD 30 billion dollars, which is continuing to increase as the utility undertakes repairs on the down power plants. The utility is looking to improving its financial situation by focusing on its capital and operational expenditures, coal inventory optimization, revenue recovery initiatives and increased international revenues. Other challenges identified, include:

- Poor implementation of the IRP - a case example, is long term contracts between ESKOM and IPPs, no endorsement from ESKOM halts entire implementation process

  Local content requirements - South Africa does not hold all supportive pre-conditions, hence LCR is not optimal; pricing of renewable energy is high due to local content and such pricing is passed on to the energy consumer.

10. PART B

1) **Solving inadequate electricity supply in South Africa**

In 2019, the DMRE released a well-received resource plan for electrical generation whereby the two main source of renewable energy, that is Onshore wind and Solar energy were scheduled to generate over 8100MW and 5670MW respectively over the next decade. In June 2021, the President further opened the door to boost Small Embedded Generation (SEG) going from 1MW to 100MW (Smith, 2021). All these strategies have set the plain for smart grid systems. South Africa already has over 84% electrification, which is among the highest in Sub-Saharan Africa. This means that to attain 100% electrification the system will be focused in two prominent ways, namely the successful collection of payment for electricity supply and the micro-grid extension to rural and off-grid communities. The table below looks into different strategies of implementation across three main categories, namely Generation, Transmission and Distribution.

Table B1: Triple Helix electrical supply solution

Generation	Transmission	Distribution
Wind & Solar IPPs	Supply to nearby local municipalities with good financial standing status. This will reduce the voltage load on the transmission lines, which would supply over long-distances.	Grid connection network needs to be more sophisticated and allow for expansion of existing grids to accommodate the unstable supply electricity from renewable energy sources, instead of having to build new grids each-time.
Small Embedded Generation (≤ 100MW)	Mandate Metropolitan municipalities like City of Jo'burg (CoJ) to self-generate and reduce their baseload. Using wind & solar, from local suppliers will reduce emissions in the city but furthermore, it will generate electricity during periods of economic activity.	By deploying smart metering systems in the Metropolitans the cities will become more energy efficient and the collection of electricity bills will become better regulated. This will help restructure the cashflow of the utility (Eskom) and the municipality
Mini/Micro-grids	Mini/Micro grids are the best solution for off-grid communities, which have shown the willingness to pay. A study showed (Kekana, 2020) that Kwa-Zulu Natal, Eastern Cape and Gauteng have the highest number of household without electrification, based on IDPs published between 2016 and 2020. Mini/Micro grids must be made mandatory for rural areas with access to electricity. These systems will fall under SEG, in collaboration with the local municipality.	Mini/micro-grids built to serve rural communities have to use a pay-as-you-go system, to ensure that the grid only services the community members who are willing to pay. The local municipality can collect connection fees from the rural community and subsidise the overall cost for pensioners and child-headed households.
Hybrid energy systems	Most economic hubs will not go off-grid completely but their willingness to self-generate some of their electricity, should be enforced and rewarded through tax-exemptions or tax reduction, as in the case of large structural buildings like malls and shopping complexes. Academic institutions and hospitals must also operate using hybrid energy. This will greatly benefit the community's demand side energy management.	Hybrid energy systems only require the charge controller, inverter and battery storage to ensure the renewable energy sourced can be used as and when needed. These systems hardly place added load on the distribution system as the main intent is for self-generation through hybridization. Such system can be seen as the added value of being load-shedding proof while also being green.

2) **High electricity prices**

Eskom is currently the biggest liability to South Africa's economy and much of its financial challenges can be directly attributed to the company itself (i.e., corruption, mismanagement and government interference), some of the blame also lies with users. To cover the financial debt incurred, Eskom currently increased the electricity tariffs by 15%. Due to the rising electricity tariffs, some households (both poor and middle-income consumers) can no longer afford to pay for electricity and as such there has been reports of consumers illegally circumventing electricity meters. Also, there has been a drop in electricity demand, largely due to dampened economic activity during the Covid-19 lockdown.

In a nutshell, while tariff hikes have done enough to cover Eskom's basic operating costs (and sometimes even yielded a small profit), the power utility's massive debt costs have now pushed the entity to a record loss. This has consistently forced the government to bail out Eskom without yielding any positive results. The current strategy being used has caused growing concern as the tariff prices among high-earning estates and communities is so high that it the rich are being made to pay for the poor and underprivileged communities who continue to receive electricity without paying for it. This strategy is obviously not sustainable and more estates are looking into micro-grid supply and residential generation in the Gauteng region.

To combat this problem, the growing small embedded generation (SEG) market will see more estates and communities having exclusive electricity generation and supply. This strategy will ensure that those willing to pay can receive reliable electricity supply for their communities and businesses without paying exuberant amounts. In the case of the net metering, the high-end communities have the leading opportunity to implement such systems. Most high-end communities are close to one another and this model can implemented should the regulating body (NERSA) encourage such a move. These solutions can be introduced in the short-term (2021-2025) while the DMRE focuses on levelling the tariff price graph, nationally.

The tariff graph, currently has peak demand in the morning between 6 am and 12pm, before it slumps into a midday (13:00-16:00) negative peak, then returning back again to the evening peak (17:00-20:00). The challenge Eskom currently has is how to level the graph without losing their profit margins during the negative troughs, when solar generation is at its highest and yet demand is relatively low. The proposed solution will be in different energy storage systems and the PPA's in place, where the off-takers are still making profit during their slumps and not over-paying during their peak demand. The long-term solution helps Eskom manage their supply and distribution and opens the window to new markets in transmission and wheeling.

Eskom's strategy to implement that the 'willing buyer, willing seller' model will help the utility from supplying to communities who cannot pay, this proposed solution will balance their financials and give them enough revenue to keep the lights on, both for themselves and the country.

3) **Moving away from coal**

Based on South Africa's nuclear energy plan of October 2019 to build one (1) GW of new nuclear capacity by 2030, this would offer a viable energy resource for base load electricity production. Indeed this will support the need for additional capacity post 2030 of expected decommissioning of 24,100 MW of coal-fired power plants. South Africa already has got two nuclear reactors generating 5% of its electricity. The complimentary role of nuclear to wind and solar is key to in ensuring South Africa attains low carbon economy beyond 2030. According to International Energy Agency (IEA), the use of nuclear power has reduced carbon dioxide emissions by more than 60 Gigatons over the past 50 years, which is almost two years' worth of global energy-related emissions. The proposed solution to moving from coal, over the next decade will include an energy mix of both renewable and alternative energy solutions. Among these, nuclear power plants must be included as the most sustainable substitute solution over the next decade, while also giving support to wind and solar generation.

4) **Poor energy infrastructure**

Poor energy infrastructure can be considered to the leading cause of load-shedding in South Africa. The challenges with poor infrastructure include frequent equipment breakdown, frequent unplanned maintenance stops and the incapability to meet the energy demand in the country. Solving this problem, will require investment into other forms of generation, such as waste-to-energy power plants, wind and solar power plants with battery energy storage to ensure as much energy supply as possible post generation. Furthermore, new transmission lines will need to be included in the IRP's development plan, to ensure that the regions and provinces with the most intensive renewable energy generation power plants have the capability of transmitting the electricity to the regions with the greatest need. This is in line with the recent report from the Northern Cape urging developers to identify other provinces for generation as the transmission network in the province will be overloaded soon (Omarjee, 2021).

In the next decade, the DMRE will have to look into decentralizing the transmission system, by allowing companies to bid for the construction of the electrical supply system, first in the areas of greatest generation, then further to the Metropolitans of greatest demand. This will also encourage international investment into growing economic hubs, which have the potential of becoming key capital generation points. Lastly the upkeep of infrastructure will impact its longevity and ensure that as the demand of electricity increases with 4IR and the use of 5G technology, energy security becomes more and more of a concern which must be strategically dealt with.

5) Vertically integrated electricity utility

Under the IRP 2019, additional capacity of 1500 MW of coal fired plants is planned until 2030. These new plants are to be based on high efficiency, low emission (HELE) technology or other clean coal technologies such as Carbon Capture, Utilisation and Storage (CCUS) and Underground Coal Gasification (UCG) and are to be modular/small scale projects. It is worth noting that clean technologies are systematically complex, and their successful utilization is highly dependent on thorough and extensive research. It is unclear from IRP 2019 what policies and plans are in place for researching and developing these clean coal technologies, how the country will source R&D funds and how long it will take before the technologies are launched.

To resolve this, should consider joining technology collaborative networks or partnering with countries (such as Germany) which have already made great strides with R&D of clean coal technologies and then come up with and pursue multiple avenues to raise funds. Examples of such are private sector engagement, green bonds, bilateral development cooperation and multilateral development banks which would go a long way in actualizing clean technology projects.

A viable alternative to clean coal technologies is coal-to-gas plant conversions for coal plants that are not nearing the end of their lifespans. The conversion will improve the plants' environmental profile while at the same time lowering their operating costs. The conversion will also promote greater use of clean energy from renewable sources since the converted plants will provide highly flexible, fast-starting baseload power for balancing the grid.

Finally, South Africa should concentrate efforts on securing the integrity of the grid in order to integrate variable renewable energy sources as opposed to increasing additional coal capacity. The deployment of smart energy equipment to help the grid match demand with volatile renewable energy supply is crucial and investments in energy storage to back up the grid will be key. These digitalization efforts would then – reduce operating expenses which could translate into more affordable power; improve capital efficiency translating to higher profits to Eskom that can be channelled to investments in new generation and transmission projects directed to 100% electrification by 2030.

6) Eskom's financial stability

a. Given the status quo, what should be done or addressed?

Government finances are unlikely to see an improvement in the near future, which implies that SA needs to attract more private sector, donor and multilateral investments in order to secure financing for a successful electrification programme. In support of this, corruption and wasteful expenditure (which takes away from budgets allocated for infrastructure) should be done away it. Additional funding available is the R100 billion Presidential Infrastructure Fund, with a portion allocated to energy access.

b. How do you propose (b) should happen?

Smart spending and doing away with corruption and wasteful expenditure

- This requires planned spending to be guided by the merits of robust and reliable research. For example, the Council for Scientific and Industrial Research (CSIR) has been using the same modelling framework employed by the DMRE, found a least cost energy mix that is R70 billion per annum less than the IRP's base case. Furthermore, the share of renewable energy would be 70%, compared to the current 30% estimated by the IRP.
- Careful due diligence as well as post investment monitoring is required to manage risks of corruption and wasteful expenditure, and to eliminate delivering low quality infrastructure or non-delivery. Financing mechanisms such as Project Finance, where the public sector works together with the private sector have been proven to work best at doing this.
- Smart spending solutions that are fitting to the SA context are required. For example, while smart metering and/or prepaid meters are hailed the world over, some aspects of it are not practical in SA. In the township of Soweto for example, residents are known to attack Eskom workers who need to install prepaid meters as the region is known for refusal to pay electricity costs. Parts of rural SA do not have supportive infrastructure for using smart meters. Therefore, a more efficient use of money is to build social housing with solar panels where this is a once off cost and non-payment of electricity services will not be an issue.

Increasing private sector, donor and multilateral investments

- Involvement of DFI's to enhance the credit worthiness of rooftop solar energy SME's so that it is viable for private sector financial institutions to invest in this sector. Policies to allow households to sell excess solar generated electricity back to the grid will also increase investments in the sector. This will work to increase competition, decrease tariffs and reduce SA's carbon footprint.
    - Timeline for a DFI solution: 6 months, pilot to be implemented by 30 April 2022
    - Timeline for enabling policy:
- Solidifying and selling Eskom's Just Energy Transition plan as a plan to support COP 26 climate change goals will attract international private investors.
    - Timeline: The plan is already in existence, it will need to be fine-tuned for presentation by 01 November 2021.
- Tapping into academic research for innovative funding of microfinance solutions to increase the viability of mini-grids and solar home systems in rural South Africa.

- Timeline for microfinance solutions: 8 months, pilot to be implemented by 30 June 2022

Conclusion

In summary and conclusion, the 14-16% electrification gap in South Africa will require an energy-mixed solution if the 100% target is to be achieved by 2030. There are various measures which the country can take to optimize its operations by the adoption of new coal conversion techniques which have been successfully proven elsewhere. The growth forecast of energy storage shows that Hydrogen Fuel Cells and BES will be game changers, and more particularly accelerators towards 100% electrification.

The team has demonstrated that from the two main challenges South Africa is facing, the adoption of mini/micro-grids will be the most proficient and effective in the next 5 years. This strategy will serve the rural and off-grid communities of South Africa, while using wind and or solar energy to generate sustainable energy. This will further improve the circular economy of rural communities, when solar water pumps are integrated into small and medium agricultural farms.

The journey to 100% electrification would be smoother if there were no power plants being decommissioned at the same time. However, our proposed plan, allows for nuclear and biomass power plants to step in the gap within the next decade. Furthermore, the improved process of using smart-metering by communities will bring energy management into the fold. We have also proposed that as the local municipalities incorporate mini-grids, the commissioning of smart-meters should follow hand-in-hand. This method allows for a tighter grip on the supply of energy to willing buyers, households and businesses. This will further deregulate and unbundle the tariff price system, making it an open market where buyers will be able to purchase energy cheaper during off-peak periods and save on their overall expenditure. This will affect how business is done and the working patterns of the country will change to suit the off-peak tariff prices.

Overall Eskom will benefit from this strategies and so will the end-user.

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