MOZAMBICAN GAS – AN ECONOMICALLY VIABLE SOLUTION TO THE SOUTH AFRICAN ELECTRICITY CRISIS?

MSc (50/50) RESEARCH PROJECT

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Declaration

I Declare that this research report is my own unaided work. It is being submitted for the degree of Master of Science (Engineering) to the University of Witwatersrand, Johannesburg. It has not been submitted for any degree or examination to any other University

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Dedication

To my Family and friend who provided me with unwavering support throughout this entire process.

Keywords

Economics of Using Mozambique Gas, Mozambique, Mozambique Gas, Mozambique Gas Cost, Mozambique Gas utilised for Power in South Africa, South African Power Shortage, Gas to Power South Africa.

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ABREVIATIONS

Btu – British Thermal Unit (unit of energy require to raise the temperature of water)

CCGT – Combined Cycle Gas Turbine

CO_2 - Carbon Dioxide

GJ - Gigajoules

GW - Gigawatt (One thousand Megawatts)

GWh - Gigawatt hour

IPP - Independent Power Producer

IRP - Integrated Resource Plan

kW - Kilowatt (One thousandth of a Megawatt)

KWh – Kilowatt Hour

LNG - Liquefied Natural Gas

MMBtu – 1 Million British Thermal Units (standard measure of natural gas)

NERSA - National Energy Regulator of South Africa; alternatively, the Regulator

OCGT - Open Cycle Gas Turbine

Abstract

Mozambican Gas – An Economically Viable Solution to the South African Electricity Crisis?

The recent significant discoveries of gas in Mozambique could provide a much needed solution to the South African electricity crisis, but at what cost? This research report seeks to determine the economic viability of utilising Mozambican Gas to produce electricity by using data from the Integrated Resource Plan 2010-2030 Update of 2013 in a levelised cost of electricity model.

The Mozambican gas fields are yet to be developed and the final price at which gas will be available is unclear, but a price range determined by ICF international in a study for the World Bank is assumed for the purposes of the study, with the results yielding a range levelised cost of energy.

The results of the levelised cost determine that Mozambican gas can be utilised to provide an economical solution to the south African electricity crisis, but the price at which gas is available will determine the type of generation, either peaking power, mid-merit and or baseload generation.

1. INTRODUCTION

Over the past 8 years South Africa has been experiencing an electricity crisis with few options at hand to solve the increasing problem of electricity shortages that results in devastating effects on economic growth. Imminent new coal fired capacity that will gradually come online over the next few years will provide some relief on the electricity system but by no means will these pants solve the electricity crisis (Mckinsey, 2015).

Insufficient power supply is causing serious economic growth constraints within the country with Deloitte estimating that load shedding “shaved 0.5% off GDP growth costing the economy R11.3 billion” (Deloitte, 2015). The South African economy is severely coal intensive with 70% of primary energy and 85% of all electricity production derived from coal (Deloitte, 2015). The heavy reliance on coal for electricity generation means South Africa contributes disproportionally to global greenhouse gas emissions. Data from the world resource institute suggests that South Africa was the 17th largest contributor of greenhouse gases while being the 33rd largest economy in the world (Deloitte, 2015).

South Africa faces challenges in safeguarding its energy security going forward and to try and understand these challenges and possible solutions, the South African Government has crafted a long term energy strategy called the Integrated Resource Plan 2010-2030 which is “built on sensible principles of diversification” (Mckinsey, 2015). The long term implementation strategy (the Integrated Resource Plan 2010-2030) seeks to realise a new mix of coal, nuclear, natural gas hydropower and renewables in order to diversify the electricity supply mix in order to meet growth in demand while trying to reduce the carbon intensity of the economy.

The Integrated Resource Plan 2010-2030 which is a comprehensive long term diversification plan will take time to implement. Recent developments in the Gas Sector in the region could present a very attractive opportunity to diversify the primary energy mix cost effectively while achieving reduced emissions targets, this is what this paper seeks to determine.

1.1 Problem Statement

The security and sustainability of electricity supply is essential for any developed economy, however "determining the appropriate level of supply security is a trade-off between the costs involved in improving power system reliability and the losses to the economy and customer welfare associated with power outages" (Wilson and Adams, 2006). To ensure electricity supply one must take into account the growth in demand for energy, types of resources available, lead time of infrastructure, environmental impact and considerations, the global political landscape, together with the ultimate capital cost and variable costs of the different types of technology.

Selecting the technology is a multi-dimensional task. One has to balance the lead time of construction to meet a constantly changing demand profile while ensuring adequate reserve margin in capacity supply that allows for fluctuations in demand and downtime for maintenance. Inadequate planning, poor execution and slow reactions to energy policy and infrastructure development can lead to catastrophic consequences for any economy. South Africa has tumbled from a state of cheap and abundant electricity supply in the late 1980's, to emergencies being declared in 2008, 2014 and 2015 resulting in rolling black-outs or more commonly referred to as "load shedding" (Trollip, et al., 2014).

As result growth expectations for Africa's most advanced economy has revised downwards with power shortages sighted as the main reason, South Africa's power supply crisis poses the biggest obstacle to growth (International Monetary Fund, 2014).

A country's economy and its energy use, particularly electricity use, are linked. In the same way energy use is linked to growth, electricity constraints or "load shedding" comes at a great cost to economy. Chris Yelland, an energy expert has reported that "Stage 1 load shedding resulting in 10 hours of blackouts per day for 20 days a month results in losses of R20 billion per month" (Yelland, 2015). South Africa is becoming economically uncompetitive, the increased scarcity of electricity combined with escalating cost of energy has serious implications for the economy, such as: Increased uncertainty, higher input costs, increased inflation and job losses. This is Important in a country that is struggling to achieve employment growth, where the unemployment rate sits at 25% (Mckinsey , 2015).

The significance of this is that the electricity problem is not only the inconvenience of having the lights go off every now and then. It is the view of the author that Consistent, reliable and affordable electricity is needed to achieve and sustain economic growth. New capacity decisions are vital to ensuring the sustainable delivery of electricity while choice of technology will determine the price of that energy. Therefore, the South African Government needs to ensure that all scenarios are thoroughly investigated in order that the correct investment decisions are made timeously to avoid a catastrophic shortage of electricity.

1.2 Purpose of this Study

This project aims to determine whether Mozambique's gas resources have the ability to provide, reliable, cost effective and efficient energy source for the South African market. This study will seek to achieve the following objectives:

- Investigate Gas Power Generation technologies to understand the advantages and disadvantages, in order to determine suitability for the South African market

- Investigate the South African energy sector by looking at
    - Current and future electricity supply and demand
    - Capacity and different types of electricity generation
    - Current carbon emissions

- Analyse Mozambique's newly discovered gas resources and reserves.

- Assess the economic and sustainable use of Mozambique's gas resources and investigate the benefit of using Mozambique's gas resources for power generation.

- Develop a levelised cost model to determine the economics of utilising Mozambican gas to generate power for the South African market.

2. LITERATURE REVIEW

2.1 Natural Gas

Natural gas is a hydrocarbon primarily made of methane (CH_4) that is formed from the "decomposition and pressurisation of algae, plankton and other organisms and organic material" (Price Waterhouse Coopers, 2015). These organisms collect on the bottom of seas and lakes and are buried by sediment over several millennia, as they are driven deeper into the earth crust they are subjected to colossal heat and pressure where they break down to form hydrocarbons (Price Waterhouse Coopers, 2015).

Natural gas is being utilised as a feedstock more extensively on a global scale, because it is seen as an attractive alternative to crude oil and coal (Mckinsey , 2015). Since it burns cleaner it is an appropriate alternative for power generation, industrial heating and as an industrial feedstock for chemical and liquid fuel products. Due to its clean burning characteristics, combined with the recent advances in extraction, and distribution technology and methods, natural gas consumption is increasing by 1.7% per annum (Price Waterhouse Coopers, 2015) making it the fastest growing fossil fuel by consumption globally.

2.1.1 Natural Gas Characteristics

Natural Gas has the following characteristics (Price Waterhouse Coopers, 2015):

- Shapeless without volume constraints
- Odourless, colourless and tasteless
- Non-corrosive
- A mix of hydrocarbon gasses mainly made up of methane (CH_4)
- Lighter than air, allowing leaks or emissions to quickly dissipate onto the upper layers of the atmosphere, making it less likely to form explosive mixtures in the air
- Efficient
- Abundant
- Lowest combustion greenhouse emission factor for fossil fuel.

2.1.2 Different Forms of Natural Gas

Once extracted and processed, natural gas is marketed, transported and utilised in 3 forms, namely,

1. Natural gas, Natural state as extracted after extraction and processing,

2. Compressed Natural Gas, pressurised to 200 – 250 bars

3. Liquefied Natural Gas (LNG), when natural gas is super cooled into a liquid at about -162^{o}C,

2.1.3 Benefits of Using Natural Gas

Price Waterhouse Coopers (2015) has identified the following as the benefits of using natural gas:

- Natural gas is one of the safest, cleanest and most efficient forms of non-renewable hydrocarbon energy
- Natural gas can serve as an efficient alternative for petrol, diesel and coal and has a lower GHG emission and carbon footprint
- Construction lead times for gas infrastructure are significantly lower than coal and nuclear power stations
- Processes Natural Gas is virtually sulphur free, which means that corrosion resulting from sulphur dioxide is non-existent and factory equipment therefore requires less maintenance and lasts longer
- Natural Gas is a preferred hydrocarbon energy source as it is versatile, clean burning, safe and economical and thus can be used directly across a number of sectors and industries

2.1.4 Global Movement toward CO_2 Reduction

The movement toward producing cleaner energy has gained significant momentum, resulting in policy changes in many countries, one of the most significant being the Kyoto Protocol (Fletcher and Parker, 2007). The “Kyoto Protocol” negotiations were completed in late 1997. The protocol establishes legally binding, mandatory emissions reductions for the six major greenhouse gases (Fletcher and Parker, 2007). This agreement signed by 37 industrialized countries that have committed to reduce greenhouse gas emissions by 5% against the average in 1990.

In 2014 electricity generation and heat production made up 25% of global greenhouse gas emissions according to the intergovernmental Panel on Climate Change (Intergovernmental Panel On Climate Change, 2014), making it the single largest contributor to CO_2 emissions. Electricity generation being the largest contributor to CO_2 emissions means that policy makers are targeting cleaner forms of electricity generation in order to achieve the goals set out in the “Kyoto Protocol”. Eskom’s generation-mix infrastructure, dominated by its 13 coal-fired power stations, has contributed to making South Africa one of the largest carbon emitters amongst developing nations (Bohlmann, et al., 2015).

2.1.5 Global Natural Gas Reserves

Natural Gas is an abundant resource, and it is estimated that recoverable reserves could last up to another 240 years (Price Waterhouse Coopers, 2015). Natural gas is commonly grouped into two variations, conventional and unconventional. Conventional natural gas is extracted by flowing or being pumped to the surface, flowing freely from a conventional rock formation.

Unconventional natural gas is more difficult to extract because it doesn’t flow freely. Recent advances in technology (such a fracking) has made unconventional gas production possible and more economical. Unconventional gas includes coalbed methane, shale gas, tight gas and gas hydrates (Price Waterhouse Coopers, 2015).

Key Facts about Natural Gas (Price Waterhouse Coopers, 2015)

- Global Annual Natural Gas Consumption is 117tcf
- Annual Natural Gas Discoveries (Average 200-1010) is 134 tcf p.a.
- Proven World Reserve (including unconventional gas) is 6569 tcf
- World Technically Recoverable Natural Gas Resources 27900 – 28605 tcf
- Proportion conventional technically recoverable natural gas reserves is 58%
- Proportion unconventional technically recoverable natural gas reserve is 42%
- Sub-Saharan % of world gas production in 2013 is 3.2%
- Sub-Saharan % of the world's proven reserves in 2013 is 3.3%

Unconventional reserves are increasing as technology advances in drilling and extraction methods enabling economic recovery of these previously unprofitable resources. Natural gas reserves are very highly concentrated in the Middle East and Russia, with 75% of proven reserves in these areas, while Africa only represents 7.6% of global reserves, with 502 tcf according to 2013 figures (Price Waterhouse Coopers, 2015).

2.1.6 Global Gas Demand and Supply

Gas is poised to become the preferred non-renewable energy source as the world moves to reduce carbon emissions and greenhouse gasses (GHG), demand is expected to grow at 1.7% compounded annual growth (Price Waterhouse Coopers, 2015).

The supply of natural gas continues to grow with increases in pipeline and liquid natural gas Infrastructure (U.S. Department of Energy, 2015). Where geographical constraints are favourable and distances from source to consumption are less than 3 000 km, a pipeline makes greater economic sense. Generally, any distances over 3 000 km, Liquefied Natural Gas tends to be more economically viable (Stanley et al., 2014).

2.1.7 Natural Gas Pricing

Natural gas due to its low in density and has traditionally been difficult to transport resulting in pricing being set in regional markets rather than in a global market (Deloitte, 2015). Because natural gas pricing in set in regional markets, the pricing mechanisms vary from region to region, with the Asian markets being oil linked and the United States markets being determined by spot rates (Stanley et al., 2014). “There is a strong argument that global prices will converge to some extent over the medium and long term” (Stanley et al., 2014). With various new supply projects coming online to serve the growing Asian market should see Asian prices drop to lower levels, resulting in a convergence of prices (Stanley , et al., 2014). The convergence is widely accepted, and the impression here is that the Asian prices will reach the USA prices (Putter, 2016)

2.1.8 Gas Value Chain

Figure 1 illustrates the natural gas value chain. The value chain is broken down into 3 segments i.e. Upstream, Midstream and Downstream.

Upstream is associated with the explorations and production of gas. **Midstream** is associated with the transportation and storage of gas. **Downstream** is associated with the processing and distribution/marketing of gas products.

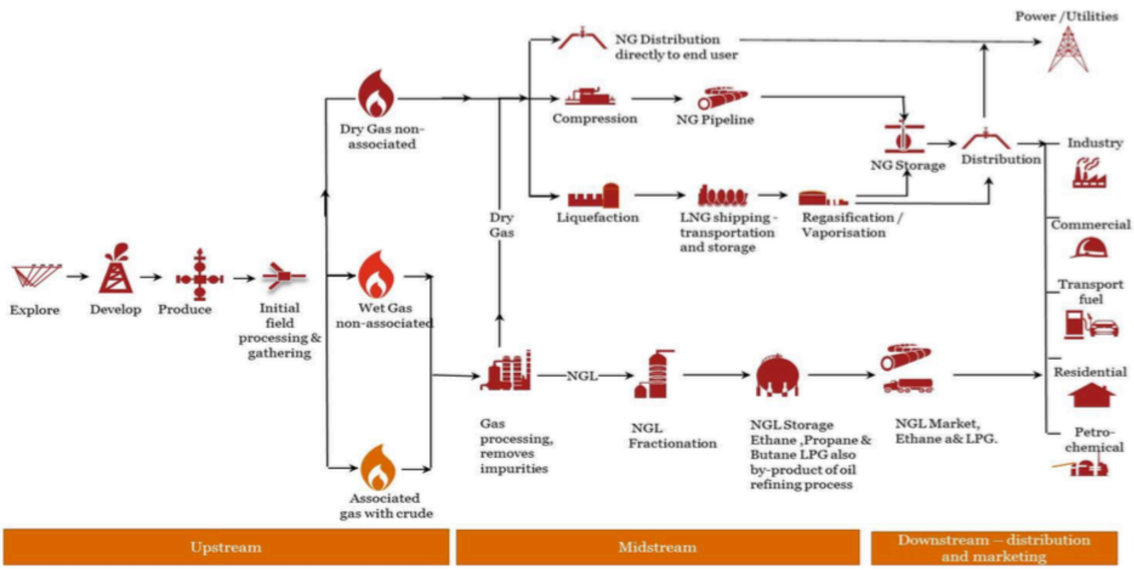

Figure 2.1: Natural Gas Value Chain (Price Waterhouse Coopers, 2015)

2.1.9 Natural Gas in SA

Natural Gas in South Africa accounted for 2.72% of total primary energy use in 2013 (BP, 2015). South Africa produced 41 billion cubic feet (bcf) of dry natural gas and consumed 173 bcf in 2013, with the difference of 132 bcf being imported from Mozambique via pipeline

(Energy Information Administration, 2015). South Africa has very limited proven domestic reserves, but a large potential upside of unconventional gas with estimated technical reserves of 390 tcf of shale gas and 12tcf of coal bed methane (Price Waterhouse Coopers, 2015).

The majority of gas produced domestically is from the aging offshore field F-A used as a feedstock for the Mosgas gas to liquids plant (Business Monitor International, 2015). A more extensive review of natural gas in South Africa will be completed in chapter 5.

2.2 South African Electricity Outlook

The South African economy is a commodity based economy that relies heavily on large scale energy intensive sectors like mining, processing and manufacturing (Bohlmann, et al, 2015). State owned utility Eskom supplies 95% of electricity and generates approximately 45% of electricity used in Africa (Business Monitor International, 2015) using a total of 23 different power generating assets that have a combined nameplate capacity of approximately 44 000 MW.

2.2.1 South African Power Crisis

South Africa has felt a “tight strain of electricity supply” (Bohlmann, et al., 2015), since a state of emergency was first declared in 2008, with load shedding (demand controlling) occurring in 2008, 2014 and 2015. According to the the Business Monitor International (2015) “South Africa's power sector is in turmoil as supply shortages and rolling blackouts continue to plague the country”. This is negatively affecting economic growth as industrial customers are encouraged to reduce their energy usage by state-owned utility Eskom. South Africa has suffered ongoing 'power emergencies' since the beginning of 2014, and warnings of load shedding have been mooted frequently (Business Monitor International, 2015).

Bohlmann, et al (2015) suggest that Eskom’s inability to meet demand has cost the economy a total amount equalling 10% total of GDP in 2015.

2.2.2 Deterioration of the Reserve Margin

U.S. Energy Information Agency (2015) states that “South Africa's electricity system is constrained as the margin between peak demand and available electricity supply has been precariously narrow since 2008”. Reserve margin is the available capacity or supply over and above demand.

2.2.3 Explaining the Supply Crisis

According to Bohlmann et al, (2015) Diminished electricity reserve margins, brought on by a steady increase in demand relative to a stagnant supply, have left the country’s electricity sector in desperate need of expansion in order to prevent further catastrophe. The post-apartheid government has key goals such as social transformation, with access to electricity being a key element of this objective. The Presidency of South Africa (The Presidency , 2015) published a 20-year review report that states states; there has also been a marked improvement in the percentage of households with access to electricity It increased from just over 50 percent in 1994/95 to 86 percent in 2013/14.

The combination of a growing population together with the amount of households connected to the grid has caused demand to grow at about 3.5% p.a. (Trollip, et al., 2014). Even though the demand growth was compounding at a severe rate policy makers made no new capacity plans until 2005 when Eskom made the investment decision for Medupi power plant (Trollip, et al., 2014). According to the the White Paper on Energy Policy of 1998 “unless additional capacity was added, demand would exceed supply by 2007” (Trollip, et al., 2014), and “investment decision would have to be made in 2000 and construction would need to begin in 2001 if the systems integrity was to be maintained” (Trollip, et al., 2014)

The result of a late capacity expansion decision by the Government combined with the compounded increase in demand lead to the deterioration of reserve margin and declining power available for distribution as a result of excessive pressure placed on the infrastructure combined with poor maintenance (Trollip, et al., 2014).

2.2.4 Declining Power Available for Distribution

The consequence of having diminishing reserve margins is that assets are placed under huge pressure to meet demand. “Given that the relatively tight supply demand balance is likely to persist for the next few years the South African power system will remain potentially vulnerable to any major power station outage either as a result of technical failures" (Wilson and Adams , 2006). With reserve margins at critical levels in 2008, unplanned maintenance to the power grid saw South Africa's first series of major load shedding hit the country. This was repeated again in 2014 when the coal silo collapsed at the Majuba Power Station (Wilson and Adams , 2006).

The result of reserve margin being under pressure is that planned maintenance at power plants has been increasingly "rolled over". This is due in part to a reduced opportunity to take plants out as the reserve margin has decreased (Wilson and Adams , 2006). With the reduced reserve margin, the electricity supply, demand balance is so tight that planned maintenance is being "rolled over" (i.e. postponed) because Eskom cannot take any supply out of the system without demand controlling (load shedding)."At the moment Eskom has a policy of trying to 'keep the lights on', which means avoiding maintenance on the power stations" (Kenny, 2015). When assets are inadequately maintained this often leads to reduction in efficiency as well as an increase in unplanned outages.

Table 2 represents the total volume of electricity available for distribution from 2009-2014. From this one can see that effects of inadequate maintenance and over-utilisation of assets, causing a declining availability of electricity for distribution.

Table 2.1: Power Availability in Gigawatt-hours (Stats SA, 2014)

2009	2010	2011	2012	2013	2014
229 599 GWh	238 272 GWh	240 528 GWh	234'174 GWh	233 105 GWh	231 445 GWh

2.2.5 Expected Demand Growth

South African demand forecasts are challenging to determine due to the following factors (Business Monitor International, 2015):

- Real demand figures are not currently being expressed due to demand control being exercised by Eskom.
- Higher electricity prices have caused consumers to "cut back"

- The National Development Plan (NDP) is looking at infrastructure spending to industrialise South Africa and create jobs (Manufacturing and industrial Industry is energy intensive).
- The South African population is growing as well as increasing average standard of living, increasing number of consumers as well as energy intensity per consumer.
- Technology advances in energy savings could reduce an increase in demand.

2.3 South Africa's New Build Policy

South African's electricity capacity expansion program is published by the Ministry of Energy in a document called the Integrated Resource Plan 2010 -2030 (IRP). The Integrated Resource Plan proposes the "new build fleet for South Africa for the period 2010 to 2030" (Department Of Energy, 2010). "The Integrated Resource Plan (IRP) is a living plan that is expected to be continuously revised and updated as necessitated by changing circumstances" (Department Of Energy, 2010). The report takes into account various inputs and objectives to plan electricity infrastructure development that ensures a "cost-optimal solution for new build options, which was then "balanced" in accordance with qualitative measures" (Department Of Energy, 2010).
These qualitative measures are matters such as:

- "Reducing carbon emissions;
- New technology uncertainties such as costs, operability, lead time to build etc.;
- Water usage;
- Localisation and job creation;
- Southern African regional development and integration; and
- Security of supply." (Department Of Energy, 2010).

2.3.1 IRP 2010 – 2030

The IRP 2010-2030 final draft released in March of 2011 takes aims to double capacity by 2030. Table 3 displays the total capacity per generation technology and figure 2 graphically represents this split

Table 2.2: Energy Supply Mix (Department Of Energy, 2010)

Power Generation Plant Type	Total Capacity MW	% Total
Coal	41'071	45.83%
OCGT	7'330	8.18%
CCGT	2'370	2.64%
Pumped Storage	2'912	3.25%
Nuclear	11'400	12.72%
Hydro	4'759	5.31%
Wind	9'200	10.27%
CSP	1'200	1.34%
PV	8'400	9.37%
Other	980	1.09%
Total	89'622	100.00%

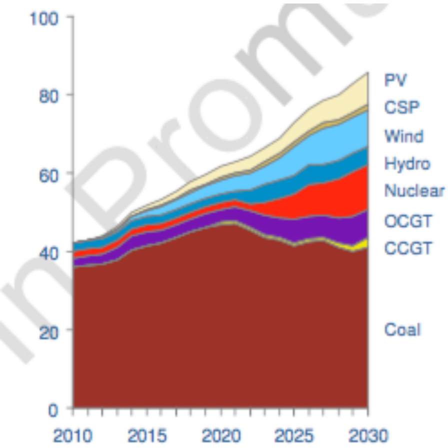

Figure 2.2: Energy Supply Mix

(Department Of Energy, 2010)

In figure 2.2 one can see growing role of renewables and nuclear power, with coal power still playing an important role. Gas represented by OCGT/CCGT (Open Cycle Gas Turbines / Combined Cycle Gas Turbines) has a smaller role to play according to the IRP 2010-2030 with lack of cost effective sourcing sighted as the problem. The significant regional developments in the gas resource discoveries have not been taken into account in the IRP 2010-2030 as they occurred after the document was formulated.

2.3.2 IRP 2010 – 2030 Update (2013)

As stated above the IRP 2010-2030 is "a living plan that is expected to be continuously revised and updated as necessitated" (Department Of Energy, 2010). In 2013 a review of the IRP 2010-2030 was released that takes into account the "number of developments in the energy sector in South and Southern Africa" (Department Of Energy, 2013).

The developments that were taken into account in the updated report are as follows:

- Revision down of electricity demand scenarios due to lowering energy intensity and lower economic growth forecasts.
- The recent developments of gas in the region as well as the potential of shale gas
- Capital cost of nuclear capacity revised upwards
- Uncertainty around future fuel costs, specifically coal and gas.

Taking these developments into account, various recommendations were made:

- The use of Nuclear power (decision) has been delayed.
- Regional and domestic gas options need to be perused, with the opinion of the Ministry of Energy that domestic shale exploration needs to be stepped up.
- Regional Hydro projects in Mozambique and Zambia need to be realised.
- An analysis of the viability of extending the lifeline of the current assets needs to be undertaken.

The result of these developments on the “Base Case” can be seen in Table 2.3:

Table 2.3: IRP 2010-2030 Updated Base Case 2013

Updated Base Case 2013		
Technology Option	IRP 2010 (MW)	Base Case (MW)
Existing Coal	34746	36230
New Coal	6250	2450
Combined Cycle Gas Turbine (CCGT)	2370	3550
Open Cycle Gas Turbine (OCGT)	7330	7680
Hydro Imports	4109	3000
Hydro Domestic	700	690
Power Schemes	2912	2900
Nuclear	11400	6660
PV	8400	770
CSP	1200	3300
Wind	9200	4360
Other	915	640

2.3.3 Stance On Gas IRP 2010-2030 Update

The first draft of the IRP 2010-2030 in 2011 identified LNG as the main source of gas available at a price of USD 10 per MMBtu, making it only viable for peaking generation with OCGT. CCGT are mentioned for their favourable low capital cost as well the the short lead time of construction but with fuel costs USD 10 MMBtu, coal is a much more favoured option for baseload electricity generation.

The development of the Mozambican Gas fields is mentioned in the update but distance from source is identified as a challenge, and as a result shipping of LNG from Mozambique northern Rovuma fields is seen as a more viable option than a pipeline. A "Big Gas" scenario is mapped out by the report but is only considered to be a result of the Karoo shale gas providing cheap fuel cost (gas) at R50/GJ (Department Of Energy, 2013). The IRP 2010-2030 updated report doesn't put any real emphasis significance of the Mozambican gas discoveries and possible benefits for the South African energy system.

2.3.4 Imminent Capacity Expansions

Imminent capacity expansions refer to the new capacity that that investment decision has been made and is not included on the IPR 2010-2030. Eskom is currently in the process of building this capacity and integrating it into the national grid.

Ingula Pumped Storage Scheme:

The Ingula Pumped Storage Scheme is located on the little Drakensburg Range on the border on the Kwa-Zulu Natal and Free state provinces. The Pumped Storage Scheme is a combination of two dams that are 4.6 km apart that are each capable of holding 2 million cubic feet of water. The dams are connected by waterways in which the water is channelled through to either generate electricity or utilise excess electricity. Eskom states (Eskom, 2013), "To generate electricity during times of peak demand, water is released from the upper dam, passing through the pump/turbines, into the lower dam. During times of low energy demand, the pump/turbines are used to pump the water from the lower dam, back to the upper dam".

Medupi

Medupi is a Greenfields dry cooled coal fired power station located in the Waterberg (to the west of Lephalale) in the Limpopo Province. The Waterberg coal fields in Limpopo are estimated to have 75.7 billion tons of coal, more than 50% of South Africa's remaining reserves (Mgojo, 2012).

Kusile

Kusile is also a Greenfields coal fired power station under construction in Nkangala, Mpumalanga. The nameplate capacity of Kusile will be 4800 MW, the same as Medupi, making them both the fourth largest coal fired power stations in the southern hemisphere (Eskom, 2014). Kusile will be the first power station in South Africa to install Flue-gas desulphurisation (Eskom, 2015). This is a technology used to eliminate oxides of sulphur from exhaust gasses.

2.4 Significant Gas Discoveries in Mozambique

The recent significant discoveries of natural gas has thrust Mozambique into the lime light, making it one of the most promising countries in Africa in terms of natural gas. Mozambique's proven gas reserves have increased substantially from 4.5 tcf in 2013 to 98 trillion cubic feet (tcf) at the end of 2015 (Business Monitor International, 2015), resulting in Mozambique having the 13th largest proven reserves in the world (Energy Information Administration, 2014). Final recoverable reserves are not yet known until exploration companies book final reserves. Business Monitor International expects (Business Monitor International, 2015) "Mozambique to make its presence felt in the global LNG market by early/mid next decade". The exploration license holders are aggressively moving ahead on plans to develop the Rovuma basin discoveries with LNG trains leading the development (Stanley , et al., 2014).

Business Monitor International's view is that final investment decision delays, falling gas prices combined with infrastructure constraints as well as ongoing regulatory changes are challenges facing the stakeholders in the pursuit of developing these huge offshore resources. (Business Monitor International, 2015). In the view of the author this discovery is opportunity for South Africa to revise its energy policy to take advantage of the close proximity of the Gas, taking advantage of the reduced carbon emissions to supplement its coal intensive assets and planned nuclear programme expansion.

2.5 Constraints and Risk of Gas for South Africa

According the the Integrated Resource Plan (Department Of Energy, 2010) “Building gas-driven CCGT power plants requires the creation of gas infrastructure. In addition to the CCGT power plants, a LNG terminal needs to be decided on unless a suitable domestic supply is developed, and built together with the associated gas infrastructure”.

South Africa faces a number of challenges is realising the use of Mozambican gas as a feedstock, mainly a lack of infrastructure and distance between market and the source.

According to Price Waterhouse Coopers (Price Waterhouse Coopers, 2015) these are the challenges that face South Africa’s adoption of Gas:

- Current local demand exceeds supply
- Costly to establish infrastructure
- Limited local availability
- High upfront Costs
- Pricing uncertainty –including oil indexation
- Lead time to supply
- Not easily portable

2.6 Opportunities for the Adoption of Gas in South Africa

Natural gas is playing an increasingly important role in the primary energy production mix globally, following this trend South Africa has undertaken to increase use of gas for electricity generation as stated in the Integrated Resource Plan 2010 – 2030 (IRP). The question that needs to be answered is; ‘can supply challenges be overcome to give the South African market access to gas cost effective price that makes it an economically viable alternative to other electricity generation technologies?’

According to Price Waterhouse Coopers (2015), there have been number of local and international developments that’s make the availability of natural gas a viable option for South Africa. Price Waterhouse Coopers goes on to say there are several ways to service the demand for natural gas in South Africa, as follows (Price Waterhouse Coopers, 2015):

- Further pipelines could link the Sasol Pande-Temane gas fields to the offshore gas found in the North of Mozambique, providing further gas to South Africa.
- A proposed pipeline from Mozambique to Richards Bay could provide a further source of gas to South Africa.
- Piped gas from the Ibhubesi gas field on the South African west coast to supply natural gas to Eskom's Ankerlig power station in Atlantis.
- LNG supply is outstripping demand as a result of developments in North America, Australia and East Africa. This provides opportunities for additional gas supply to South Africa. Companies such as PetroSA, Sasol and Shell are investigating the feasibility of LNG import options. Larger ships and Floating LNG (FLNG) and Floating Production, Storage and Offloading (FPSO) facilities provide greater flexibility into the sector.
- Coalbed methane exploration is looking promising with Molopo oil and Kinetiko Energy evaluating results from their exploratory drilling activities.
- Shale gas exploration permits are being processed by the Petroleum Agency of South Africa (PASA). If the reserves are commercially viable then possible production from around 2023. Shale gas technology has significantly improved over the last few years and will assist the development of shale gas exploration and production going forward.
- CNG tankers supplying natural gas from Angola to the Western Cape are being investigated.
- "Chemical conversion options, of which the biggest potentials are Gas to Liquids, ammonia, methanol and ethylene. They are already practised in South Africa, but there is certainly potential for more GTL and ammonia (depending on cost of feed gas), whereas ethylene is also possible" (Putter, 2016)

From the above it can be seen there are various opportunities for South Africa to increase the use of gas in its primary energy mix. According to McKinsey (2015) the urgency to act on natural gas opportunity is growing. McKinsey (2015) also states that new coal assets Kusile and Medupi coming online should secure supply until 2020 only, and that demand growth combined with upcoming de-commissioning of existing assets will create a pressing need for new capacity. Nuclear power is a possible option but due to its complexity and safety requirements the lead time of construction is very long.

McKinsey (2015) also positions that although new coal and nuclear assets are important for the base load supply of electricity neither is likely to be available in time to address the capacity crunch of 2020-2030. "Natural gas power has to be added on a schedule that would work to bridge the gaps until South Africa can realise its longer-term energy plans. Due to the modular nature of construction, the total lead time required to plan, design, and build a gas plant is two to four years" (Mckinsey , 2015). Once demand for Natural Gas has been established by the power sector, it can then be integrated into industry, transportation and housing markets growing the demand. A large demand base for gas means economies of scale for gas infrastructure can be leveraged off in order to reduce the input or cost price of gas.

3. Gas Power Generation

Natural gas power stations have the benefits of generating large amounts of reliable electricity with lower greenhouse gas emissions than any fossil fuel based power station while having no nuclear waste disposal problems (Price Waterhouse Coopers, 2015).

3.1 Types of Gas Power Stations

Gas power stations are a versatile technology that can be integrated into a power system in various sizes and forms to generate a reliable consistent base load, mid-merit generation or intermittent peaking load into an energy supply pool (Evans, et al., 2013). There are two main types of large scale gas power station plants: Open Cycle Gas Turbines and Combined Cycle Gas Turbines (as the names suggest these are both based on turbine technology). Gas turbines work on the same principles of a jet engines, they are theoretically very simple and have 4 stages: Intake (air and fuel), Compression, Combustion, Expansion Exhaust (where energy is converted).

This basic principle can be seen in Figure 3.1 below:

1. Air comes into the intake
2. Compression takes place in the compressor
3. Fuel and compressed air is mixed and combustion takes place
4. Air/fuel mixture combusts and expands, through the turbines that drive the output shaft.
5. Combusted hot air is expelled through the exhaust.

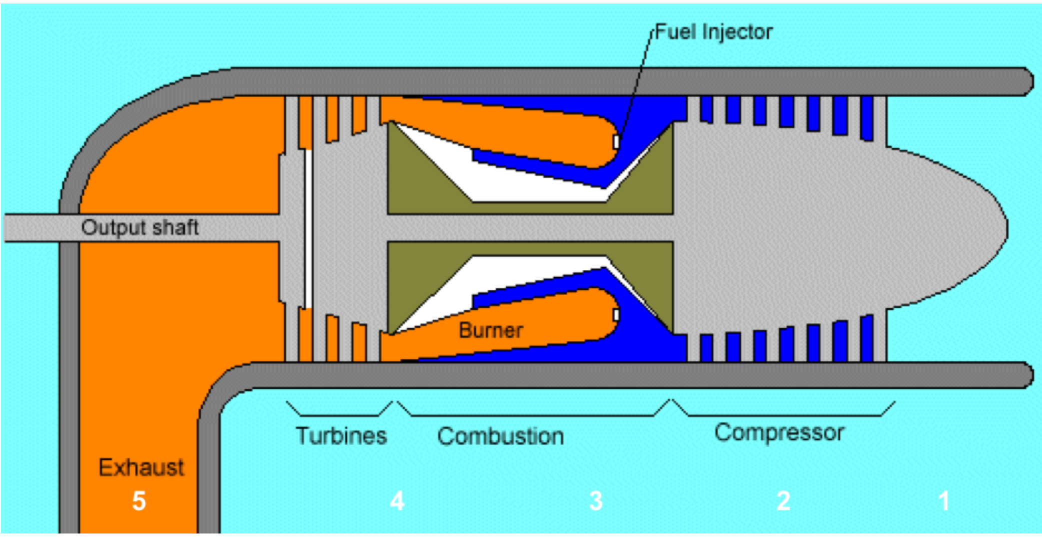

Figure 3.1: Basic Principles of Turbines (Brain, nd)

Open Cycle Gas Turbine (OCGT)

An open cycle gas turbine is a stand-alone gas turbine combustion unit that is typically operated to meet peak load demands as they have short start-up and shutdown cycles. The typical size of these units are 100-400MW and they have thermal efficiency of around 35-40% (Price Waterhouse Coopers, 2015).

Combined Cycle Gas Turbine (CCGT)

Combined cycle gas turbines are a combination of a combustion unit that is integrated with a steam turbine unit. These two turbine units are integrated to achieve greater efficiency by using the exhaust gases that are otherwise wasted (out of the Open cycle gas turbine to generate steam for a steam turbine unit). CCGT's are run at higher temperatures to create increased amounts of exhaust gases which are captured to boil water and create steam, for the steam turbine therefore, generating more power from the same amount of fuel input (Price Waterhouse Coopers, 2015). This results in a much greater (50-60%) thermal efficiencies (Price Waterhouse Coopers, 2015).

3.2 Natural Gas and Liquefied Natural Gas

Natural gas can be supplied in various ways to a power station but it is predominantly supplied via a pipeline. The source of the gas may come from a direct transmission pipeline from the gas processing facility, or from a LNG regasification facility.

Natural Gas Transmission Pipeline

Where the proximity to source (under 3000 km) and geographical conditions will allow the cheapest and safest way to transport gas is through a pipeline network from source to end users (Stanley et al., 2014).

Liquefied Natural Gas

Where proximity and geographical conditions do not allow for natural gas to be transported through pipelines, the natural gas is liquefied at the source and transported by specifically designed refrigerator ships. If the distance is greater than between 2000 and 3000km then LNG transport solution is more viable than a pipeline (Price Waterhouse Coopers, 2015). The typical LNG process is that natural gas is extracted and processed to remove impurities, it is then cooled down to -162^0 C to liquid form and transported in specialised refrigerator ships to a LNG receiving terminal. The LNG is re-gasified into natural gas and distributed by pipeline to end users (Price Waterhouse Coopers, 2015).

3.3 Comparison to Other Forms of Power Generation

When generating large amounts of electricity various technologies are used in conjunction with each other to create in order to to create a balanced supply scenario that accommodates for demand cycles, while taking into account various constraints, objectives and requirements of the system. Table 3.1 below shows a comparison of a number of electricity generation technologies showing a rating of their characteristics of between 1 and 5 (1 - being unfavourable and 5 - being most favourable).

Table 3.1: Comparison of various power generation technologies: (Price Waterhouse Coopers, 2015)

	Natural Gas	**Coal**	**Nuclear**	**Hydro**	**Wind**	**Biomass**	**Geothermal**	**Solar**
Construction Cost	5	4	1	3	4	3	2	3
Electricity Cost	5	5	4	2	3	3	3	2
Land Use	4	3	5	3	2	1	4	2
Water Requirements	3	1	1	3	5	1	3	5
$C0_2$ Emissions	3	1	5	5	5	4	4	5
Non-CO_2 Emissions	3	1	5	5	5	2	4	5
Waste Products	5	1	3	5	5	2	4	5
Availability	5	5	5	3	0	5	5	1
Flexibility	5	3	2	5	0	3	4	1

1 = Least Favourable: 5 = Most Favourable.

From this table one can establish that natural gas is a well-balanced technology that offers a low construction cost, low operating cost, relatively small land usage, has below average water requirements, produces less pollution than coal, has little waste product, it is very flexible, while having high availability.

3.4 CO_2 Intensity

The global movement toward reducing greenhouse gas emissions in order to combat global warming as discussed in chapter 2.1.4 illustrates that policy makers are looking at alternatives that produce lower greenhouse gas emissions.

Table 3.2 indicates the amount of CO_2 emissions for fossil fuel based thermal power stations for each source of energy in pounds of CO_2 emitted per million British thermal units (Btu) of energy for various fuels.

Table 3.2: Fossil Fuel CO_2 Emissions per Btu (Energy Information Administration, 2015)

Fossil Fuel	Pounds Of CO_2 per Btu
Coal (anthracite)	228.6
Coal (bituminous)	205.7
Coal (lignite)	215.4
Coal (subbituminous)	214.3
Diesel fuel and heating oil	161.3
Gasoline	157.2
Propane	139
Natural gas	117

From Table 3.2 it can be seen that natural gas emits the lowest amount of CO_2 per thermal unit, making it the cleanest option of the fossil fuel power generation. According to McKinsey (2015) New combined-cycle gas turbine plants produce less than half the carbon emissions of new coal plants (at 388 kilograms per megawatt-hour, compared with 947 kilograms for coal). “Gas is also practically free from sulphur dioxide and carbon monoxide emissions” (Deloitte, 2015). From an environmental stand point natural gas provides a very attractive solution for South Africa as it has low greenhouse gas emissions, and no nuclear waste disposal issues.

3.5 Cost of Producing Power from Gas

Capital Expenditure

The United States Energy Information Agency released a comparative cost of electricity generating technologies. The costs in Table 3.3 are shown as:

1. Construction (Overnight Capital Cost)
2. Fixed Maintenance Costs (Fixed Operational and Maintenance (O and M) Costs)
3. Variable Maintenance Costs (Variable Operational and Maintenance (O and M) Costs)

From Table 3.3 it is clear that gas power technology on a relative capital cost for construction and operation (this does not include the cost of the fuel feedstock) basis is a very cost effective choice of technology.

Table 3.3: Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants: (Energy Information Administration, 2013)

Type Of Technology	Plant Characteristics		Plant Costs (2012$)		
	Nominal Capacity (MW)	Heat Rate (Btu/kWh)	Overnight Capital Cost ($/kW)	Fixed O and M Cost ($/kW-yr)	Variable O and M Cost ($/MWh)
Coal					
Single Unit Advanced Pulverized Coal	650	8'800	$3'246	$37.80	$4.47
Dual Unit Advanced Pulverized Coal	1'300	8'800	$2'934	$31.18	$4.47
Natural Gas					
Conventional Combined Cycle Turbine	620	7'050	$917	$13.17	$3.60
Conventional Open Cycle Turbine	85	10'850	$973	$7.34	$15.45

Advanced Open Cycle Turbine	210	9'750	$676	$7.04	$10.37
Uranium					
Dual Unit Nuclear	2'234	N/A	$5'530	$93.28	$2.14
Wind					
Onshore Wind	100	N/A	$2'213	$39.55	$0.00
Offshore Wind	400	N/A	$6'230	$74.00	$0.00
Solar					
Solar Thermal	100	N/A	$5'067	$67.26	$0.00
Photovoltaic	20	N/A	$4'183	$27.75	$0.00
Photovoltaic	150	N/A	$3'873	$24.69	$0.00
Conventional Hydroelectric	500	N/A	$2'936	$14.13	$0.00
Pumped Storage	250	N/A	$5'288	$18.00	$0.00

The cost of the fuel is not taken into account in the above Table 3.3. This cost has to be calculated on a case by case basis as there are many variables such as geographical location, infrastructure and market conditions.

3.6 Load Factors

Load factors are the average output of a power station divided by the peak load output. This calculation gives an indication the utilisation of a plant: below are the approximate load factors for the different electricity generation categories.

- Peaking power generation - 0%-20%
- Mid-merit generation - 20%-50%
- Baseload generation - 50% and above

Historically these Open Cycle Gas Turbines and Combined Cycle Gas Turbines have been used for peak load and mid-merit generation due to their short start-up and shutdown cycles however, advances in technology and efficiency combined with a larger availability of gas has resulted in new plants being used for base-load requirements (Price Waterhouse Coopers, 2015). The cost of gas in South Africa will determine to what extent gas can be utilised. The lower the cost the more economical generating power from gas will be, the more economical gas power is the greater the load factor will be.

4. Analysis of South African Electricity Market

As discussed in the the literature review South Africa's power sector is in turmoil, supply shortages are causing load shedding across the country that is causing economic growth to slow (Business Monitor International, 2015).

Eskom produces and distributes 95% of South Africa's electricity and according to the Business Monitor International Research Institute, failure to win regulatory permissions to hike electricity tariffs will inhibit Eskom's ability to stabilise its financial position "making it harder to fund measures needed to end load-shedding" (Business Monitor International, 2015). The recent supply shortages in 2014 and 2015 are an indicator of how vulnerable the South African Power infrastructure is currently.

According to Eskom in their latest financial report (Eskom, 2015), Significant operational constraints and uncertainties face them in the short term. These are centred on the trade-offs between meeting the country's electricity demand while operating their Generation fleet in a sustainable manner, as well as meeting legal and regulatory requirements and remaining financially viable. As discussed in the chapter 2.2.2 Eskom has seen a dramatic reduction in the electricity reserve margin, putting the existing power infrastructure under significant strain to keep the lights on.

The new generating capacity coming online will "merely be playing catch-up to demand" (Business Monitor International, 2015). In a strengths, weaknesses, opportunities and threats (SWOT) analysis of the South African Electricity market done by Business Monitor International shown in table 4.1, demonstrates that maintenance delays as well as new build project delays are having a considerable effect on the ability of Eskom to deliver on its mandate. There are significant opportunities within South Africa but Eskom's dire financial position will hinder its ability to exploit these opportunities, privatisation may be the answer to South Africa's problems, as reported by Business Monitor International (Business Monitor International, 2015) Privatisation could be forced on the government in the long run - although they do not think this will occur in 2015/2016 as it would be too contentious politically.

Table 4.1: South African Power SWOT Analysis: (Business Monitor International, 2015)

Strengths • Abundant indigenous supplies of coal make this fuel the favoured choice in terms of the cost of capacity expansion, as it is cheap and not vulnerable to international supply concerns. • Considerable renewable energy potential, with the country making progress in exploiting it. • Highest level of electrification rate in Sub-Saharan Africa. • South Africa's business environment and the power sector's level of development give the country an edge over many of its regional peers, incentivising developers to use the country as a base. • Broad political stability is likely to persist, owing to the African National Congress (ANC)'s dominance at a national and provincial level.
Weaknesses • Extensive use of coal in electricity generation implies rising carbon emissions; this will be a concern if a carbon tax is introduced by the government. • Outages are commonplace, having a severe impact on key industries such as mining and the manufacturing sector. • Delays in maintenance of existing power stations and the completion of those under construction give Eskom very little margin to cope with seasonal surges in power demand. • Lack of progress in privatising the power sector limits investments. • High currency volatility over the years has hampered investment planning.
Opportunities • Demand for South African coal is driving investments into expanding the mining sector and supporting infrastructure, including power. • Investment into the development of offshore gas fields and plans to import liquefied natural gas should support the development of new gas-fired power stations. • Relatively strong, independent institutions, including the judiciary and security services. • Research into underground coal gasification of poor-quality coal reserves should help widen the energy mix in the long term. • The lifting of a moratorium on hydraulic fracturing (fracking) and continued exploration across the offshore Ibhubesi gas project underpin their view that gas will ultimately play a greater role in the energy mix. • The power plant and transmission grid infrastructure will continue to offer investment opportunities over their forecast period and beyond, thanks to a buoyant renewables industry, pressure on state utility Eskom to boost generation and South Africa's nascent nuclear expansion plans. • Lack of energy supply has been identified as a critical challenge by the government.
Threats • The financial pressure facing Eskom has continued to mount over the last few years as delays in bringing large power projects online have eaten into projected revenue streams and exacerbated Eskom's debt exposure. • South Africa's power sector is in turmoil as supply shortages and rolling blackouts continue to plague the country.

- The economy continues to attract relatively low levels of foreign direct investment (FDI).
- South Africa's worsening corruption profile, particularly in political circles, could deter investment.

4.1 Market Regulation and Competition

The National Energy Regulator of South Africa (NERSA) regulates the electricity market, along with the pipeline and petroleum pipeline industries. NERSA is mandated to regulate electricity prices, as well as market participants through licensing Eskom dominates the South African electricity supply market, producing over 95% of South Africa's electricity (Business Monitor International, 2015). Eskom is also the sole licensed distributor of electricity in South Africa making this vertically integrated utility one of the largest power companies in the world (Business Monitor International, 2015). According to Business Monitor international the remaining 5% of electricity generation is produced by municipalities and other major companies (like Sasol) and the IPSA Group in Newcastle is the only independent Power Producer operating in South Africa (Business Monitor International, 2015).

4.2 Eskom Company Profile

Eskom is the South African electricity utility, formed in 1923 it became a wholly owned subsidiary of the government in accordance with the Eskom conversion action of 2002, forming Eskom Holding SOC ltd. According to Eskom its mandate is to "to provide electricity in an efficient and sustainable manner, including its generation, transmission, distribution and sale" (Eskom, 2015). They continue by stating that "Eskom is a critical and strategic contributor to Government's goal of ensuring security of electricity supply to the country as well as economic growth and prosperity" (Eskom, 2015).

Table 4.2 below is a SWOT analysis of Eskom compiled by Business Monitor International in their South African Power Report.

Table 4.2: Eskom SWOT Analysis (Business Monitor International, 2015)

Strengths
• Eskom generates approximately 95% of the electricity used in South Africa and approximately 45% of the electricity used in Africa. • Dominant generation portfolio. • Control of transmission network. • Monopoly position • Stock exchange listing.
Weaknesses
• State control reduces flexibility. • Inadequate historic investment levels. • Heavy emphasis on costly thermal power. • Inadequate generating capacity.
Opportunities
• Additional power stations and major power lines are being built on a massive scale to meet rising electricity demand. • Diversification into other power forms. • Eventual privatisation.
Threats
• The financial pressure facing Eskom has continued to mount over the last few year • Eskom's funding gap has been estimated at about R225bn for the next four to five years • Changes in national energy policy. • Macroeconomic headwinds. • Vulnerable to changes in coal prices.

Although Eskom benefits from a monopoly position in, this seems to have done little to protect the power utility from deteriorating performance and escalating financial vulnerability (Business Monitor International, 2015). "The government presented Eskom with a massive challenge, by failing to support the state owned group in developing generating capacity that would provide adequate supply as demand rose" (Business Monitor International, 2015).

4.3 Current Power Mix

Eskom Operates 23 power stations with a nameplate capacity of 44 094 MW. Table 4.3 below gives a breakdown of the power mix and their respective generating capacity and location.

Table 4.3: Eskom Total Installed Capacity (Eskom, 2015)

Type	Name	Installed Capacity (MW)	Location
Coal Fired PowerStation's	Arnot	2352	Middelburg, Mpumalanga
	Camden	1520	Ermelo, Mpumalanga
	Duvha	3600	Witbank, Mpumalanga
	Grootvlei	1200	Balfour, Mpumalanga
	Hendrina	1965	Hendrina, Mpumalanga
	Kendal	4116	Witbank, Mpumalanga
	Komati	940	Middelburg, Mpumalanga
	Kriel	3000	Kriel, Mpumalanga
	Lethabo	3708	Sasolburg, Free State
	Majuba	4110	Volksrust, Mpumalanga
	Matimba	3990	Lephalale, Limpopo
	Matla	3600	Kriel, Mpumalanga
	Tutuka	3654	Standerton, Mpumalanga
Nuclear Power Station	Koeberg	1910	Melkbossstrand, Western Cape
Conventional Hydro-Stations	Gariep	360	Norvalspont, Freestate
	Vanderkloof	240	Petrusville, Northern Cape
Pumped Storage Schemes	Drakensberg	1000	Bergville, KwaZulu Natal
	Palmiet	400	Grabouw, Western Cape
Gas/Diesel Fired Power Stations	Acacia	171	Cape Town, Western Cape
	Port Rex	171	East London, Western Cape
	Ankerlig	1338	Atlantis, Western Cape
	Gourikwa	746	Mossel Bay, Western Cape
Wind Farm	Klipheuwel	3	Klipheuwel, Western Cape
		44094	

Figure 4.1 is a geographical representation of these power stations locations. From figure 4.1 it is clear to see that concentration of coal power generation (85%) in the north east of the country with nuclear, OCGT and renewables making up the balance in the south.

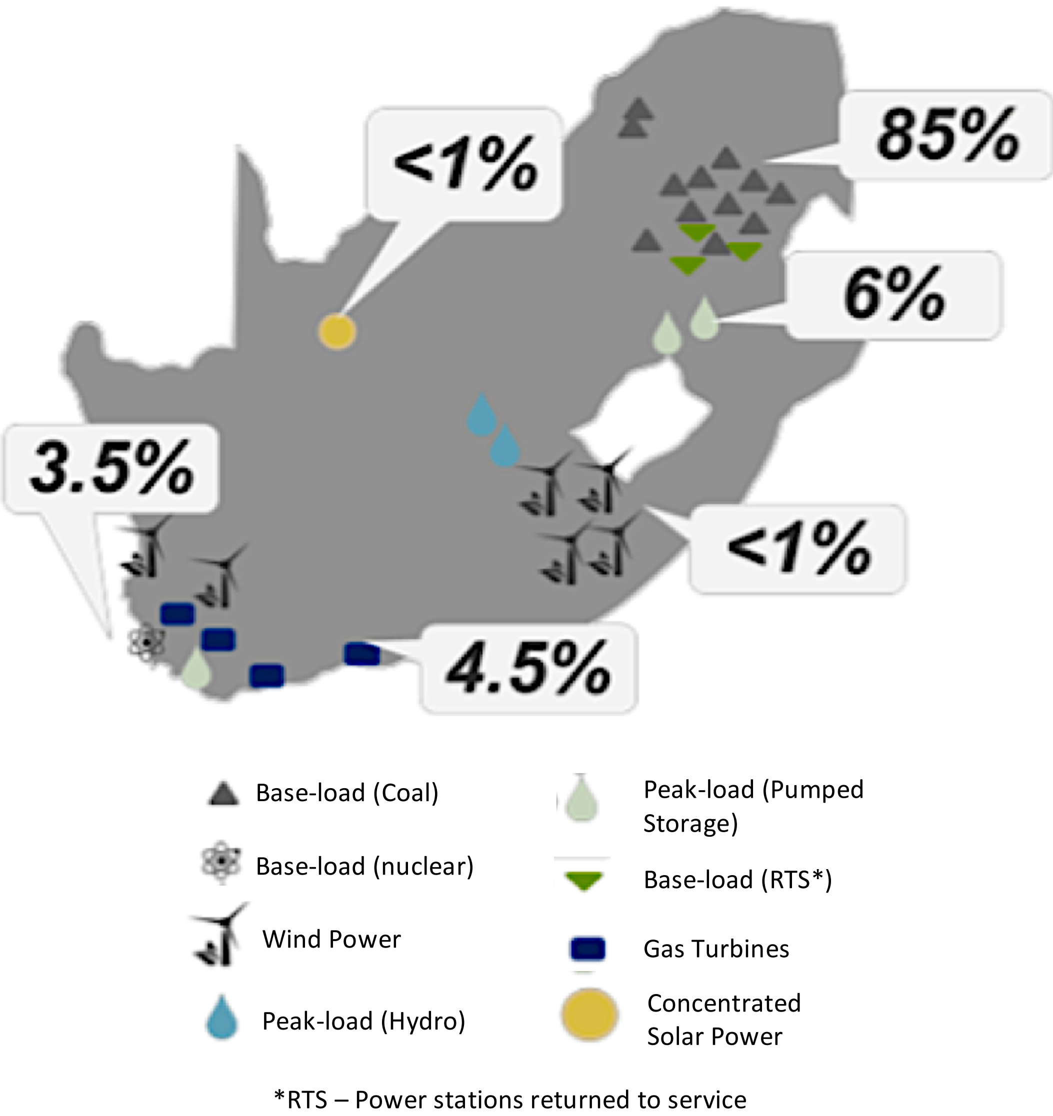

Figure 4.1: Geographical illustration of South African Electricity Supply Mix (Deloitte, 2015)**.**

4.4 Capacity Availability

As examined in the literature review South Africa has been experiencing declining power available for distribution. Chris Yelland (2015) reports, there has been a rapid decline in availability in generation capacity as a result of unplanned breakdowns combined together with increasing planned maintenance that is needed. Yelland (2015) continues to say that South Africa is in a situation of capacity constraints combined with low availability. Plant availability factor has decreased from 87.40% to 73.73% over the past 5 years (Eskom , 2015). Yelland states that a normal functioning utility should have an availability capacity of 85% (Yelland, 2015). According to Brian Molefe, the acting executive chairman of Eskom, “as a result of the tightness of the system, the opportunity for maintenance has reduced” (Molefe, 2015).

Molefe (2015) goes on to say that a large portion of the assets are past their midlife and therefore require longer maintenance outages and extended restoration programmes. Due to the low reserve margin, Eskom doesn’t have enough reserve margin to take units offline for maintenance, and as a result units are being run harder with less maintenance increasing the risk of breakdowns and unplanned outages (Molefe, 2015).

4.5 De-commission Schedule

New build planning and capacity expansion is vital to ensuring energy security, but equally important is the decommissioning schedule. All electricity generating assets have a finite lifespan and new capacity may only be replacing outgoing assets causing a zero sum scenario. According the Integrated Resource Plan for electricity 2010-2030 update of 2013, Table 4.4 below represents the planned decommissioning schedule for the current asset base.

Table 4.4: Eskom Decommissioning Schedule (Department Of Energy, 2013)

	mw		mw		mw		mw		mw		mw		mw		Total MW	Accumulated Total	Symbol	Station
2013	90	Ag													90	90	Ag	Aggreko
2014															0	90	PW	Pretoria West
2015															0	90	C	Camden
2016	90	PW													90	180	H	Hendrina
2017															0	180	Mt	Matimba
2018															0	180	K	Komati
2019															0	180	G	Grootvlei
2020	380	C													380	560	R	Rooiwaal
2021	190	C	380	H											570	1130	S	Sasol SSF
2022	570	C	380	H											950	2080	Ac	Acacia
2023	380	C	190	H	60	Mt									630	2710	Pr	Port Rex
2024	200	K	190	H											390	3100	Kr	Kriel
2025	100	K	190	H	740	Ar	180	G	180	R	500	S			1890	4990	Kd	Kendal
2026	100	K	190	H	370	Ar	360	G	480	Kr	180	Ac	180	Pr	1860	6850	D	Duvha
2027	300	K	380	H	370	Ar	180	G	480	Kr	60	Kd			1770	8620	Ml	Matla
2028	200	K			370	Ar	360	G	960	Kr					1890	10510	L	Lethabo
2029	360	K	580	Ml					960	Kr					1900	12410	Ak	Ankerlig
2030	1160	D	1160	Ml											2320	14730	Gk	Gourikwa
2031	580	D	580	Ml											1160	15890	Cge	Co Gen Etc
2032	580	D	580	Ml											1160	17050	T	Tutuka
2033	580	D	580	Ml											1160	18210	Ko	Koeberg

2034	580	D													580	18790
2035	580	T	590	L											1170	19960
2036	1160	T	590	L			360	Cge							2110	22070
2037	580	T			1220	Mt	1350	Ak	750	Gk					3900	25970
2038	580	T	1180	L	610	Mt	630	Kd							3000	28970
2039			590	L	610	Mt									1200	30170
2040	580	T	590	L	610	Mt									1780	31950
2041	280	mtp			610	Mt	1890	Kd							2780	34730
2042							630	Kd							630	35360
2043	150	S					630	Kd							780	36140
2044	1860	Ko													1860	38000
2045															0	38000
2046	610	Mj	1020	Ak											1630	39630
2047	610	Mj													610	40240
2048	610	Mj													610	40850
2049	670	Mj													670	41520
2050	670	Mj													670	42190

Mj	Majuba
Mtp	MTPPP
Ar	Arnot

The accumulated total of the decommissioning schedule shows the significant problem facing the South African electricity supply scenario. By 2028, the increased capacity of Kusile and Medupi will be offset by the planned de-commissions.

4.6 New Build Programme

The South African government has had significant success in adding renewable energy capacity to the South African power pool. The REIPPP (Renewable Energy Independent Power Producer Procurement Programme) that was introduced in 2011 has made South Africa a renewable energy hotspot, and has been successful in attracting the developers to the market (Business Monitor International, 2015). "The high rate of capacity growth registered by the market of the past two years and the strong investor interest shown in the auction, particularly from international renewables developers such as SunEdison, Enel Green Power and Mainstream, attest to the REIPPP's success" (Business Monitor International, 2015). This is reflected in the number of completed renewable energy projects that have been implemented, a total 3731 MW (out of 3913MW added) of renewables have been added to the power pool – this can be seen in Table 4.6.

Table 4.6 is the new capacity expansion that has been committed to and approved up to 2019, this is a total 14 375 MW of additional capacity. This new capacity has 3 major projects contributing to it, Medupi, Kusile and the Ingula Pumped storage scheme (10 896 out of 14 375 MW). Beyond 2019 there is currently 2 657 MW planned - all in renewables. All these renewable energy projects go a long way to achieving reduced carbon emissions but renewable energy has a very low capacity factor. Capacity factor is the average power generated by an asset, determined by dividing nameplate capacity by the average capacity generated by the plant.

In the United States the average availability factor per generation type is displayed in Table 4.5 as follows:

Table 4.5: Average Availability Capacity: (Ozgur, 2013)

Generation Type	Availability Factor
Solar Panels	10-15%
Wind Turbines	25%
Combined Cycle Gas Turbine	38%
Hydroelectric	40%
Coal Fired Power Plants	70%
Nuclear	89%

Table 4.6 illustrates that the availability factor of renewables can be extremely low due to their reliance on sun or wind which is subject to weather variability. Renewables then don't provide a strong reliable base load, which is what South Africa needs (Mckinsey , 2015).

Table 4.6: South African Power Projects Database (Business Monitor International, 2015)

Name	Province	Type	MW	Timeframe End	Status	Total MW Category
Sasolburg Gas Power Plant	Free State	Gas Fired Power Plant	140	2012	Completed	3'913
Rustmo 1	North West	Solar PV	7	2013	Completed	
Konkoonsies	Northern Cape	Solar PV	9.7	2013	Completed	
Aries	Northern Cape	Solar PV	9.7	2013	Completed	
Koeberg Upgrade	Western Cape	Nuclear	1'840	2013	Completed	
Kalkbult Solar	Northern Cape	Solar PV	75	2013	Completed	
Jasper	Northern Cape	Solar PV	96	2014	Completed	
Hopefield	Western Cape	Wind Farm	66.6	2014	Completed	
Noblesfontien	Northern Cape	Wind Farm	73.8	2014	Completed	
Greefspan	Northern Cape	Solar PV	11	2014	Completed	
Kathu	Northern Cape	Solar PV	75	2014	Completed	
Letsatsi	Free State	Solar PV	64	2014	Completed	
Lesedi Solar	Northern Cape	Solar PV	64	2014	Completed	

Kliphuewel	Northern Cape	Wind Farm	27	2014	Completed	
Sishen Solar	Northern Cape	Solar PV	94.3	2014	Completed	
Solar Capital De Aar	Northern Cape	Solar PV	85	2014	Completed	
Dreunberg	Eastern Cape	Solar PV	75	2014	Completed	
Linde Solar	Northern Cape	Solar PV	40	2014	Completed	
Droogfontien	Northern Cape	Solar PV	50	2014	Completed	
SlimSun	Western Cape	Solar PV	5	2014	Completed	
Herbert PV	Northern Cape	Solar PV	22	2014	Completed	
Soutpan Solar	Limpopo	Solar PV	28	2014	Completed	
Witkop Solar	Limpopo	Solar PV	30	2014	Completed	
De Aar Solar	Northern Cape	Solar PV	50	2014	Completed	
Dassiesklip	Western Cape	Wind Farm	27	2014	Completed	
Metro Wind Van Stadens Wind Farm	Eastern Cape	Wind Farm	27	2014	Completed	
Jeffreys Bay Wind Farm	Eastern Cape	Wind Farm	138	2014	Completed	
Grasridge	Eastern Cape	Wind Farm	60	2015	Completed	
West Coast One	Northern Cape	Wind Farm	94	2015	Completed	
Neusberg	Northern Cape	Hyrdo Electric	10	2015	Completed	
Sere Wind Farm	Western Cape	Wind Farm	100	2015	Completed	
KaXu Solar One	Northern Cape	Consentrated Solar Park	100	2015	Completed	
Red Cap Koega	Eastern Cape	Wind Farm	80	2015	Completed	
Dorper Wind Farm	Eastern Cape	Wind Farm	100	2015	Completed	
Cookhouse Wind Farm	Eastern Cape	Wind Farm	138.6	2015	Completed	
Dedisa	Eastern Cape	Open Cycle Turbine	335	2015	Under Construction	14'375
Gouda Wind Park	Western Cape	Wind Farm	138	2015	Under Construction	

Waainek Wind Farm	Eastern Cape	Wind Farm	24	2015	Under Construction	
Chaba Wind Farm	Eastern Cape	Wind Farm	21	2015	Under Construction	
Touwsriver	Western Cape	Solar PV	44	2015	Under Construction	
Bokpoort CsP	Northern Cape	Consentrated Solar Park	50	2015	Under Construction	
Boshoff Solar Park	Free State	Solar PV	60	2015	Under Construction	
Amakhala	Eastern Cape	Wind Farm	134.4	2016	Under Construction	
Tsitsikamma Community Development	Eastern Cape	Wind Farm	95	2016	Under Construction	
Ingula	KZN/Free State	Spumped Storage Scheme	1'332	2016	Under Construction	
Mulilo	Northern Cape	Solar PV	86	2016	Under Construction	
Avon Power Plant	Kwa Zulu Natal	Open Cycle Turbine	670	2016	Under Construction	
Khi Solar one	Northern Cape	Consentrated Solar Park		2016	Under Construction	
Eskoms Upinton CSP	Northern Cape	Consentrated Solar Park	100	2016	Under Construction	
Copperton	Northern Cape	Wind Farm	102	2017	Contract Awarded	
Xina Solar One	Northern Cape	Solar PV	100	2017	Under Construction	
KiPower	Mpumalanga	Coal Fired	600	2018	At Planning Stage	
Garob Wind Farm	Northern Cape	Wind Farm	140	2018	At Planning Stage	
Mzimvubu	Eastern Cape	Water Project	180	2018	Under Construction	
Kusile	Mpumalanga	Coal Fired	4'800	2018	Under Construction	
Grootegeluk	Limpopo	Coal Fired	600	2018	Under Construction	
Medupi	Limpopo	Coal Fired	4'764	2019	Under Construction	
Noupoort	Northern Cape	Wind Farm	80	Nd	Under Construction	2'657

Nojoli	Eastern Cape	Wind Farm	88	Nd	Under Construction	
Paleisheuwel	Western Cape	Solar PV	82.5	Nd	Under Construction	
Tom Burke Solar	Limpopo	Solar PV	66	Nd	Under Construction	
Kathu Solar	Northern Cape	Solar PV	100	Nd	Under Construction	
Gauteng Solar Project	Gauteng	Solar PV	300		At Planning Stage	
Mulilo	Northern Cape	Solar PV	9.7		At Planning Stage	
Khobab	Northern Cape	Wind Farm	140		Project Finance Closure	
Loeriesfontien	Northern Cape	Wind Farm	140		Project Finance Closure	
Redstone Solar	Northern Cape	Termal Solar	100		At Planning Stage	
Gibson Bay	Eastern Cape	Wind Farm	111		At Planning Stage	
Scatex Solar	Northern Cape	Solar PV	258		At Planning Stage	
Nxuba Wind	Eastern Cape	Wind Farm	141		At Planning Stage	
Oyster Bay Wind Farm	Eastern Cape	Wind Farm	142		At Planning Stage	
Karusa Wind Farm	Northern Cape	Wind Farm	142		At Planning Stage	
Aggeneys Solar	Northern Cape	Solar PV	45		At Planning Stage	
Konkoonsies II	Northern Cape	Solar PV	86		At Planning Stage	
Golden Valley	Eastern Cape	Wind Farm	120		At Planning Stage	
Roggeveld		Wind Farm	140		At Planning Stage	
Droogfontien 2	Northern Cape	Solar PV	86		At Planning Stage	
Lephalale Solar	Limpopo	Solar PV	30		At Planning Stage	
Kangnas	Northern Cape	Wind Farm	140		Contract Awarded	

Perdekraal	Western Cape	Wind Farm	110	Contract Awarded	
Total			**20'945.25**		

The Project database table (Table 4.6) reveals that 63.75% of new capacity is from wind and solar. Although South Africa have a high installed capacity the reality is that over 60% of that capacity has very low availability factors. Considering that supply is already constrained, and that renewables represent a large portion of new capacity, the renewable build program will do little to solve South Africa's Power Problems (Mckinsey , 2015).

McKinsey (2015) points out that Kusile and Medupi will add 9.8 MW of supply, and that this will secure electricity needs through 2020, but the combination of demand growth with the added pressure of the de-commissioning schedule this will create a pressing need for new capacity.

Coal fired power stations have a lead time of approximately 8 years in South African (Mckinsey , 2015), while nuclear power could take longer due to the increased complexity and increased safety requirements of the technology (Mckinsey , 2015). Taking this into consideration, nuclear or coal energy is likely to be available in time to address the crunch expected between 2020-2030 although both remain important for base-load supply beyond this period (Mckinsey , 2015). From this one can easily determine that beyond 2020, there will be a shortage of power supply resulting from extensive de-commissioning of existing assets, current new capacity being built is over 63% renewable energy based.

4.7 CO_2 Intensity

South Africa has extensive coal reserves, making coal power generation a "frugal choice" (Business Monitor International, 2015) in terms of cost of capacity expansion. Coal is "cheap and not particularly vulnerable to international supply concerns" (Business Monitor International, 2015). The result of this is that South Africa has a very carbon intensive economy. Eberhard (2011) states that South Africa is a major consumer of coal, mainly for electricity production, it also operates the world's only commercial coal synfuels (CTL) plant. It is amongst the twenty most carbon-intensive economies in the world. Carbon emissions are a key element in the decision making criteria of the Integrated Resource Plan 2010-2030 (Department Of Energy, 2010), and this commitment can be seen in South Africa's climate change pledges. South Africa promised to halt its rising greenhouse gas pollution by 2025, (Department Of Energy, 2013).

The implication of this is that South Africa has pledged to the United Nations Framework Convention on Climate change that will allow its emissions to plateau at current levels, then emissions will peak from 2020 until 2025, and then reduce from 2025 onwards. The South African Government will be investing heavily in the transformation of its energy sector to achieve these goals, according to the submission to the United Nations Framework Convention on Climate change.

The commitment to lower carbon emissions can be seen by the South African governments encouragement through policy, for the private sector to participate through the Renewable Energy Independent Producer Procurement (REIPPP) program. "According to Eskom over 1000 MW of renewable projects have been connected to the grid and a further 4280MW have been contracted" (Deloitte, 2015), this is reflected in the data in table 4.6.

Table 4.6 gives insight into the the success of the REIPPP program with over 63.75% of new build commitments being in renewables. As discussed in the new build section, while this is certainly a step in the right direction in terms of emissions renewables will do little to provide the large baseload capacity the South Africa desperately needs (Mckinsey , 2015).

4.8 Electricity Supply / Demand Forecast

Determining future electricity demand is a challenging feat that often yields unreliable results. This combined with unnatural market elements such as forced demand controlling (load shedding) and underwhelming GDP growth makes forecasting demand for South Africa particularly difficult.

The Mckinsey (2015) has forecasted the demand/supply balance into: high, medium and low demand scenarios after taking into account the existing and new committed sources of supply.

- **The High demand scenario** is based on 5.4% GDP growth as stated in the National Development Plan, modelling electricity demand growth on energy demand growth observed in other emerging economies of similar income levels

- **The Medium Demand Scenario** of 2.8% growth as stated in the Integrated Resource Plan for electricity (IRP) 2010–2030: Update report 2013, Department of Energy, 2013

- **Low Demand Scenario** of 1.8% growth in demand, this can be seen in figure 4.2

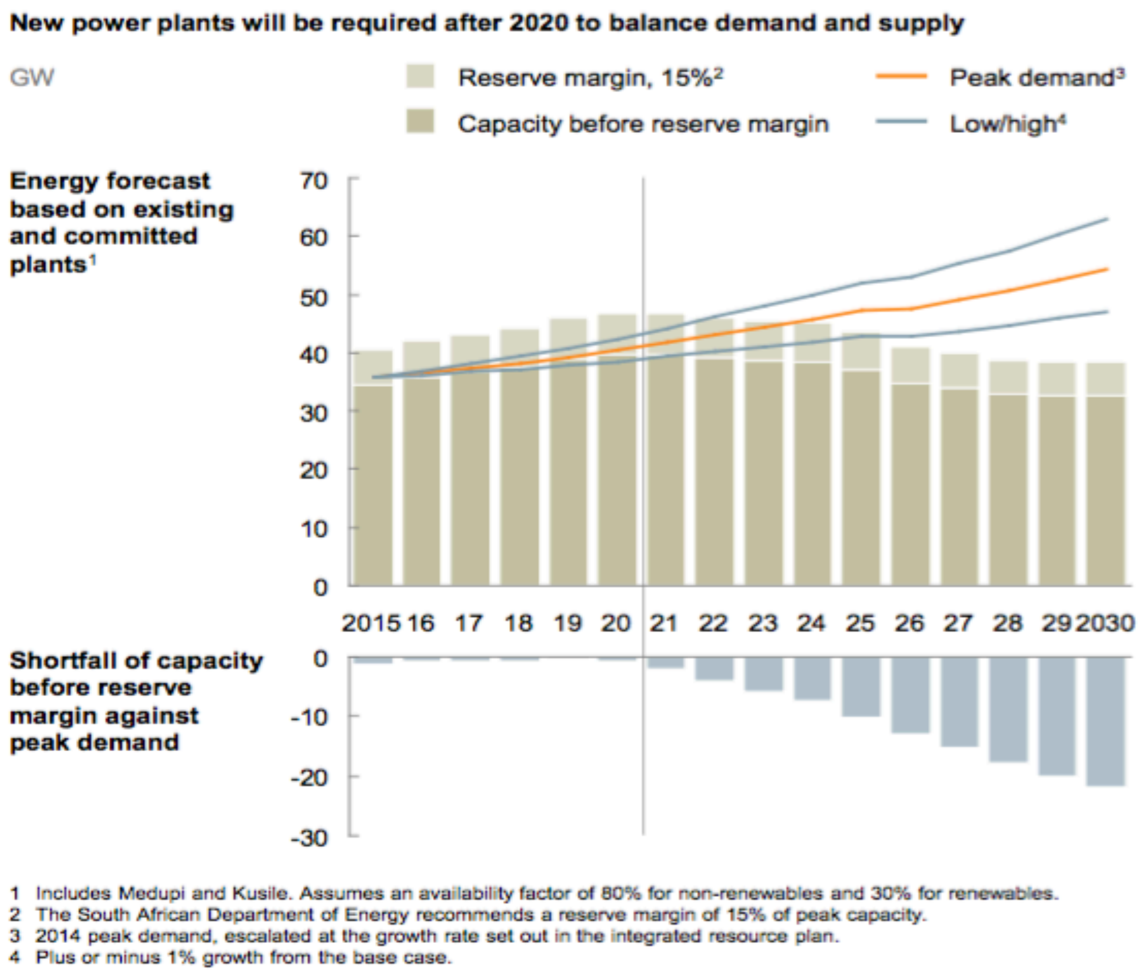

Figure 4.2: Supply/Demand Balance Forecast: (Mckinsey , 2015)

According to the Mckinsey report (2015), the results of this forecast are that South Africa will have severe under capacity of electricity supply, the resultant shortages (before reserve margin) in 2025 (these include the new projects in the power project database – table 4.6)

- **High Demand Scenario:** 11.6 MW Shortage (Mckinsey , 2015)
- **Medium Demand Scenario**: 10.2 MW Shortage (Mckinsey , 2015)
- **Low Demand Scenario**: 5.8 MW Shortage (Mckinsey , 2015)

4.9 Current Cost of Power

Table 4.7 below shows the cost per MW hours as per the Eskom financial statements (Eskom, 2015), from this it is clear to see that the real cost producing power has increased substantially, increasing over 100% in a 5-year period. In order to avoid power outages Eskom has been operating the diesel Open Cycle Gas Turbines for significantly longer than intended time periods (higher load factors). "Eskom ran these plants at a load factor of 19.3% in 2013/2014 which is well above the 5% - 10% for which they were designed" (Deloitte, 2015).

The diesel bill for the OCGT in the Western Cape alone was 10.5 billion rand for 2013/2014 (Deloitte, 2015). During December 2015 when there was extensive load shedding countrywide the Western Cape OCGT were run at over 60% load factor at a cost of R2 billion (Deloitte, 2015).

Table 4.7: Cost of Electricity: (Eskom , 2015)

Year End	**2015**	**2014**	**2013**	**2012**	**2011**
Cost of Electricity (Excluding Depreciation), R/MWh	610.43	541.92	496.24	374.19	296.36
Electricity Operating Cost per KWh (including Depreciation and Amortisation) R/KWh	0.6752	0.5967	0.5415	0.4182	0.3278

Eskom's escalating costs of producing power is causing financial pressure to mount, resulting in an estimated funding gap of R225 billion (Business Monitor International, 2015).

5. Natural Gas in South Africa

Prior to 2004, natural gas accounted for less than 2% of South Africa's primary energy demand. This demand is predicted to grow to 7% over the next 15 years to meet the growing electricity requirements (Price Waterhouse Coopers, 2015). The revised IRP 2010-2030 indicates that 2652 MW of electricity should be generated by gas by 2030 (Department Of Energy, 2013)

Although the forecasted growth in gas consumption will be for gas to electricity, the gas market was founded on the demand for gas to liquids and coal to liquids facilities firstly by Petro SA, for the production of Petroleum products and later Sasol for synfuels and chemical production.

5.1 Policy

The key drivers for increased consumption of natural gas in South Africa will be the implementation of the Integrated Resource Plan 2010-2030. Reduction of greenhouse gas emissions are a key function of the IRP 2010-2030 and gas has been identified as a source of electricity generation that could help South Africa reduce its greenhouse gas emissions from electricity generation (in the form of peaking power capacity). There are a number of policies and plans that support the utilisation of gas for the development of cleaner energy in South Africa and they are as shown in Table 5.1.

Table 5.1: Policies and Plans for the Development of Gas and Cleaner Energy (Deloitte, 2015)

Overreaching Economic Development Framework	National Development Plan 2011
Key National Energy Plans	Draft Integrated Energy Plans (IEP) 2012 Integrated Resource Plan 2010 Integrated Resource Plan 2013 Update
National Gas-Specific Energy Plans	Gas Infrastructure Development Plan 2005 (GIP) Gas Utilisation Masterplan (GUMP) - Forthcoming
Other Relevant National Plans	Industrial Policy Action Plan - IPAP 2014

There are key themes seen across all the development policies and plans seen in Table 5.1, these form the rationale behind the promotion of natural gas as an energy source in South Africa.

Table 5.2 below illustrates the unilateral rationale for the adoption of gas in South Africa for electricity generation seen across various policies and plans. This indicates that there is wide support of the utilisation of gas if it presents an economically viable solution.

Table 5.2: Key rationale for the adoption of gas across various policies and plans (Deloitte, 2015)**.**

Key Rationale or Economic Benefit	Description	NDP	IRP	IRP Update	GIP	IAPP
Lower Emissions	Substituting diesel or coal for gas lowers carbon emissions	✓	✓	✓		✓
Diversity in energy mix to improve security of supply	Gas available at lower prices (below $10 per MMBtu) could help SA to diversify its energy mix	✓		✓	✓	
Improves electricity grid stability	Gas power generation capacity is flexible supports renewables and improves electricity grid stability	✓		✓		
Attract private sector investment in power generation	The modular low-risk nature of gas-fired power plants means they are suitable private sector investments	✓				

Gas is price competitive alternative in a carbon-pricing or emissions constrained environment	Gas and particularly LNG is still expensive relative to coal but when a carbon price or emissions constraints are introduced its more competitive	✓	✓	✓		
Gas-fired power plants can be built in shorter time frames, at lower risk	Gas power plants are small modular investments relative to nuclear and mega coal and there is less construction and financial risk			✓		
Facilitate the development of local upstream and downstream industries	Gas can supports the development of specific downstream and upstream industries locally				✓	✓

NDP	National Development Plan
IRP	Integrated Energy Plan 2012
IRP Update	Integrated Resource Plan Update 2013
GIP	Gas Infrastructure Plan
IAPP	Industrial Action Policy Plan 2015

5.2 Key Stakeholders

The key stakeholders in the gas industry in South Africa are summarised below

5.2.1 Regulators

Price Waterhouse Coopers (Price Waterhouse Coopers, 2015) lists the following as the regulators of the South African gas industry:

- Minister of Mineral Resources
- Minister of Energy
- The Petroleum Agency of South Africa (PASA)
- National Energy Regulator (NERSA)

- The Transnet National Ports Authority
- Ports Regulator

5.2.2 Consumers of Gas

80% of all gas consumption in South Africa is feedstock for Synfuel and chemical production (Price Waterhouse Coopers, 2015). Sasol consumes 140 MGJ/a which is about 60% of total gas consumed while Petro SA consumes 48 MGJ about 20% of total gas consumed is South Africa (Price Waterhouse Coopers, 2015).

The remaining 20% is made up of 16% methane rich gas and 4 % natural gas and is consumed by a total of about 404 major end users (Price Waterhouse Coopers, 2015).

5.2.3 Gas Traders

Price Waterhouse Coopers states that there are six main gas traders in South Africa, Sasol Gas, Spring Lights, Reatile, Novo Energy, NGV gas and Virtual Gas Network (Price Waterhouse Coopers, 2015)

5.3 Upstream Production

Domestic production of natural gas for South Africa was estimated by Business Monitor International to be 42.37 billion cubic feet for 2014 (Business Monitor International, 2015). The majority of this gas is drawn from the offshore F-A and South Complex fields for the Mossel bay gas to liquids facility (Business Monitor International, 2015).

5.4 Gas Consumption

Business Monitor International States (2015) South African gas consumption is heavily constrained by supply, due to the lack of domestic production as well as importation and distribution infrastructure. The two Gas to Liquid facilities (Petro SA and Sasol Secunda) account for the bulk of demand with industrial and residential users absorbing the remainder (Business Monitor International, 2015). Gas Consumption for 2013 was 162.4 billion cubic feet, of that 120 billion cubic feet of this was imported (Business Monitor International, 2015).

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Figure 5.1 Shows the Business Monitor International forecast for natural gas consumption (light blue), production (dark blue) as well as the percentage year on year increases in demand (red). From the forecast one can see that domestic supply of gas is a huge constraint of demand and that local production increases to a peak in 2019, illustrating that the importation of natural gas supply will play in important role in meeting growing demand in the future.

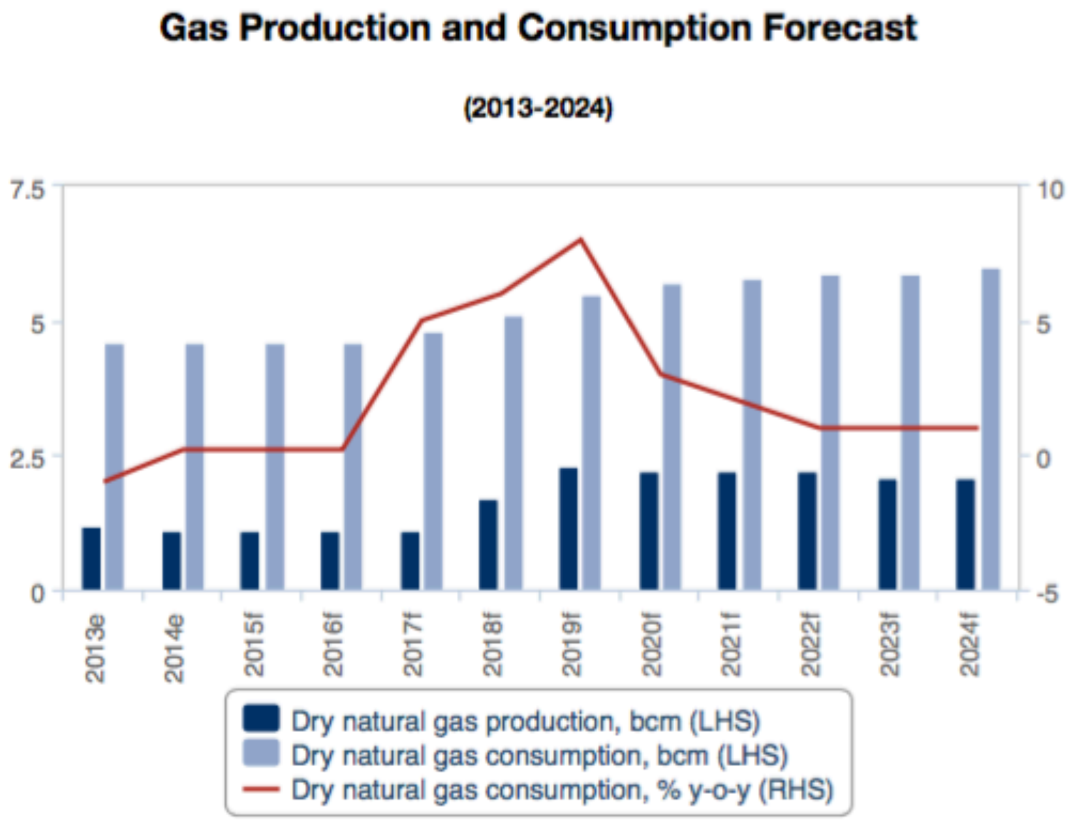


Figure 5.1 Gas Production and Consumption Forecast (Business Monitor International, 2015)

5.5 Potential Gas reserves of South Africa

5.5.1 Upstream Projects Conventional Gas

Ikhwezi

Petro SA (South African State Oil Company) is in the process of developing the Ikhwezi field (F-0 Field), this field is off the south coast and holds gas reserves of approximately 988.8 billion cubic feet which represents about 6 years of production (Business Monitor

International, 2015). This is aimed at sustaining the Gas to Liquids feedstock of the existing gas to liquids facility until other gas is available (Price Waterhouse Coopers, 2015).

Ibhubesi

The Ibhubesi field is located on the West coast of South Africa in the Orange Basin. This field is under development and has proven reserves of 210 billion cubic feet (Business Monitor International, 2015). Sunbird (the operator) has signed an agreement with Eskom for the delivery of 30.01 billion cubic per year to be used for supply of the Ankerlig open cycle gas turbine, replacing costly diesel feedstock (Business Monitor International, 2015).

5.5.2 Unconventional Gas - Coal Bed Methane and Shale Gas

Pilot coal bed methane projects with planned shale gas exploration has a significant upside potential for South Africa gas reserves. If the reserves are economically recoverable it has the ability to change the energy landscape of South Africa. Price Waterhouse Coopers (2015) expects the exploration process for shale gas is to take between 3 to 7 years and only once viable reserves are proven will gas infrastructure be setup which will take around two years.

Shale gas estimated technical reserves of 390 trillion cubic feet 8^{th} largest globally, while Coal Bed Methane technically recoverable reserves is 12 trillion cubic feet 12^{th} largest in the world (Price Waterhouse Coopers, 2015). Underground coal gasification from coal bed methane is a new and untested process that has yet to be proven commercially in South Africa and has no definitive timeline (Price Waterhouse Coopers, 2015).

5.6 Infrastructure

Natural gas in South Africa is almost entirely transported to customers via pipelines (Price Waterhouse Coopers, 2015). Figure 5.2 below illustrates the Gas pipeline infrastructure in South Africa.

- Sasol Gas that has about 1100 km of pipeline that they operate represented in blue. (Price Waterhouse Coopers, 2015)

- ROMPCO is the 865km gas importation Pipeline from the Temane Processing facility in Mozambique, to the Sasol Secunda facility - represented in green (Price Waterhouse Coopers, 2015)
- The Lilly Transmission Pipeline is 537 km, owned and operated by Transnet from Secunda to Durban for the transmission of methane rich gas represented in red (Price Waterhouse Coopers, 2015)

Figure 5.2: Main gas transmission and distribution lines on South Africa (Price Waterhouse Coopers, 2015)

*MRG - methane rich gas.

5.7 Drivers for Natural Gas Growth in South Africa

The biggest anticipated driver for natural gas in South Africa will be a feedstock for Electricity generation (Price Waterhouse Coopers, 2015). This is being driven by the IRP 2010-2030 on the back of governments commitment to reduce greenhouse gas emissions. Once demand is established by an "anchor client" such as electricity generation, gas utilisation can be expanded to industrial, transport and household users as discussed in Chapter 2.6.

6. Analysis of Mozambican Gas Reserves

6.1 Occurrence and Estimation of Natural Gas in Mozambique

The Gas industry in Mozambique was kick started in 2000 when Sasol conducted surveying activities in partnership with CMH S.A. (a subsidiary of ENH – the national hydrocarbon company) in a project aimed at developing 120 million Giga Joules of natural gas for use domestically and in South Africa (Republic of Mozambique Cabinet Council, 2014). This resulted in the exploration and production from the Pande and Temane onshore gas fields, along with the construction of an 865 km pipeline between Temane, Mozambique and Secunda, South Africa.

The most recent developments in Mozambican gas have been in the Rovuma basin in the north forming the bulk of new discoveries, together with the Mozambican Basin in the central part of the country. Table 6.1 represents the total discovered and undiscovered (assumed) gas resources in Mozambique as per a publication by ICF International.

Table 6.1: Discovered and Undiscovered Gas Resources Mozambique (ICF, 2012)

Region Name	Total Assessed tcf*	Discovered tcf 3P*	Undiscovered tcf 3P*
Rovuma Offshore North	199.4	124.4	75
Rovuma Offshore South	36		36
Rovuma Onshore	3.1		3.1
Central offshore	17.9		17.9
South offshore	13.1		13.1
Maniamba basin onshore	1.2		1.2
South and west onshore	9.2	3.5	5.7
Total	**279.9**	**127.9**	**152**

*Tcf = Trillion Cubic feet

*Discovered Plus Undiscovered equals total assessed

*3P is defined as: proven, plus probable, plus possible resources.

From Table 6.1 one can see that although proven reserves of 100tcf (as discussed in chapter 2.4) have been recorded, there is a huge upside potential for greater reserves in undiscovered areas of existing exploration concessions. New exploration concession of the 5th licensing round are also being issued which could add to the existing base of assessed gas resources.

Figure 6.1 below is a map displaying the 2 Mozambican Gas hot spots, the Rovuma basin in the north and the Mozambican Basin in the central part of the country. The yellow demarcated areas are the concession blocks that exploration and production concession have already been issued.

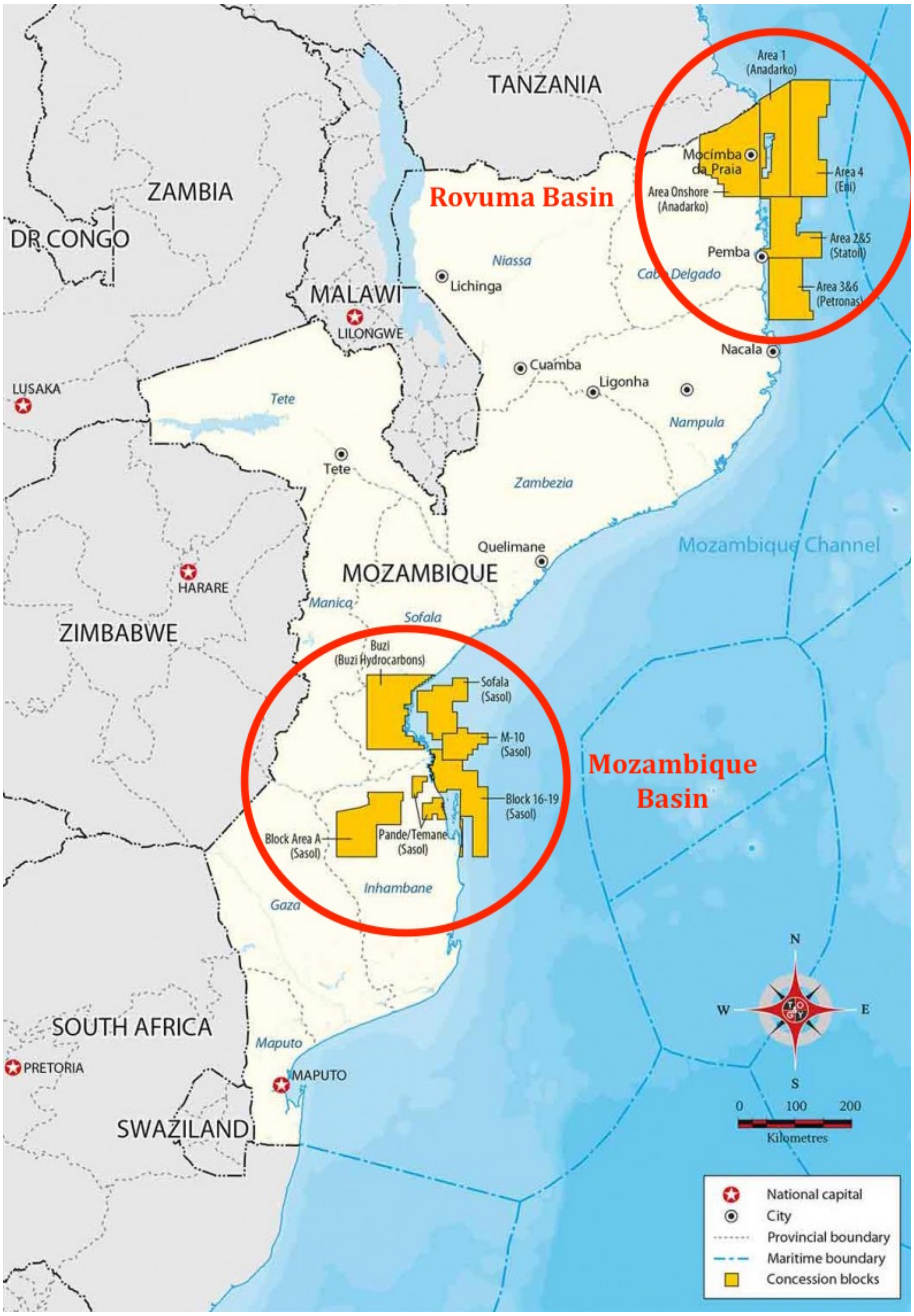


Figure 6.1: Mozambique Gas Map: (The Oil and Gas Year, 2013)

6.2 Mozambican Gas Industry SWOT

The Business Monitor Institute (Business Monitor International) completed an extensive analysis of the Mozambican Gas industry and has presented the following SWOT analysis:

Table 6.2: Mozambican Gas Industry SWOT (Business Monitor International, 2015)

Strengths • Strong prospectively offshore - Large gas discoveries to date • Substantially unexplored acreage both onshore and offshore • Geographically well positioned to tap into lucrative Asian market
Weaknesses • Undeveloped physical infrastructure. • Regulatory framework in place, but still no Final Investment Decision (FID). Timing important given several large LNG projects are already coming online elsewhere in the world.
Opportunities • Significant opportunities for new discoveries. • LNG exports as discoveries move closer to development stage. • Wide-ranging opportunities for infrastructure and gas-based industries: power generation, methanol and fertiliser production, gas to liquids etc.
Threats • Lower oil prices and company Capex cuts run the risk of threatening GTL and LNG projects within their forecast period to 2024. • Large LNG capacity coming online elsewhere and slowing Asian demand for LNG could threaten the profitability of an onshore LNG project.

6.3 Upstream Exploration

6.3.1 Offshore

Business Monitor International (2015) has concluded that the Large offshore appraisal campaigns by both Anadarko and Eni have come to an end, with the results yielding significant revisions on the countries reserves of gas. While appraisal activities have come to an end it It is still unclear how much will be booked as proven reserves (Business Monitor International, 2015). The completion of the fifth licensing round should lead to more exploration of offshore prospects in the northern and central basins, as mentioned above.

6.3.2 Onshore

The majority of the investment into gas exploration has gone into offshore exploration, but in September 2013 there was a discovery of onshore gas at the Buzi block located in the central region of the country (Business Monitor International, 2015). The Buzi block in located in the Mozambique basin, represented in figure 6.1. The completion of the fifth licensing round will lead to more exploration of onshore and offshore prospects on the central and north eastern region.

6.3.3 5th Licencing round

The fifth licencing round is a competitive bidding round for new exploration and production concession licences. This licencing round consisted of fifteen new areas which include areas within offshore Rovuma, offshore Angoche, offshore Zambezi, onshore Pande-Temane and onshore Palmeira covering approximately 74,259 sq. kms. Bids were received from potential operators for eight of the fifteen areas on offer (INP, 2015).

INP (2015) has issued statements that the following companies have been invited to engage in negotiations for exploration and production concession contracts (INP, 2015)

- eni Mozambico S.p.A
- ExxonMobil E and P Mozambique Offshore Ltd.
- Sasol Petroleum Mozambique Exploration Ltd.
- Delonex Energy Ltd

The noteworthy interest in the fifth licensing round despite low oil and gas prices confirms the high potential of Mozambican gas exploration and production and the rising industry confidence in the stability and regulatory attractiveness of the country as an exploration and production market (Business Monitor International, 2015).

6.4 Upstream Production

Current upstream production from the onshore Pande and Temane fields are set for an expansion in a bid to increase export to South Africa, with the largest increase in exports expected to come with the development of the deep-water gas fields in the Rovuma Basin (Business Monitor International, 2015). Business Monitor International predicts that 2020 will be the year that gas is first produced from the deep-water fields in the Rovuma Basin, this will be produced from the Eni Coral Floating Liquid Natural Gas project which is located in Area 4 (see Figure 6.1) (Business Monitor International, 2015).

Business Monitor International (2015) goes on to predict that 2021 will have the largest increase in gas production when the Afungi onshore Liquid Natural Gas (LNG) terminal comes online. This is a terminal planned by Anadarko and Eni who will co-ordinate their independent offshore activities in support of a common onshore Liquefied Natural Gas processing terminal. Although predicted for 2021, the onshore LNG terminal timing is becoming increasingly uncertain states Business Monitor International, this is due to the following reasons (Business Monitor International 2015)

- Increasing price uncertainties (Gas)
- Absence of Infrastructure
- Shortage of skilled labour
- increasingly well supplied LNG market

6.5 Trade – Gas

Mozambique currently produces and trades small amounts of gas of which the majority going to Sasol in South Africa from the onshore Pande and Temande fields via pipeline. Local demand for gas in Mozambique is small and will continue to be in the near future meaning that most of the gas production will be exported to South African until the large offshore Rovuma fields come online (Business Monitor International, 2015).

When the Rovuma fields come online in 2020 and 2021 as stated by Business Monitor International (2015), it is expected Mozambique to export 607 bcf of LNG by 2024, the most likely destination of these exports will be Asia.

6.6 Policy

In August 2014 a long awaited new bill proposed by the Mozambican Government which was passed in parliament by MP's for the hydrocarbons sector, setting out a clearer framework for production and export of hydrocarbons (Business Monitor International, 2015). The new laws are not a complete overhaul of previous laws, but rather put into law what was previously agreed in contracts (Business Monitor International, 2015). It also formalises the allocation of oil and gas production rights, ensuring more transparent concession allocation while formalising a stronger role for the state in order to maximise local benefits and participation in this sector (Business Monitor International, 2015).

6.7 Mozambique Gas Infrastructure

Mozambique is one of the poorest counties in the world that is recovering from a crippling civil war that only ended in 1992, leaving most of the countries limited infrastructure destroyed. The result of this is that Mozambique is critically lacking gas infrastructure. Lack of infrastructure is a key restraint on the development of the gas sector (Business Monitor International, 2015), as reflected in the Business Monitor International SWOT analysis above in Table 6.2. Mozambique has 3 major ports: Maputo in the south, Beira in the central region and Nacala in the North. The Temane – Secunda pipeline is the other mentionable infrastructure.

6.8 Price Benchmarks of Mozambican Gas

6.8.1 Price Benchmarks for Natural Gas Production

Minimum Wholesale Price

The minimum wholesale price is a bottom up price build-up of the cost factors for the extraction gas. These cost factors consist of "capital and operating costs plus fiscal expenses and a 15 percent rate of return for the producer" (Stanley et al., 2014). Although this is not a direct measure of pricing it does indicate the lowest price that can be sustained in the market that still preserves the economic incentive required for the producers (Stanley et al., 2014).

LNG Netback Price

The LNG netback price is the opposite of minimum wholesale; it is a top down analysis, calculating the costs of getting an equivalent load of gas to the location from an existing market and deducting shipping and associated liquefaction costs. This results in a wellhead cost that can be used as a benchmark to compare against other gas wellhead costs in different regions. The LNG netback price then serves as a global market reference price of gas (Stanley et al., 2014.

Netback vs Minimum Wholesale

The Minimum Wholesale Price and the LNG netback price define a range of potential gas prices that ensures sufficient returns to warrant development of the gas assets while remaining competitive on an international price scale (Stanley et al., 2014). The relationship between these two elements is reflected in Figure 6.2

The range between these two prices will be the assumed range of the possible cost of Mozambican Gas for this study

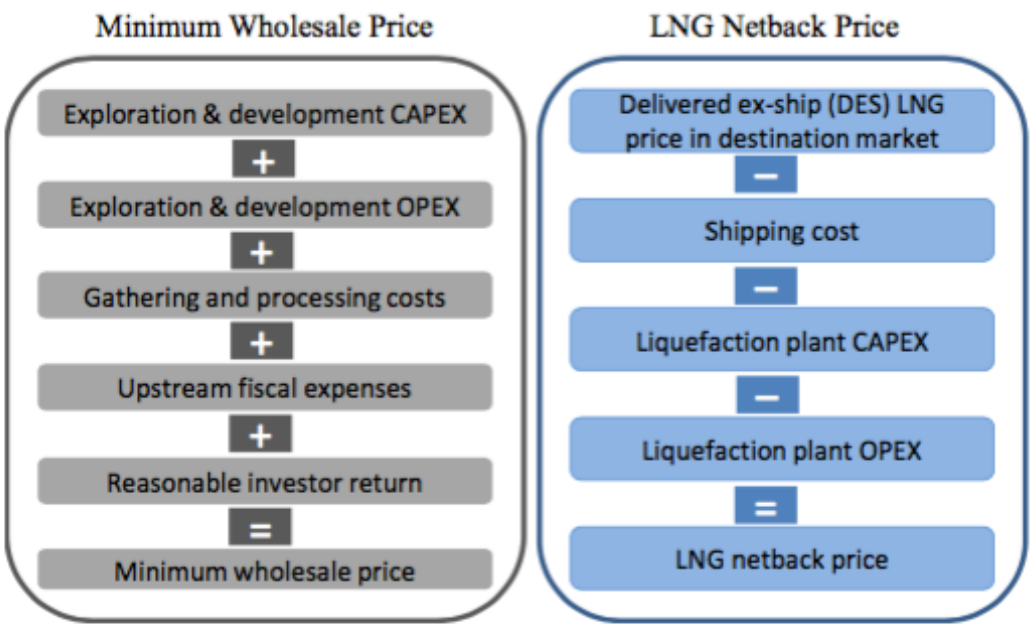


Figure 6.2: Cost Factors Determining Price Benchmarks (Stanley et al., 2014)

6.8.2 Mozambique Price Benchmarks

Minimum Wholesale Price

Stanley et al (2014) using data submitted to them from ICF international (used to develop the gas master plan of Mozambique), states the minimum wholesale gas prices for the different fields in Mozambique as seen in Figure 6.3.

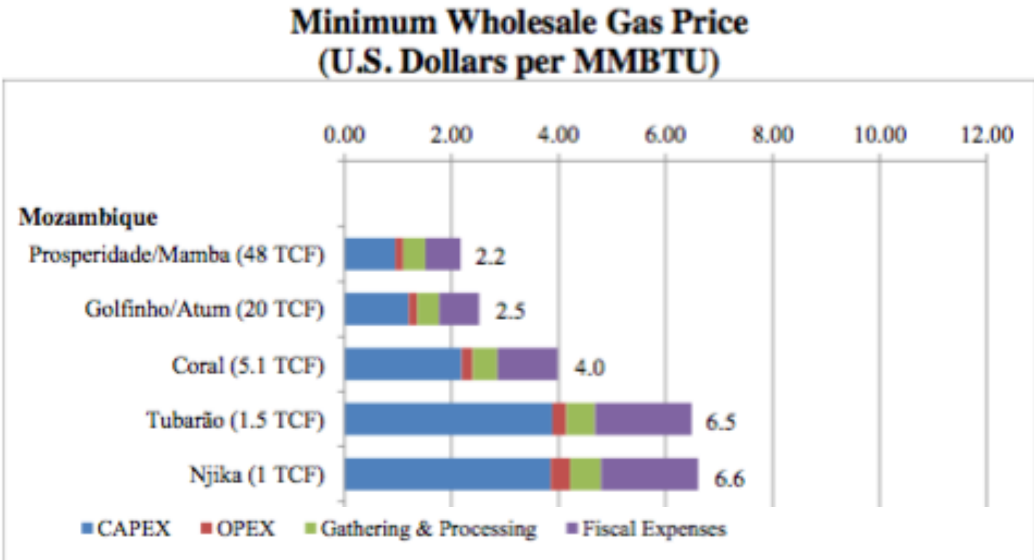


Figure 6.3: Mozambique Minimum Wholesale Gas Price (Stanley et al., 2014)

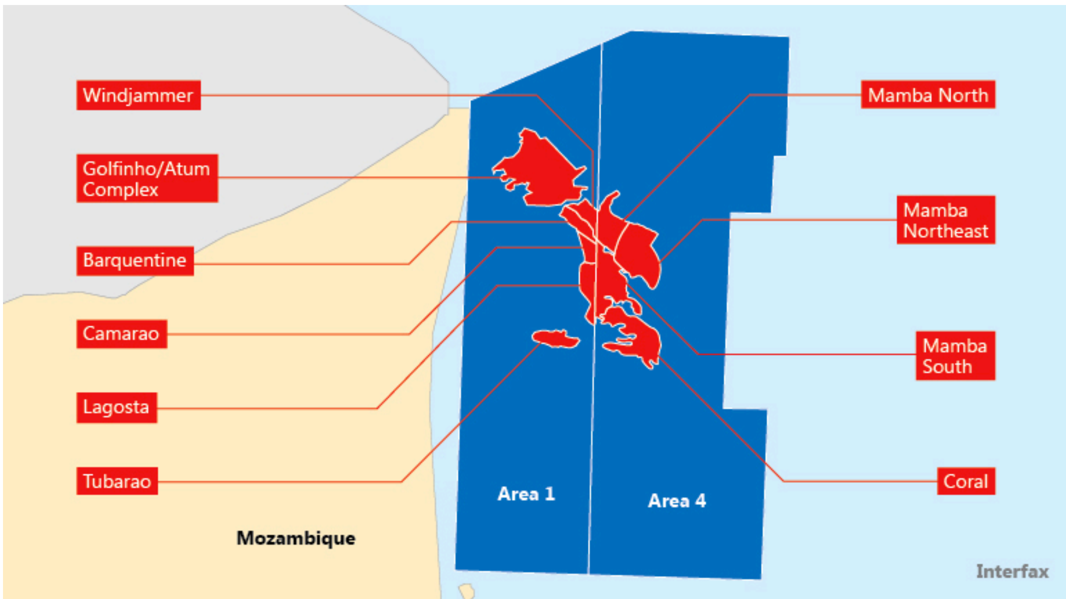


Figure 6.4: Gas Fields Within Areas 1 and 4. (Interfax Energy, nd)

Figure 6.4 demonstrations the locations of the gas fields discussed in figure 11.

From this one can see that the larger fields are producing much cheaper gas showing that the cost of smaller fields escalates substantially, reflecting the strong economies of scale in upstream gas development (Stanley et al., 2014). For the purpose of this study the assumed average minimum wholesale price of 2.5 USD/MMBTU is used, as per the study done by Stanley et al (2014).

LNG Netback Price

Stanley et al, believes that the LNG global prices will converge over the medium to long term as discussed in chapter 2.1.7.

Taking this newly emerging market pattern into account of declining Asian delivered ex ship prices, combined with the liquefaction capex estimates for Mozambique and Stanley et al forecasts that in 2025 the LNG netback price will be 7.7 USD/MMBTU (Stanley et al., 2014). The same LNG netback price will be assumed in this study.

7. Cost of Mozambican Natural Gas in South Africa

7.1 Palma – Johannesburg Pipeline

The ICF study submitted to The World Bank for the development of the Mozambican Gas Master Plan, has a conceptual study of a pipeline from Palma, Mozambique to Johannesburg, South Africa. The study determines a pipeline cost by assuming a new 36-inch pipeline between these two destinations using Inflation adjusted cost data for U.S. Pipelines in 2009, while making adjustments for African labour costs and terrain costs (Stanley et al., 2014). The results of the study was a cost of $64,300 per inch-kilometre, this falls in line with existing data for pipelines in the region (completed, under construction and at feasibility study stage) of $66 238 (Stanley et al., 2014).

In order to calculate the transport tariffs the capital amounts are converted by using a 30-year discounted cash flow model at a 10 percent discount rate (Stanley et al., 2014). The resultant transport tariff is **3.2 USD/MMBTU**, for a 114.245 billion cubic feet per annum throughput (Stanley et al., 2014). With this information one can determine that with a pipeline from Palma to Johannesburg the cost of gas would range between **USD5.70 and USD 10.90 per MMBTU** using the minimum wholesale price as well as the LNG netback price range.

7.2 LNG Imports

In study completed by Deloitte (2015), a study for the Western Cape Government on the socio-economic impact of importing LNG into the West Coast of the Western Cape. The Study determines calculated a landed cost elements of Mozambique LNG at Saldanha, Table 7.1 displays the results:

Table 7.1: Cost Components of Mozambican LNG delivered to Saldanha (Deloitte, 2015)

Cost Components	Estimated Landed LNG Price	
	Low	High
Liquefaction Costs USD/MMBtu	3.3	4

Shipping Costs USD/MMBtu	0.4	0.4
Additional Infrastructure Cost/Risk Premium USD/MMBtu		1.5
Total	3.7	5.9

Deloitte (2015) determines a range of costing for the LNG scenario. The first “low road” scenario based on industry standard estimated costs while the “high road” has an additional premium for possible risks associated with a greenfield project exploration and production in a such a remote location. Assuming the minimum wholesale and the LNG netback price range from the assumed cost range (Chapter 6.8.2) of cost of Mozambican LNG landed in Saldanha of **USD 6.2/MMBtu to USD 13.6/MMBtu**.

8. METHODOLOGY - LEVELISED COST OF ENERGY

In order to determine the economic viability of using Mozambican Gas in South Africa one needs to compare the cost of producing the energy from gas and compare this cost of other possible alternative electricity generating technologies. The levelised cost of energy calculation is a tool that is used by the energy sector to compare the total cost of producing energy from different technologies. The levelised cost of energy is an economic calculation taking into account the the capital cost, fixed and variable operating costs while accounting for the weighted average cost of capital as well as time value of money.

Levelised cost of energy breaks down the capital, fixed and variable operating costs as well as fuel costs into a price per MWh. The result is the total price of producing electricity can be compared on a level basis of a unit of cost per MWh. The calculation of levelised cost of energy can be calculated in the following manner:

Firstly, one would need to calculate the Adjusted Capital Cost. Overnight capital cost is the cost of the plant if it was to be built overnight, the reality is that power plants take several years to construct ranging from 18 months to 16 years (Department Of Energy, 2010), and are phased online over a period of time.

The adjusted capital cost accounts for the phasing of construction and the costs associated with that (Equation 8.1).

Adjusted Capital Cost = Overnight Capital Cost + Interest During Construction **[8.1]**

Once the adjusted capital cost has been determined the Capital Recovery Factor (CRF) must be calculated in order to determine the levelised capital cost. Capital Recovery Factor (equation 8.2) is a ratio that determines that annual capital cost annuity for a set period of time, in other words it determines the capital cost in an annuity over the lifetime of the asset.

$$CRF = \frac{r(1+r)^n}{(1+r)[(1+r)^n - 1]} \qquad \textbf{[8.2]}$$

Where:
r = interest rate

n = Period (number of Years)

Annualised Capital (equation 8.3) is the amount of capital that the annuity or capital recovery factor allocates for each year that of the lifetime of the plant.

$$Annulased\ Capital = Adjusted\ Capital\ Cost\ Per\ Kw \text{ x } CRF \qquad \textbf{[8.3]}$$

Once the annualised capital is determined this can be used to calculate the levelised capital (equation 8.4) . Annualised capital is divided by the number of hours that the plant is planned to be in operation to get a capital cost per MWh. There are a possible 8760 hours in a year, this must be multiplied availability and load factor to calculate the number of hours the plant will be operating in a given year.

$$Levelised\ Capital = \frac{Annualised\ Capital}{Capacity \text{ x } Load\ Factor \text{ x } Avalibility \text{ x } 8760} \qquad \textbf{[8.4]}$$

Levelised Operations and Maintenance Costs (O and M) (equation 8.5) have two cost elements, firstly the variable cost element quoted in unit of cost per MWh (therefore already in a levelised cost comparison format), secondly there is a fixed cost element.

Fixed costs are cost that the plant will incur no matter the circumstance or way in which the plant is run. Like capital cost, fixed cost needs to be converted into a MWh element in order to be levelised:

$$Levelaised\ Fixed\ O\ and\ M = \frac{Fixed\ operations\ and\ Maintenance\ Costs}{Capacity \text{ x } Avalability \text{ x } Load\ Factor \text{ x } 8760} \qquad \textbf{[8.5]}$$

Once the fixed operational and maintenance costs have been calculated into a MWh cost, one can determine the total levelised operations and maintenance costs by adding the levelised fixed, and variable costs to determine the total levelised operational and maintenance costs (equation 8.6).

$Total\ Levalised\ O\ and\ M/MWh =$ *Levelised Fixed O and M/MWh*
+ Variable O and M/MWh **[8.6]**

Fuel cost is the final component that needs to be considered in order to determine the levelised cost of energy, the Levelised cost of fuel is (equation 8.7):

$$Levelised\ cost\ of\ Fuel = Fuel\ Cost\ per\ (kJ) \times Heat\ (kj/kwh) \qquad \textbf{[8.7]}$$

Where:

1 MMBtu = 1.05587 GJ

Total Levelised Cost is a function of all the above formulas (equation 8.8);

$$Levelised\ Cost\ of\ Energy = Levelised\ Capital + Levelised\ O\ and\ M + Levelised\ Fuel\ Cost \qquad \textbf{[8.8]}$$

Assumptions

Calculating the levelised cost of energy using range of Cost of Mozambican Gas assumed (Chapter 6.8.2) will be done using the IRP 2010-2030 Update of 2013 adjusted assumptions, most importantly the 2013 exchange rate. The reason for this is that the most current data produced by Government and this report serves as the basis on which the Government makes policy decisions. It is important to use the assumptions in the report including exchange rate in order that the economics of using Mozambican Gas can be determined against other possible alternatives on a level basis.

The deterioration of the value of the rand over the past 3 years will have significant effect on all the considered electricity generation technologies as many of the inputs technologies (Capital, Operations and Maintenance as well as fuel) for all of these are linked to the US Dollar. The result of the devaluation of the rand will have a significant impact on cost determination of all elements (capital, O and M and fuel) and with the information that is available it will be hard to determine the exact effects this will have proportionately to each component. For this reason, the analysis will be done according to the assumptions in the IRP 2010-2030 Update of 2013 together with the the gas prices assumed in chapter 7.

IRP Assumptions

- Levelised Cost of Energy Based on IRP 2010-2030 update (Department Of Energy, 2013)
- Exchange Rate is ZAR 8.01 to the US Dollar (Department Of Energy, 2013)

- Inflation rate 6% p.a. (Department Of Energy, 2013)
- Cost of Debt 10% p.a. (Department Of Energy, 2013)
- Carbon taxes have not been taken into account as there is no clear timeframe indicated on the implementation of this from government.
- Figures are without learning rates (Department Of Energy, 2013)

Objectives of Methodology

- Analysis of Levelised Cost of Energy according to Range of cost of Gas According to IRP 2010-2030 update of 2013.
- Levelised cost comparison of alternative electricity generation technologies to determine if Mozambican Gas can be utilised to economically produce electricity for the South African market.

9. RESULTS AND DISCUSSIONS

9.1 Analysis and Interpretation

South Africa has a number of options for increasing electricity generation capacity as stated in the IRP 2010-2030. Of these options coal fired generation is still the more frugal option even when a carbon tax of USD15 per ton of CO_2 emitted (Stanley et al., 2014), but due to the impending limit on emissions of CO_2 as discussed in Chapter 4.7 a limited number of new coal fired power plants will be built (Mckinsey , 2015).

The intended diversification away from coal into nuclear, gas and renewable energy options as stated in the IPR 2010-2030, is a clear indication of the intent to adhere to the hard cap on emissions. Gas has been given a small role in this new energy mix due to the supply and price constraints.

There are 3 ways to integrate the use of Natural Gas into South African electricity supply,

- Cheaper Alternative to Diesel to supply Peak Demand Loads.
- Mid-merit supply of a varying load factor average of 50% to compliment renewables.
- Base Load supply – consistent, high load factor supply.

The price at which South Africa has access to gas will determine the utilisation in electricity generation (peaking, mid-merit and baseload) and related sectors.

9.1.1 Levelised Cost of Energy for Range of Gas Prices

The levelised cost of energy for the cost range of Mozambican gas assumed in this study results in a linear relationship between the cost of gas and the levelised cost of energy. The Gas price, converted from MMBtu to GJ then placed in the Levelised Cost of Energy Model results is a parallel relationship of gas cost and levelised cost of energy. The levelised cost of energy is based on the OCGT (due to its higher efficiency levels) technology at the assumed exchange rate of ZAR 8.01 to the USD as per the IRP 2010-2030 Update.

Table 9.1: Conversion of MMBtu to Gigajoules (GJ)

USD /MMBTU	5.70	6.49	7.28	8.07	8.86	9.65	10.44	11.23	12.02	12.81	13.60
USD/ GJ	6.01	6.85	7.68	8.51	9.35	10.18	11.02	11.85	12.68	13.52	14.35

Figure 9.1 below is an illustration of the cost build-up (as calculated in appendix 1) of the levelised cost of energy for CCGT in South Africa according to the cost data from the IRP 2010-2030 update of 2013 combined with the range for gas costs assumed in this study.

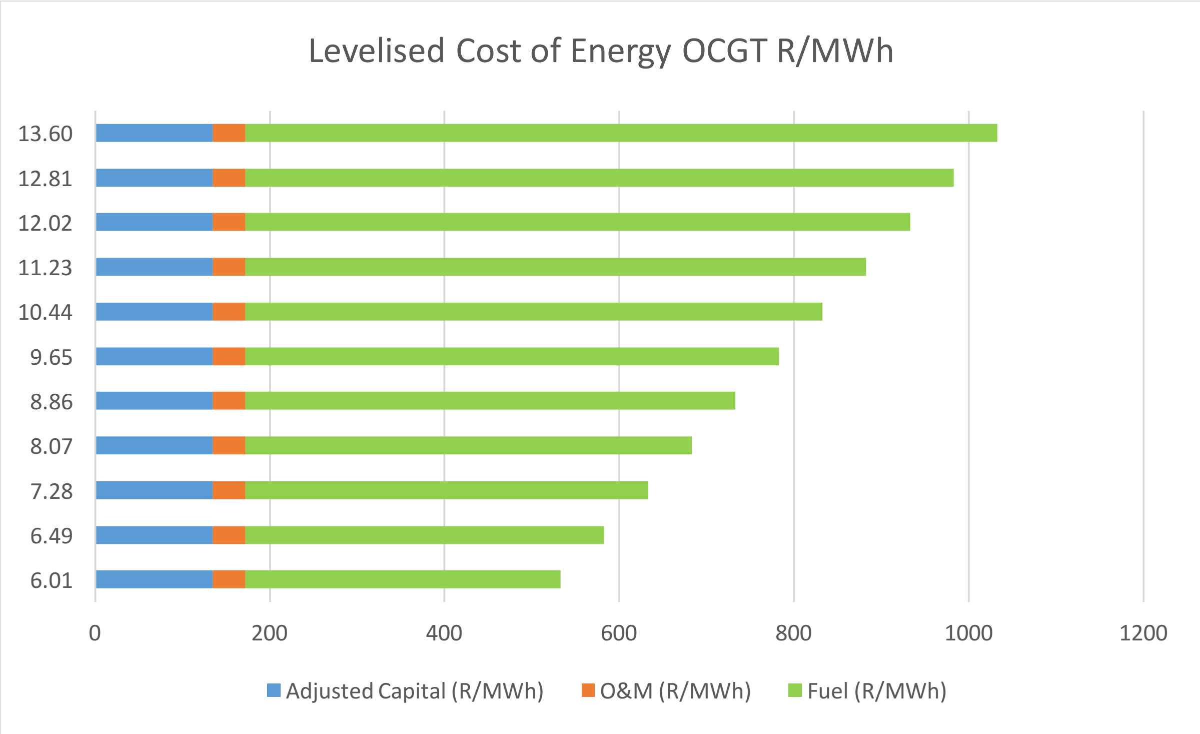


Figure 9.1: Gas Price and Levelised Cost of Energy Relationship

Table 9.2 is the displays the relationship of the levelised cost of energy at the assumed range of gas prices assumes in this study. The calculation of this can be seen in Appendix 1

Table 9.2 Gas Input Cost and Total Levelised Cost of Energy

USD/ GJ	6.01	6.84	7.68	8.51	9.34	10.18	11.01	11.84	12.68	13.51	14.34
R/GJ	48.17	54.84	61.52	68.2	74.87	81.55	88.23	94.9	101.58	108.26	114.93
Total (R/MWh)	532.82	582.81	632.8	682.79	732.77	782.76	832.75	882.74	932.72	982.71	1032.7

From the above data (Table 9.2) and graph (figure 9.1) one can see that fuel cost is a large portion of the cost of Gas power generation using the CCGT.

This highlights the importance of the price at which South Africa can source gas from Mozambique, as it will greatly affect the possibility of economic viability of integrating gas into the South African power generation fleet due to its high proportion of the levelised cost.

9.1.2 Comparison of Levelised Cost of Energy to Other Forms of Electricity Generation

In order to make a baseline comparison of the cost of using Mozambican power to produce power in South Africa, the data from the IRP 2010-2030 2013 update was used to make a levelised cost of energy analysis (Figure 9.2).

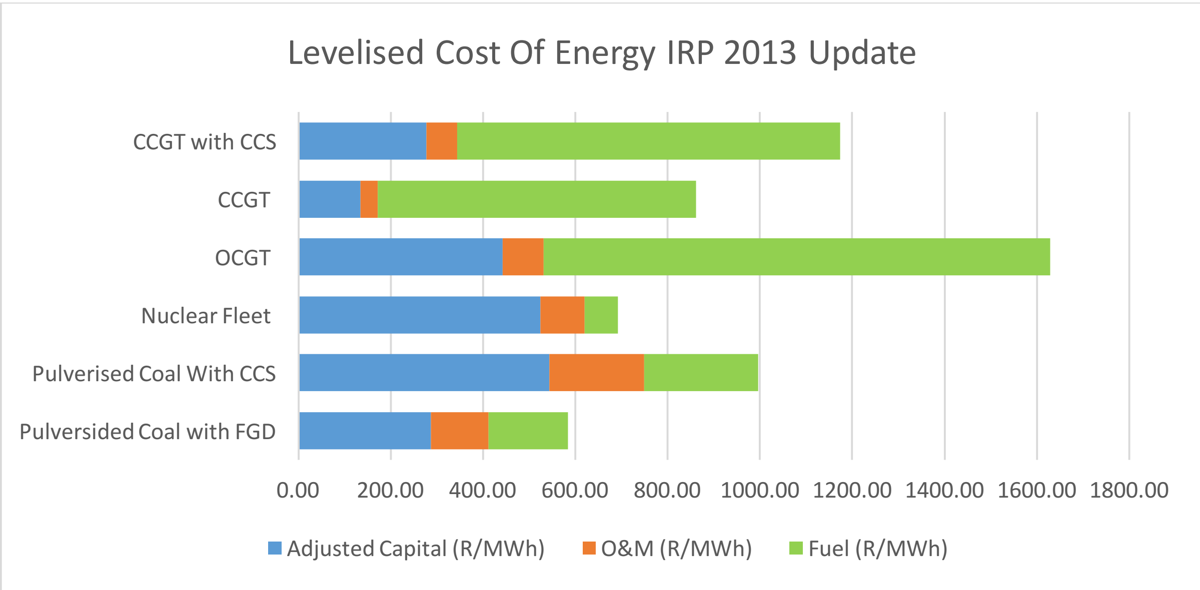


Figure 9.2: Levelised Cost of Energy as per IRP 2010 – 2030 Update 2013 (Department Of Energy, 2013)

Figure 9.2 is a graphic representation of the cost build-up of electricity generation options that the South African government has assessed as per the IPR 2010-2030 2013 update. IPR 2010-2030 2013 update assumes a cost of R92 per gigajoule resulting in a total levelised cost of energy for CCGT of ZAR 860.97, resulting in gas power generation (CCGT and OCGT) being one of the more expensive alternatives. This would most likely result in its integration into the power system for peaking electricity generation only.

Figure 9.3 is a graphic representation of the total levelised cost of according the price range of gas assumed in this study of USD 6 – 14.35 per gigajoule. The calculation of this can be seen in annexure 2.

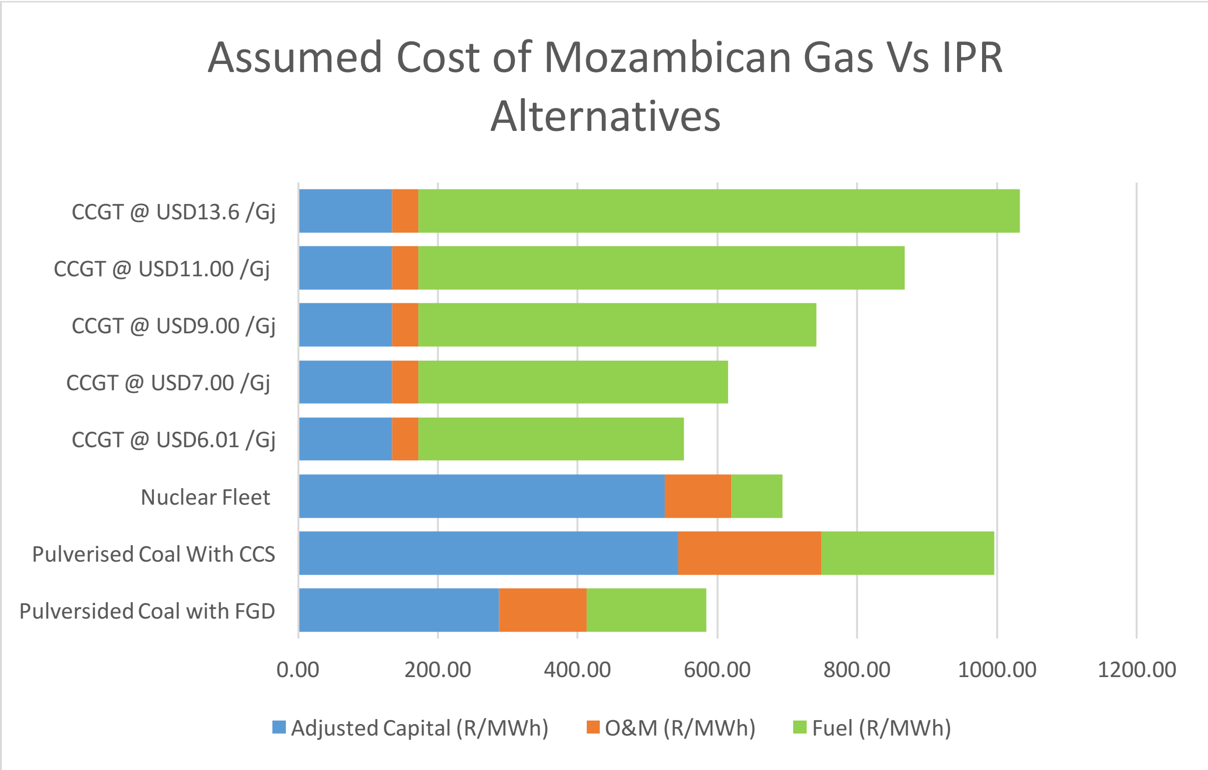


Figure 9.3: Levelised Cost of Energy at various Gas Prices

From this one can see at the assumed rage of the cost of gas, integrating Mozambican gas for electricity could be an economically viable alternative for peaking, mid-merit as well as baseload generation depending on the landed cost of the gas in South Africa.

Gas imports from Mozambique could present an economically viable alternative in the long and medium term, using the prices assumed in Chapter 7. However much depend on the price at which Mozambique is prepared to sell gas to South Africa as well as the volumes delivered and hence the cost of transportation (Stanley et al., 2014).

9.2 Medium Term Opportunities

LNG will be the first gas available from the large offshore fields of the Rovuma Basin as discussed in Chapter 6.4. This presents an opportunity for South Africa to use LNG to boost electricity supply in the medium term, for peaking and mid – merit supply. Deloitte (2015) study completed an analysis on LNG imports to Saldanha and concludes that there is a strong economic case for the import of LNG for electricity generation. This is further support by Business Monitor International (2015) stating that, Of the import projects under proposal, we believe Saldanha Bay to be the most feasible. Saldanha is a naturally deepwater port, accessible to large bulk carriers.

The report goes on to say “It is also comparatively favourable on the demand side. The IDZ provides a number of major industrial consumers - in particular in the metals industry. It is also close to the Ankerlig power plant at Atlantis” (Business Monitor International, 2015) The conversion of the existing Ankerlig facility from a 1350 MW OCGT to more efficient 2070 CCGT setup, would generate peaking and mid-merit electricity supply at a much reduced rate per KWh.

9.2.1 Cost Savings

According to Deloitte (2015), if one assumes a LNG cost of USD 10/MMBtu the assumed price of LNG in South Africa for LNG sourced outside of Mozambique, as per the IRP 2010-2030. At a load factor of 45% for the CCGT, a levelised cost analysis taking into account Initial capital required for the conversion, operating costs, fuel costs and cots of capital. This results in a levelised cost of energy 65% cheaper than the cost of producing power from diesel. (Deloitte, 2015)

Eskom is running their open cycle gas turbines on diesel at an astronomical cost of R3.13/KWh (May 2011 figures), the adoption of LNG in the Western Cape would mean the Ankerlig facility would produce electricity for R1.10 /Kwh (Deloitte, 2015).

The total fuel cost savings Eskom could realise at a 45% load factor is R5 billion per annum offsetting the capital cost of between R17 – R19.5 Billion in under 4 years. (Deloitte, 2015)

9.2.2 Other Benefits

- The Western Cape economy would be realising a boost from the infrastructure spend of between R17 and R19 billion. (Deloitte, 2015)

- The Western Cape would realise greater energy independence – meaning less electricity imports from the north eastern parts of the country. Additional 800 MW of coal power plus transmission losses of about 10% making a total of 880MW available to the rest of the grid. (Deloitte, 2015)
- Reduced greenhouse gas emissions, CO_2 intensity of gas is 27% less than diesel (as displayed in table 3.2 in section 3.4.) (Deloitte, 2015).
- Gas as a mid-merit load capacity support the nuclear and renewable energy mix in the region well. (Deloitte, 2015)
- Due to shorter lead time of gas infrastructure, and the higher load factor of gas will provide much needed support in the energy supply mix in the medium term. (Deloitte, 2015)

9.2.3 Additional LNG Opportunities

Other coastal industrial zones such as Coega Industrial Zone and Richards bay could be developed into power generating hubs that could integrate gas into the industrial sectors in these areas. Coega is similar to Saldanha in that it has a large compliment of renewables in the region with no baseload generation capacity and relies heavily on electricity imports. Coega like Saldanha could implement LNG to generate electricity to supplement the renewable energy in the area.

Coega being an industrial zone could distribute gas direct to industry, and because the large city of Port Elizabeth is nearby gas can be integrated into the transport and household sectors. Richards Bay Industrial Zone also presents an opportunity to produce electricity for the area, with Durban close by gas can be integrated into the transport and household sectors in additional to the industrial users and electricity generation. Having these 3 LNG power nodes will alleviate significant pressure on the current supply of electricity and transmissions networks.

9.3 Long Term Opportunities

Gas being available through a pipeline could offer cheaper landed gas as calculated in Chapter 7, cheaper gas adds merit to the prioritisation of gas baseload generation capacity.

9.3.1 Price of Gas to Displace Coal

Utilising the levelised cost of electricity model we can determine the cost at which gas will start to displace coal power generation.

According to the IRP 2010-2030 update the costs of producing power from coal are as follows:

- Pulverised Coal with FGD - ZAR 584.14/MWh

The comparison of the cost to displace coal will be done on Pulverised Coal with flue gas desulphurisation as this is the most cost competitive. Carbon taxes have not been taken into account in this calculation as mentioned above.

The Result from the model is as follows as seen in appendix 2

- USD 6.511/MMBtu - ZAR 584.14/MWh

This is further supported by Stanley et al (2014), stating that gas imports via pipeline from Mozambique are currently competitive with coal at a delivered price of USD7/MMBtu (USD 7.39/Gj) or less. This estimate is also closely maintained by McKinsey (2015) stating that gas prices would need to drop below USD6/MMbtu (USD 6.33/Gj) to begin to displace coal on the cost curve.

9.3.2 Price of Gas to Displace Nuclear

According to the IRP 2010-2030 update there are the following costs of producing nuclear power as seen in appendix 2:

- Nuclear Fleet Cost - ZAR 692.83/MWh

The cost of gas needed to displace the cost of nuclear power according the the levelised cost of energy model is:

- USD 8.229/MMBtu - ZAR 692.85/MWh

Figure 9.3 illustrates that landing gas in the lower quartile of the cost estimate would result in gas displacing the cost of new coal assets as well as nuclear alternatives.

The Mozambican onshore gas processing facilities timeline is more uncertain than the LNG facilities but based on the cost assumptions in this paper the integration of Mozambican Gas via pipeline presents a credible opportunity that stakeholders should be perusing.

10. Conclusion and Recommendations

Mozambican Gas has the potential to provide an economically viable solution to the South African power crisis, but the final price at which South Africa can buy the gas is unclear due to the early stage of development the gas fields are currently in. The cost assumption made in this study (based on the IRP 2010-2030 Update of 2013) show that based on current information Mozambican gas could provide an economic solution to South Africa’s electricity crisis. Taking all these factors into account it is clear that the Government should be prioritising a Big Gas scenario utilising gas for peaking power, mid merit and baseload capacity expansion. Adopting the Big Gas approach based on the current available information offers a feasible way for South Africa to meet its current and future electricity shortfalls.

10.1 What is the Big Gas Scenario?

A Big Gas scenario according to the IRP 2010-2030, a big gas scenario would mean 62 480 MW of CCGT and 6720 MW of OCGT totalling 69 200 MW of installed power being gas, resulting 65.34% of total installed capacity would be power generated from gas with the balance made up of hydro, coal and renewables.

10.2 Implementation

Gas infrastructure has the shortest lead time and the lowest capital requirement of any power generation technology as discussed in Chapter 3. The fact that coal fired powered plants have a lead time of approximately eight years, and nuclear could take significantly longer due to the technical complexity (Mckinsey , 2015). This means that no new coal and nuclear expansion will be ready by at least 2026, and the renewable build program will not generate enough additional electricity to meet demand putting significant stress on the power supply system.

LNG gas Infrastructure can be implemented over the short to medium alleviating the immediate pressure on the electricity system while a pipeline for gas is being built in order to land gas at the cheapest possible price to integrate gas baseload electricity generation. All this can be achieved before any coal or nuclear assets would be integrated into the power supply pool.

10.3 Capital Cost Savings

Gas power stations need significantly less capital per unit capacity and achieve a similar and competitive levelised cost of electricity, this means that the investment is a more feasible option for the financially distressed Eskom or a more attractive investment to possible Independent Power Producers. Adopting the Big Gas scenario would drastically change envisaged energy mix (base case) of the IRP 2010-2030, but based on the assumes figures in this study could result in a very similar or better levelised cost per KWh, with a significantly reduced capital outlay.

Appendix 3 is an extract from Mckinsey (2015) report from this it is clear to see the dramatically reduced capital expenditure a Big Gas adoption would realise. Over R 244 billion would be saved (a saving of 29% on capital expenditure) to realise a similar levelised cost of electricity (Mckinsey , 2015). In order to adopt a Big Gas scenario where gas would be used for the full range of capacity including base load generation, (therefore displacing coal and nuclear) gas prices would have to be in the region of USD 7/MMBtu.

10.4 Shale Gas Opportunity

The largest potential upside of developing a "Big Gas" scenario is the possibility of shale gas development and production in South Africa. If the development of the shale gas is successful the source can be switched to the domestic shale gas, potential utilising cheaper domestic gas for power, which will change the energy dynamics in South Africa significantly.

10.5 Downstream Gas Opportunities

Once the gas infrastructure is in place and gas is further integrated in the downstream sector, gas utilisation can be expanded into the industrial, transport and residential sectors creating a larger demand base which could offset the transport costs, possibility reducing the cost of gas further. The volume of gas that can be transported through a pipeline increases exponentially with the increase in the diameter of the pipe, costs on the other hand an increase more or less linearly (Stanley et al., 2014). "The combination of exponential volumes and liner costs leads to powerful economies of scale in the unit cost of pipeline transportation” (Stanley et al., 2014). The development of a downstream gas sector in South Africa would go a long way in creating new manufacturing hubs aiding in the creation of much needed jobs and contributing significantly to the Gross Domestic Product.

10.6 Recommendations

The South African Government needs to lead the process by firstly updating its stance on natural gas, identifying the recent Mozambican gas fields as a Mozambique as a key potential source of gas. The Integrated Resource Plan as the steering document must to be updated to reflect the Mozambican gas as a potential source of gas to produce economically viable electricity for the South African market. The Integrated Resource Plan must also update the effects of the exchange rate on the levelised cost of energy for each of the electricity generating options in order to get an accurate cost of gas, that can displace coal and nuclear options in order that the Big Gas scenario can be adopted.

Once these updated numbers have been determined, the ministry of energy needs to start approaching South Africa gas stakeholders in order that a combined approach can be made to the Mozambican gas stakeholders in order to acquire additional and more accurate information about the costs of LNG and Natural Gas to determine with certainty the cost that gas would be available to the South African market. Once this has been established the ministry can then make an informed decision about how to move forward with gas development before any other commitments are made to other new build technologies, specifically nuclear.

Appendix 1: Levelised Cost of Energy OCGT Calculation

CCGT											
Rated Capacity MW	711	711	711	711	711	711	711	711	711	711	711
Life of Program	30	30	30	30	30	30	30	30	30	30	30
Load Factor	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Overnight Capital Cost	6406	6406	6406	6406	6406	6406	6406	6406	6406	6406	6406
Lead Time	3	3	3	3	3	3	3	3	3	3	3
Availability Factor	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8
Adjusted Overnight Capital Costs, Accounting for Capex Phasing Discount Rate R/Kw	7089	7089	7089	7089	7089	7089	7089	7089	7089	7089	7089
Fixed O and M (R/Kw)	163	163	163	163	163	163	163	163	163	163	163
Variable O and M (R/Gj)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Variable Fuel Costs (R/GJ)	48.17	54.85	61.53	68.20	74.88	81.56	88.23	94.91	101.59	108.26	114.94
Heat Rate Kj/Kwh	7487	7487	7487	7487	7487	7487	7487	7487	7487	7487	7487
CO2 Emissions Kg/MWh	388	388	388	388	388	388	388	388	388	388	388
Adjusted Capital (R/MWh)	134.25	134.25	134.25	134.25	134.25	134.25	134.25	134.25	134.25	134.25	134.25
O and M (R/MWh)	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91
USD/ GJ	6.01	6.49	7.28	8.07	8.86	9.65	10.44	11.23	12.02	12.81	13.60
Fuel (R/MWh)	360.67	410.66	460.64	510.63	560.62	610.61	660.59	710.58	760.57	810.56	860.54
Total (R/MWh)	532.83	582.82	632.80	682.79	732.78	782.77	832.75	882.74	932.73	982.72	1032.70

Source IPR 2010-2030 Update as well as data from this Report

Appendix 2: Levelised Cost of Energy Comparison Calculation:

	Pulverised Coal with FGD	Pulverised Coal With CCS	Nuclear Fleet	CCGT @ USD6.01 /Gj	CCGT @ USD7.00 /Gj	CCGT @ USD9.00 /Gj	CCGT @ USD11.00 /Gj	CCGT @ USD13.6 /Gj
Rated Capacity MW	4500	4500	9600	711	711	711	711	711
Life of Program	30	30	60	30	30	30	30	30
Load Factor	85%	85%	92%	50%	50%	50%	50%	50%
Overnight Capital Cost	21572	40845	44010	6406	6406	6406	6406	6406
Lead Time	9	9	16	3	3	3	3	3
Availability Factor	91.7	91.7	94.1	88.8	88.8	88.8	88.8	88.8
Adjusted Overnight Capital Costs, Accounting for Capex Phasing Discount Rate R/Kw	25772	48789	59226	7089	7089	7089	7089	7089
Fixed O and M	552	923	532	163	163	163	163	163
Variable O and M	51.2	81.4	295	0.7	0.7	0.7	0.7	0.7
Variable Fuel Costs R/GJ	17.5	17.5	6.8	50.79	59.16	76.06	92.96	114.94
Heat Rate Kj/Kwh	9812	14106	10762	7487	7487	7487	7487	7487
CO2 Emissions Kg/MWh	947.3	136.2	0	388	388	388	388	388
Levelised Cost	Pulverised Coal with FGD	Pulverised Coal With CCS	Nuclear Fleet	CCGT @ USD6.01 /Gj	CCGT @ USD7.00 /Gj	CCGT @ USD9.00 /Gj	CCGT @ USD11.00 /Gj	CCGT @ USD13.6 /Gj

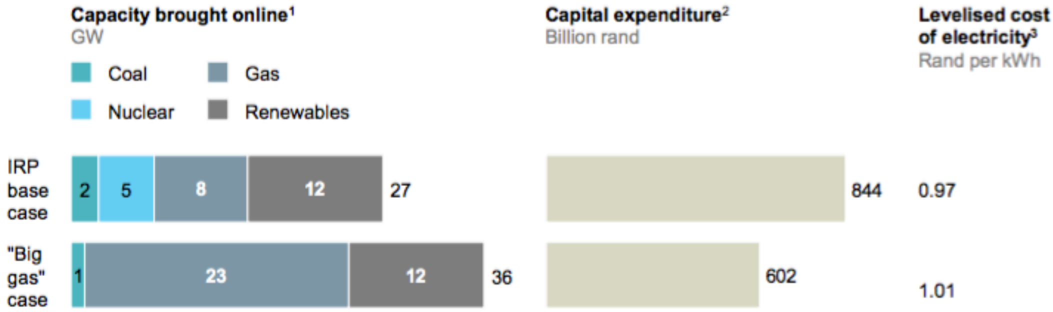
Adjusted Capital (R/MWh)	287.10	543.51	524.14	134.25	134.25	134.25	134.25	134.25
O and M (R/MWh)	125.33	205.36	95.51	37.91	37.91	37.91	37.91	37.91
Fuel (R/MWh)	171.71	246.855	73.18	380.28	442.93	569.48	696.03	860.54
Total (R/MWh)	584.14	995.73	692.83	552.44	615.09	741.64	868.19	1032.70

Exchange Rate					8.01
USD /MMBTU	6.010	7.000	9.000	11.00	13.60
USD/ GJ	6.34	7.39	9.50	11.61	14.35
R/GJ	50.79	59.16	76.06	92.96	114.94

Source IPR 2010-2030 Update as well as data from this Report

Appendix 3 – Capital Cost Savings

Energy mix: Integrated Resource Plan (IRP) base case vs. "big gas" case



1 Both cases include 1.5GW imported hydro, not shown here.
2 Capital expenditure of 31,481 rand/kW for coal, 70,891 rand/kW for nuclear, 5,706 rand/kW for open cycle gas turbine, 8,659 rand/kW for combined cycle gas turbine, 19,477 rand/kW for wind, 35,596 rand/kW for solar photovoltaic.
3 Levelised cost of electricity, based on IRP figures, inflated to 2015, and higher coal power fuel costs of 415 rand/MWh (vs. 222 rand/MWh in the IRP). Assumes gas price of $10/MMBtu. Comparison does not include carbon tax.
NOTE: Numbers may not sum due to rounding.

(Mckinsey , 2015)

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