FFF OSSIL FUEL OUNDATION

Unlocking the past for the future

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The Value of the Continued Use of Coal in the Energy Plan for South Africa

1. Introduction

South Africa is facing long term energy security challenges, brought about by a myriad of factors that are somewhat unique or exacerbated compared to the global context. These include: energy access and affordability; mounting environmental concerns with all forms of energy generation; balancing the power system due to increasing uptake of non-dispatchable renewable energy sources; mounting environmental liabilities with defunct mining operations; and lastly but by no means less importantly, fluctuating currency exchange rates and energy commodity prices. Against this backdrop, the Department of Energy (DOE) has drafted an Integrated Resources Plan (IRP 2016) issued for public comment in November 2016.

This IRP 2016 submission by the Fossil Fuel Foundation of Africa (FFF) argues a balanced case for coal as a continued energy and material resource. Coal currently satisfies almost 70% of the country's primary energy needs, and the FFF believes coal can still provide an energy solution and is capable of adapting to South Africa's aspirations for environmentally sustainable economic and social development.

2. The Role of the Fossil Fuel Foundation (FFF)

The FFF was founded in 1994 to address the growing needs of the coal industry and the broader community, by providing an impartial, professional forum to engage, debate and deliver consensus views.

The FFF is an INDEPENDENT internationally recognised institution providing knowledge of the Southern African fossil fuel and related energy industries in the region. This is achieved through conferences, courses, newsletters and networking amongst its database of more than 3 000 people from all walks of life in the energy world, from academia to producers, consumers, manufacturers, traders, innovators and government. It covers coal, alternative fossil fuels and related energy sectors – including renewable, hydro and nuclear. In doing so it promotes safe and efficient practice in the production, extraction and use of coal, carbon and alternative energy resources and it provides education and information at all levels for the benefit of the technical and lay public including government, industry, academia and schools.

The FFF does not take strong positions on major policy issues, as it rather believes in airing and disseminating valid and varying perspectives. This approach is maintained in order to provide the technical public with as balanced a set of views as possible from which individuals can derive their own opinions.

‘*It was thinking in this vein that led to the past participation of FFF representatives in debates with the World Energy Summit in 2005, the WWF, various renewable and nuclear associations and fossil fuel bodies. This type of involvement is fundamental to the functions of an organisation such as ours, and must, I think, be made a priority for the future.*’ Bill Lamont, Chairman of the Fossil Fuel Foundation 2013

Currently the FFF is faced with providing a balanced response to concerns specifically with respect to environmental footprint, cost and socio-economic impact.

Much of the negative perception around fossil fuels is the result of largely *unbalanced facts and misconceptions*, which fail to inform the public of the on-going research into clean technologies and the positive results obtained. The Fossil Fuel Foundation seeks to set the balance right - to provide facts and figures that are truthful and verifiable, and which would set the scene for a series of stages of energy security going forward in a cost effective and sustainable manner, considering environmental responsibility, accessibility of energy to all and thereby ensuring national growth through industrial development, employment and reduction (if not elimination) of poverty.

3. The Coal Industry in South Africa

South Africa has an intense reliance on coal, which is used to:

- generate 91% of its electricity,
- produce 30% of its liquid fuels,
- derive 98% of carbon reductants in the metallurgical industry -iron, steel, ferrochrome,
- produce more than 200 major chemicals and over 7 000 carbon-based products (including paints, plastics, fertilisers, plastics, explosives, food and many other carbon-based products).
- export, to provide the highest foreign exchange income of any mining commodity including gold, platinum and diamonds.

In all these ways, it is a vital multi-billion Rand contributor to the country’s GDP.

As a developing country, South Africa requires abundant, secure, reliable and cost-effective energy to increase its industrialisation and meet the needs of its economy. Coal is a valuable chemical mineral commodity, as well as a source of heat and power. It should be protected, nurtured and used wisely.

Given this vital importance, it is necessary to find alternative ways to continue to use coal in a clean and sustainable manner.

To fully understand the role of coal in the economy it is necessary to consider the various components of the coal value chain.

<u>Coal Mining Sector</u>

During 2016 some 181 million tons of coal were sold locally while exports amounted to some 69 million tons. The total revenue derived from coal sales amounted to R171 Billion for 2016 as shown in Table 3.1.

Table 3.1 RSA Coal Consumption and Value

Market	%	Mass (Mt)	Value (MR)	Average R/t
Electricity	47	118.6	35 818	302
Synfuels	17	42.0	14 407	344
Industries	3	8.0	4 758	587
Merchant & Domestic	3	7.0	2 257	323
Metallurgical	2	5.6	4 171	747
Exports	28	69.0	109 271	1 583
Total 2016	100	250.2	170 682	682

In 2016 the coal mining sector employed some 78 000 direct people in mining operations and some (Chamber of Mines, 2016) in supporting industries and institutions.

<u>Coal Sector Structures and Institutions</u>

The coal sector is well structured with a high degree of collaboration between producers. The following structures underpin the cooperation:

- Chamber of Mines of South Africa is a mining industry employers' organisation that supports and promotes the South African mining industry. The Chamber serves its members and promotes their interests by providing strategic support and advisory input.

  A key role of the organisation is to facilitate interaction among mining employers to examine policy issues and other matters of mutual concern to crystallise and define desirable industry standpoints. A variety of initiatives are in place to promote collaboration between members. Consultation and collaboration are voluntary and never encroach on the autonomy of members.

  The Chamber also acts as a principal advocate for mining in South Africa to government, communicating major policies endorsed by its members. A further vital function of the organisation is to represent some sectors in collective bargaining with organised labour.

  The Chamber has two structures in place that deal exclusively with coal sector matters, namely the Coal Leadership Forum and the Collieries Committee.

- The South African Mining Development Association (SAMDA) was started in 2000 as the Junior Mining Initiative by a group of like-minded people associated with various South African junior and black economic empowerment (BEE) mining companies. SAMDA's vision is to be the vehicle for the development of a vibrant and sustainable junior mining sector which contributes towards the growth and prosperity of the mining industry. This entity is (according to the people involved) no longer operating.

- South African Colliery Managers Association (SACMA) is a professional organisation that aims to empower members through effective interaction and to promote professionalism.

- South African Colliery Engineers Association (SACEA) promotes the general advancement of engineering and its particular application to the coal mining and associated industries nationally and internationally.

  Other professional associations in the coal mining sector are the South African Colliery Environmental Professionals Association, the South African Colliery Administrative & Financial Managers Association and the South African Colliery Human Resource Association.

- The Coal Processing Society is established with the primary objectives being to create a forum for the exchange of ideas and to advance the use and processing of coal.

- The Fossil Fuel Foundation is an internationally recognised institution providing knowledge of the Southern African fossil fuel and related energy industries. This is achieved through a network of specialists, the hosting of conferences and industrial courses, the distribution of information for the promotion of the energy resources and the understanding of the technical requirements of the industries in the region.

Supporting Institutions

- The Coaltech Research Association NPC was initially established in 1999 as the Coaltech 2020 Collaborative Research Programme. Its objective is to develop technology and apply research findings that will enable the South African coal industry to remain competitive, sustainable and safe well into the 21st century.

- The Rescue Drilling Unit maintains and operates a Schramm 130XD drill capable of drilling a 635 mm diameter hole to a depth of 300m for the evacuation of personnel trapped in underground workings. It also maintains and operates a pilot drill that can drill 150 mm diameter holes to locate trapped personnel and serve as communication links.

- The Colliery Inertisation System provides inert gas (Nitrogen) to be pumped underground into collieries in order to extinguish a coal mine fire.

- Mines Rescue Services is an industry owned organization, providing training for rescue brigadesmen and a complete, structured emergency rescue system primarily to the mining industry with the objectives of minimising the loss of life.

Education and Training

- Universities - Mining and coal metallurgy education are provided by the Universities of the Witwatersrand, Pretoria and Johannesburg at degree level. Some other universities also provide coal related courses.

- The Collieries Training College (CTC) was founded in 1962 to train artisans, miners and coal processing operators for the coal sector. It is owned by a number of coal producers.

Service Providers

- The CSIR has the following capacity that relates to coal mining:
  - Fires and Explosion Test, Training, Research and Development Facility (Kloppersbos)
  - Coal Processing.

- SABS provides services for coal analyses.

- Transnet Freight Rail operates the heavy haul coal line extending from Ogies in Mpumalanga to Richards Bay. It is connected to most major export collieries by private sidings.

- Road Transporters transport coal by road from mines, mostly to Eskom power stations, but also to rail sidings and other consumers.

- Transnet Port Terminals operate two coal terminals, one in Richards Bay and one in Durban.

- Grindrod Terminals operates the Navitrade terminal in Richards Bay. There are plans to expand its capacity from the current 3 mt/a to 20mt/a.

  Grindrod's Terminal de Carvão da Matola operates a dry-bulk terminal in Mozambique which has an export throughput capacity of 7.5 million tons, handling magnetite and coal. Phase 4 of the expansion project will increase the terminal capacity to more than 20 million tons, and is currently in advanced feasibility stage.

- Richards Bay Coal Terminal is a privately-owned facility with a design capacity of 91 mtpa. There are plans to expand its capacity to 110mtpa.

  An allocation, reserved for emerging miners, is managed by UBU on behalf of Government.

Equipment Suppliers

The Construction and Mining Equipment Suppliers Association (CONMESA) is an association of mining equipment suppliers. Many of its members are purveyors of coal mining and coal processing equipment.

Coal Users

The major coal users are:

- Eskom
- Sasol
- Arcelor Mittal S A (coking coal)
- Ferroalloy, other iron and steel manufacturers (coal, char, coke is reductant/electrode)
- Clay brick manufacturers
- Cement and lime producers
- Pulp and Paper producers
- Sugar producers
- A host of food and chemical manufacturing industries, hospitals, mines, transport, etc.

Regulators/Regulations in the Coal Sector

- Department of Mineral Resources
- Mineral and Petroleum Resources Development Act
- Mine Health and Safety Act
- Department of Water and Sanitation
- National Water Act
- Water Services Act
- Department of Labour
- Occupational Health and Safety Act

- Basic Conditions of Employment Act
- Department of Energy
- National Energy Act
- National Energy Regulator Act
- Department of Environment
- National Environmental Management Act.
- Department of Transport
- National Railway Safety Regulator Act
- Department of Public Enterprises

4. The Socio-economic Benefits of Coal

In order to remain competitive in today's globalised economy, a country must use those natural resources that enable the production of the highest-quality products at the lowest possible cost. Electricity is undoubtedly the largest contributor towards production cost as electricity consumption is a necessary part of any manufacturing or service process. We must optimise the use of our natural energy resources in order to ensure our comparative economic advantage in negotiations with our trading partners and when competing in exports.

South Africa hosts an abundance of coal resources which, subject to conducive economic and energy policies, would continue to serve as an affordable, reliable source of energy for local industries, businesses, and households. The utilisation of domestic energy resources reduces our need to import, thereby promoting energy security and limiting our exposure to increasingly volatile commodity prices and currency rates. By refurbishing Eskom's existing power stations with available technologies (see Section 6) and ensuring proper maintenance practices, as well as opening the sector to independent coal-fired power producers, it would be possible to retain this tried-and-tested power generation fuel in our energy mix.

A portion of our coal is also in demand internationally which creates an indispensable stream of foreign revenue, helping to offset the currency risks we face when importing goods. The mining of export-grade coal is technically possible and economically viable due to the simultaneous extraction of lower coal grades. The latter is currently consumed by Eskom in generating over 90% of our electricity and would otherwise have gone to waste.

The coal mining industry is not limited to mines and power stations alone. It is supported by a complex network of traders, logistics suppliers, and service providers, who, owing to years' investment in training and development, ensure that South Africa is one of the lowest cost coal suppliers in the world.

Decades of coal utilisation in South Africa has enriched our expertise in and understanding of each of the many stages of the supply chain. South African researchers, academics, and engineers continue to develop world-class methods and technologies to improve coal supply and utilisation efficiency, as well as reduce the environmental impact of coal use.

The coal sector includes an increasingly important group of emerging black industrialists, many of whom have been part of the industry for several years and who are currently investing their efforts in developing the future means for enlarged participation in the envisioned South African coal industry.

The following sectors and industries have significant socio-economic dependence on coal.

Electricity production

Eskom Holdings SOC Ltd operates the following 14 coal fired power stations, as shown in Table 4.1.

Table 4.1 **Eskom Power Stations** (Eskom Holdings SOC Ltd, 2016 Integrated Report)

Name of station	Location	Years commissioned – first to last unit	Number and installed capacity of generator sets MW	Total installed capacity MW	Total nominal capacity MW
Base-load stations					
Coal-fired (14)				**38 548**	**36 441**
Arnot	Middelburg	Sep 1971 to Aug 1975	1x370; 1x390; 2x396; 2x400	2 352	2 232
Camden[1,2]	Ermelo	Mar 2005 to Jun 2008	3x200; 1x196; 2x195; 1x190; 1x185	1 561	1 481
Duvha[3]	Emalahleni	Aug 1980 to Feb 1984	6x600	3 600	3 450
Grootvlei[1]	Balfour	Apr 2008 to Mar 2011	4x200; 2x190	1 180	1 120
Hendrina[2]	Middelburg	May 1970 to Dec 1976	5x200; 2x195; 2x170; 1x168	1 893	1 793
Kendal[4]	Emalahleni	Oct 1988 to Dec 1992	6x686	4 116	3 840
Komati[1,2]	Middelburg	Mar 2009 to Oct 2013	4x100; 4x125; 1x90	990	904
Kriel	Bethal	May 1976 to Mar 1979	6x500	3 000	2 850
Lethabo	Vereeniging	Dec 1985 to Dec 1990	6x618	3 708	3 558
Majuba[4]	Volksrust	Apr 1996 to Apr 2001	3x657; 3x713	4 110	3 843
Matimba[4]	Lephalale	Dec 1987 to Oct 1991	6x665	3 990	3 690
Matla	Bethal	Sep 1979 to Jul 1983	6x600	3 600	3 450
Tutuka	Standerton	Jun 1985 to Jun 1990	6x609	3 654	3 510
Kusile[4]	*Ogies*	*Under construction*	*6x800*	–	–
Medupi[4]	*Lephalale*	*Unit 6: Aug 2015*	*6x794*	794	720

The combined coal usage of these 14 coal stations was 114.8 Million ton in FY 2015/16. The average of these 14 stations conservatively employs an estimated 1000 staff permanently, with at least another 3000 contractors and support staff outsourced. This translates to **56,000 jobs** employed in the coal power industry at the stations (excluding head office staff). There is additionally a formal social structure that develops around each station, sometimes leading to creation of a town (e.g. Kriel).

Trucks and Transport

Whilst many of the Eskom stations have tied-collieries supplying coal by conveyor belt, it is Eskom's stated intent to procure consignment coal from small-scale BBBEE suppliers. Eskom transports about 39Mt of coal on roads in the Mpumalanga province out of a total of 114Mt of coal burnt in 2015. This represents a total of more than 34% of Eskom coal burnt in 2016. There are 3000 trucks transporting Eskom coal and assuming 2 shifts this translates to **6,000 jobs**, excluding the support staff.

Coal Mines

The coal mining industry directly provided **78,000 jobs** in 2016, which excludes merchants and other traders.

Industrial Coal-fired Users

There are some 6 000 industrial-scale users of coal, including hospitals, food, chemical and other manufacturing factories such as brick and tile, cement, paper and pulp, metallurgical plants (kilns etc), mines (such as for platinum processing), transport etc. A conservative estimate of 5 staff per industrial site would translate to **30,000 jobs**, plus the additional distribution network for transport coal to such sites.

SASOL

South Africa's pioneering coal-to-liquids industry provides 30% of this country's liquid fuel products (petrol, diesel and paraffin), and a multitude of additional products including, inter alia, plastics, paint, explosives, fertilisers for the agricultural industry, tar and bitumen for road making, binders for the metallurgical iron and steel and ferroalloy industries, textiles, pharmaceutical products (e.g. lipsticks), food products, and many additional items for the manufacturing world. Without the element carbon forming the basics of these products, the country would inevitably have to revert to importing materials from abroad at significantly high cost.

Sasol employed some 25,394 staff in South Africa in 2016, and this can be multiplied by a factor of more than 3 to account for outsourced contractors and support staff. This translates to some **76,000 jobs**.

Metallurgical

Coal is the primary 'reductant' or mineral needed to reduce and thereby extract iron, chrome, platinum, manganese, silicon, vanadium etc. from their host ores in order to make products such as steel, ferroalloys etc. Coal and its carbon derivatives (coke, char, semi-coke, anthracite) provide 95% of the materials used to reduce (extract) such valuable mineral elements. Without these valuable mineral elements there would be no aircraft, cars, busses, trains, ferries, bikes and stainless steel objects such as cutlery, building frames and so on. An average refrigerator requires 70 kg of steel alone. Every solar frame is made from some form of steel. Every 1 MW of wind turbine capacity requires 220 tons of coal or the equivalent steel found in 220 small cars. Even the foundation of a wind turbine is made from concrete, which in turn is made using coal.

The metallurgical industry provided an estimated **10,000 jobs** during 2016.

SUMMARY

In summary, the coal industry directly provides some **255,000 jobs per year,** for just the industries examined. This is summarised in Table 4.2.

Table 4.2 South African Coal Sector Jobs and Dependents

SECTOR	JOBS PROVIDED
MINES	78,000
SASOL	75,000
ESKOM	56,000
INDUSTRY	30,000
METALLURGICAL	10,000
TRANSPORT SECTOR	6,000
TOTAL JOBS	255,000
DEPENDENTS/JOB	4
TOTAL DEPENDENTS	1,020,000

Assuming each salaried person carries 4 or more other dependants then an estimate would be that the coal industry has some **1,020,000 dependents** as shown in Table 4.2**.** The coal industry supports a further informal trading economy, of which no account has been taken in the above estimates.

At this stage FFF can only estimate additional impacts of a major decline in the coal industry and industries associated with it, which includes inter alia:

- The **cost to replace the items that coal provides that renewables cannot provide.** i.e. The value of coal as a source of carbon for the hundreds of thousands of products currently produced in SA – including but not limited to petrol, diesel, plastics, paints, ammonia, fertilisers, explosives (for the mines), food, hundreds of chemical and material products, bitumen and tar, binders and fillers for electrodes, coke, char and other reductants etc.
- The **cost of the closure of towns, schools, hospitals, clinics, infrastructure, training centres, etc.** supported by the mines and power stations, Sasol, and metallurgical industries – towns such as Witbank, Middelburg, Secunda, Sasolburg, Lephalale, Delmas, Ermelo and Carolina.
- A **GDP decline**, **investment loss**, **tax income reduction**, **balance of payment decline** due to increased importation of gas/diesel to supplement capacity, **reduction in forex** derived from the export of coal that is dependent on a parallel domestic market, and **rising electricity costs**.

There are many examples internationally of local and regional economies devastated by the closure of a major industry, as evidenced recently with the closure of the USA coal industry. A very good case study has been summarised from the lessons learnt during the closure of the coal industry in The Netherlands in the 1960's (see Section 8 below).

5. Environmental Aspects of Coal

There are many environmental problems associated with all technologies associated with generating electricity, including coal. Whilst coal emissions can be mitigated to some extent (e.g. scrubbing SOx or reducing NOx), reducing CO_2 emissions remains coal's most obvious challenge. International efforts regarding factors possibly affecting climate change are coordinated through the United Nations Framework Convention on Climate Change (UNFCCC). The parties to the UNFCCC have met annually since 1995 in Conferences of the Parties (COPs), to assess progress in dealing with climate change. COP21 closed in Paris on 12th December 2015 with an agreed statement known as the Paris Agreement. This agreement set long term objectives but left each country to determine their own timetable and the steps that they needed to take. However, South Africa has already made a commitment (the Peak-Plateau Decline trajectory), which shows the mid-range of GHG emissions in 2050 at 60% of today's.

The FFF recognises the problem of emissions associated with coal usage, and will describe technological solutions that can be taken in the South African context in Section 6.

6. New Coal Technologies

I. Introduction

South Africa has an escalating energy and electricity requirement, as outlined in the draft Integrated Energy Plan and the Integrated Resource Plan ("IRP 2016") respectively. These plans seek to satisfy the accelerating demand of electricity by diversifying the country's energy sources, and achieve a balance of availability, affordability, and cleanliness.

South Africa's energy needs are presently served by several indigenous and imported primary energy carriers, but almost 70% is derived from coal. Coal is likely to decline in predominance as legislation leads the introduction of alternative lower carbon energy sources and new technologies. However, the coupling of escalating demand and diversification still results in coal continuing to play a significant role in the country's primary energy supply.

Therefore, a pragmatic approach necessitates that coal will continue to serve the country's energy needs for the foreseeable decades, and new coal-based technical solutions are therefore essential to ensure this is accomplished efficiently, cleanly, with as much operational flexibility and with as low a cost as possible. This is recognised by South Africa's National Development Plan – 2030, *"coal technologies will be promoted through research and development investments and technology-transfer agreements in, among others, the use of ultra-supercritical coal-power plants, fluidised-bed combustion, underground coal gasification, integrated gasification combined cycle and carbon capture and storage"*.

Sustainable coal technology options are those that seek to match or better existing energy production, and reduce water usage and waste/emission streams, whilst maintaining affordability and availability. Each stream has a natural benchmark technology, for example, in the case of pulverised coal electricity production, this would be super-critical pulverised fuel technology as implemented at Medupi and Kusile Power Stations. Figure 6.1 illustrates several of the coal-based technology options, and an indication of localisation and development already underway by local institutions.

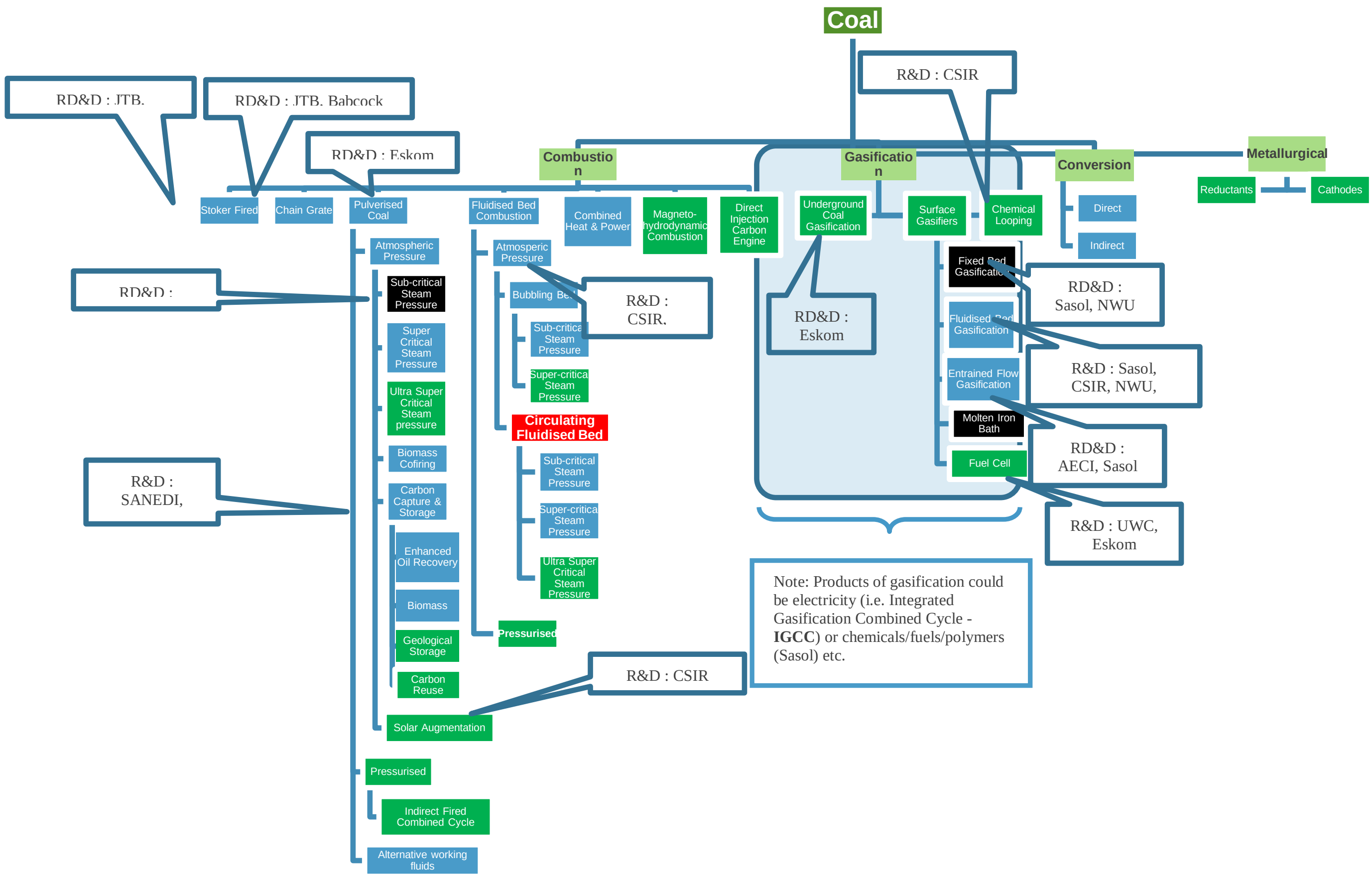

Figure 6.1. Typical historical, current and future coal technology options
(Shading: black = no longer built, blue = current, green = under development).

II. Technology

The various key Clean Coal Technology options are described in more detail in this section. The fundamental drivers for cleaner coal technologies can be diverse, with the key factors generally being to reduce emissions and cost. For example, high efficiency cycles are typically applied where the fuel costs are high, as in Europe. Fuel costs for indigenous coal resources are lower in South Africa, and while local generating costs are important there is an equal drive to lower emissions.

The actual boiler combustion/thermal efficiencies (that is for conversion of coal to steam) are usually above 95%, therefore the focus has shifted to the steam cycle, where thermodynamically higher efficiency can be achieved by raising the temperature of the high temperature side of the cycle and/or lowering the temperature of the lower temperature side of the cycle. This is typically achieved by raising main steam and reheat temperature and pressure, and lowering condenser pressure.

For combined cycle plants the developing trend is for higher efficiency achieved through lower excess air gas turbines combined with supercritical heat recovery steam generators (HRSG's) where cycle efficiencies of the latest models are greater than 50%. In a similar way, other technologies using water as a working fluid (such as Circulating Fluidised Bed Combustor (CFBC) boilers) can be configured as supercritical water/steam cycles to yield higher cycle efficiencies.

It must be recognised that in South Africa, given our water scarcity, that dry cooling will likely be prescribed on all new plant. As such, local plant will be penalised on the condenser pressure, and a compromise will need to be found between water conservation and reducing CO2 emissions through efficiency gains.

New cleaner coal technologies are under development that use different thermodynamic cycles (e.g. fuel cells, magnetohydrodynamics - MHD), intermediaries (such as in chemical looping), and combined fuels (e.g. biomass with coal).

Other achievements by Eskom and modern coal plants are reductions in Greenhouse Gas (GHG) emissions. Eskom's oldest plants produce emissions of 1.10 – 1.25 t CO2e/MWh. New super-critical technology plant (such as Medupi and Kusile) produce emissions of just under 0.80 tons CO2e/MWh, which is a reduction of 33%. These reductions compare favourably with the savings made by switching to gas (0.6 tons CO_2e/MWh for open-cycle turbines).

A short technology summary follows.

Pulverised coal (PC)/Pulverised Fuel (PF) technologies (comprising Supercritical, Ultra-supercritical and Advanced Ultra-supercritical)

Pulverised coal (PC) technology, otherwise known as pulverised fuel (PF) technology in some countries, has been in operation internationally since the 1920's and has replaced chain grate/stoker technology on all power stations in South Africa since the 1970's. PC/PF technology is therefore relatively mature, both internationally and certainly in South Africa where it is still currently the technology of choice for all the currently operating coal power stations.

The latest evolution in PC/PF technology has been the increase in steam cycle temperature and pressure (as described above), in variations termed Super-critical (SCPC/SCPF), Ultra-super critical (USCPC/USCPF) and Advanced Ultra-supercritical (AUSCPC/PF) plant. Both variations are commercially available, although the USC and AUSC are still in developmental phases. The existing South African coal power station fleet runs sub-critical PC/PF technology, and the new Medupi and Kusile power stations will be the first SCPC/PF units in the country.

Integrated Gasification Combined Cycle technologies

Integrated Gasification Combined Cycle (IGCC) uses part of the energy in the coal to drive gasification reactions, that converts the coal into a gaseous fuel (called synthesis gas or syngas). The gas is then cleaned to remove impurities before it is combusted in a gas turbine integrated with a steam turbine. The combined Rankine and Brayton cycles lead to the "integrated" portion of the technology name. This technology has lower emissions of sulphur dioxide, particulates, and mercury, and lends itself to easier removal of carbon dioxide compared to combustion processes.

South Africa is a world leader in fixed bed gasification and syngas cleaning through the enormous efforts of Sasol, and Eskom has decades of experience with steam turbines and more recently gas turbines. The area therefore requiring most research and development is the next generation of gasification processes, where both Sasol and Eskom have already made significant advances. Sasol has optimised fixed bed gasification, and explored both fluidised bed and entrained flow surface gasifiers. Both Sasol and Eskom have explored Underground Coal Gasification (UCG), and Eskom successfully ran a pilot UCG plant on the Majuba coalfield from 2007-2011, proving its commercial viability under local conditions with local coal. UCG has a unique ability to cost-effectively, cleanly and very efficiently mine three quarters of the country's coal resources that are presently "unminable" with conventional technologies. Eskom's intent is to commercialise the technology through partnership, with the eventual aim being to pair UCG with IGCC for a leading edge clean coal technology.

Fluidised Bed Combustion (FBC)

There are several industrial scale Bubbling Fluidised Bed (BFB) plants operating in South Africa, most of which operate in combustion mode (i.e. BFBC). These were pre-empted by lab and pilot scale BFBC research facilities that exist at the CSIR, Eskom, Mintek (primarily for minerals treatment), Sasol (for Fischer-Tropsch reaction research), the University of the Witwatersrand, North West University, the University of Pretoria and the University of KwaZulu-Natal.

All of the research and development efforts to date in South Africa have focussed on BFBC. The next evolution of FBC is Circulating Fluidised Bed Combustion (CFBC). The benefit of CFBC is the circulating bed, which results in a lower bed density, lower temperatures and less risk of agglomeration.

CFBC has developed as the most competitive coal combustion technology in comparison to PC/PF, with an excellent, proven track record internationally. However, there are no CFBC boilers in South Africa and local application and optimisation of the technology is required.

Other Clean Coal Technology Options

Many other coal-based technologies are still under development, driven by the need to improve the sustainability of coal as a fuel, and by the generally declined quality of coal resources remaining. Such technologies (Zhu, 2015) range from:

- direct processes such as Oxy-fuel combustion, Magnetohydrodynamics (MHD), Kalina cycle, organic Rankine cycle, Goswani cycle, Solar hybrid etc.
- indirect processes (involving an intermediate step) such as:
  - Fuel Cells
  - High Performance Power generating Systems (HIPPS) / Indirectly Fired Combined Cycle (IFCC)
  - Chemical Looping
  - and others.

All of these technology options are being carefully monitored by the entities in Figure 6.1 for commercial readiness, and for possible implementation in South Africa.

III. Technology Performance

The performance of the various generating technology options (including coal) are indicated in Table 6.1 below.

Table 6.1. **IRP Technology Performance** (Power Generation Technology Data for Integrated Resource Plan of South Africa, Technology Update, EPRI USA, Aug 2015)

		Water	Sorbent	Emissions			Solid Waste	Economic Life	Fuel
Technology	**Description**			**CO2**	**SOx**	**NOx**			
		l/MWh	kg/MWh	(kg/MWh)	(kg/MWh)	(kg/MWh)	(kg/MWh)	Years	
PC w/out FGD	1 x 750 MW net	33.4	0	930.2	9.03	1.91	169.5	30	
PC w/ FGD	1 x 750 MW net	231	15.8	947.3	0.46	1.94	196.5	30	
PC w/ CCS	1 x 750 MW net	320	22.8	136.2	0.66	0.42	282.5	30	
IGCC w/out CCS	1 x 644 MW net	256.7	0	930	0.18	0.23	182.3	30	COAL
IGCC w/ CCS	1 x 644 MW net	1027	0	120	0.23	0.29	234.3	30	
FBC w/out FGD	1 x 250 MW net	33	0	1003	10	0.28	187.7	30	
FBC w/ FGD	1 x 250 MW net	33	41	1003	0.5	0.28	224.5	30	
FBC w/ CCS	1 x 250 MW net	50	59	150	0.72	0.41	322.9	30	
AP1000	1 x 1117 MW net	0	0	0	0	0	radioactive	60	NUCLEAR
Areva	1 x 1600 MW net	0	0	0	0	0	radioactive	60	
OCGT	1 x 132 MW net	0	0	574	0	0.3	0	30	
CTCC w/out CCS	1 x 732 MW net	12.8	0	367	0	0.17	0	30	LNG
CTCC w/ CCS	1 x 635 MW net	19.3	0	42	0	0.21	0	30	
ICE	1 x 1.9 MW net	0	0	491	0	1.34	0	30	
Wind	10 x 2 MW net	0	0	0	0	0	0	20	WIND
Parabolic Trough w/o Storage	1 x 125 MW net	319	0	0	0	0	0	30	
Parabolic Trough w/ Storage	1 x 125 MW net	298	0	0	0	0	0	30	
Central receiver w/ Storage	1 x 125 MW net	302	0	0	0	0	0	30	SOLAR
CdTe PV	1 x 1 MW net	6.4	0	0	0	0	0	25	
C-Si PV	1 x 1 MW net	8.3	0	0	0	0	0	25	
CPV	1 x 10 MW net	15.1	0	0	0	0	0	25	
Forestry residue	1 x 25 MW net	227	0	1243	0.75	0.58	25.1	30	BIOMASS
Municipal Solid Waste	1 x 25 MW net	227	0	1633	0.57	2.21	365.8	30	
Landfill Gas	1 x 5 MW net	0	0	806	0	0.61	0	30	BIOGAS
Biogas	1 x 5 MW net	0	0	787	0	0.59	0	30	

7. Eskom's Plan to Decommission Power Station Units

The current IRP is based on a relatively rapid decommissioning of the existing coal plant, and FFF contends that the life extension of existing plant needs to be seriously considered.

The current fleet of Eskom Power Stations has been built over the period of 1967 to the present. However, the bulk of the capacity was commissioned in the period from 1976 to 2000. This means that they presently range in age from 17 to 40 years. By 2050, at the end of the IRP 2016 planning period, they will range from 50 to 75 years. Obviously, all mechanical equipment has a practical and economic life. It has been stated by Eskom that although the original design life was 40 years, in their planning they have extended this to 50 years.

Thus, by the end of the IRP planning cycle in 2050, it has been assumed that a total of 37,800 MW of capacity will have been decommissioned and needs to be replaced. The numbers can be seen in Table 7.1, taken from the 2016 Eskom Integrated Report.

Table 7.1 **Eskom Power Station Decommissioning Dates**
(Eskom Holdings SOC Ltd, 2016 Integrated Report)

Power plant	Province	Date commissioned (planned)	Capacity MW (planned)	Status	Coordinates	Operator	Planned decommissioning dates[14]
		Total:	40,036 (8770)				
Arnot Power Station	Mpumalanga	1971-1975	2,352	Operational	25°56′38″S 29°47′22″E	Eskom	2025-2029
Camden Power Station	Mpumalanga	1967-1969; 2005-2008	1,561	Operational	26°37′13″S 30°05′38″E	Eskom	2020-2023
Duvha Power Station	Mpumalanga	1980-1984	3,600	Operational	25°57′50″S 29°20′14″E	Eskom	2030-2034
Grootvlei Power Station	Mpumalanga	1969-1977; 2008-2011	1,180	Operational	26°46′S 28°30′E	Eskom	2025-2028
Hendrina Power Station	Mpumalanga	1970-1976	1,893	Operational	26°01′59″S 29°36′00″E	Eskom	2021-2027
Kelvin Power Station	Gauteng	1957	214	Operational	26°06′58″S 28°11′38″E	Aldwych International	
Kendal Power Station	Mpumalanga	1988-1992	4,116	Operational	26°05′24″S 28°58′17″E	Eskom	2038-2043
Komati Power Station	Mpumalanga	1961-1966; 2009-2013	990	Operational	26°05′24″S 29°28′19″E	Eskom	2024-2028
Kriel Power Station	Mpumalanga	1976-1979	3,000	Operational	26°15′15″S 29°10′46″E	Eskom	2026-2029
Kusile Power Station	Mpumalanga	(2017–2021)	(4,800)	Under construction	25°54′59″S 28°55′02″E	Eskom	
Lethabo Power Station	Free State	1985-1990	3,708	Operational	26°44′31″S 27°58′39″E	Eskom	2035-2040
Majuba Power Station	Mpumalanga	1996–2001	4,110	Operational	27°06′02″S 29°46′17″E	Eskom	2046-2050
Matimba Power Station	Limpopo	1987-1991	3,990	Operational	23°40′06″S 27°36′38″E	Eskom	2037-2041
Matla Power Station	Mpumalanga	1979-1983	3,600	Operational	26°16′57″S 29°08′27″E	Eskom	2029-2033
Medupi Power Station	Limpopo	(2015–2019)	1588 (4,764)	1st Unit Operational	23°42′S 27°33′E	Eskom	
Pretoria West Power Station	Gauteng	1952	180	Operational	25°45′28″S 28°08′49″E	City of Tshwane	2016
Rooiwal Power Station	Gauteng	1963	300	Operational	25°33′21″S 28°14′18″E	City of Tshwane	2025
Tutuka Power Station	Mpumalanga	1985-1990	3,654	Operational	26°46′43″S 29°21′07″E	Eskom	2035-2040

The IRP assumes that this capacity must be replaced with new build at considerable cost. To illustrate this, refer to Figure 7.1 which has been taken from the recent CSIR presentation. It can be seen here that the total supply gap by 2040 will be about 330 TWh/yr. Of this amount, over 45% is created by the decommissioning plans.

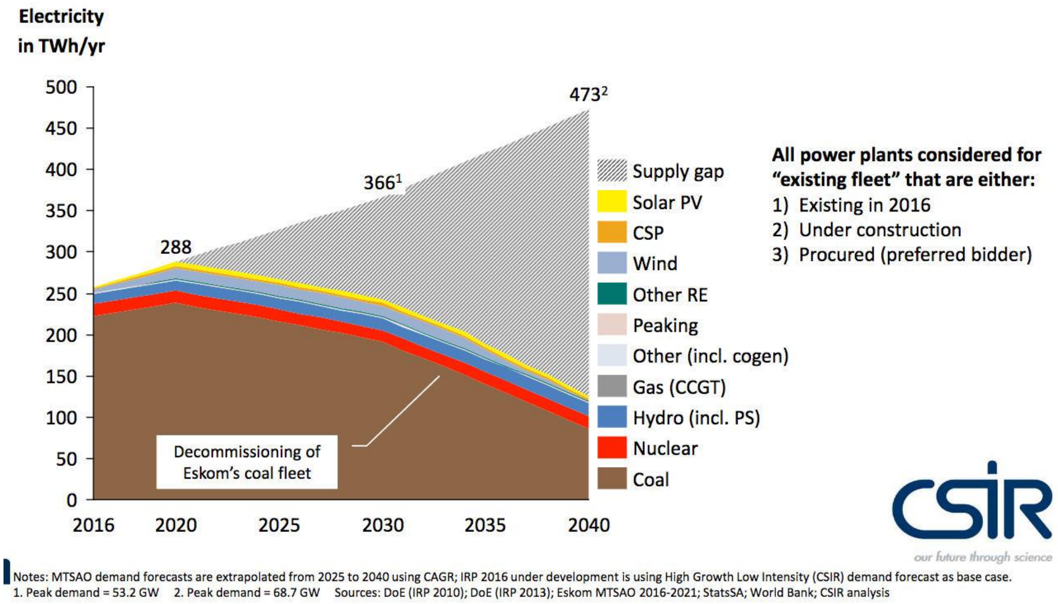

Figure 7.1 **CSIR Electricity Supply Gap**

Apart from the economic cost associated with this replacement there will also be severe socio-economic costs, which are illustrated in Section 8. It is the view of the FFF that it will be worthwhile and necessary for the Department of Energy to consider other alternates for some or all of the newer Eskom stations (those built after 1976).

The Fossil Fuel Foundation therefore recommends that life extension of many of the existing Power stations be considered as an option in the IRP. The cost of such life extension projects would clearly be less than the envisaged new build and would alleviate some of the destruction of communities that would otherwise ensue.

Options that could be considered include:

a) Life extension by replacement and upgrading of components and auxiliary systems, addition of enhanced particulate, SOX and NOX removal equipment, conversion to dry cycle etc.
b) Major refurbishment of all steam boiler and generator equipment
c) Replacement of the entire power station unit with new and improved HELE units or CFBC technology which would lower emissions, reduce water consumption and improve efficiencies while still relying on the existing technical and social infrastructure.

8. Destruction of Communities

Without exception Eskom's large power stations are located in rural areas and have been created together with residential areas or towns. Over time these have expanded into large communities, but still with the coal mine and power station as their sole source of employment. It must be realized that closure of the power station would in many cases result in the destruction of the communities as has been seen in the case of the Free State goldfields and many other similar communities globally.

Serious consideration must be given to the impact of closures on coal-based mines and manufacturing industries. By way of example, Kriel, a town and community of 55,000 residents is TOTALLY dependent on the two power stations in and near the town, namely Kriel and Matla and the two supporting mines. Both of these power stations are presently scheduled by Eskom to shut down between 2026 and 2032, i.e. TEN YEARS from now.

Such closure of the power stations and mines would destroy the town. There would be virtually NO employment, thousands of housing units would become worthless and many small and medium enterprises would be closed. Eskom and the associated coal supply mines probably employ 3000 to 4000 persons each, but the resulting closure would affect more than 4 times this.

The **Minister of Public Enterprises Honourable Lynne Brown** recognised the problem in an article in Business Day ("South Africa is not about to turn its back on power from coal", 17 March 2017) in which she stated "**SA's journey from a coal-fired economy to an energy mix combining coal, nuclear, gas and renewable sourced energy is underway. It is a highly complex journey that must be undertaken with due consideration for the tens of thousands of our compatriots who rely on coal for a living**"

There are relevant lessons to be drawn from experience in the Netherlands in the 1960s and 1970s. Whilst The Netherlands of this period bore no resemblance to present South Africa economically, the lesson learnt from their poor planning is relevant. Coal production had expanded tremendously at the beginning of the 20th century, but after World War 2 the energy market in oil became a new source of energy substituting coal for energy supply. In addition, the Netherlands discovered large amounts of natural gas in the north in 1959, and after that, natural gas emerged as a good substitute for the energy provided by coal and oil. The Dutch government announced the closure of the coal mines at the end of 1965. Over a period of approximately 70 years the Dutch coal mine industry had started, grown, matured, declined and ended and in 1974 the last Dutch coal mine was closed. At the time of the announcement 53.000 people were employed; a further 30.000 depended indirectly on the coal mines (e.g. suppliers of materials, goods and services). The industry was dominant in a small geographic area (South Limburg) and contributed largely to the region's well-being and the regional income.

A report was issued in 2012 by Maastricht University on 35 years of economic redevelopment, reconversion or restructuring after the 1974 coal mining industry closure, explaining what strategic decisions and measures were taken to solve the economic and social problems that the area experienced after the closure. The report "The aftermath of the closure of the Dutch coal mines in South Limburg: regional economic and social reconstruction" is available at http://nowa-energia.com.pl/wp-content/uploads/2013/03/raport_uniwersytet_w_maastricht_en.pdf.

Description of the problem: the report notes:

- "The regional economy was largely dependent on the coal mine industry. Indeed, this dependence on and domination of one industry in the area resulted in the under-development of entrepreneurship and other domains. With the closure, not only would the "economic domination" change, but the social domination would change as well. The mining companies had taken care of their employees 'from the cradle to the grave', offering jobs and support not only for the employees but also for their families. Beyond being solely an employer, the coal mines were also an important player in creating social cohesion as a sponsor or organizer of many (social) events, parties and festivities in the region. In addition to the loss of jobs, the fear was that the social structures provided by the mining companies and the church would also be demolished." (p.5)
- "Miners who lost their jobs also lost status in society. Their self-esteem deteriorated, and social isolation occurred—the mines were no longer guiding the social infrastructure of society. Together with the upcoming secularization, the closing of the mines caused insecurity among the miners and unrest in families. Although this problematic situation was acknowledged, the government did not take large-scale action to avoid and solve the problems. Little money was invested in solving the social problems; rather, creating new jobs was the highest priority." (p.8)
- "Less money was invested in restructuring and improving the industrial structure of the area and in solving the social problems." (p.8)

1965 - 1974: special measures the Dutch government took included:

- Subsidies on the price of buying land by existing and new industrial firms or by service firms that promote/drive new employment;
- Guarantees for loans to companies when a (new) company met the criteria of the restructuring of the area and its equity was a reasonable part of total assets;
- Establishment of offices for national public services (e.g. taxes, statistics, pension funds;
- More than 25 larger and smaller institutions came to the area);
- Establishment of the DAF automobile factory in Born (1967);
- Arrangements with privately owned mining companies. The contracts specified that these companies should invest the resources that were present at the moment of

closure in principle in new industrial activities in the Netherlands, preferably in South Limburg;

- Information, advice and education on jobs, schooling and employment finding.
- Measures were also taken to improve the infrastructure (e.g. highways, railways, waterways, airport) to enable better accessibility to the area.

1978 – 1990: more decentralized policy making by the province of Limburg

- All efforts were geared toward creating a durable and stable new economic infrastructure, with long term-benefits for the entire region. In addition, more attention was given to the social and personal welfare of the people in the region. Attention was also aimed at projects to further improve the physical infrastructure (e.g. highways, railways, bridges, conference and exhibition centre).
- The change in national policy from a defensive policy to protect and keep employment (even in companies that were not viable in the long run) to an offensive, technology policy guided the new regional restructuring policy – a focus on stimulating innovations in successful firms rather than supporting weak and unsuccessful companies in the short run.
- A crucial role was given to the Provincial government: it was charged with selecting and initiating projects and, through both formal meetings (annual budget talks) with the national government and informal routes (lobbying), ensuring that projects received the necessary funding.
- A more focused approach on economic redevelopment was taken. Four different sub-regions were distinguished within the region of South Limburg, with different specialisations.
- Members of Parliament with different political backgrounds, who all came from the Limburg area, joined forces to lobby for Limburg interests and took initiatives in Parliament to allocate specific financial means and institutions to the region.

There is clearly a wealth of experience from the South Limburg coal mine closure, which should be examined in some detail and used to guide the transition from a totally coal-dominated nation to one in which coal continues to play a major part in an increasingly diverse energy mix in South Africa.

9. Summary and Conclusions

Coal production, consumption and export is a significant industry in South Africa. Coal has a legacy that extends back almost 150 years in South Africa, and it drove the country's industrialisation. As a commodity and an energy and chemical source, it is in many respects irreplaceable. However, the continued usage of coal has many environmental implications which necessitate the use of alternative energy resources. This report argues a balanced case for coal as a continued energy and material resource in an environmentally sound manner.

Planning for low-baseload electricity growth in the IRP 2016 is a self-fulfilling prophecy, and setting South Africa on a path of slow growth and lack of both domestic and foreign investment primarily in the mining and manufacturing industries. Public policies need to focus on making South Africa attractive for investment. Industrialised countries must recognize that emerging and developing economies have different needs and priorities. Emerging markets need secure baseload electricity at the lowest possible cost to give them a comparative economic advantage, whether the natural resource used is oil, hydro, renewables or a fossil fuel such as coal or gas. The developed world needs to recognize that, at this stage of technological development, fossil fuels in the form of gas and coal will continue to play a substantial role as a major energy source for emerging economies. Earlier this year, former US president Obama acknowledged that emerging economies such as India, China, and the ASEAN countries would be building coal-fired power stations out of necessity, but advised they should use clean coal HELE technologies. Current US president Trump also appears to endorse this approach.

The FFF summarises the following advantages of continuing the usage of coal:

- **Coal can be used as a clean, low emission source of electricity** for South Africa with the correct application of modern HELE technologies for new coal power stations. **Coal-based HELE technologies therefore need to be included in the IRP.** Asia, another region heavily dependent on coal, has embraced clean efficient, HELE coal-fired generation with some 725 units in place while a further 1142 installations are under construction or planned.

  HELE coal-fired generation is significant as it emits up to 40% less emissions than the oldest technology in place. Furthermore, the most modern plants are using accompanying technology to reduce all other emissions including particulates to levels that comply with the most stringent urban air quality requirements.

- **Old coal power stations can be refurbished by installing HELE technologies.** This could be the lowest cost for new capacity. Life extension and maintenance therefore needs a full economic study.

- **Coal is a vital part of the economy,** ensuring access to electricity, a high standard of living and job creation. **Rapid reduction in its use would lead to considerable unemployment, higher costs and a destabilised manufacturing industry** with loss of key commodities being manufactured in this country (petrol, diesel, iron, steel, ferrochrome and a host of diverse downstream products). **The socio-economic impacts must be urgently studied in detail**, to fully appreciate the complexity of reducing the country's use of coal as a primary energy resource. A solution to South Africa's future energy needs must be determined in a way that meets the environmental requirement to move away from fossil fuels in due course but at the same time this should be done with due regard to the socio-economic impact, particularly on small communities in Mpumalanga, Limpopo and the Free State which would be devastated by the planned shutdown of so many Eskom Power Stations and their related coal mines at the same time.

- **It is essential for the DOE to undertake a full economic impact study of effectively reducing the role of coal** in the economy.
- The transition, and particularly **the speed of transition from coal to alternative energy sources must be managed**, bearing in mind the socio-economic aspects.
- **South Africa has the capacity to commercialise new and adapted technologies** to achieve

  I. **lower carbon emissions and**
  II. **secure, consistent and reliable supply of electricity for the country and the region**

The following recommendations are proposed by the FFF for further investigation:

- **Baseload power from coal, gas and/or nuclear must remain for the foreseeable future** whilst introducing large scale, renewable energy sources.
- **Coal technologies need greater flexibility** to support grid integration of multiple energy sources.
- **South Africa will need to develop its "own plan"** for the most sustainable, efficient and market-appropriate mix of primary energy resources.
- For coal to continue as a vital element in the energy mix in South Africa, **clean and efficient coal-fired technologies most suited to South/Southern African coal types are required**.
- **South Africa should attract large-scale energy-intense heavy users** to create employment, and add value to the country's mineral resources. For this to happen, an inexpensive, sustainable and secure mix of reliable power is essential.

In conclusion, a strong appeal is made for the country to develop a formula that considers the region's QUADRILEMMA: namely, the relevance of, and balance between, Energy, Employment, Economics and the Environment. Without energy, economic development cannot happen, and without development and industrialisation, employment is limited or lacking and without employment poverty is rife. While the environment is an equal leg in this four-legged Quadrilemma, it must be addressed in proportion to its relevance in the country's growth and development.

The view of the Fossil Fuel Foundation is that:

- **Coal is the primary baseload energy source** in South Africa in the short to medium term
- **Coal-fired energy should be supported, promoted, produced and utilised** in the most environmentally sound and efficient manner whilst introducing other sources of energy in the longer term
- **Any plan to deviate from such a plan would be detrimental** to the country's national, social, economic and industrial fibre.
- **A balanced view is required** when introducing other sources of energy in the long term