

# ENERGY AND CCS POTENTIAL IN SOUTH AFRICA – A REVIEW



**AFRICARY**  
**African Carbon Energy**

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# Roadmap of presentation

- ❑ Background on South-Africa
- ❑ Coal – primary energy source
  - ❑ Coalfields
  - ❑ Role of coal in current economy
  - ❑ Power and liquid fuels production from coal
- ❑ Energy and coal related challenges
- ❑ Energy efficiency improvement
  - ❑ Clean Coal Technologies
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- ❑ Carbon capture and storage options
  - ❑ Sequestration options
- ❑ Coal Policy, Government and Legislation
- ❑ Future developments and R&D needs



# Background on South Africa



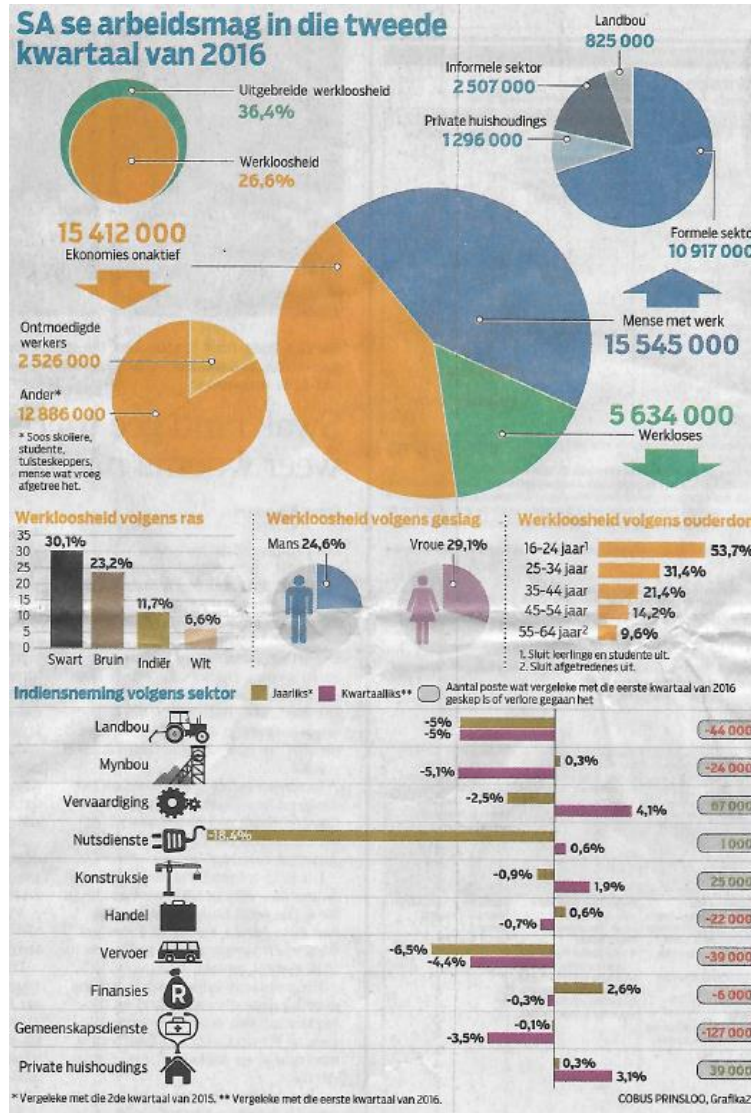
- ❑ 2 798 km's of coastline along the southern Atlantic and Indian Oceans.
- ❑ 25<sup>th</sup>-largest country in the world by land area and >55 million people.
- ❑ Today about 80% South Africans are of Sub-Saharan African ancestry, speaking different dialects, nine of which have official status, with the remaining population consists of European (white), Asian (Indian), and coloured ancestry - referred to as the "Rainbow Nation".
- ❑ Upper-middle income economy by the World Bank. 3<sup>rd</sup> largest economy in Africa and is the 34<sup>th</sup>-largest in the world.
- ❑ **>25% of the population unemployed and living on <US\$1.25 a day.**
- ❑ **World's largest and oldest commercial coal to liquids (CTL) plant.**
- ❑ **In Top20 of the most carbon-intensive economies in the world.**

# Background on South Africa (cont.)

Extended unemployment  
36.3% (real 26.7%)

Scholars, pensioners, home  
workers, etc.

Unemployment by race



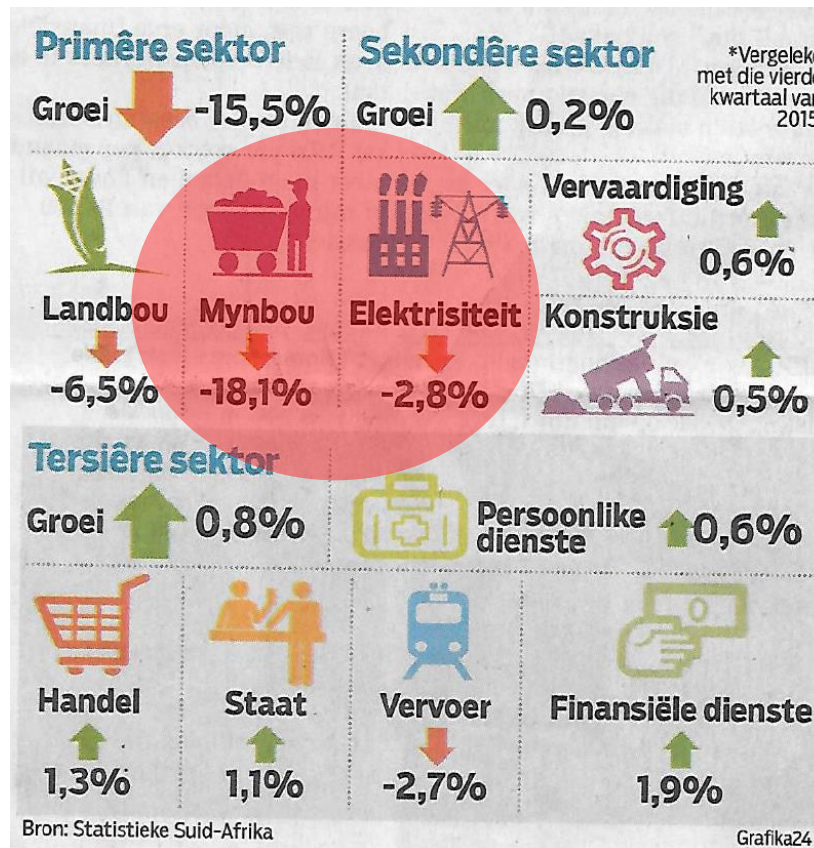
Qualified people  
unemployed >5M

Unemployment by age

Decline in mining sector 5.1%  
-24 000 employees

# Background on South Africa (cont.)

**MINING – A VOLATILE SECTOR**  
FROM A 6.8% GROWTH IN LABOUR MARKET  
TO 18,1% DOWN IN CONTRIBUTION TO SA'S  
ECONOMY (Q4 2015 TO Q1 2016)

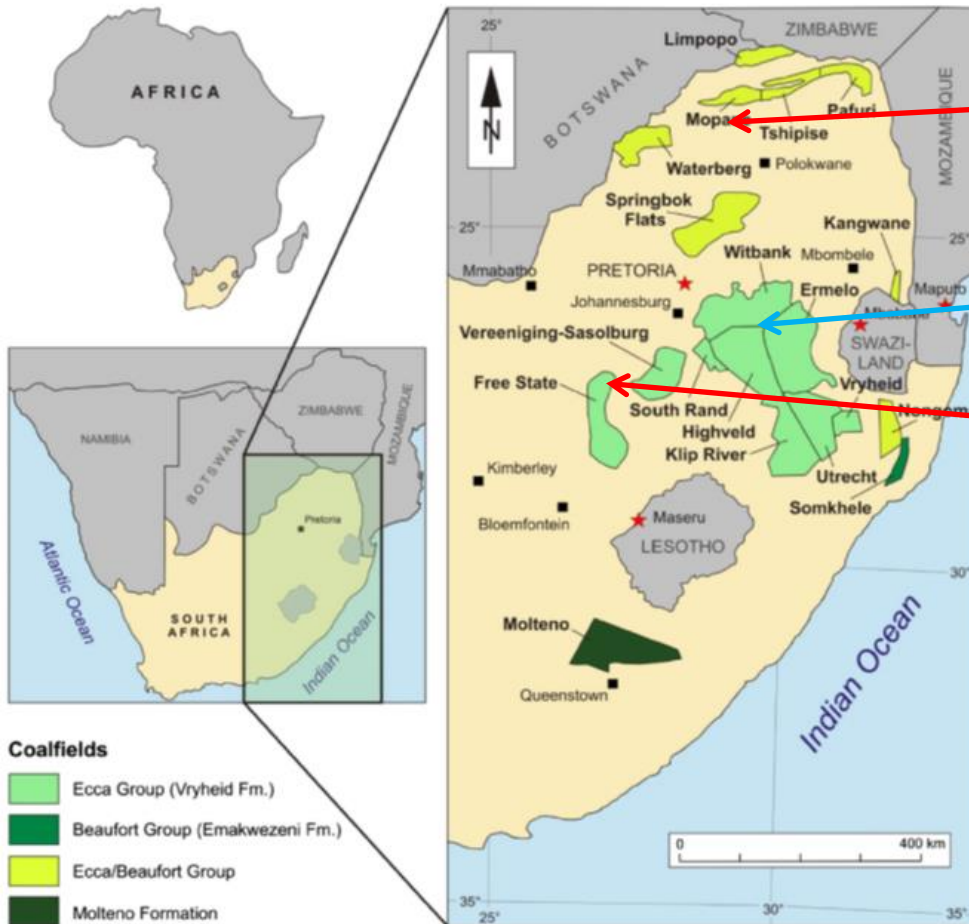


# Coal – primary energy source



- ❑ First mined on a commercial basis in South Africa in 1857.
- ❑ Currently 6<sup>th</sup> largest coal producer in the world.
- ❑ Primary energy source for domestic power generation – and set to dominate the energy mix for the foreseeable future.
- ❑ **Eskom (<http://www.eskom.co.za>), the state-owned national electricity supply utility, has generated >96% of the country's electricity (1923).**
- ❑ **Sasol - 160 000bbl/day coal-to-liquids plant**
- ❑ Coal is furthermore used extensively in the metallurgical industry (titanium, ferrochrome, ferromanganese and steel industries).
- ❑ The largest energy resource was and remains coal; the country is endowed with estimated coal reserves sufficient to cater for both domestic and export demand for 200 years.

# Coalfields



Future development

Current main production area

**AFRICARY UCG DEVELOPMENT**

- Occur in the rock strata of the Main Karoo Basin (MKB) and its associated sub-basins.
- The MKB forms part of a major series of Gondwana basins.

# Coalfields (cont.)

- ❑ Estimates for **economical recoverable reserves range from 9 - 59 billion tons** - latest estimates by the Minerals Bureau suggests 33 billion ton.
- ❑ As much as 70% of that coal is located in the Waterberg, Witbank, and Highveld coalfields, with smaller percentages in the Ermelo, Free State and Springbok Flats coalfields.
- ❑ 96% of the reserves are bituminous coal, 2% metallurgical and the remainder mainly anthracite.
- ❑ Coal reserves as referring 'only to that portion of the total coal resources of which the nature and distribution have been fairly well established and which is at present economically recoverable or borders on economic recoverability'.

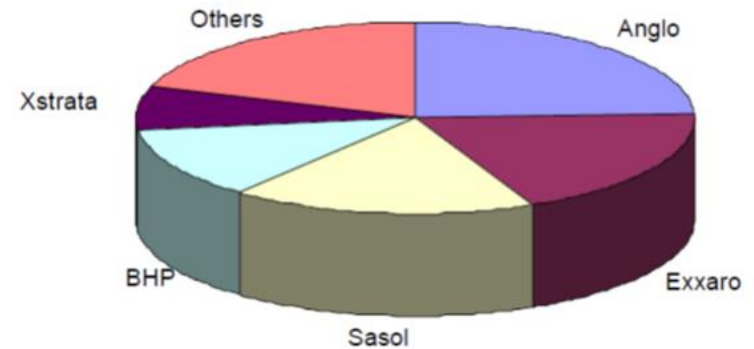
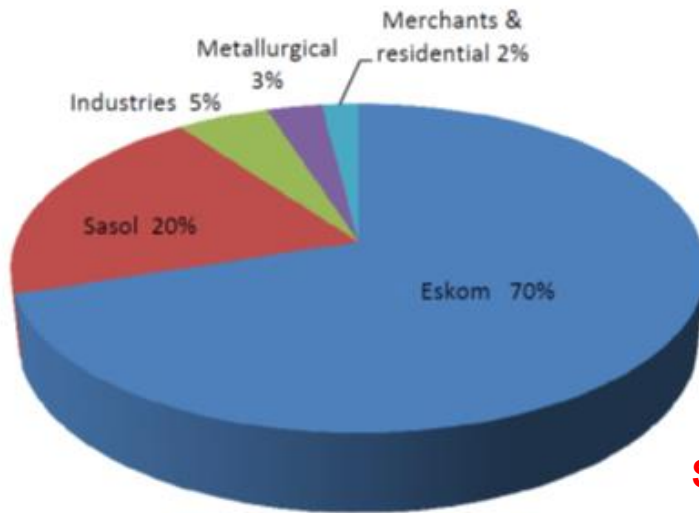


# Coalfields (cont.)

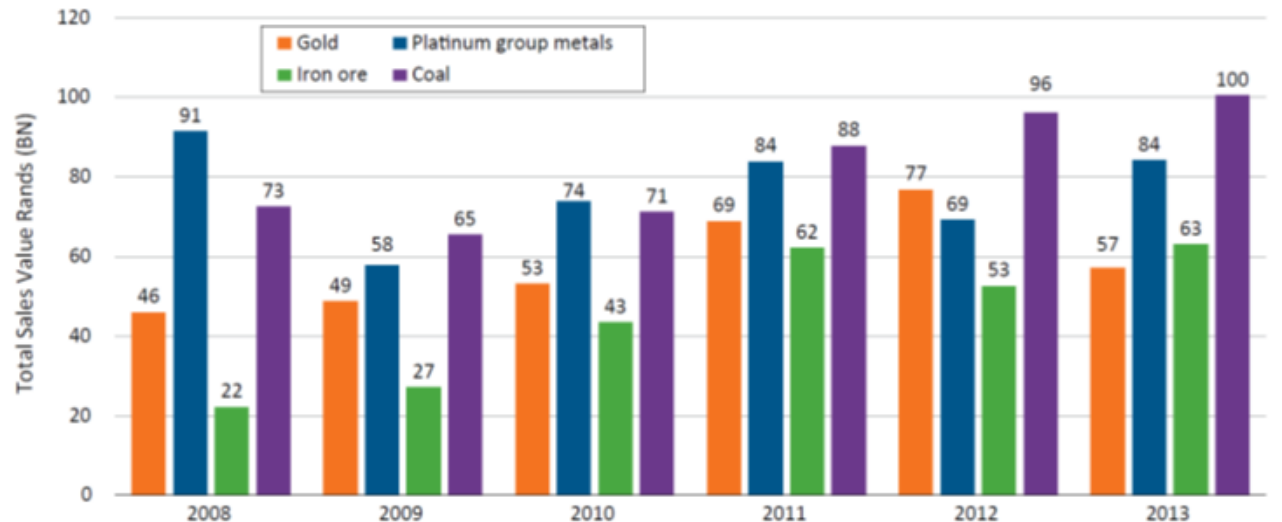
- ❑ New extraction technologies such as Underground Coal Gasification, as well as suitable uses and markets for low-grade, high-ash coal, are required before the country can utilize its vast coal resources to full potential.
- ❑ Total coal output for 2012, was 285 million tons (Mt), and ranked fifth as a hard coal exported at 67 MT in 2009 – current output similar but not verified

PRODUCERS	MT / annum (2009 <sup>1</sup> and 2012)	EXPORTERS	MT / annum
China	2971 / 4017	Australia	262
USA	919 / 1106	Indonesia	230
India	526 / 649	Russia	116
Australia	335 / 463	Colombia	70
Indonesia	263 / 488	<b>South Africa</b>	<b>67</b>
<b>South Africa</b>	<b>247 / 285</b>	USA	53
Russia	229 / 390	Canada	28
Kazakhstan	96 / 138	Vietnam	26
Poland	78 / 158	China	23
Colombia	73 / 98	Kazakhstan	23
<b>WORLD</b>	<b>5990 / 8687</b>	<b>World</b>	<b>944</b>

# Role of coal in current economy



## SOUTH AFRICAN COMMODITY SUMMARY FOR TOTAL SALES IN RANDS (ZAR)



# Role of coal in current economy (cont.)



>8 GW of new coal capacity is required to achieve the higher levels of economic growth required by the National Development Plan.

Coal is the only source of local energy that can provide sufficient security for base load electricity supply for this to be a realistic, achievable goal.

FEBRUARY 2015

## Powering Africa

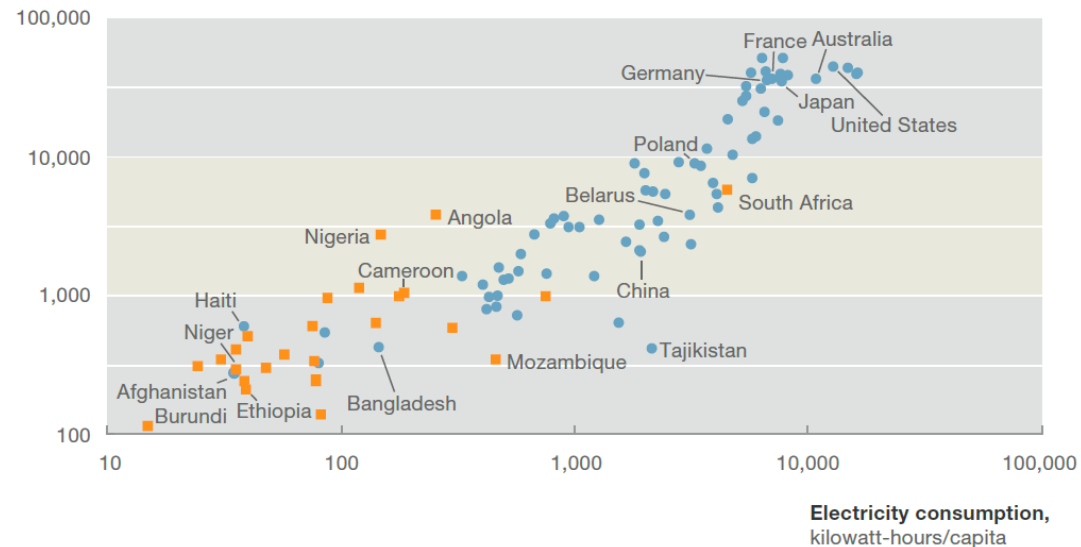
Antonio Castellano, Adam Kendall, Mikhail Nikomarov, and Tarryn Swemmer

There is a direct correlation between economic growth and electricity supply. If sub-Saharan Africa is to fulfill its promise, it needs power—and lots of it.

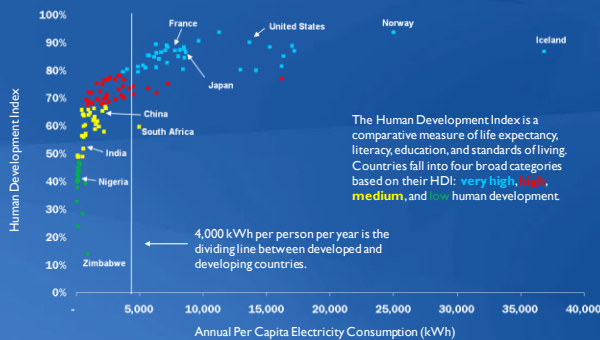
Relationship between electricity consumption and GDP,<sup>1</sup> 2011

● Other countries    ■ Sub-Saharan African countries

GDP,  
current \$/capita



### Correlation Between Human Development and Per Capita Electricity Consumption



The Human Development Index is a comparative measure of life expectancy, literacy, education, and standards of living. Countries fall into four broad categories based on their HDI: very high, high, medium, and low human development.

4,000 kWh per person per year is the dividing line between developed and developing countries.

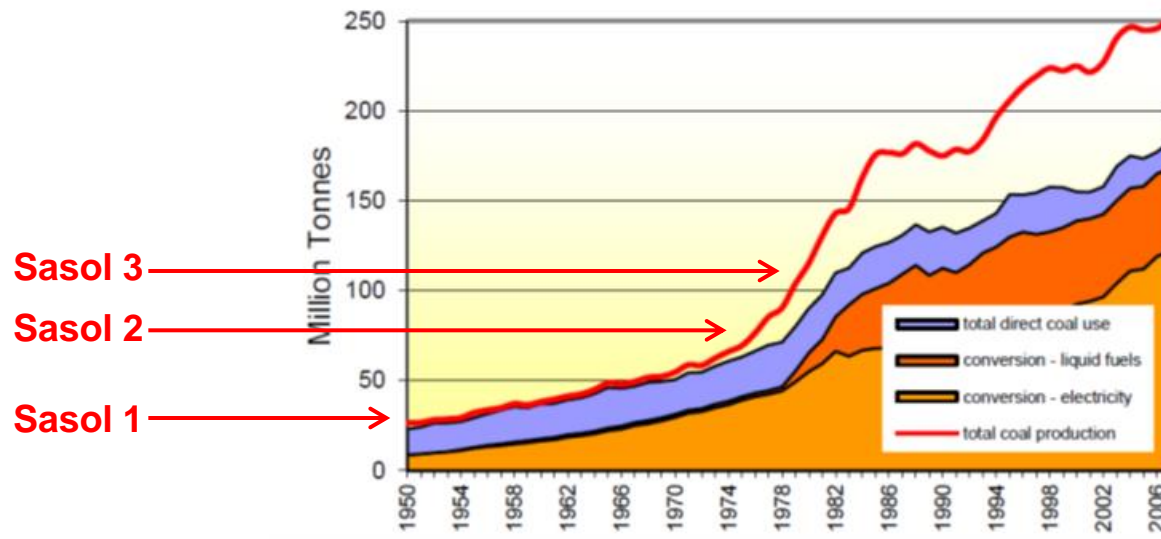
Source: Human Development Index - 2010 data United Nations; Annual Per Capita Electricity Consumption (kWh) - 2007 data World Bank  
Updated: 4/11

# Power and liquid fuels production

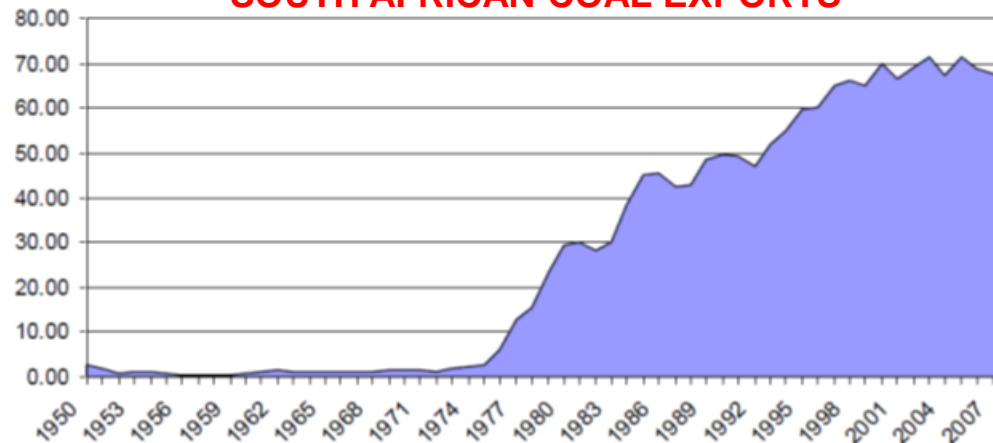


- ❑ Eskom operates a fleet of 23 power stations with a total nominal capacity of 42 090MW, comprising 35 721MW of coal-fired stations, 1 860MW of nuclear power, 2 409MW of gas-fired, 600MW hydro and 1 400MW pumped storage stations, as well as the recently commissioned 100MW wind farm .
- ❑ Two new coal-fired power stations, Medupi and Kusile (similar supercritical coal-fired power stations with a planned efficiency of 38% compared to 34% of the subcritical technologies in the older stations), are currently in construction or commissioning.
- ❑ **Integrated Resources Plan for Electricity (IRP) envisages a further 6250 MW of new coal being required by 2030. It is believed this will be totally inadequate if South Africa is to achieve higher rates of economic and industrial growth.**

# Power and liquid fuels production (cont.)

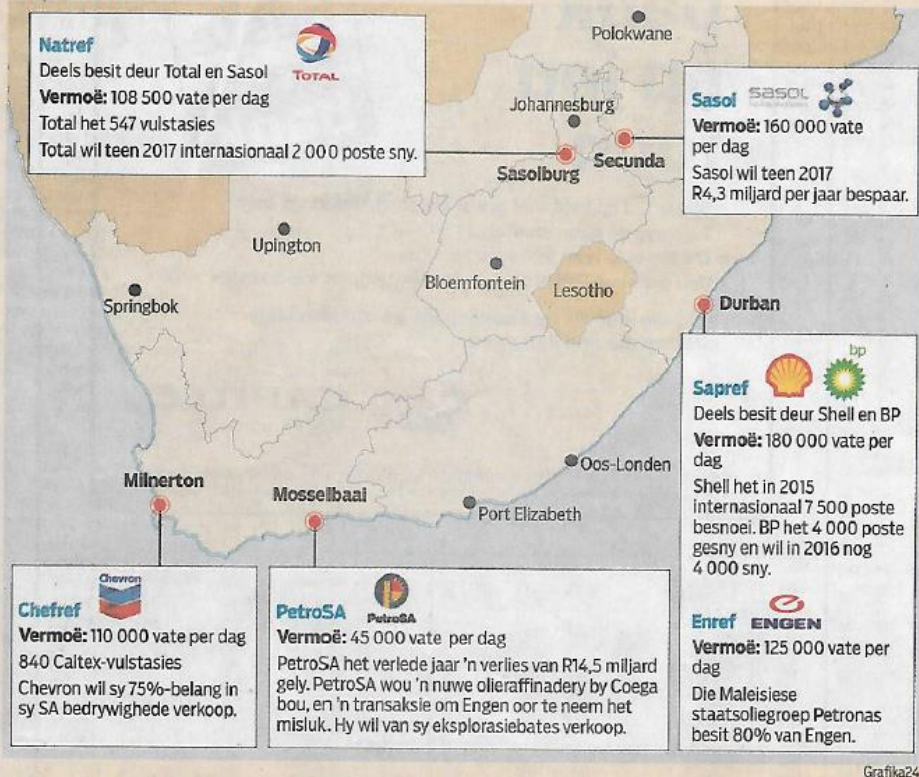


## SOUTH AFRICAN COAL EXPORTS



# Power and liquid fuels production (cont.)

## Raffinaderye in SA



Fuel from coal <22%

OWNERS	CAPACITY (bbls/ day)
NATREF (Total + Sasol)	108 5000
SASOL	>160 000
SAPREF (Shell + BP)	180 000
PETROSA	45 000
CHEFREF (Chevron + Caltex)	110 000

# Power and liquid fuels production (cont.)



- ❑ The IRP envisages an additional 9600 MW of new nuclear power by 2023 – questionable given the accepted lead time for nuclear power is 14 years.
- ❑ Coal is a more reliable and lower-cost for base load option in the short to medium term – (also lowest capital cost)
- ❑ **South Africa is facing a dramatic power crisis largely caused by the lack of sufficient coal for power generation over the next five years. The size of the coal shortfall ranges from 60 to 120 Mt and is expected to impact the country between 2014 and 2019.**
- ❑ **South Africa's biggest near-term energy challenge, therefore, is:**
  - ❑ **To secure Eskom supply over the next five years.**
  - ❑ **Ageing Eskom's Power Plants – replacing capacity**

# Power and liquid fuels production (cont.)

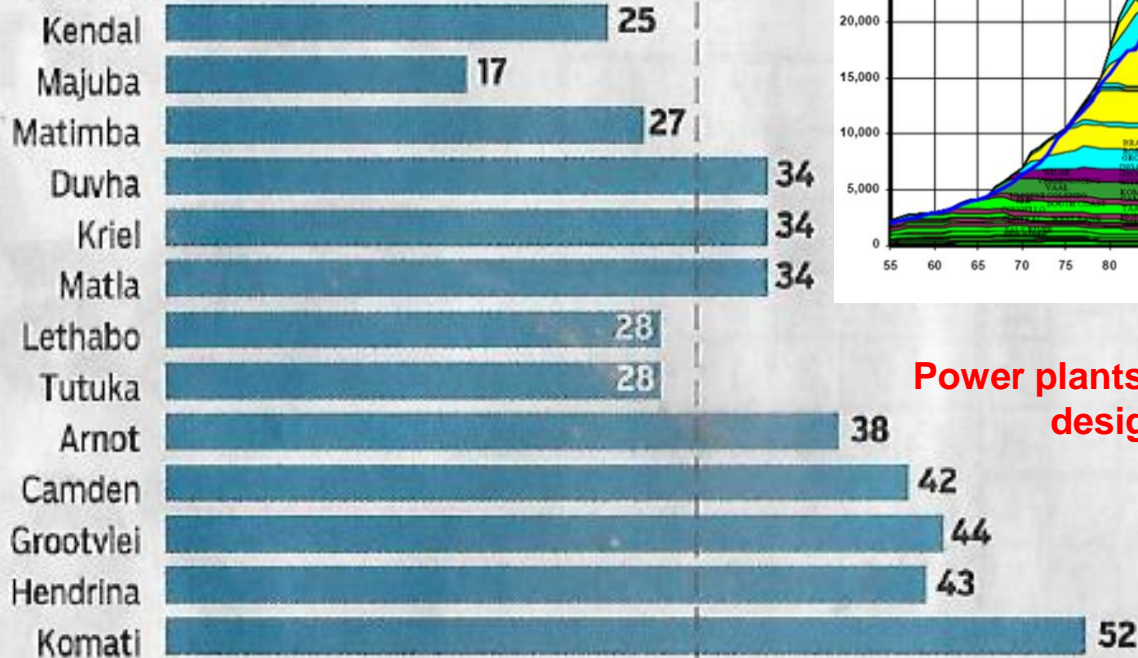
## THE CONCERNING FUTURE OF SA'S POWER PLANTS

### Steenkoolkragstasies kry baard

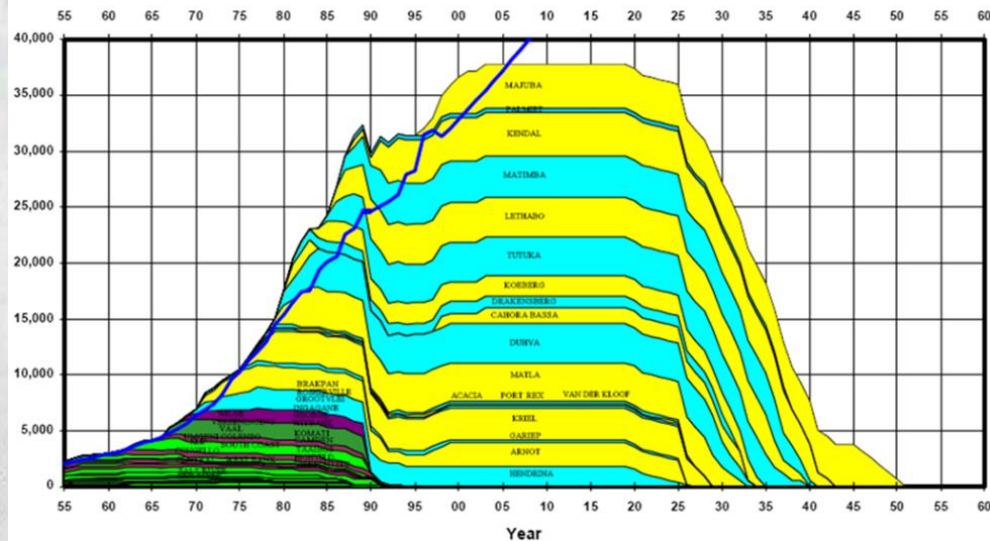


OUDERDOM IN JARE

Ontwerplewe



Bron: Eskom



Power plants already past design life

Grafika24



# Energy and coal related challenges



Coal is the heart of the energy in South Africa as the primary source, but the future of coal in South Africa also faces many challenges, not the least of which is a lack of a clear strategy for the future.

The National Planning Commission (NPC) noted: ***“While most of South Africa’s energy comes from coal, it is striking that government has no integrated coal policy. South Africa ranks fifth internationally as a coal producer and exporter, yet government has no clear export strategy.”***

*There is also no integrated development of mining, rail and port infrastructure to facilitate either exports or anticipated increases in local production and consumption, within acceptable environmental constraints”.*

# Energy and coal related challenges

## - most critical challenges

1. ROM coal qualities are **higher in ash content** (lower grade) with better quality coal already been extracted. Higher grade coal still available but mostly exported. Beneficiation is therefore mandatory to provide products for local usage and export market purposes.
2. **Shortage of water** - this is a limiting factor in the complete value chain from coal to product. Key performance target reduce to 1.20 L/kWh by 2017.
3. Coalfields of the future will require considerable infrastructure and development. **Logistics** for the transport of coal to and from remote coalfields export terminal are constrained by railgate limitations.



# Energy and coal related challenges

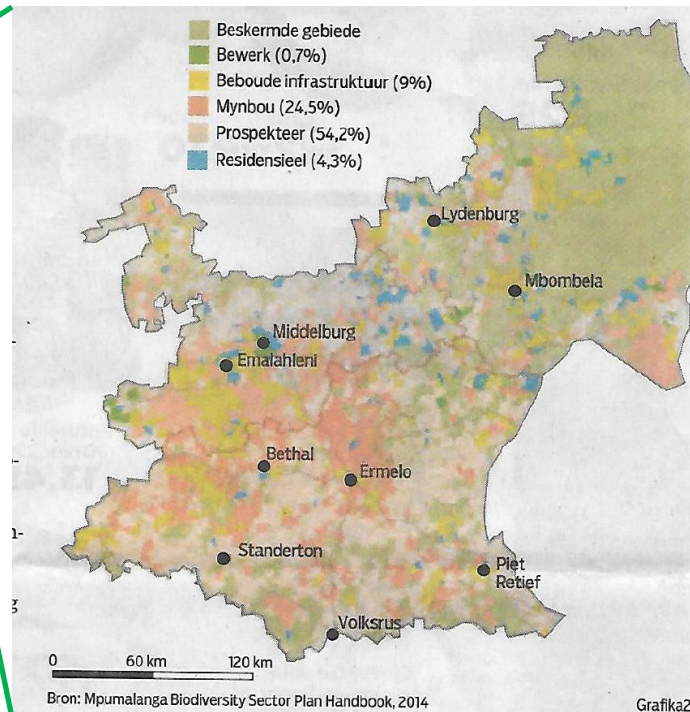
## - most critical challenges



4. Ever-increasing tonnages of **discard stockpiles**. Currently >2 billion tons are stored in stockpiles, with >60 million tons accumulating each year.
5. **Acid mine drainage**. Conventional mining breaks up the rock mass, allowing free access of water and sulphuric acid producing reactions between iron sulphide (pyrite) and acidifies soil and rivers. Threat of acid mine drainage from defunct mines remains an ever-present concern.
6. The storage of CO<sub>2</sub>, produced predominantly from the power stations boilers and petrochemical gasifiers, may be limited by a **lack of underground storage capacity** in South Africa.

# Energy and coal related challenges

## - in numbers



- ❑ ±5 000 trucks on road daily
- ❑ Transport responsible for 49% of carbon emissions
- ❑ 2015 – 239 active mines and 788 abandoned mines with only 5 government safety officers for this area
- ❑ Only 2 officers from Department of Water
- ❑ Illegal mines received licenses, not adhering to mining regulation and safety but still in operation
- ❑ Conventional mining threatened food security

# Energy efficiency improvement (the policy / dream)

Policy / Action	Cumulative emissions	Period	Annual emissions*
Montreal protocol	135.0bn	1989-2013	5.6bn
Hydropower worldwide	2.8bn	2010	2.8bn
Nuclear power worldwide	2.2bn	2010	2.2bn
Increase average global efficiency of coal-fired power plants to 40%			2bn
China one-child policy	1.3bn	2005	1.3bn
Other renewables worldwide	600m	2010	600m
US vehicle emissions & fuel economy standards <sup>†</sup>	6.0bn	2012-2025	460m
Brazil forest preservation	3.2bn	2005-2013	400m
India land-use change	177m	2007	177m
Clean Development Mechanism	1.5bn	2004-2014	150m
US building & appliances codes	3.0bn	2008-2030	136m
China SOE efficiency targets	1.9bn	2005-2020	126m
Collapse of USSR	709m	1992-1998	118m
Global Environment Facility	2.3bn	1991-2014	100m
EU energy efficiency	230m	2008-2012	58m
US vehicle emissions & fuel economy standards <sup>‡</sup>	270m	2014-2018	54m
EU renewables	117m	2008-2012	29m
US building codes (2013)	230m	2014-2030	10m
US appliances (2013)	158m	2014-2030	10m
Clean technology fund	1.7bn	project lifetime	na
EU vehicle emission standards	140m	2020	na

**Increased efficiency to  
40% (2bn annually)**

\* Annual emissions are cumulative emissions divided by the relevant period.

The estimate for the current emissions avoided under the Montreal protocol is eight billion tonnes of CO<sub>2</sub>e.

The annual figure for the collapse of the USSR refers to the years 1992-1998. <sup>†</sup>Cars and light trucks <sup>‡</sup> Heavy trucks

# Energy efficiency improvement (the policy / dream)



- ❑ Divestment from coal does not recognise the reality of growing energy demand. The 21<sup>st</sup> century has been dominated by coal. Coal's share of global primary energy consumption in 2013 reached 30.1% (3% growth).
- ❑ IEA predicted that half of the on-grid electricity needed to meet the “energy” demand would need to come from coal. Coal is an easily accessible, reliable source and the most affordable base load energy option.
- ❑ The role of technology, and specifically the application of efficient and clean fossil fuel technologies, is the key to divestment. **Cleaner coal technologies urgently needed as coal demand is going to continue.**
- ❑ Raising the global average efficiency of coal plants from 34% to only 40% with the off-the-shelf technology available today would save 2 Gt of CO<sub>2</sub>.

# Clean Coal Technologies



Examples where South Africa resulted world-class coal R&D achievements:

- ❑ **Acid mine drainage** - water can be used for agriculture, with fly ash from power stations used as a filter in the upgrading/treatment process.
- ❑ **Advanced beneficiation** on fine coal, which provides cleaner coal that can improve plant efficiencies and reduce CO<sub>2</sub> emissions.
- ❑ **Dry coal technologies** to reduce the amount of water.
- ❑ **Upgrading and use of discards** as a source of energy in fluidized bed combustion and gasification processes.
- ❑ **Ash utilization** and upgrading for use in cement manufacture, building and road materials.
- ❑ Cleaner and more environmentally friendly processes such as **UCG** is being developed.

# Clean Coal Technologies (cont.)



- ❑ **Super-critical pulverised fuel combustion** - increasing the steam temperature and pressure in conventional pulverised fuel plants. The current efficiency of Eskom's plants is between 33% and 36%. Super-critical design can achieve improvements of 2,5%, resulting in less coal utilised and lower emissions.
- ❑ **Fluidised Bed Combustion (FBC)**, with the addition of a sorbent to the coal that will mitigate environmental impacts - the sorbent “scrubs” the gases that are released. Advantage to burn extremely low grade coal and using significantly less water in the control of emissions, but currently not economically viable for South Africa. Adding to the challenges of FBC is that limestone and dolomite, are not widely available.



# Underground Coal Gasification

the obvious solution for clean coal



- ❑ 25% less CO<sub>2</sub> per MWh and in large-scale combined-cycle mode can reach energy efficiencies of up to 58% versus 35% in boilers.
- ❑ No particulate emissions or ash handling and little or no leaching of trace elements from ash when operated correctly.
- ❑ Less sulphur and heavy metals are released or emitted.
- ❑ Monetize economically unmineable coal. (<26% of SA coal reserves are economically / technically recoverable with conventional mining.)
- ❑ Deployment can create new high-value jobs.
- ❑ UCG projects can be located in economically depressed areas.
- ❑ 90% less water usage
- ❑ No chemicals are used - only air and water are required.
- ❑ Fracking is not required and no drilling chemicals are injected to create the boreholes.

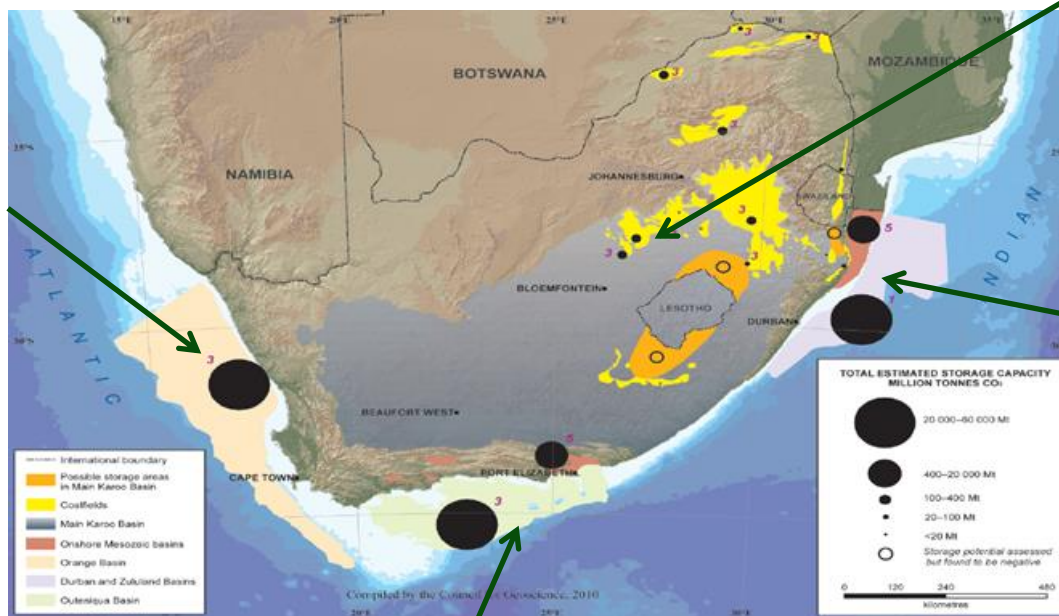
# Carbon capture and storage options



# Carbon capture and storage options (cont.)

## 150 G tonne theoretical potential

Orange Basin: Area of previous natural gas exploration, however the gas finds were too small to commercialise.



Karoo Basin: On-shore and near the majority of the coal-based electricity generation stations and synfuels production plants.

Durban/Zululand Basin

Outeniqua Basin + Algoa Basin. The offshore area includes the only gas/petroleum producing wells.

Unmineable Coal Seams: Such storage may render those coal seams 'sterile' as potential exploitation with future technology is likely to release the CO<sub>2</sub>.

# Carbon capture and storage options (Biological sequestration)



Medium to long term storage of carbon, derived from the atmosphere, in living and dead plants and organic soil matter.

The Net Primary Productivity in the biological arena is relatively small and implies that the carbon sequestration potential is also small.

BIOME	Delta (gC/m <sup>2</sup> )	Period (yr)	Area (Mha)	Total (gC (Mt))	Rate (gC/y (Mt/y))
Savannas	7000	30	40	2800	93
Karoo	1000	30	38	380	13
Thicket	8000	30	2.5	200	7
Low tillage farming	2400	30	10.6	254	8
Grassland to forest	8000	30	1.8	144	5
<b>TOTAL</b>				<b>3778</b>	<b>126</b>

# Carbon capture and storage options (Geological sequestration)



Direct or indirect sequestration where CO<sub>2</sub> is stored in underground formations (depleted oil / gas reservoirs, non-mineable coal seams and saline reservoirs)

## ❑ Oil and gas reservoirs

Recently become an oil and gas producing country – mainly offshore. Production figures of 1.4 billion m<sup>3</sup>/y, may result in 0.7 billion m<sup>3</sup>/y CO<sub>2</sub> being able to be sequestered\*. (\*Extracted gas calculated at normal pressure and the sequestered CO<sub>2</sub> at 80 bar pressure)

## ❑ Deep saline formations

Vryheid formation (average thickness of 350m over an area of 1km<sup>2</sup> and only 2% of its volume, is ±7 million m<sup>3</sup> assuming all volume pore-space could be used. This equates to 183 750 million m<sup>3</sup> of storage capacity, which would be sufficient to store all SA's CO<sub>2</sub> emissions for 500 year.

Katberg Formation can add another 16 000 million m<sup>3</sup> to the potential

# Carbon capture and storage options (Summary of SA's potential)



POTENTIAL SINK	Tonnage (million t/yr)	Duration (years)	Comments
Afforestation	3.9	20	An effort is required to store CO <sub>2</sub> in "perpetuity"
Reduced tillage	0.4	20	
Savanna thickening	7.9	20	
Gas reservoirs	1	Long	Enhanced gas recovery is possible
Mines	>10	Site specific	More study is required
Vryheid Formation	>18 375	Very long	Poor porosity and permeability, more study is required
Katberg Formation	>1 600	Very long	
Coalbed methane	Small	Long	May enhance methane recovery
Chemical capture	1-5	Indefinite	Large volumes of reactive material is needed
Deep ocean	Unlimited	Hundred of years	Ocean sequestration poorly understood
Ocean fertilization	Not known	Not known	Study required

**From the latest results published, it is estimated that of the >400 million tonnes of annual CO<sub>2</sub> emitted, ±60% can be sequestered**

# Coal Policy

- ❑ **No approved explicit coal policy**, although draft regulation and working legislation are in progress. Focus on programmes to increase household access to energy, with little attention to security of supply.
  
- ❑ Eskom initiated a forum for government departments and related to coal supply challenges and take the lead on regulation support:
  - ❑ Concerns around the quality, security and price of its coal supplies.
  - ❑ **South African Coal Roadmap** - it aims to facilitate policy, planning and strategy together.

# Coal Policy (cont.)

- ❑ Energy Policy White Paper published in 1998:
  - ❑ *Continued deregulation*
  - ❑ *Maintaining a coal resource database*
  - ❑ *Promotion of low-smoke coal for households*
  - ❑ *Use of discard coal*
  - ❑ *Promotion of end-use efficiency*
  - ❑ *Clean Coal Technologies*
  - ❑ *Use of coal-bed methane*



- ❑ A number of key policy questions remain unanswered - the most important is the answer around carbon tax and future exposure to international climate change commitments aimed at reducing greenhouse gas emissions.

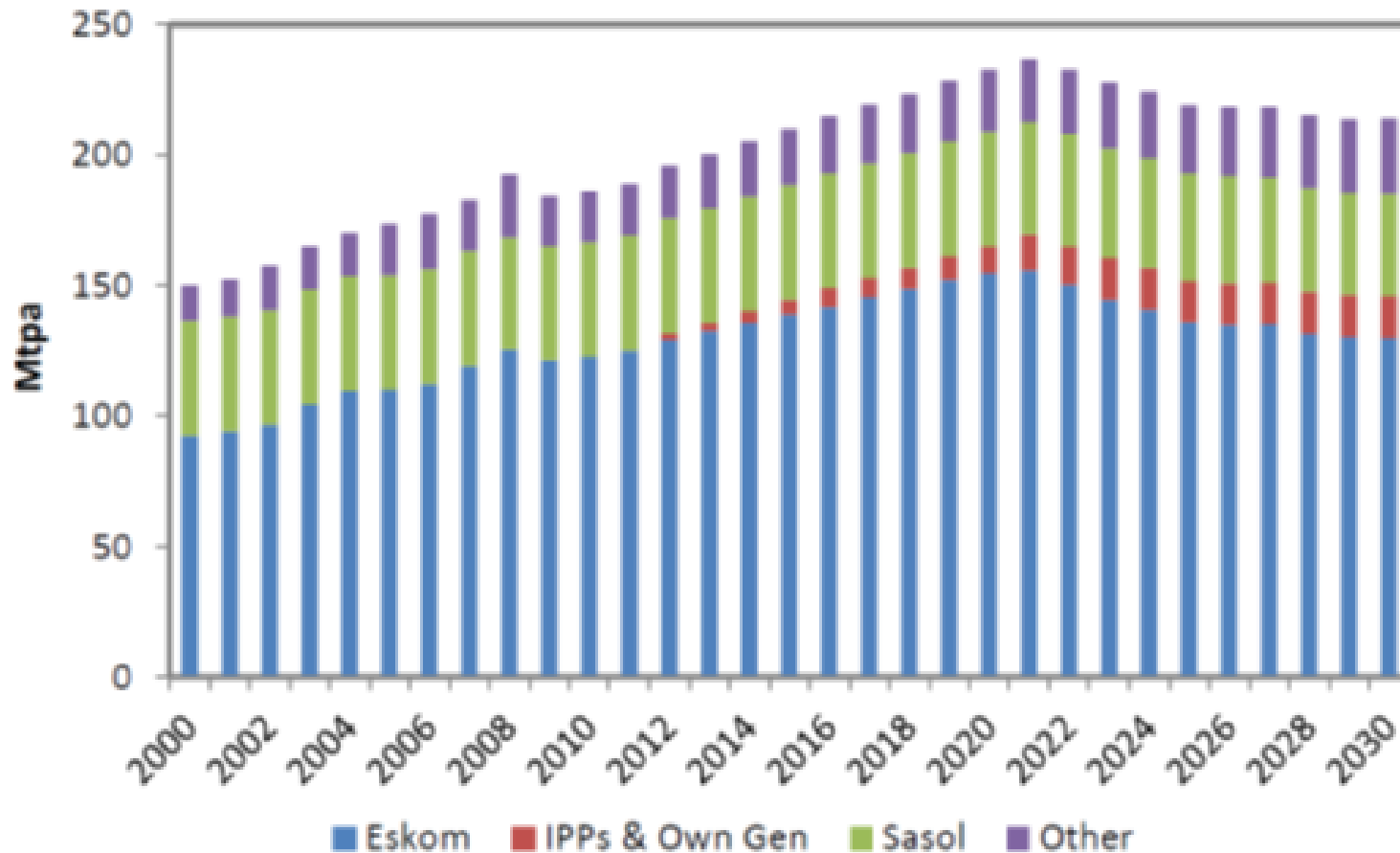


# Legislative Framework



- ❑ Effort to increase ownership and participation by black South Africans in the economy and in the mining sector.
- ❑ Overhaul of the licensing regime for prospecting and mining - dramatic increase in black-economic empowerment BEE.
- ❑ Minerals and Petroleum Resources Development (MPRD) Act No. 28 of 2002 - previously owned by the land-owner, the legislation transferred ownership of mineral rights to the state, which is now empowered to grant, control, administer or refuse prospecting or mining rights.
- ❑ Policy and legislative initiatives have had a positive effect on black-economic empowerment, but overall impact on the mining sector has been more mixed. Investment and production of most commodities in South Africa has stagnated or even declined over the past decade.

# Market drivers



# Future developments and R&D needs



- ❑ <ZAR1 billion spent as gross expenditure on R&D on energy-related topics
- ❑ Investments in R&D and Clean Coal Technologies not sufficiently funded
- ❑ Very little / insufficient attention is given to research into shale gas
- ❑ Research in renewable energy is growing, albeit at a pace lower than required to meet the national targets and expectations
- ❑ Human capital development, as well as R&D in nuclear energy is diminishing and the country is losing critical skills in this field
- ❑ Energy efficiency efforts towards long-term planning
- ❑ Energy-related Masters and Doctoral degree output is not growing
- ❑ Coordination and cooperation in energy and energy-related R&D is insufficient, resulting in overlaps / duplication and gaps in terms of national priorities

# Future developments and R&D needs (cont.)



- ❑ A number of research strengths have been identified. South African National Energy Development Institute (SANEDI) is supporting a significant and well-coordinated suite of energy projects, aligned with national priorities. The following institutes have well coordinated research programs:
  - ❑ Eskom (fossil fuels and renewable energy)
  - ❑ Sasol (fossil fuel and Fischer-Tropsch)
  - ❑ NWU (coal, renewable energy and energy efficiency)
  - ❑ SU (renewable energy)
  - ❑ and other such as UCT, UWC, WITS and UP.

# Future developments and R&D needs (cont.)



- ❑ Coordination – government departments with an energy budget establish a formal coordination mechanism, with a mandate to steer, plan and coordinate energy R&D funded with public money and eliminating gaps.
- ❑ Funding – a more substantial portion of the national R&D vote be allocated to energy research. 1.5% of the fiscal appropriation is proposed for R&D support, with a higher proportion towards energy.
- ❑ Human capital development – More research chairs and Centres of Excellence be established and funded.
- ❑ Coal, Gas, Renewable Energy, Nuclear Energy, Energy efficiency, Energy economy and policy

# Conclusions

- ❑ Energy is vital to our daily lives – produce food, fuel transport and power communication channels.
- ❑ As global population rises (including South Africa), more people are moving out of poverty by gaining access to energy.
- ❑ Human capital, innovation and technology have to be aligned to power the future and limit our impact on the environment.
- ❑ Growth in SA will be primarily driven by domestic coal power.
- ❑ Environmental constraints will more than likely imply that total coal usage will reach a plateau in the next decade and penalised with Carbon Tax.
- ❑ New coal mines will have to be developed as existing mines exhaust reserves (i.e. Highveld area), together with Eskom, Sasol and new IPP's must expand alternative production.

# Conclusions



- ❑ The future sustainability of energy in South Africa—whether based upon coal, gas, nuclear, or renewables—will depend on the ability of the government of the day to attract and fund large infrastructure projects.
- ❑ But, The Consumer, who ultimately foots the bill, will be the deciding factor in determining what the energy mix of the future looks like.

***“The future will depend on the vision of those yet to come, for the road is long and the plans of action are more than one generation in duration.***

***One thing is certain, however: The value of coal as an energy and highly prized carbon-based chemical source can never be underestimated.***

***Coal is arguably the most important commodity of the South African economy.”***

# References

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