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The power of ideas

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The rise and fall of Eskom — and how to fix it now

Eskom is seldom out of the news these days and always in it for the wrong reasons. South Africa's precarious electricity supply, for which Eskom is almost entirely responsible, presents a national crisis. The desperate shortage of electricity is crippling our economy. Because of inadequate generation capacity, our existing power stations, now creaking with age and wear, are being run into the ground and failing more and more often. Their availability – ability to produce power at any moment – is dropping dangerously. The new power stations are years behind schedule. Load shedding and blackouts threaten us every month. To explain these problems and to solve them, there is a clamour from our public commentators and 'experts', some of it sensible, most silly. This is an attempt to show what went wrong and how it can be remedied.

The nature of electricity

Electricity was the most important new technology of the 20th Century. It changed the world profoundly, and entirely for the better. It is now the backbone of every modern economy. In households around the world, it is one of the three essential services along with water and sewerage. Modern industry is impossible without it. The better lives we live now are to a considerable extent because of it. Every poor country, notably in Africa, should make the provision of electricity for all one of its highest priorities.

Electricity has some unique features. The most important is that it must be consumed at the moment it is produced. This is because it is difficult to store. As electricity itself, it can be stored only in capacitors (condensers) and these are very

limited. Energy in other forms, such as chemical energy in a battery or gravitational energy in a dam of water, can be stored and quickly converted into electricity, but these options have their limits.

The fact that electricity generation must always exactly match demand imposes an onerous condition on the supplier. To produce exactly the right amount of electricity at any given time is difficult. It can also be expensive. The value of a kilowatt-hour (kWh) varies radically from time to time. At 6pm on a Wednesday evening in July (in the midst of the South African winter), the value is very high; at 2am on a Sunday morning in January, it is very low.

Electricity must be consumed at the moment it is produced because it is difficult to store.

One notable aspect of electricity supply is that the product never changes. We are now using exactly the same electricity as we did more than a hundred years ago. (In 1882, Kimberley became the first place in the Southern Hemisphere to have electric street lighting.) It is highly unlikely that it will be any different in a hundred years time. This has important economic consequences. For most industrial ventures, one of the biggest risks is that the market will change and there will be no customers for the product in question. With electricity, this risk has long been very much reduced: the supplier has been guaranteed customers. This has made a power station a uniquely safe investment.

A third distinctive feature is the high capital costs of power stations. The capital costs of Medupi, Eskom's new coal station, exceed R100 billion. Yet the capital costs per unit of product (a kWh of electricity) are actually very low, since the power station, over its projected life of 40 years or more, will produce an enormous amount of electrical energy. However, to build a power station in the first instance takes a vast amount of capital.

The present state of electricity supply

Electricity supply rests upon three functions: generation, transmission and distribution.

Generation is the production of electricity in power stations. Eskom provides over 95% of South Africa's generation, the rest coming from small municipal power stations and some independent power producers (IPPs). Until recently, these IPPs have usually been factories or mills, which generate electricity for their own use or as a by-product of their production processes, but occasionally sell some of it to Eskom.

Electricity generation must always exactly match demand, but to produce exactly the right amount of electricity at any given time is difficult and expensive.

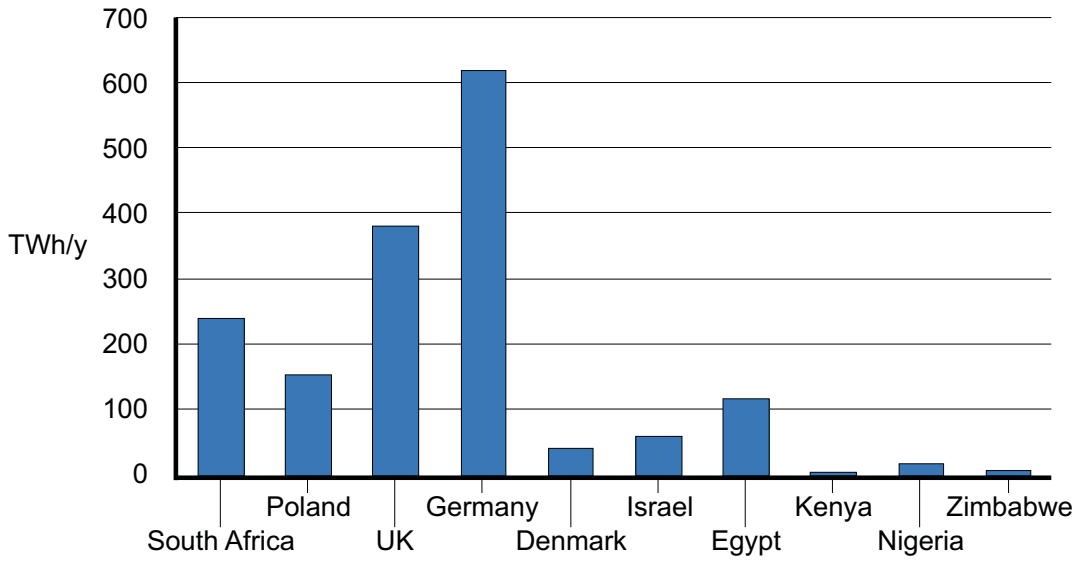
Transmission is the bulk transfer of electricity from power stations to centres of demand. Eskom does 100% of our transmission. South Africa's transmission lines are sometimes more than 1 500km long (as between the coal stations in the north and Cape Town). They use very high voltages so as to minimise losses.

Distribution is the transfer of electricity from substations at centres of demand (at the ends of the transmission lines) to final customers, such as factories, offices and households. The substations are responsible for reducing the voltage to the standard voltage (220v) used by households and other final consumers. About 50% of distribution is done by Eskom and 50% by municipalities. The municipalities mark up the price of the electricity they buy from Eskom

and provide to their customers, this mark-up being a major source of revenue for them.

South Africa's electricity consumption is as high as that in many European countries and far higher than that in any other African country. Here are typical figures for the annual consumption of some countries, in TWh per year, in 2014:

SA electricity production compared to some other countries, 2014



Source: International Energy Agency, Electricity Outlook

Compared with European countries, South African industry consumes a much higher proportion of total electricity than do households and commerce. This is illustrated in the graph below (see p4), which shows sectoral electricity usage in South Africa and the United Kingdom in 2010, the latest year for which such data is available.

In these graphs, 'industry' includes mining and 'agriculture' includes fishing. 'Commerce' includes offices, banks, government buildings, cinemas and shops.

The second graph (on p4) shows the different sources, such as coal and gas, which are used in South Africa in generating electricity. It includes both power stations in operation and those still under construction.

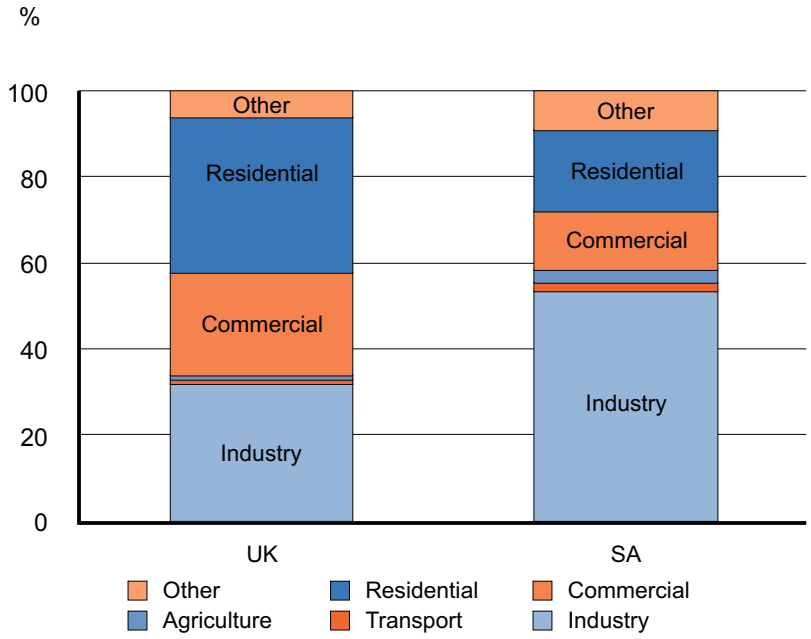
Over 92% of our electricity is from coal. Nuclear contributes about 6%. Although the country's gas turbines have a greater capacity (2 426 MW) than Koeberg (1 910 MW), Koeberg produces far more electricity because it is a baseload supplier with very low production costs.

History of Eskom's rise and fall

To understand the mess we are in now, the reasons for it and the possible remedies, it is necessary to have a brief look at Eskom's history.

In 1923 the South African Government established Escom (the Electricity Supply Commission) under the 1922 Electricity Act. Its Afrikaans name was Evkom (Elektrisiteitsvoorsieningskommissie). The two names were combined as Eskom in 1986. Eskom was a state-owned electricity supply company.

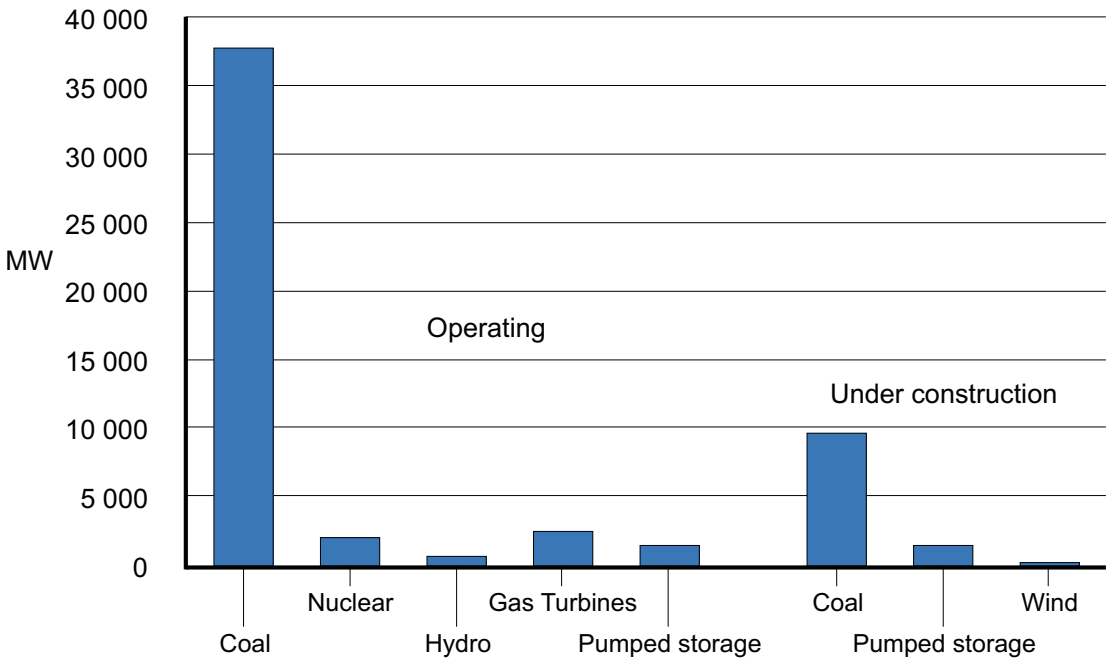
Sectoral usage of electricity in SA and the UK, 2010



Totals: UK: 329 TWh SA: 213 TWh

Source: UK Department of Energy and Climate Change, SA Department of Energy

Eskom generation capacity by energy source, 2014



Source: Eskom fact sheet

The main curse of any state-owned industry is political interference. Eskom was free of this from 1923 until 1994. Its brief was simple: to make sure that South Africa had enough electricity. It was very lightly regulated, much less so than private electricity utilities in the United States of America (USA). It was an autonomous organisation run by technocrats. Engineers were in charge and were appointed entirely on merit. Even under apartheid, there was no attempt to Afrikanerise Eskom's senior management. Eskom's greatest CEO was Ian McRae, an English-speaker. Eskom was entirely self-financing. There were no state subsidies for electricity.

Eskom embarked on a concerted programme of building huge coal stations of standardised design, each one having six identical units.

In about 1969, after South Africa's economic growth rate had topped 6% in various years in the 1960s, electricity demand threatened to outstrip supply. In those years, growth in electricity demand was double economic growth. Near panic set in. Then Eskom made its best ever strategic decision: it decided to embark on a concerted programme of building huge coal stations of standardised design, each one having six identical units. The result was that vendors and contractors from all over the world tripped over themselves to give Eskom the best prices and conditions. The stations were built on time and on budget. They were funded via cheap debt and all the debt was timeously repaid. The taxpayer didn't have to pay a cent. By the end of the programme, Eskom had plentiful and very reliable electricity at probably the lowest prices in the world – lower than that from private utilities in other countries.

South Africa's vast reserves of cheap, easily mined (although low quality) coal was partly responsible for this success. More important was the clear-sighted, well-planned, consistent programme of new building, which was based entirely on technical and commercial considerations.

The unprecedented high economic growth of the 1960s did not continue. Because of the strangling effects of apartheid, the growth rate slowed down in the 1970s and even more so in the 1980s. Growth in electricity demand slowed down too. By the middle of the 1980s, South Africa was seen as having a surplus of electricity supply. Through some rather strange psychology, belief in this surplus took a strong hold over many senior Eskom managers and many politicians. It persisted for a long time, even when South Africa was in fact beginning to run out of electricity. Three elderly coal stations, Camden, Grootvlei, and Komati, all in the eastern Transvaal (now Mpumalanga), were shut down and mothballed.

After 1994, highly skilled and experienced white engineers, managers, and technicians were given generous 'packages' to get out and make way for persons of the correct skin colour and political affiliation.

In 1994, when the ANC took power, there were unfortunate changes at Eskom: some of them predictable, some of them surprising. Race-based affirmative action, political interference, and political appointments were predictable. Highly skilled and experienced white engineers, managers, and technicians were given generous 'packages' to get out and make way for persons of the correct skin colour and political affiliation. This was sometimes known

as 'space creation'. To Eskom's previous single brief – providing sufficient electricity – were added various political and ideological objectives.

The unexpected changes were even worse. The ANC had long been regarded as Marxist in outlook and was expected to favour state-run institutions. To everyone's surprise, there soon began to be talk about Eskom being 'unbundled' or privatised. The State also seemed to be intent on taking away Eskom's obligation to supply. In 1998 it forbade Eskom to build new stations. However, the new directives were also vague and confusing, lacking clarity and consistency. Eskom fell into a void. It no longer knew what it was meant to be doing, or even what its key function was. In addition, no private generators so much as offered to come in because the price of electricity was much too low.

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Meanwhile, the country was running out of electricity. This was clear to a school child. After 1993 growth in electricity demand, as a ratio of economic growth, fell from 2:1 to 1.1, but remained very steady at this ratio. Electricity demand was growing in tandem with the economy, and our 'surplus' electricity was steadily and predictably shrinking to nothing.

In its election campaign in 1994, the ANC had promised an annual economic growth rate of 6%, which South Africa could easily have attained – especially as other developing countries were growing even faster. If we had increased growth to 6% a year, we would have run out of electricity in 2001. As it was, we seldom had growth much above 3% a year, and so we ran out in about 2007. One of the greatest lies of this era, often repeated by many ANC politicians, was that we ran out of electricity because we were 'victims of our own success' (unexpectedly high growth). Actually growth was unexpectedly low, and we still ran out of electricity.

The fundamental problem that is crippling us now is that we didn't build power stations when it was glaringly obvious that we had to. Eskom is at least as much to blame as the Government. It is true that the Government ordered Eskom not to build more stations, but the Government seemed not to understand the problem whereas Eskom did – or should have. Had Ian McRae been CEO of Eskom at the time he would have shaken ANC cabinet ministers by the throat and shouted at them that we had to build stations quickly to avoid a crisis. Nobody in Eskom did anything of the kind. Some mumbled softly that there might be a problem and that was all.

ANC ministers seemed to regard Eskom as a sort of magic machine that would automatically make as much electricity as was needed, but could also be diverted to other purposes.

ANC ministers seemed to regard Eskom as a sort of magic machine that would automatically make as much electricity as was needed, but could also be diverted to other purposes, social and political. The new managers at Eskom, mainly political appointments, seemed to have little interest in ensuring future electricity supply. Instead, they were preoccupied with other goals, such as racial transformation and keeping the price of electricity artificially low for social purposes. Accountants replaced engineers at senior levels, and those accountants

lost sight of Eskom's fundamental purpose, which is simply to provide electricity and cover its costs – not make a big profit or a high rate of return. Eskom became blighted with a damaging combination of ANC ideology and business school fashion.

Eventually the Government reversed its position; and in 2004 Eskom began planning to build two big new coal stations: Medupi (Limpopo) and Kusile (Mpumalanga). Both will have six units of 800 MW each, giving each a total capacity of 4 800 MW. It also embarked on a pumped storage scheme at Ingula (in the Little Drakensberg). None of them is yet on stream, but Eskom hopes the first unit of Medupi will start in 2015.

Eskom became blighted with a damaging combination of ANC ideology and business school fashion.

Eskom initially said that the first unit of Medupi would be on line by 2012 and the first unit of Kusile by 2013. By February 2015, neither was on line. The latest estimate for the first unit of Medupi to supply power to the grid is about June 2015, and for Kusile over a year later. The long, extremely expensive delays have been caused by various factors. Among these is the fact that Eskom had not built a major power station since Majuba, begun in 1983, and had lost memory and experience of such construction; the contracting was hasty and often ill-considered; there was debilitating labour strife at the construction sites; and there was a severe shortage of artisan skills, notably in welding. Perhaps the worst of all was the unique design of the stations. Both Medupi and Kusile are one-offs, first of a kind, and both are huge. Using smaller, more standardised units would have sacrificed some economy of scale but allowed simpler and quicker construction.

Eskom's incompetence has added other problems to the generation shortage. In January 2008, during a period of heavy rain, a large number of the big coal stations failed, plunging much of the country into blackouts and shutting down all the gold mines. The economic losses were enormous. The reason was a disastrous decision by Eskom to shift some of its coal supply away from its established contracts with big coal mines and instead start buying coal from a variety of small, black-owned mines. This was done for reasons of racial procurement. As a result, Eskom started receiving poor coal of varying quality. This problem was compounded by an idiotic decision by Eskom accountants to reduce coal stockpiles at power stations so as to save on stock costs. When persistent rain fell on low, messy stockpiles of bad coal, it turned them to sludge, which clogged up the mills, chutes and nozzles feeding pulverised coal to the boilers. They shut down.

The 2008 blackouts were caused by a decision to start buying coal from a variety of small, black-owned mines, which provided poor coal of varying quality.

Duhva coal station near Middelburg, one of Eskom's workhorses, with a capacity of 3 600 MW, recently suffered two major and expensive accidents. In February 2011, unit 4 was badly damaged when the turbine flew apart during an over-speed test. In the event of a turbine unexpectedly losing load, it will speed up dangerously unless its steam supply is closed off. This should happen automatically. This protection must be regularly tested. During the tests, there should always be an operator with his finger on the emergency stop button in case the automatic protection does not work. On this occasion, there was no such operator in position,

the automatic protection failed, and the turbine reached dangerous speeds and broke up. In March 2014, the furnace in unit 3 was badly damaged in an 'over-pressure incident' (translation: 'explosion'.) Modern coal power stations burn coal powder or 'pulverised fuel' (PF). It is highly explosive. When starting up a coal furnace, you should first put in a flame and then feed PF into it. It seems that on this occasion they fed flame into a furnace filled with PF. Both incidents suggest negligence and incompetence.

In starting up a coal furnace, you should first put in a flame and then feed in coal powder. Instead they fed flame into a furnace filled with coal powder. It exploded.

In November 2014, one of the three coal silos at the Majuba coal station in Mpumalanga, with a capacity of 4 110 MW, collapsed. As Majuba is the newest operating coal station (construction was from 1983 to 2001), this seems most peculiar. It appears that Majuba's silos, unlike those of other Eskom stations, were not lined, which might have caused the collapse. In the same month, the ash removal system failed at Lethabo coal power station (3 600 MW) in the Free State, causing it to lose three units or 1 800 MW.

White paper on energy in 1998

In 1998 the Department of Energy published its 'White Paper on the Energy Policy of the Republic of South Africa'. This document outlined the department's ideas and proposals for all types of energy in South Africa, including electricity. (Electricity makes up about 28% of the final energy used by consumers.) In a 'ministerial foreword', the white paper made the unfortunate mistake of describing uranium as a 'fossil fuel', though this might just have been a typo. The document's stated aim was to 'clarify government policy regarding the supply and consumption of energy for the next decade'.

In its 'vision for the electricity supply industry', the white paper said: 'Electricity supply throughout the world is undergoing a revolution. This is being caused mainly, but not solely, by electricity utilities having to meet new pressures resulting from global markets and governments opening up their countries to foreign investors to help fund power sector expansion and development. As a result, utilities are having to see themselves as businesses, and act accordingly. South Africa is not immune from these forces, and will have to move broadly in line with developments taking place in the rest of the world, while also ensuring that the industry's evolution meets South Africa's special requirements.'

There is an alarming confusion of thought in this paragraph, which converted itself into an alarming confusion of policy on electricity supply for the next fateful six years. Completely contrary to its statist instincts, the Government seemed to be bowing to a fashion for private electricity supply, but without any commitment or coherency. The sentence 'utilities are having to see themselves as businesses' was particularly fateful, as will be shown later.

The Government seemed to be bowing to a fashion for private electricity supply, but without any commitment or coherency.

The white paper added: 'To ensure the success of the electricity supply industry as a whole, various developments will have to be considered by Government over time, namely:

- giving customers the right to choose their electricity supplier;

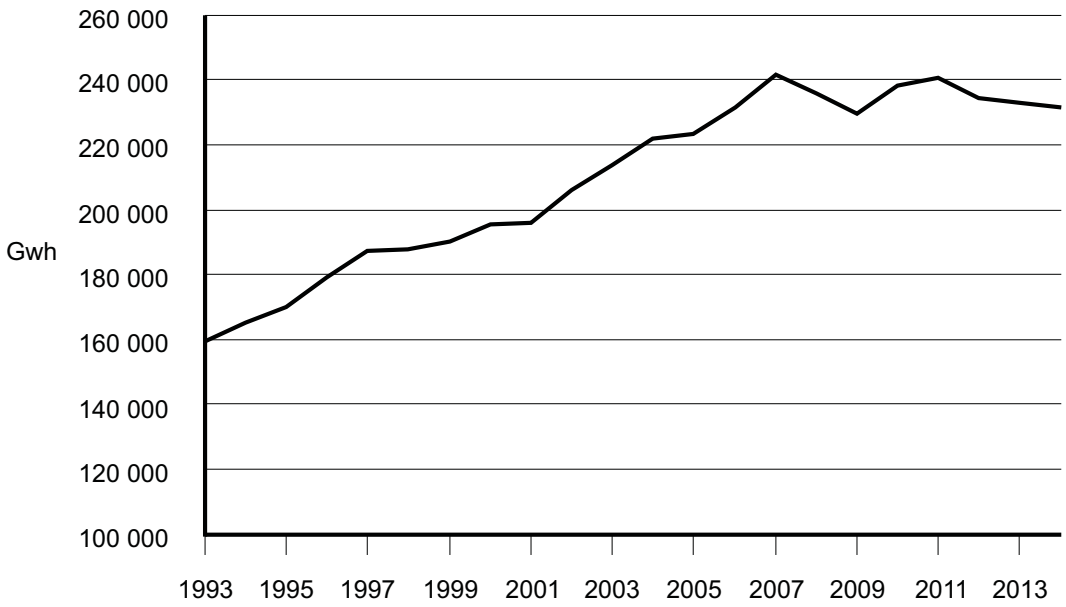
- introducing competition into the industry, especially the generation sector;
- permitting open, non-discriminatory access to the transmission system; and
- encouraging private sector participation in the industry.'

All these proposals are perfectly sound. However, they failed to address the fundamental problem of electricity in South Africa, which has led to the present crisis. The problem is this: how do we price electricity, plan future electricity supply, and frame electricity policy so as to get constant, reliable, affordable electricity at all times for our people and our economy?

In keeping with the white paper's ideas, the Government then ordered Eskom not to build new stations – an instruction that Eskom's managers were delighted to accept. At the same time, however, the price of electricity was kept much too low for any private power producer to have an interest in entering the supply market. In addition, the Government's policies on privatisation were vague and strongly resisted by its trade union and communist allies. So no privatisation took place – and no power station building began until after 2004, when policy changed. But by then it was too late to prevent blackouts.

Future requirements for electricity supply

SA electricity consumption, 1993-2014



Source: Stats SA

The graph above shows South Africa's electricity consumption from 1993 to 2014. Its implications are obvious. By 2007, Eskom had run out of electricity and just couldn't meet rising demand any more. Some silly suggestions have been made, notably by the Integrated Resource Plan for Electricity (IRP), that electricity demand fell unexpectedly after 2007 because of a sudden change in the structure of our economy, with services now predominating over mining and manufacturing. This is nonsense, for structural changes of this kind don't happen from one year to the next.

The truth is that Eskom ran out of supply and so couldn't meet all the demand, which perforce went down. How much further demand would have grown if Eskom had been able to keep pace with increasing consumption is not known, but the figure is sure to be substantial. If our economy is to grow – and if we are to add more value to our raw minerals and further develop our manufacturing sector – demand will inevitably increase even further.

As electricity demand has outstripped supply, so Eskom has shed its load in four ways, the last being the most damaging. First, it has done deals with industrial customers to shed load. Often it has paid them to do so. Second, it has ordered these customers to shed load under an emergency law. Third, it has at times simply disconnected certain districts and big customers. Fourth, it has let it be known that it is unable to provide sufficient electricity to power new mining and industrial projects or the expansion of existing ones. This warning has prevented much investment in our mines and industry.

The truth is that Eskom ran out of supply and so couldn't meet all the demand, which perforce went down.

Eskom's inability to meet demand is illustrated by the record of its Open Cycle Gas Turbines (OCGTs). When Eskom finally realised the crisis it was in, it built the quickest power plants it could to meet peak demand. These were gas turbines. (The term 'gas turbine' does not refer to the fuel being used, but rather to the thermodynamic cycle. A gas turbine is very much like the jet engine on an aeroplane. The fuel it uses may be gas, paraffin, or diesel. Aeroplanes use paraffin.) Eskom built five of these machines at Mossel Bay and nine at Atlantis. Each has generating capacity of 150 MW, giving them a combined capacity of 2 100 MW. This is slightly more than Koeberg's generating capacity of 1 910 MW.

These gas turbines were cheap to build, but they are extremely expensive to run because they use diesel as fuel. Typically, whereas Koeberg's average selling price is 70 cents/kWh, it costs over R3.20 for a kWh from a gas turbine. The idea was that the turbines would be run only for short periods, at times of peak demand. But because of the desperate shortage of available power stations, the gas turbines have had to be run often and for long periods at huge costs. The fuel costs of running them increased from R5 billion in 2013 to R10.9 billion in 2014. This is a very large amount of money for a relatively small amount of electricity.

Demand is probably now in the region of 40 000 MW, which means that Eskom ought now to have generating capacity of 46 000 MW.

Eskom now has operative generation capacity of just over 44 000 MW. Its biggest ever supply peak was just under 37 000 MW. But this, of course, was not the biggest ever demand for electricity. At a guess, that demand would be in the region of 40 000 MW. A healthy electricity supply system has a 'reserve margin' of 15%. This means that Eskom ought now to have generating capacity of 46 000 MW.

South Africa's massive absolute advantage over every other country on Earth is her huge non-oil mineral resources. To take full advantage of them, we need to beneficiate them, turn them into products of high value, and develop our industries and our manufacturing. But all this requires large amounts of electricity – much larger than are now available.

If the South African economy grows at 3% a year, a modest and in fact wholly inadequate rate, and if electricity demand grows at the same rate, as it did from 1993 to 2007, then by the

year 2030 we will need generating capacity of 73 000 MW to give us a reserve margin of 15%. When Medupi, Kusile and Ingula have all been completed, which should be in about 2020, our capacity will instead be 55 000 MW. So we will need another 18 000 MW, equivalent to four more Kusiles or eight more Koebergs.

If the economy grows at 3% a year, by 2030 we will need another 18 000 MW, equivalent to four more Kusiles or eight more Koebergs.

What makes the problem far worse is that many of our coal-fired power stations will run out of life by 2030. The first big six-unit coal-fired stations were built in the 1970s, with an expected 40-year life. That 40-year life is coming to an end.

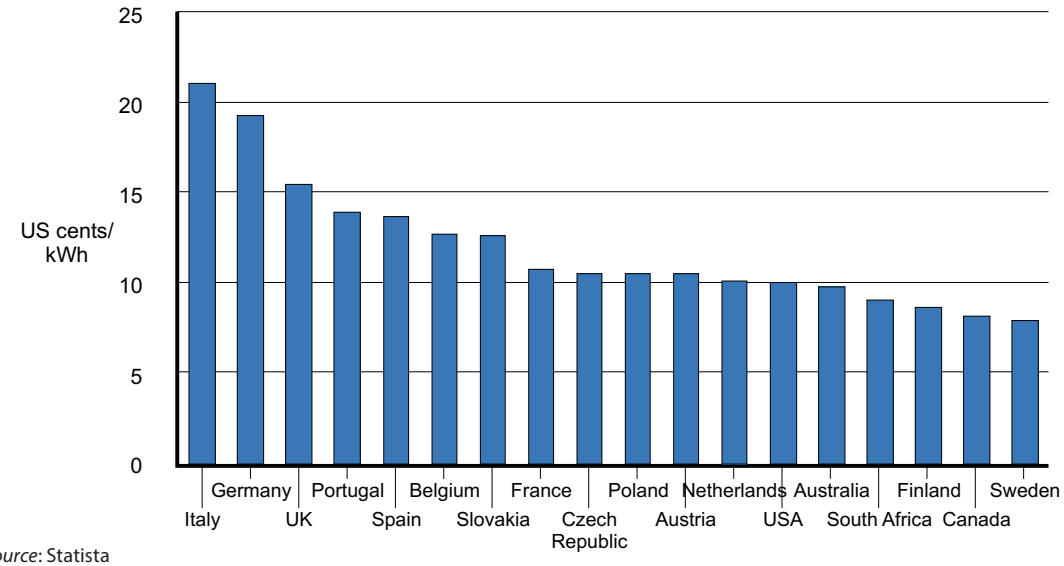
Electricity pricing

Since 1994 Eskom's electricity pricing has been all over the place, to an extent that borders on the insane. At first it kept prices much too low, because it was bowing to a political imperative to provide affordable energy for all – a laudable objective, but one that is likely to be disastrous unless prices cover costs. This is one of the key reasons Eskom did not want to build new stations: the costs would necessarily have raised electricity prices.

Then suddenly Eskom's financial department flipped over to the opposite extreme, asking for crazy increases: 18.7% in 2007, 60% in 2008, 45% in 2009, and 16% in 2012. Fortunately, the National Energy Regulator of South Africa (Nersa) refused this madness. Instead, it granted Eskom perfectly reasonable increases, all of them much lower than Eskom had asked for, but all of them sufficient for Eskom to cover its operating costs and fund the three new stations.

South Africans commonly complain about the high price of electricity here. These gripes are unfounded. Eskom's average electricity prices today are still quite low by world standards. Its prices are lower than those in Denmark, Germany, the United Kingdom, and other European countries. They are also lower than those in the USA, New Zealand, Brazil, Chile, and almost every country in Africa. They are lower than in most countries where electricity generation is privately owned. The graph below shows electricity prices in selected countries in 2014.

Electricity prices in selected countries, 2014



Source: Statista

Comparing countries' electricity prices is difficult since they use different tariff structures, some shifting the costs from industrial consumers to households, some doing the reverse. Nonetheless the graph above gives a clear indication that South African electricity prices are still quite low by world standards.

Power stations for profit or to provide a service?

Free markets and the pursuit of profits generally bring great benefits to all, and for obvious reasons. In almost all cases, the private sector will provide services cheaper and better than the state sector. A 'greedy' capitalist, who is competing against other capitalists, seeks profits for himself, for he knows that his business is likely to collapse if he keeps making losses. But he can make a profit only by satisfying customers, which means providing the best goods at the lowest prices in the most efficient way possible. There is nothing mysterious about Adam Smith's 'invisible hand'. In addition, the private firms are less vulnerable than parastatals to the harm and inefficiency of political directives and direct state interference. But electricity supply may be an exception to the general rule – perhaps the only one.

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A power station is a gigantic oddity. It requires enormous amounts of capital to build. But it requires no great skill or imagination or inventiveness to run. All the power station owner has to do is to foster the necessary technical skills and follow the instructions of the private companies that provided its equipment. The product – electricity at a specified frequency and voltage – never varies. All the power station has to do is turn a generator shaft at 50 cycles a second (or 25 times a second in the case of Koeberg) for the life of the station, which today may be 60 years. The key expense is the upfront cost of capital.

The State can generally raise debt more cheaply than the private sector. This is because the risk of its defaulting on a loan is much lower. 'Sovereign debt' is thus usually cheaper than private debt. So the cost of capital for a state generator will generally be lower than for a private generator. On top of this, the State has no shareholders to please other than itself, and so it can be satisfied with a low return on investment (a 3% real return or even less). It can also accept a very long payback time. The State's aim should simply be to provide a service, and not to make a profit. This means that a state-owned power station will generally provide electricity more cheaply than a privately-owned one.

However, a state-owned power station will generally provide electricity more cheaply than a privately-owned one.

However, Eskom today does not seem to understand these essentials. Its financial managers, in pleading for high electricity prices, pretend that Eskom is a high-risk business. In 2009, in their price increase application to Nersa, they claimed that Eskom was more risky than the average private company. They also act as if Eskom were a private company trying to earn high returns and make big profits. They pretend they must have far more revenue to fund the new building, when in fact their own latest annual general report (of March 2014) shows this is not so.

On the contrary, Eskom's operating profits are sufficient to fund its building programme at present electricity prices, provided Eskom borrows more money for this purpose. This it can still do. Despite Eskom's downgrading by the ratings agencies, Eskom bond yields remain

very low, typically less than 2% above inflation. If Eskom now offered a bond at 3% above inflation, corresponding to a very low cost of capital, it would be trampled to death in the rush to buy them. The problem is its unwillingness to follow this path. Instead, it wants consumers to fund most of the huge costs of building new power stations over only a few years, whereas the more sensible option – as Eskom did in the 1970s – is to borrow at low interest rates and pay back the full sum (capital and interest) over the 40-year to 60-year life of the new plants. If the Government guaranteed Eskom's loans, this would probably reduce the interest on these borrowings even more, for there is an implicit understanding that the Government would never let Eskom default on its debt repayments.

Eskom's operating costs have, of course, risen steeply in the last two years, but many of these can be reduced. The obvious one is the high cost of the diesel fuel currently being used to run the gas turbines. Once the new coal stations come on line, the gas turbines will be run far less frequently.

It should borrow money at low interest rates and pay it back over the 40-year to 60-year life of the new plants.

Who should own our electricity supply?

Around the world, privatisation of state-owned industries has mainly been very successful. British privatisation of telecommunications was a brilliant success. Privatisation of national airlines is usually successful and South African Airways should be privatised. But privatisation of electricity supply has not been so obviously successful. Customers might have a choice of suppliers to buy from, but electricity prices have not noticeably gone down.

Part of the problem is a necessary monopoly as regards electricity transmission. Single transmission lines transfer electricity from a power station to thousands of customers. It would be extremely wasteful if different electricity companies each built their own transmission lines between the same two points – just as it would be if bus companies built their own roads or railway companies built their own railway lines. But if different generating companies are to use the same transmission lines, they must pay for their use of these lines. How much must they pay? Must they pay from hour to hour, or for long fixed periods? Whom do they pay? The customer might be able to choose between various generators using the same transmission lines, but who sets the transmission price and by what criteria?

Privatisation of electricity supply has not been so obviously successful. Customers have a choice of suppliers, but prices have not gone down.

This helps explain why, in practice, privatised electricity supply is always highly regulated and usually in a complicated way. However, often there are also ideological imperatives that take precedence over commercial considerations. This is particularly evident as regards 'green' preferences and climate change policies. In various countries, grid operators are often forced to buy 'renewable' energy (mainly wind and solar) at very high prices, whether they need it or not, and despite its being very unreliable and troublesome. Electricity purchase contracts thus become extremely complex.

South African electricity supply is still via old-fashioned state-ownership. Eskom has a near monopoly in generation, a complete monopoly in transmission, and does 50% of distribution, the rest being done by municipalities, as earlier described. Eskom's own distribution is far more efficient and reliable than that of municipalities. Most of the electricity failures suf-

fered by households and businesses flow from deficiencies at the municipal level (including City Power in Johannesburg) and not from Eskom itself. Hence, any factory would far rather receive electricity from Eskom than from a municipality.

The main reason is that Eskom is a large centralised organisation, with central depots for maintenance equipment and specialist engineers. By contrast, municipalities are generally small organisations lacking the necessary equipment and skills. This was one of the reasons the ANC earlier proposed replacing the municipalities with six Regional Electricity Distributors (REDs). However, the policy failed because of predictable opposition from the municipalities, which rely on electricity distribution for much of their revenue.

Eskom's transmission lines should be taken from it and run by an independent operator, probably owned by the State.

It has been suggested that Eskom should sell off some of its power stations to private buyers, and there might be a role for this. Here is a fairly simple suggestion for the future ownership of our electricity.

Transmission

Eskom's transmission lines should be taken from Eskom and run by an independent operator, probably owned by the State. A bill proposing such a change, the Independent System and Market Operator (ISMO) Bill, came before Parliament in 2014 but was not passed – probably because of political pressure from Eskom. Recently, the ANC has stated that it is opposed to an ISMO and wants Eskom to remain the operator.

An independent transmission operator would buy electricity from generators and sell it to distributors. It is essential that its purchases be based purely on commercial considerations and not on ideological or political ones. Price and reliability alone should decide each purchase: not black economic empowerment goals, political favours, or green ideology. This, as experience elsewhere shows, is difficult to achieve.

Electricity purchases could take place under long-term purchase contracts and via instantaneous hourly purchases in a spot market. In times of emergency peak demand, these purchase prices would be high. Private generators would want to take advantage of them, so would plan to meet these peak demands. This would benefit grid reliability.

Any private generator should be free to compete with Eskom on electricity generation and sales.

Generation

Subject to one important proviso, as outlined below, Eskom should remain a state-owned generation company. However, any private generator should be free to compete with it on electricity generation and sales. This private generation should take place on a strictly commercial basis, and so must be kept free from distorting subsidies or political/ideological considerations.

Eskom should be the generator of last resort, obliged by law always to ensure the country has adequate electricity.

Private generators or IPPs will seldom be able to compete with Eskom on price, for reasons already given. However, there will be times when they can do so – and are, in fact, already doing so. To meet peak demand, Eskom is currently obliged to rely on its gas turbines, which generate electricity at a cost of more than R3.20/kWh. IPPs are already able to better this

price at the relevant times. In the year ending March 2014, Eskom thus bought 3 671 GWh of electricity from a range of IPPs at an average cost of 88 cents/kwh. This is higher than Eskom's average selling price of 71 cents/kwh, but lower than the cost of electricity from the parastatal's gas turbines. Until at least 2020, when all the new Eskom stations should be in operation, IPPs could profitably provide the grid with at least this much electricity every year.

It should be made easy and automatic for any IPP of a suitable size and reliability to sell electricity to the grid. The bureaucratic and financial impediments that now make it difficult for them to do so should be removed.

It should be made easy and automatic for any IPP of a suitable size and reliability to sell electricity to the grid.

Calls are often also made for households with small wind turbines or photovoltaic solar panels to be able to sell electricity into the grid. This option brings with it various problems and must be treated with caution. The 'feed-in' tariffs in Germany and some other countries are iniquitous. They guarantee the householder an artificially high price for his electricity, even if he supplies it at an off-peak time when there is no demand for it – which is usually the case. His high price is then passed on to other electricity customers. Since it is only the rich who can afford to install these expensive solar systems, the effect of the feed-in tariffs is a transfer of wealth from the poor to the rich. Moreover, the intermittent supply of tiny amounts of electricity from the solar panels presents the grid operator with expensive difficulties. If a suitable system could be devised, so that a householder sells his electricity at commercial prices only when it is needed, this would be acceptable. Modern 'smart meters' will probably soon make this possible.

The important proviso (referred to above) for Eskom to remain under state ownership is that the State should refrain from interfering in Eskom politically. Since 1994, however, the ANC Government has not met this proviso at all. Instead, as earlier noted, it has appointed incompetent senior managers with no suitable expertise at all, purely on the grounds of race and political connections. It has also made vital decisions on Eskom's behalf, with scant regard for engineering and economic reality. The result is the crisis we now suffer.

There is also, of course, a logical contradiction in this proviso. The best option for Eskom is to remain state-controlled, provided it can function autonomously and without state interference. If the Government insists in interfering, it would be better for Eskom to be privatised. But for as long as the State is so keen on interfering, it is unlikely to allow privatisation. A conundrum.

Eskom should remain under state ownership, but only if the State refrains from interfering in Eskom politically.

Distribution

This is the easiest problem to solve technically, but the most difficult politically. Private electrical engineering companies could almost certainly distribute electricity more cheaply, more reliably, and more efficiently than municipalities. Many would be large companies serving bigger districts than individual municipalities currently supply, making them rather like privatised REDs. They would cure most of the electrical failures suffered by households now. But how to persuade or force the municipalities to relinquish distribution would be a very difficult problem. Local authorities now get a large proportion of their revenue from electricity distribution. Without it, they might claim a need to increase rates steeply – though they could, of course, save money by operating more efficiently. They could also increase their revenue

through effective debt collection. Instead, the overall debt owed to municipalities by households, businesses, and state entities has steadily increased and now stands at a whopping R94bn.

Energy sources for electricity generation

In a rational world, the choice of energy sources for generating electricity would be strictly scientific and economic. It would seek the greatest benefit at the least cost to mankind and the environment. Unfortunately, the world is not rational.

In a rational world, the choice of energy sources for generating electricity would be scientific and economic. Instead, it is fraught with ideology and superstition.

Today, energy choices are fraught with ideology and superstition. Some people hold with religious fervour that 'renewable' always means 'good' and that 'nuclear' always means 'bad'. (But if you stop to think about it, renewable energy includes slave labour, which is not good; and solar power originates in a gigantic nuclear reactor in the sky.) And, of course, belief in global warming or 'climate change' pervades the politics of energy like a new apocalyptic faith.

The key belief in the climate-change faith is that mankind, by increasing the amount of carbon dioxide (CO_2) in the air, is changing the climate in a dangerous way. This belief has no backing in science. The essential facts are rather easy to find and are supported by huge amounts of data and other evidence. Since the middle of the 19th century, CO_2 has increased from about 280 to 400 parts per million (ppm) and global temperatures have risen slightly, by about 0.7°C. That's the entire basis of the scare, and it bursts like a soap bubble when pricked by the facts.

The slight warming of the 20th century was no different from previous, natural warming periods, such as the worldwide Mediaeval Warm Period, from about 900 AD to 1200 AD, when temperatures worldwide were on average higher than now and CO_2 was lower than now. Basic physics shows that CO_2, a weak greenhouse gas, cannot have much effect on global temperatures. Since the advent of multi-celled life about 500 million years ago, CO_2 has averaged over 2 000 ppm, but has varied between 180 ppm and 7 000 ppm. These variations have never been seen to have any significant effect on the Earth's climate. In the last 18 years, despite rising CO_2 and despite frightening predictions to the contrary, there has been no global warming. There is no physical theory why rising CO_2 should cause more extreme weather events. There has also been no increase in the frequency or severity of extreme weather events, such as hurricanes, floods, droughts and storms. There is no scientific support for a future rise in temperature of 2°C because of rising CO_2. There is no reason at all to fear rising CO_2.

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However, belief that climate change is dangerous is a political fact. It therefore influences the politicians who take decisions on energy sources. Coal undoubtedly emits the most CO_2 per kWh of electricity. Gas emits about half of this. Nuclear emits none and is by far the best technology for avoiding CO_2 emissions, but nuclear faces other ideological opposition. Solar and wind do not reduce emissions but are perceived to do so. In the ideology of climate change, false perceptions mean more than reality.

Against this background, South Africa's energy options are as follows:

Coal

Advantages: Cheap, reliable, and plentiful; and the technology is tried and proven. South Africa is a world leader in burning very low quality coal and in dry cooling, while coal provides over 92% of our electricity.

Disadvantages: Coal is the dirtiest source of electricity. Coal stations emit particles (smoke), sulphur oxides, nitrogen oxides and heavy metals such as mercury, all of which are damaging to health. (However, the air pollution you would suffer from a coal fire inside your home is a thousand times worse than the air pollution from a coal power station next to your house.) Coal also emits the most CO_2.

Nuclear has by far the best safety record of any energy source.

A particular problem for South Africa is the location of its coal fields. A typical Eskom coal station uses about 16 million tons of coal a year (1 800 tons an hour), so the coal station must be sited next to the coal field. But all our coal fields are in the north east of the country, which means there are no big coal stations in the entire west and south.

Nuclear

Advantages: Nuclear has by far the best safety record of any energy source. Two of the three worst ever nuclear 'disasters', Three Mile Island in 1979 and Fukushima in 2011, killed nobody through their radiation. The worst nuclear accident was at Chernobyl in the Union of Soviet Socialist Republics (USSR) in 1986. Its huge release of radiation killed about 55 people, mainly the workers who cleared the broken reactor. The accident was caused primarily by a bad reactor design, and secondarily by operators deliberately violating safety procedures during a commissioning test. (If South Africa were to get nuclear power stations from Russia, they would have a different design and a very good safety record.)

Nuclear is clean and has a small environmental footprint. Because the energy source is so concentrated, you need very small amounts of it, with corresponding small disruption to the environment. There are no CO_2 emissions in its operation, and the waste is tiny, stable, and easy to store safely. (The problem of nuclear waste is a political one not a technical one.) It is sustainable indefinitely because there are such vast amounts of uranium and thorium in the ground and the sea. It is very reliable, with high load factors. (The load factor is a measure of how much electricity a power plant actually produces, compared with its theoretical capacity.) It is economic everywhere and often, as in France and the USA, the cheapest source of electricity. There have been embarrassing delays in the construction of the new French reactors at Olkiluoto in Finland and Flamanville in France but, since 2004, 21 new nuclear power units have been built in China, Japan and South Korea with an average construction time of 5.4 years. Capital costs are by far the biggest costs of nuclear power but programmes that build fleets of standardised designs, as in China and South Korea, are bringing them down.

Since 2004, 21 new nuclear power units have been built in China, Japan and South Korea with an average construction time of 5.4 years.

Nuclear plants can be sited anywhere because the fuel is so small in mass and can be easily transported. So South Africa can put down nuclear stations where we need electricity – on the coasts and in the west of the country.

Disadvantages: The danger of nuclear weapons proliferation is a horrifying one. But nuclear

power and nuclear weapons have little in common. Israel has the weapons but not the power; Sweden, Switzerland and Japan have the power but not the weapons. The technology of the atomic bomb is well known. The only method of dealing with this threat is political.

A bigger disadvantage is public perception. Nuclear, which in fact is very safe, clean and economical, is widely regarded as dangerous, dirty and expensive. Nuclear public communication has been disastrous until fairly recently, and is still poor. Persuading the public and the politicians of the truth about nuclear power is the most important task if its use is to expand.

Nuclear is very safe, clean and economical, but is widely regarded as dangerous, dirty and expensive.

A local problem for nuclear power is that any nuclear power deal between South Africa and Russia offers prospects of huge corruption based on the recent behaviour of both governments.

Hydroelectricity

Advantages: Clean, reliable and proven. Low operating costs. Gigantic potential in Central Africa.

Disadvantages: South Africa is a dry country with very few suitable rivers. Most of our tiny hydro potential is already being used. Dams can present environmental problems, with silting, disruption to river life, and dislocation of populations.

Gas Turbines

Advantages: Clean, reliable, proven, flexible, quick and cheap to build. Half the CO_2 emissions of coal.

Disadvantages: Can be very expensive to run. Everything depends on the price and availability of gas. The quantity of shale gas in the Karoo might be very big but this is yet to be proven. The gas fields off Mozambique are certainly huge, but we don't yet know how much Mozambique is going to charge us for the gas. She will want the best price possible, and is likely to have lots of international customers to which she could sell it instead.

Renewable energy

This requires a separate section since it is a rather different topic, which has more to do with ideology than engineering.

Wind and solar power have a range of wonderful small-scale applications, but are useless for grid electricity.

Renewable energy, which usually means wind and solar power, has a range of wonderful small-scale applications: solar water heating; wind-powered pumps on Karoo farms; small solar or wind electricity generators powering remote schools, clinics and households; solar panels on the decks of yachts, providing limited but very useful power. The list is long. But, with one exception, solar and wind are useless for grid electricity. They are very expensive, hopelessly unreliable, usually unpredictable, and environmentally blighting. They require huge resources per kWh and cause trouble to electricity quality and stability.

Despite all these problems, there have been colossal investments in wind and solar power around the world. These have been driven entirely by ideology. They have also been a universal failure, except to a small number of wealthy developers who have made lots of money from their large subsidies.

The key example is Germany. There was a spectacular demonstration of nuclear safety at Fukushima in Japan in 2011. A monstrous earthquake and tsunami killed 16 000 Japanese people and severely damaged four old-fashioned nuclear reactors. The resulting radiation release killed nobody, and is unlikely ever to kill anybody. Better proof of nuclear safety is difficult to imagine. Yet Germany then decided to phase out nuclear power, her cheapest and most reliable source of electricity, and replace it with wind and solar. The result has been calamitous. Electricity prices have soared to the point where 800 000 Germans were unable to pay their bills in June 2012. People are stealing wood from German forests. There have been frequent blackouts and major problems with electricity quality. Ironically, there has also been increased pollution, because Germany was forced to start up more coal stations to compensate for the unreliability of wind and solar. CO_2 emissions have risen for this reason.

Germany decided to phase out nuclear power and replace it with wind and solar. The result has been calamitous.

The capacity factor of wind power in Germany in 2013 was 16.6%. (This means that, on average, the wind turbines produced a mere 16.6% of their rated capacity.) German wind, with a capacity of 32,500 MW, produced a miserable 47 TWh in 2013. By comparison, South Africa, with a total capacity of 44 000 MW produced 240 TWh. On 4 September 2013, there was a period where total power from German wind was only 120 MW – 0.4% of its rated power.

To meet the violent fluctuations of the wind, some other generator, usually a gas turbine, has to ramp up and down. This makes it run inefficiently, which means it uses more fuel per kWh and thus emits more CO_2. This is one of the reasons why renewable energy does not reduce CO_2 emissions.

Solar power in Germany is even worse than wind, for it is even more expensive and even more unreliable. But South Africa is a different matter. We have some of the world's best solar conditions, especially in the Northern Cape, where high levels of solar energy reach the ground and cloud cover is limited. Even so, however, solar power for grid electricity would generally be far too expensive, subject to one exception.

This single exception is concentrated solar power (CSP) with storage. In this case, sunlight is not converted directly into electricity, as in photovoltaic (PV) panels, but is used as a source of heat. Sunlight is concentrated by mirrors on to a collector which heats up a working fluid, such as oil or molten salt. Molten salt is the best for storage. The very hot molten salt is stored in a large tank. (Heat is quite easy to store, as the geyser in your roof shows.) When there is a high demand for electricity, the molten salt can be fed into a boiler to make steam to drive a turbine to drive a generator to make electricity. Such electricity will be far too expensive for baseload electricity, but it might well be cheaper than Eskom's gas turbines in catering for peak demand electricity.

Concentrated solar power with storage is too expensive for baseload electricity, but it might well be cheaper than Eskom's gas turbines in catering for peak demand.

A successful CSP plant has to be gigantic. Eskom's proposed 100 MW CSP plant near Upington will have 10 000 mirrors, each 100 square metres in size. The central tower will be 200 metres high. But of course the wind turbines are also gigantic: colossal machines producing small amounts of electricity. 'Gigantic is Beautiful!' would be a fitting slogan for renewable energy for grid electricity.

Under South Africa's Renewable Energy Independent Power Producers Programme (REIPPP), private companies have tendered to establish several solar and wind power stations and Eskom will be obliged to buy the electricity they generate. In three rounds of tendering thus far, the REIPPP has awarded 3 725 MW of capacity, which will require an investment of about R100 billion to install. This has been hailed as an example of market choice and value for money. It is neither. Market forces played no part in the prices the IPPs will get for the electricity they produce. Instead, these prices were simply fixed in the contracts they were awarded. The value for money is very poor. For R100 billion, South Africa could have bought far more electricity supply from nuclear power plants, which would also have been far more reliable. The one saving grace of the REIPPP so far is that it might from time to time have displaced the need to run the ruinously expensive gas turbines.

Value for money in the REIPP is poor. For R100 billion, we could have bought far more electricity supply from more reliable nuclear power plants.

Immediate remedies

South Africa faces five years of blackouts. The only permanent solution is to build sufficient power stations to cope with our electricity demand, but it will take years for Medupi and Kusile to meet present demand let alone future demand. Is there anything that can be done in the interim to alleviate the problem?

At the moment Eskom has a policy of trying to 'keep the lights on', which means avoiding maintenance on the power stations. It would probably be better if Eskom did all the necessary maintenance, which would mean more blackouts, and scheduled the blackouts so that consumers could plan for them. It might even make financial sense for Eskom on occasions not to run the gas turbines and accept even more blackouts. Key industrial customers, such as mines and smelters, which are dependent on continual electricity supply, should then be favoured over households and businesses that are better able to cope with blackouts

All bureaucratic, regulatory, and political obstacles against private power suppliers selling electricity into the grid at times when this makes commercial sense should be removed.

Since the time of peak demand in South Africa and elsewhere is at supper time, about 19h00, it has been suggested that the country should be divided into two time zones, an hour apart. Supper time in the western half would be an hour after that in the eastern half, reducing the national peak demand. This should be investigated.

Some African countries, notably Ghana, get electricity from 'power ships', which are essentially floating power stations. This could be a possibility for Durban, East London, and other coastal cities. However, such electricity would be powered by oil or gas, which would determine whether its price was economic for South Africa.

It would probably be better if Eskom did all the necessary maintenance, which would mean more blackouts.

All measures to reduce electricity demand or shift from electricity to other sources of energy would help. Householders using gas rather than electricity for cooking at breakfast and supper time would help greatly. The obstacle to this now is that gas is more expensive than electricity.

The problem with the pricing of household electricity is this. Municipalities buy electricity from Eskom at 'time of use' (TOU) tariffs. At peak times they have to pay far more than at off-peak times. However, they sell it to householders at flat tariffs – the price of electricity

does not vary during the day. The municipalities make money by selling electricity off-peak and lose it by selling electricity on-peak. The solution would be to have 'smart meters' in each household and to charge the householder by 'time of use'. At supper time, the price would be much higher than during the day; and it would then make sense for the householder to use gas instead. Similarly it would incentivise householders to switch off their geysers at peak times.

Conclusions

The best way forward is to keep Eskom as a state-owned generator, while allowing any company to compete against it for the generation and sale of electricity – provided this competition is strictly on a commercial basis and is not skewed by subsidies. Eskom must also be depoliticised. It should resume its old function: to provide sufficient, reliable electricity and to cover its costs. Nothing else. It should be forbidden from pursuing political, social, or racial ambitions. It must appoint its engineers and other technical staff entirely on merit. Its financial managers must be forced to accept that Eskom's purpose is to provide a service and not to make a profit. They must also accept that it is happy with a low rate of return (3% real or less) and a long payback time. They must borrow to fund the new stations, with repayment scheduled to take place over a period of some 40 years, and they must manage the debt responsibly.

Eskom must be depoliticised and resume its old function: to provide sufficient, reliable electricity and cover its costs.

Eskom's transmission system must be taken from it and given to an independent operator. All large-scale generators must be entitled to use the transmission system in return for a reasonable fee, based solely on technical and commercial considerations. Unless current problems of erratic and unnecessary supply can be eliminated, households which generate small amounts of solar power should not be allowed to sell their electricity to the national grid. They will in any event save on the costs of buying from Eskom or other suppliers.

Electricity distribution should be taken away from municipalities and given to private electrical engineering companies. These will have to compete with one another in supplying final customers, which will help keep their prices down and their efficiency up.

Energy sources for future electricity generation must be chosen on scientific and commercial grounds, so as to serve the best interests of mankind and the environment. Ideology must have no say.

For baseload electricity, there are two present options and two possible options in the future. The present options are coal and nuclear, of which nuclear is the better. The future options are gas (from the Karoo or Mozambique) and hydroelectricity imported from Central Africa.

For peaking power, the options are gas turbines (which have low capital costs and high operating costs) and pumped storage (high capital costs, low operating costs). Concentrated solar power (CSP), with storage, might be a third option.

Electricity supply is of supreme importance to economic growth and the well-being of all South Africans. At present, it is beset with unnecessary problems. But sensible solutions lie readily at hand if the State is willing to grasp them.

— **Andrew Kenny**

*** Kenny is an engineer and energy expert.**

Glossary of key terms

W (Watt)	—	Unit of power
kW (kilowatt)	—	1 000 W
MW (megawatt)	—	1 000 kW
MWh (megawatt-hour)	—	1 000 kWh
GW (gigawatt)	—	1 000 MW
GWh (gigawatt-hour)	—	1 000 MWh
TW (terawatt)	—	1 000 GW
TWh (terawatt-hour)	—	1 000 GWh
Wh (watt-hour)	—	Unit of energy (energy = power x time)
kWh (kilowatt-hour)	—	1 000 watt-hours
Baseload power	—	Bulk power provided 24 hours a day, 365 days a year
Peaking power	—	Power provided for short periods at times of peak demand
Capacity factor (load factor)	—	If a power plant has a capacity of 100 MW and over a period of time produces on average 70 MW, its capacity factor is 70%.