The Global Energy Revolution and What it Means for South Africa

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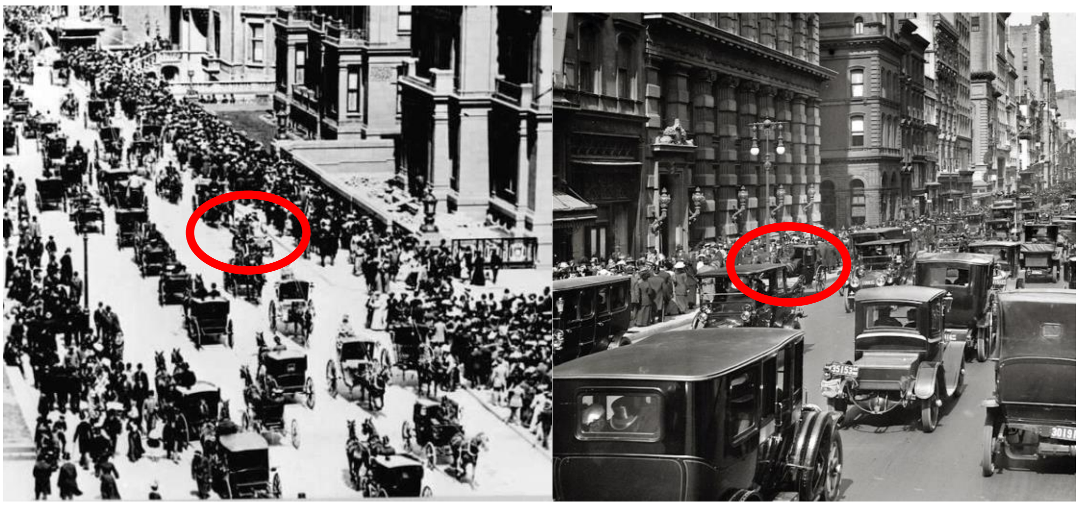
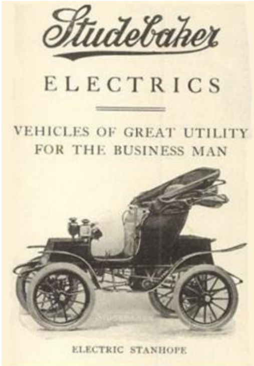
The world of energy is changing, and it is changing profoundly and rapidly. Accelerated innovation in power technologies, services and markets are shifting and upending relative prices, resource shares, and the location and pattern of energy production and use. In the midst of an energy revolution, it is often difficult to comprehend the nature and extent of these changes. Indeed, some still contest their validity and value. But the economics are inexorable. New low-cost, clean, flexible technologies and services are breaking through.

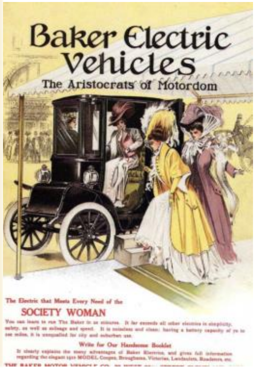
Energy transitions are, of course, not new. The steam engine transformed manufacturing in the first industrial revolution in the 18th century in Britain and Europe, and then in the 19th century in many parts of the globe. The steam engine also enabled the rapid roll-out of railways, and faster and more reliable shipping.

At the end of the 19th and beginning of the 20th centuries, developments in electrical energy – including Edison's light bulb and the first central power station in Pearl Street New York - plus the internal combustion engine, facilitated mass production, improved the quality of life of the wealthy and middle-classes, and further transformed transportation. The pace of change was radical.

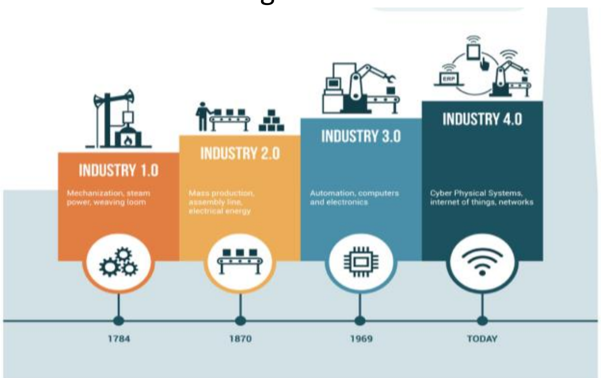


A photograph taken in 1900 in 5th Ave New York city shows a street clogged with horse drawn buggies and, if one looks carefully, a single automobile. Barely thirteen years later, a photograph shows the same avenue congested with cars and again, if one looks carefully, a single horse-drawn carriage. In just over a decade, transportation was completely transformed.



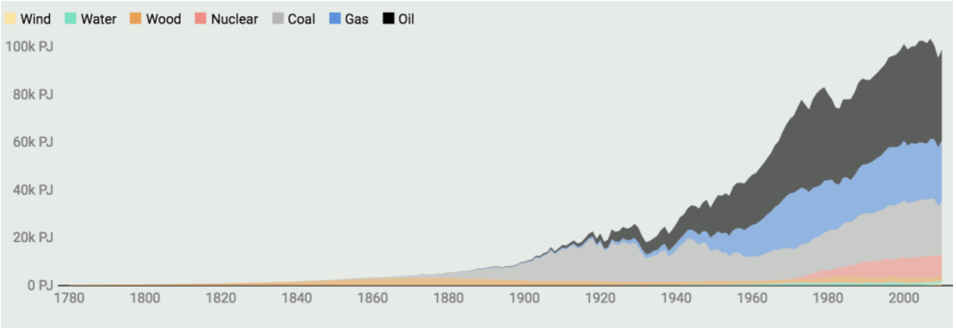


A fascinating side story around the wave of energy innovations at the beginning of the 20th century and the consolidation of the 2nd industrial revolution, was the initial competition between internal combustion engines and electric vehicles. Despite the latter's many attractions, the former won, as petroleum production and distribution expanded, while electrical networks and battery technology lagged. Ironically, a century later, we are about to see the relative merits of these technologies reversed. But more of that later.

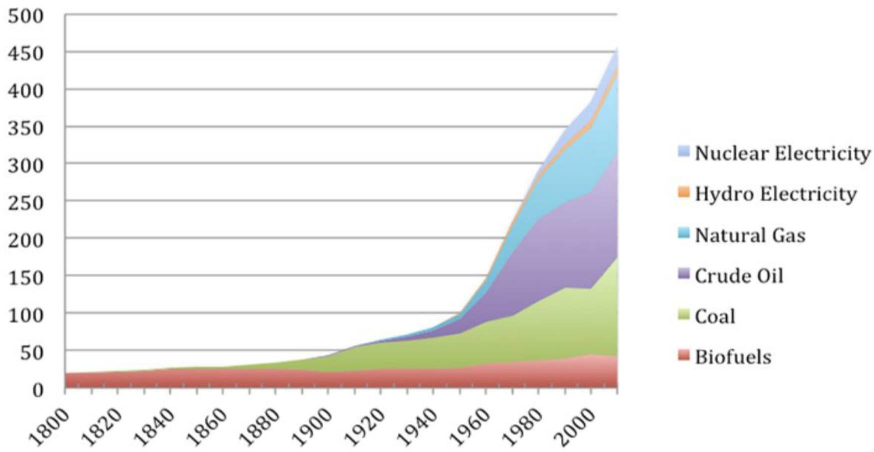


Energy, transport and communications have been fundamental to successive industrial revolutions, with the telegraph and telephone paralleling innovation in the other sectors. The third industrial revolution, beginning in the 1970s and 80s, transformed communications, media, and finance, with innovations in electronics, computing and automation, but energy and transport lagged in this period. The promise of renewable energy in the 1980s was not fully realised and transportation systems remained addicted to cheap and polluting oil.

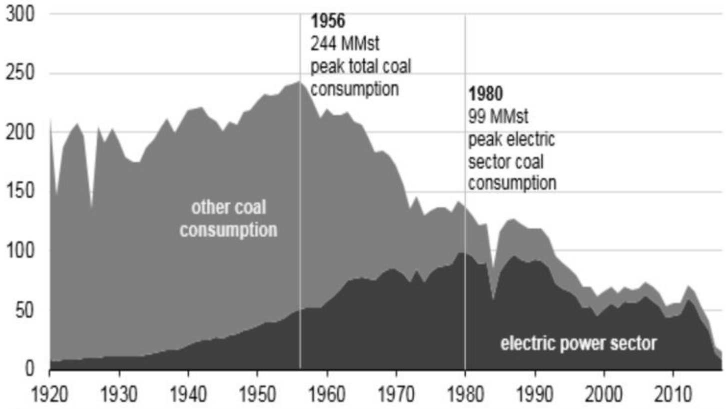
But now, as we enter the 4th industrial revolution, with an explosion of connectivity, bandwidth, artificial intelligence and machine learning, and the internet of things, energy and transport are catching up. The auto-oil industrial complex of the 20th century is in decline. Fossil fuels are increasingly expensive and environmentally unsustainable. Expensive Infrastructure investments in coal, oil and gas are looking less sure bets, and old infrastructure could become stranded assets.
As communication technology and infrastructure is used in more complex and decentralised ways, and innovation and markets for renewable energy, batteries and electric vehicles expand, we begin to see a new convergence between energy, transport and communication technologies. The pace of innovation is such that some of us here have already lived in three of these industrial revolutions. We know it was not always like it is now.



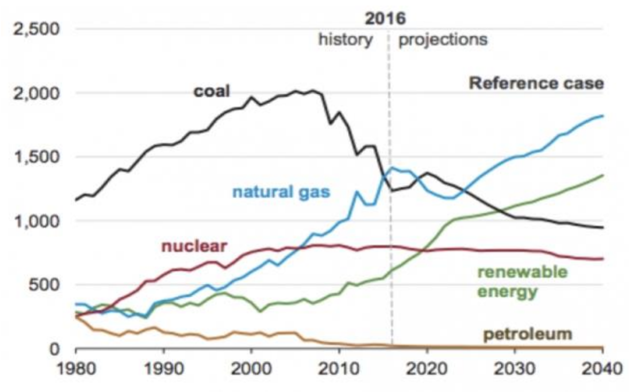
Here is the historical trend of energy consumption in the US. The use of fuelwood, and wind and water mills in previous centuries was quickly overtaken by massive exploitation of coal, gas and petroleum resources.



This general pattern was mirrored globally. While the poor remained dependent largely on biomass fuels, industrialised nations relied on exponential growth in the use fossil fuels. Nuclear power has been a bit of side show: it enjoyed rapid growth and glory days in the last decades of the last century but is now hardly growing.

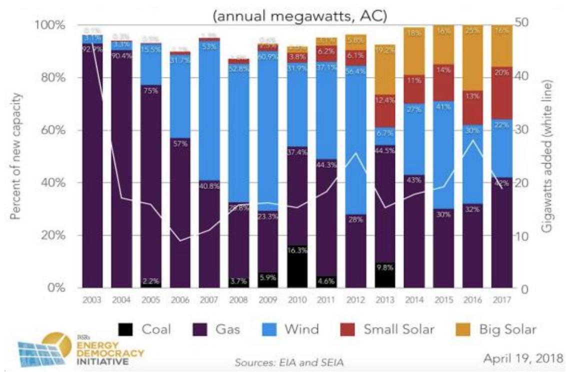


But this pattern of energy development, evident over much of the 20th century is changing. Coal, which powered the industrial revolution in England, is now in terminal decline there. Peak consumption was in 1956. Coal may be fully phased out in the UK by 2025, and probably sooner.

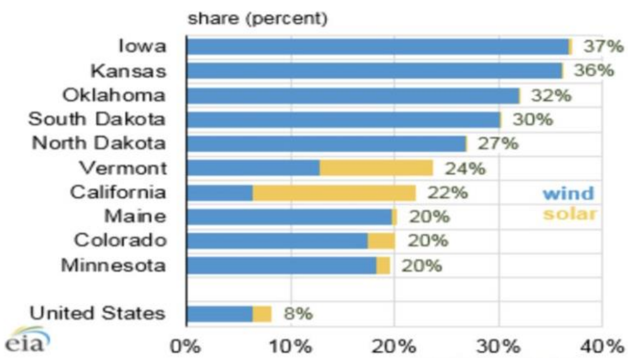


The energy transition is most apparent in electricity where we see a global shift away from fossil fuels and the growth of renewable energy; long apparent in a host of OECD countries, this trend is also beginning to show in countries such as India and China where growth in coal consumption is slowing and investments in renewable energy is rapidly increasing.

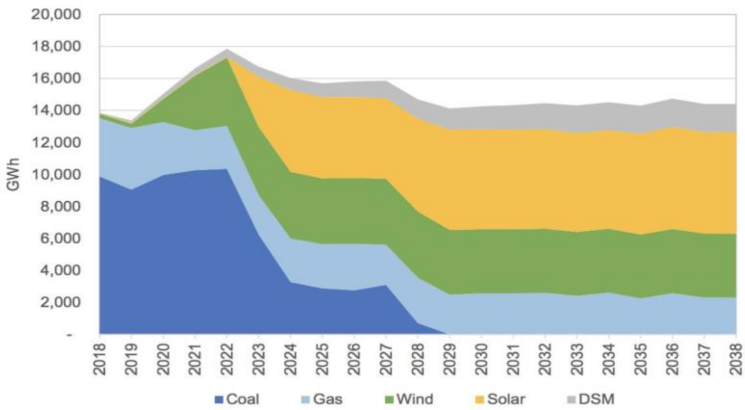
This chart of the share of different energy sources in electricity production in the US, shows how petroleum now makes almost no contribution, coal use is half what it was at the turn of century, while natural gas has grown, initially mostly through LNG imports and latterly through innovations in shale gas drilling. Renewable energy is also taking off.



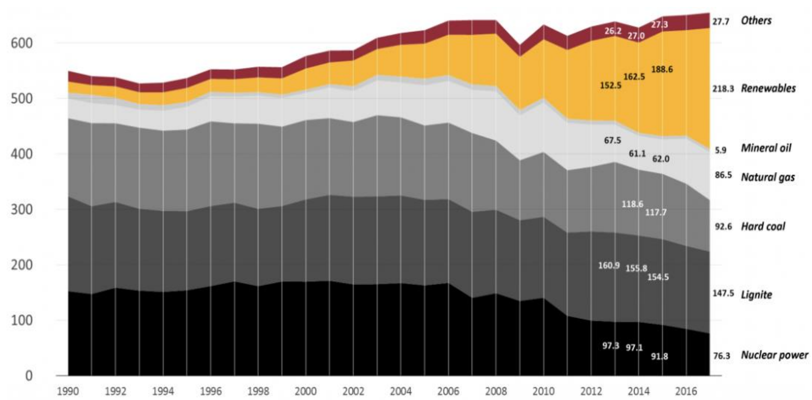
New power capacity being built in the US is now almost exclusively gas, wind and solar.



Already the share of wind and solar in electricity production in some US states is significant: as high as 36, 37% in Iowa and Kansas.



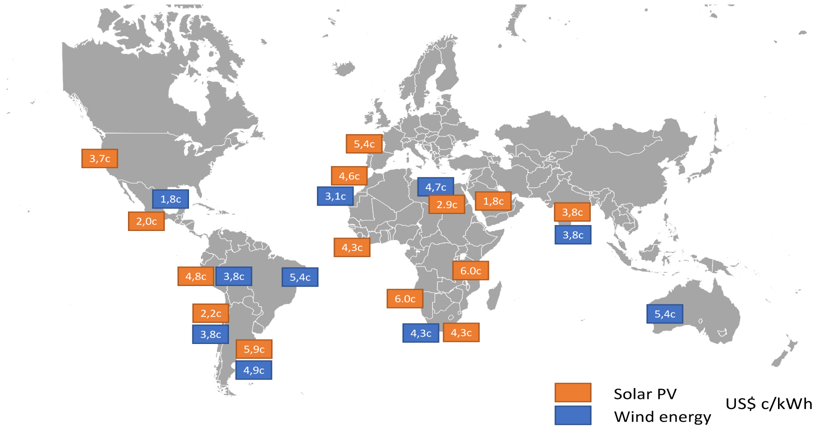
The pace of change is staggering. Here is Indiana's new electricity plan. It's all solar, wind, gas and demand-side management. I use these US examples, not because they are unique, but to illustrate the inexorable economics that underpin these energy transitions. Despite the Trump administration's removal of policy support and the shift of subsidies from renewables back to coal and nuclear, these are having almost no effect as the business case for renewables becomes better and better, and that for coal and nuclear more dire.



The most celebrated, and equally criticized, example of a country in the midst of an energy transition, is Germany with its Energiewende. The share of renewable energy there has grown, nuclear is being wound down, while coal and gas persist in the energy mix, prompting a new commission to determine next steps in reducing fossil fuel emissions and meeting their climate change mitigation commitments.

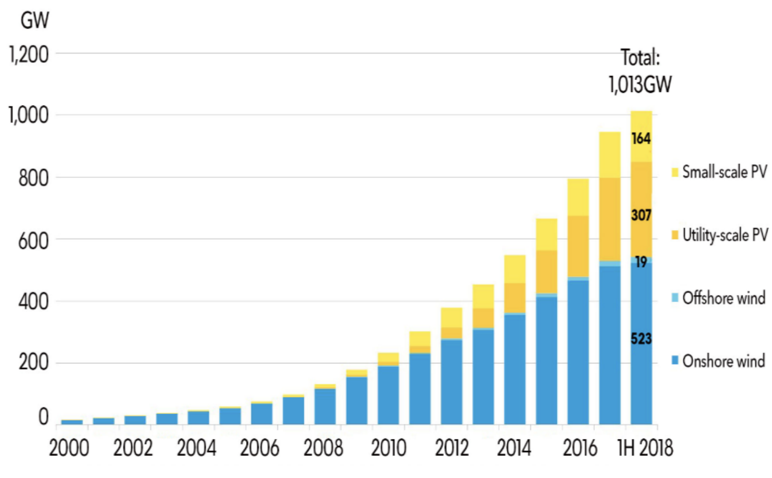
One of the consequences of the support of Germany (and other countries, such as Denmark) for solar and wind energy through generous feed-in tariffs was a significant expansion of global production of these technologies which prompted investment in further innovation. As a result, we have seen a dramatic fall in prices for solar and wind energy, as shown in this chart.

Renewable energy is breaking through:
record low auction prices for solar and wind energy

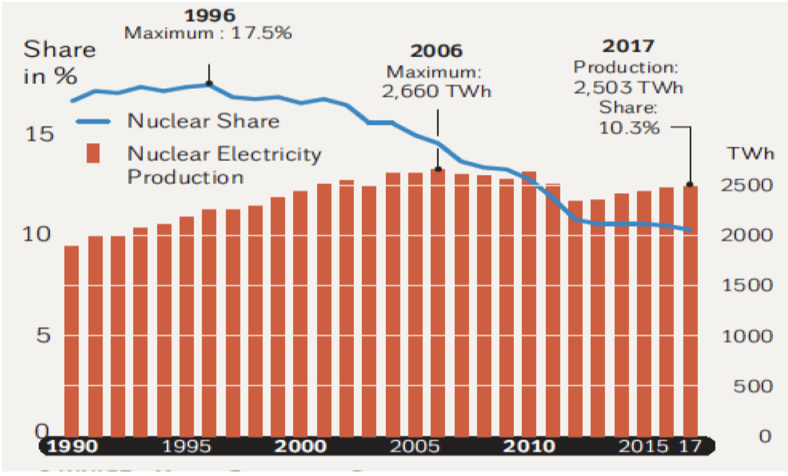


I've worked in the energy sector for more than 35 years. My PhD in 1980 was on solar energy and rural development. For decades, these technologies were restricted to high value applications, such as microwave repeater stations or refrigeration for vaccines in remote clinics, financed mostly through development assistance.

That has all changed in the past 5 years. Wind energy prices have dropped 50%, solar photovoltaic by 80%. And energy auctions, rather that administratively determined feed-in tariffs, are resulting in record low prices, not only in the Middle East with their favourable solar resources and concessionary finance, but in countries such as Chile and Mexico which has seen bid prices below US 2c/kWh – i.e. less than ZAR 30c/kWh.

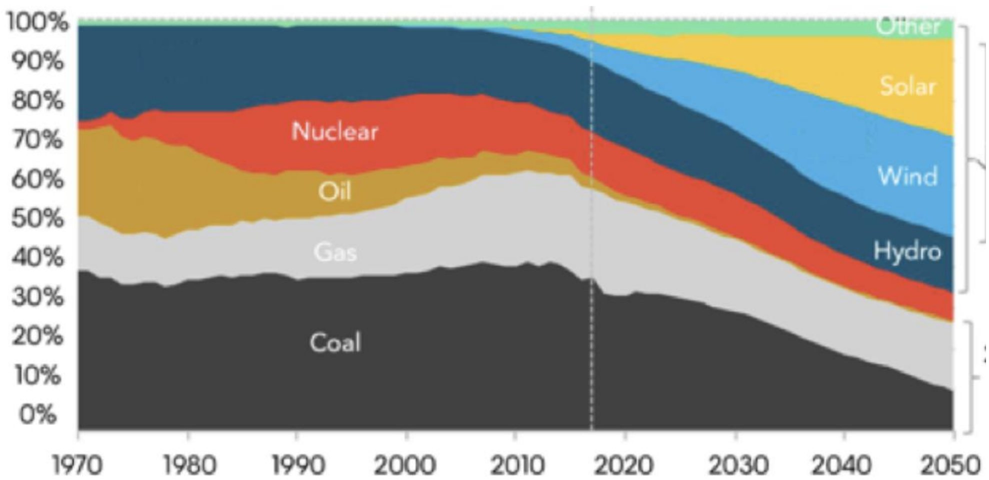


New solar and wind capacity additions now exceed those from fossil fuel and nuclear power.

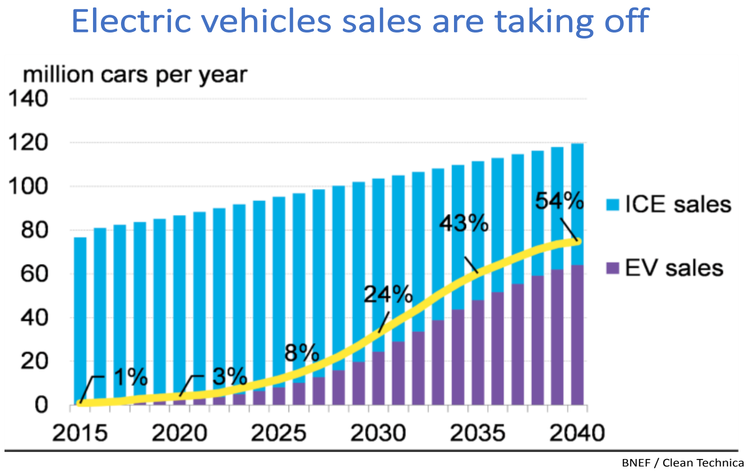


The nuclear sector produces less electricity than a decade ago. Its share of global electricity production reached a peak of 17% in 1996; it is now 10%. Nuclear power plants are still being built in 15 countries, but about two thirds of these are experiencing delays. The US has only one nuclear construction site left. A second, the VC Summer plant South Carolina, was abandoned last year, mid-construction with US$ 9 billion investment having to be written off.

The contrast between the nuclear and renewable energy industries could not be greater. The one is a growth industry. The other is moribund. In the face of uncertainty, investors are moving away from mega projects, which are prone to time and cost overruns (Eskom's Medupi and Kusile coal plants being prime examples) to smaller, incremental investments which are more responsive to these market changes.

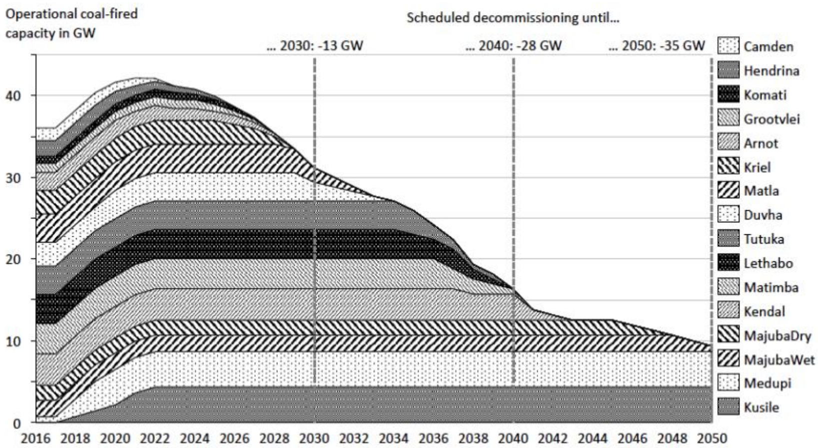


Right now, we're right on the tipping point of a fundamental energy transition, as shown in this chart by Bloomberg Energy New Finance.

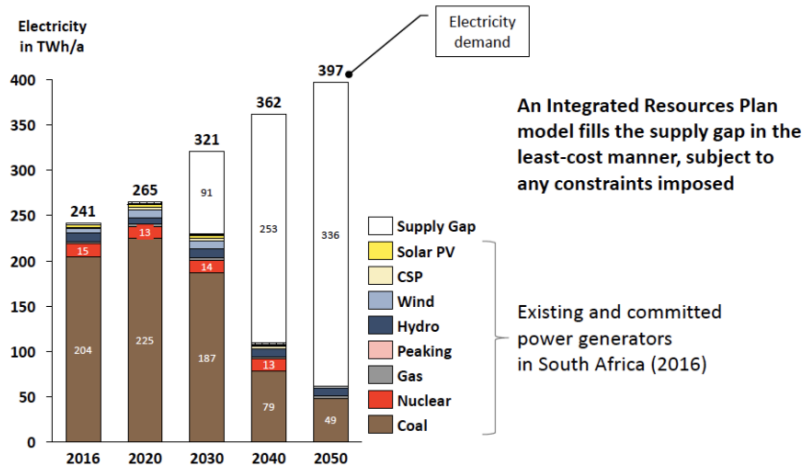


And electric vehicles are experiencing a renaissance. In South Africa, where plug-in vehicles are rare, there is little awareness of how rapidly this market is growing. Anyone who has travelled to Scandinavia recently cannot miss the number of road-side charging stations and the fact that the majority of new vehicle sales are electric. These developments will alter our energy landscape.

What are the implications of these global innovations for South Africa? The first, obvious point to note is that South Africa is overwhelmingly dependant on coal for electricity production – currently around 87%. Many of the power stations are old, and will need to be de-commissioned over the next couple of decades.

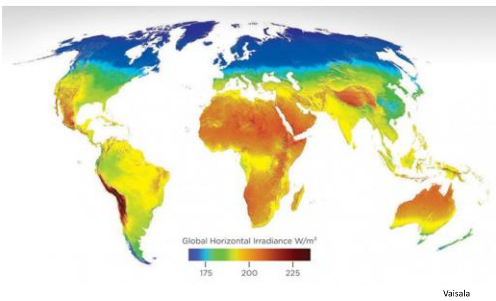


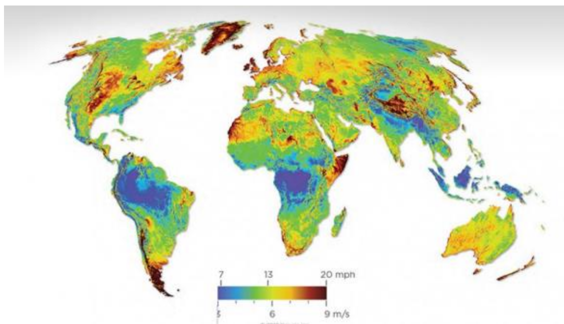
As power stations age, they become more expensive to maintain. And, without new investments, the costs of old coal mines also increase. Environmental regulations are being tightened. Eskom's power stations will need to meet minimum emission standards for air pollution by 2025 and will only obtain an exemption for individual power stations if they will be decommissioned by 2030. An Eskom study has estimated that the cost of emission control retrofits, plus associated increases in operating costs, for its power stations, totals R350 billion, a sum that is clearly unaffordable. It is thus likely that old, non-compliant coal power stations will be forced to close early.



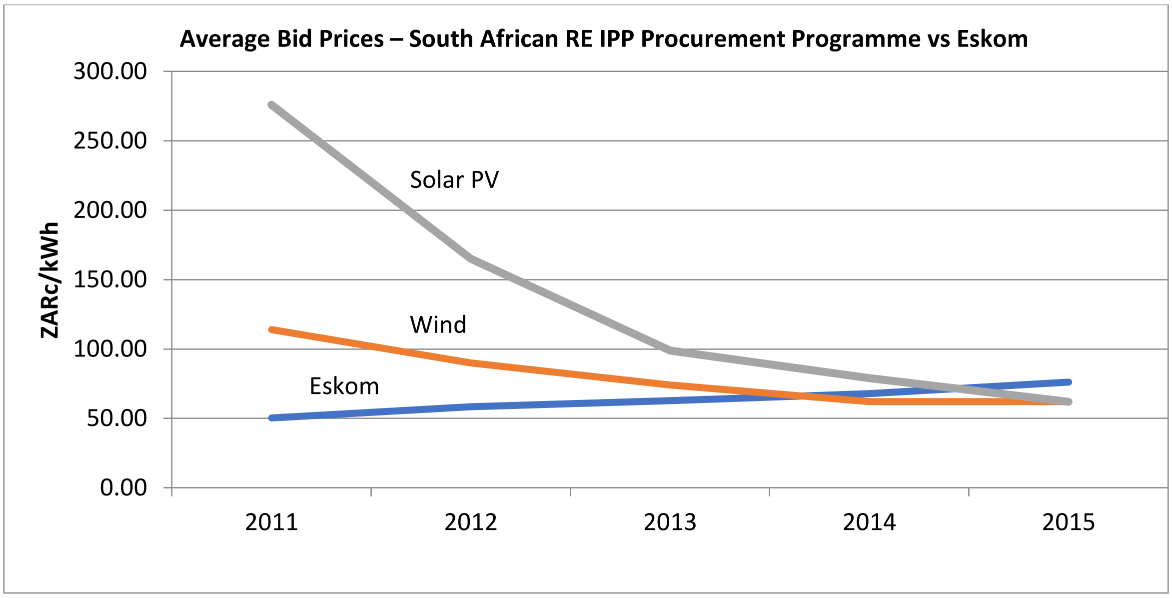
As coal generating capacity declines, new power sources will need to fill the demand gap. South Africa's electricity road map, the Integrated Resource Plan (IRP) seeks to model the least cost energy mix to provide a reliable electricity supply.

South Africa has great solar resources

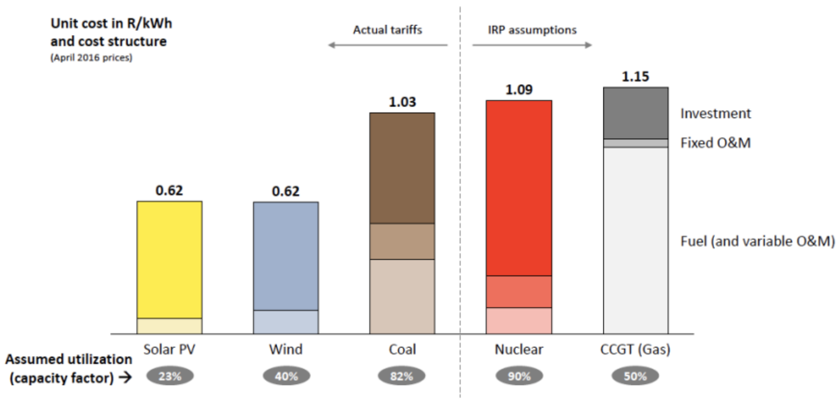




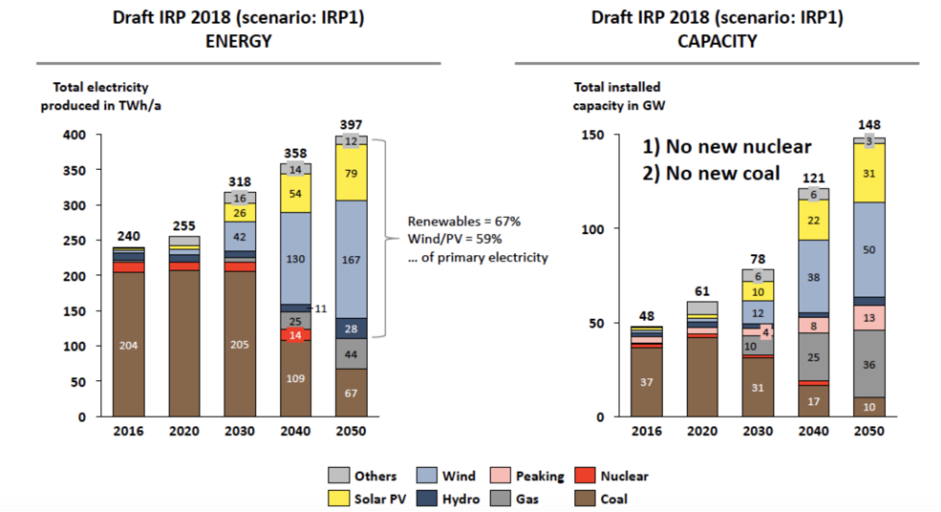
In considering new options, we need to note that South Africa has great solar resources and, in parts of the country, also more than useful wind resources. These are far superior to the European countries that have been at the forefront in renewable energy developments.



The drop in solar and wind energy prices internationally, has been mirrored in South Africa. In the last, expedited renewable Energy IPP round, prices were down to ZAR 62 c/kWh, a third lower than Eskom's average cost of supply and roughly equal to Eskom's current short-run average cost of generation. The next REIPPP auction will likely deliver prices below ZAR 50c/kWh, i.e. below the cost of running many of Eskom's coal power stations. With every successive REIPPP round this gap will widen as the cost of coal power continues to escalate while renewable prices fall further. That will be a game changer and will hasten the transition.

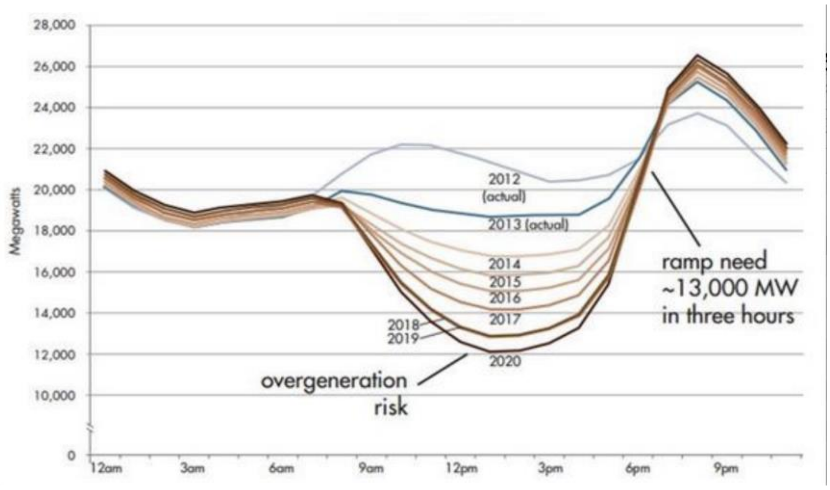


The 2018 version of South Africa's electricity plan – the IRP 2018 – is probably conservative in its price assumptions. It does not take into account likely new auction prices for solar and wind. And it probably underestimates the cost of coal and nuclear.

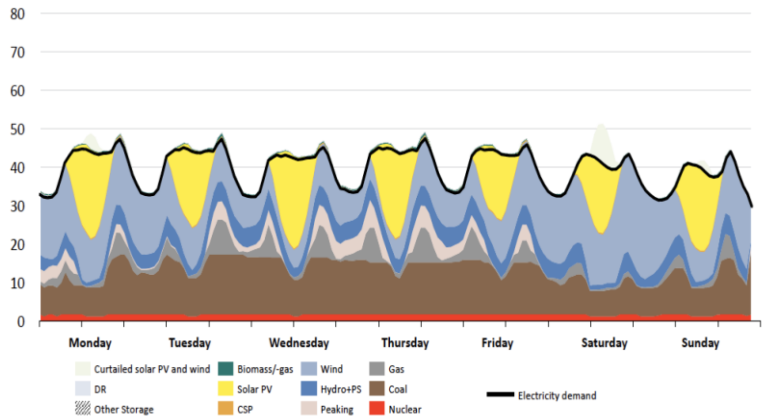


Yet all the planning scenarios pick solar plus wind plus gas, rather than coal or nuclear. Our energy future thus seems clear, but it is not uncontested, as I shall discuss later.

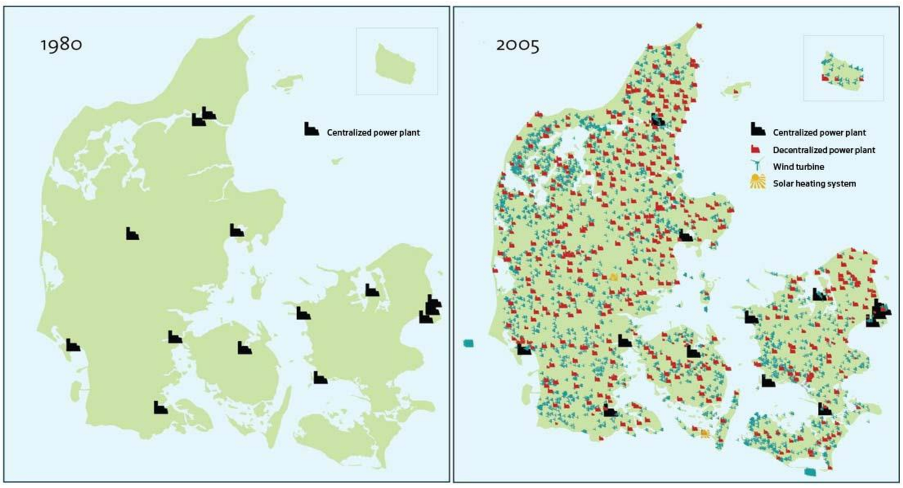
The rate of growth, location and shape of electricity demand is changing. Electricity is being used more efficiently and, in many industrialised countries, electricity demand is actually declining. Even in South Africa, electricity demand today is lower that it was 10 years ago.



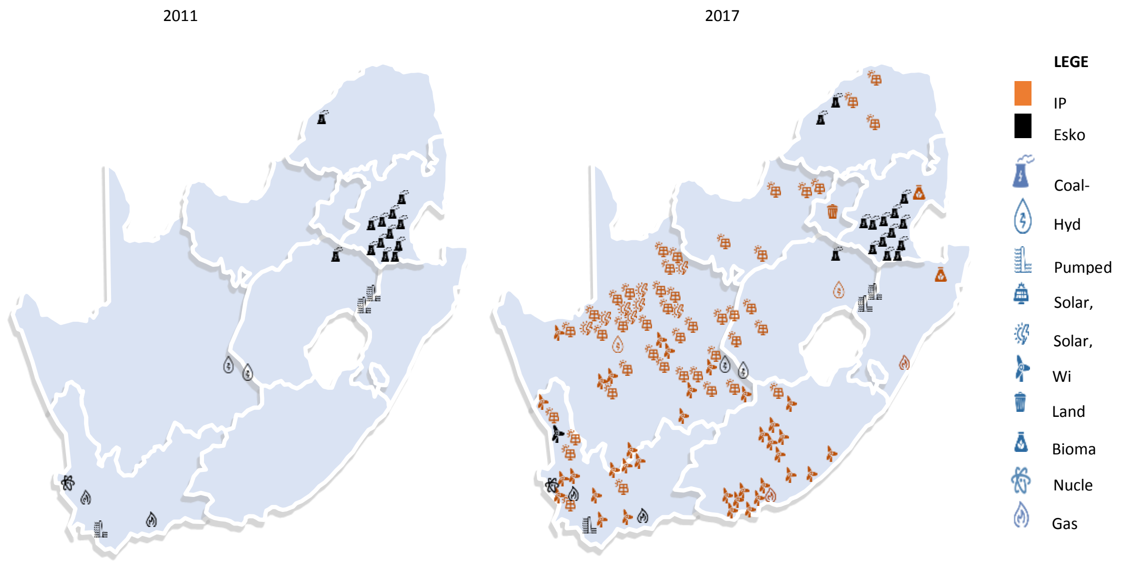
A consequence of a growing share of solar energy is to change the residual demand curve. As the production of solar during the day increases, the residual demand sags, and changes also with variable wind production. The consequences for the remainder of the power system are profound. We need to maximize the share of the cheapest grid-connected power sources – wind and solar. Over time, as the grid penetration of these resources increase to higher levels, we will need complementary resources which are flexible and can fill the troughs when the sun doesn't shine and the wind doesn't blow. Complementary power will need to be responsive and ramp up and down quickly. Potential candidates are gas turbines. Other flexible resources are flexible hydro or pumped storage or batteries or demand-side responses. Coal and nuclear, unfortunately, don't fit the bill. They are not well suited to being operated in this way, to ramping up quickly to meet residual demand.



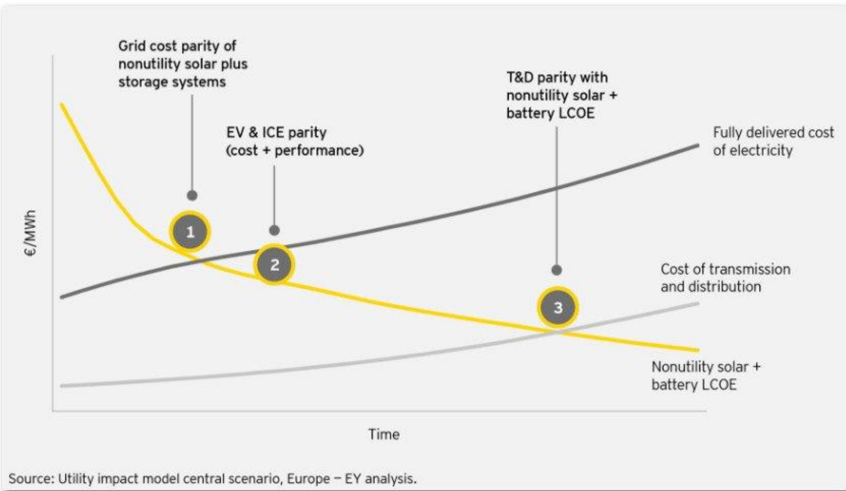
Shifting from a traditional power system, which is typically built around steady baseload, to one which is designed around variable renewables, requires a major mind-shift. This new paradigm only makes sense if the weighted average cost of solar + wind + additional flexible resources is lower than that of baseload plus peaking power. We also need to be confident that the new system will meet quality of supply standards, including system strength or inertia, and voltage and frequency support. Fortunately, we are seeing that these new systems, especially when they include utility-scale batteries, can also provide these additional reliability services at competitive costs.



The increased use of renewable energies, which rely on distributed resources, means that the electrical system will be increasingly decentralised. This chart shows the transformation of the Danish power system between 1980 and 2005. Today it is even more decentralised.

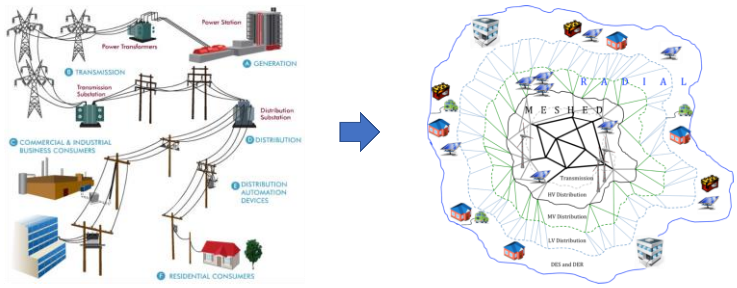


The same is happening in South Africa. Look how the locational distribution of power generation has changed from 2011, when it was mostly Eskom centralised power stations, to 2017, after three REIPP procurement rounds totalling 64 independent renewable energy power projects. Round 4 will bring this total to 92. And these are only utility-scale grid connected projects. We could add hundreds more roof-top solar installations, mostly on industrial and commercial properties, and increasingly on upper income residential homes.



As battery prices fall, the break-even between Eskom and defecting from the grid is becoming a reality. The really radical tipping point will be when the cost of solar + batteries is cheaper even than cost of grid infrastructure.

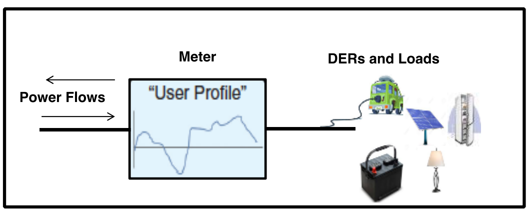
As consumers become also producers of electricity networks will look very different in the future



Changes are proving devastating for business models and finances of conventional utilities

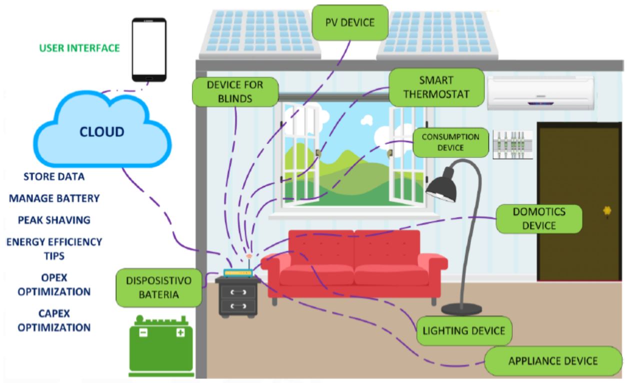
So the nature of our electricity system and grid is changing. No longer will it look like Thomas Edison's 1882 New York Pearl Street central power station with its distribution grid to consumers, a model emulated all over the world over the past century. Instead, consumers will become producers – "prosumers" if you like - increasingly decentralised, distributed, multiple. Electricity could flow in both directions. Grids and power systems will not be linear. They will be radial, meshed, fractal.

As power flows both ways, advanced metering and payment systems need to reflect time differentiation in energy costs as well as peak-coincidental capacity charges for networks and flexible resources



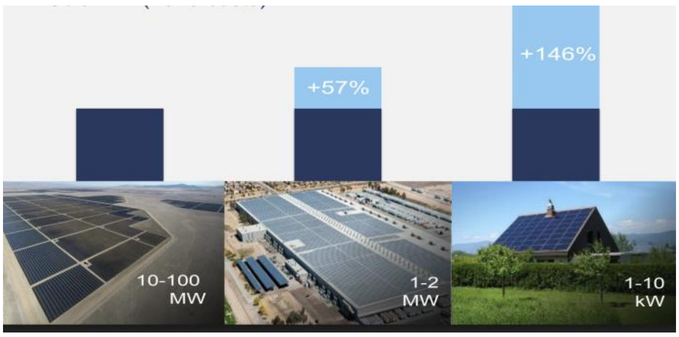
Block chain payment systems are emerging

Advanced metering and payment systems will be required and regulated charges will need to reflect time differentiation in energy costs (i.e. when it is cheaper or more expensive to produce or consume electricity) as well as peak-coincidental capacity charges for networks, flexible resources and reliability services (to complement one's own generation). We would also need to progressively increase the locational component of charges.

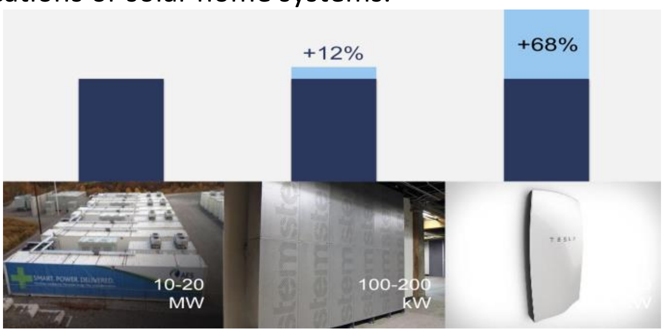


People will increasingly choose how and when to control their energy services, from whom and to whom. Smart meters will be complemented by smart devices and controls, with machine learning and artificial intelligence, to maximize comfort and economy. Payment systems could use block chain technology for accounting purposes. The 4th industrial revolution is truly upon us.

Some may adduce that the future is entirely transactive energy between prosumers and that large utilities will no longer have a role. Indeed we are seeing the phenomenon of the utility death spiral . As consumers defect, utilities or regulators hike tariffs to cover fixed infrastructure costs, and then more consumers defect with the consequence that utility revenues decline even further.



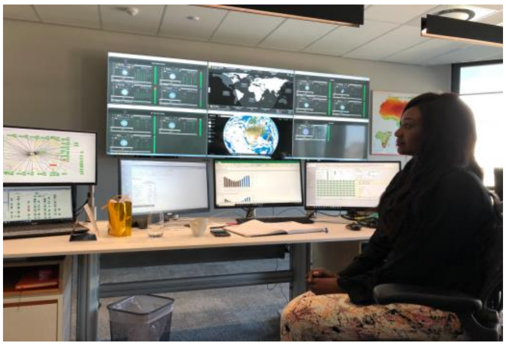
But there are still economies of scale for renewable energy. For example, a utility-scale solar pV plant of 10 or 20 MW or greater will be significantly cheaper than C&I (Commercial and Industrial) applications or solar home systems.



Likewise, there are economies of scale in storage systems, which imply that there is a business case for utilities in providing these reliability service. System and transmission operators will become ever more critical for optimising future power systems.

National control centres will need to integrate with numerous decentralized control centres and systems

Eskom National Control Centre Germiston



Scatec control centre in Cape Town monitoring and controlling a global portfolio of solar projects

But the nature of system operation and control will change as well. On the left we have picture of Eskom's National Control Centre. On the right is a solar company in Cape Town that is monitoring and controlling its global portfolio of solar projects, while also connecting to Eskom's control room, forecasting weather and day-ahead production from its South African solar farms.

Many countries are now beginning to anticipate the changes these disruptive technologies will bring to power markets

The world of energy is changing fast, and South Africa will need to catch up

So what about Eskom?

Eskom is in trouble: it is facing a classic utility death spiral
and cannot trade its way out of its financial difficulties

	2007	2017
Total installed capacity (MW)	42 618	44 134
Electricity sales (GWh)	218 120	214 121
Revenue (R millions)	39 389	177 136
Average selling price (c/kWh)	18	83.6
Coal purchases (Mt)	117.4	120.3
Coal costs (R millions)	+/- 10 000	50 300
Employee costs (R millions)	9 451	33 178
Employee numbers	32 674	47 658
Debt securities & borrowings (R millions)	40 455	355 300

Source: Eskom Annual Reports

Actually, Eskom is in deep trouble. It is already experiencing the Utility death spiral. Its electricity sales are lower than a decade ago. But its costs are up significantly: coal, payroll and debt. It cannot trade its way out of this. In other words, it cannot increase revenue by much and it is not controlling its costs.

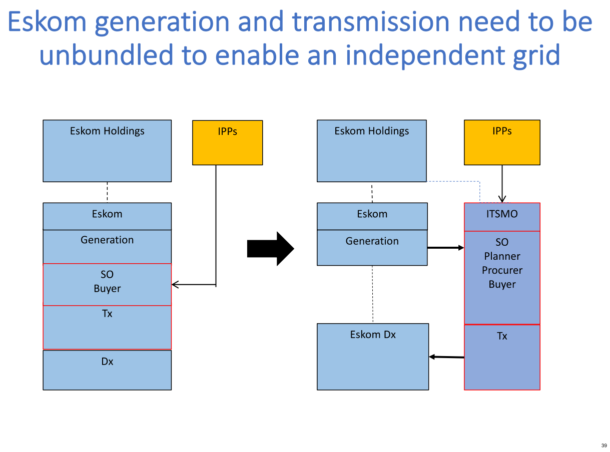
Eskom's organizational structure and ownership – a vertically-integrated, state-owned utility – may have suited the last century, when there were significant economies of scale in coal power plants and large amounts of capital were needed. But that model is no longer fit for purpose. Mega coal or nuclear plants are no longer competitive and distributed energy resources are breaking through. ICT innovation allows for coordination of the system, even if unbundled. And growth in financial markets has generated new sources of finance which facilitate private investment. The electricity system is no longer considered a natural monopoly; it is possible to have competition in generation and in customer choice.

South Africa has experienced firsthand how Eskom's monopoly structure has encouraged large inefficiencies not only in fuel and O&M but also capital expenditure. Eskom has restricted access by competitors to the transmission grid. It has suppressed energy sector entrepreneurship and innovation. It's structure results in information asymmetries, management moral hazard, and has allowed rent-seeking and large-scale corruption. Cost overruns are simply passed to consumers or the fiscus, with huge costs to economy

A few years ago, in a public lecture, I recalled an Eskom executive asserting that Eskom's business model was big coal, big nuclear and big networks. I noted then that I could not think of a more Neanderthal business model. That is even truer today.

President Ramaphosa and Minister Pravin Gordhan's cleanup of Eskom's board, management and governance systems will help, but they will not be enough. Eskom now also needs to be restructured. Eskom missed the first wave of global power sector reforms that were initiated in the 1980s and 1990s, which advocated unbundling of generation, transmission and distribution, and the introduction of private sector participation and competition. Yes – we did introduce an independent regulator, and renewable energy independent power producers were procured by the Department of Energy, despite Eskom fighting them tooth and nail: malicious compliance, I call it – Eskom says it accepts government policy and then does all in its power to protect its monopoly.

That now needs to be confronted. We need to break up Eskom. Its generation business should be open to competition and it needs to be separated from transmission and distribution which remain natural monopolies. The president, in his State of the Nation Address has announced that Eskom will be split into three entities: Gx, TX and Dx, starting with a separate, independent grid entity.



The heart of the system – the system and transmission operator – is in pretty good shape. It needs to be protected from financial contagion from Eskom's generation business, where the major costs and debt reside. An independent grid will be well positioned to contract least-cost power and deliver reliable electricity to consumers. It should also be re-positioned to respond to the energy revolution we have outlined above. It should start providing the infrastructure and reliability services for businesses and homes that are investing in new, clean, low-cost power technologies. We need further policy and regulatory reforms to free the power market for willing seller, willing buyer deals. This will spur a wave of new innovation and investment, providing more choice, diversifying our power supplies, strengthening security of supply, and lowering costs.

Change involves uncertainty. We should thus not try to predict the future exactly, rather we should put in place a framework for pro-active policy, regulatory, market and institutional reforms that are robust in terms of uncertain changes already underway; capable of facilitating emergence of an efficient portfolio of both centralized and decentralized energy resources; and the structure of the electricity sector should be carefully evaluated to minimize potential conflicts of interest.

It is to be expected, that in the midst of a revolution, there will be conflict, and we do see that now in the energy sector. Energy policy debates are increasingly partisan and fractious. There will be winners and losers, unfortunately. Some cling to the energy industries and institutions of the past century. With Eskom as a large, state-owned monopoly, there were more rent-seeking possibilities. Some have spent their entire professional careers in coal or nuclear industries. Their demise seems catastrophic, and they cannot imagine a power system, which is not founded on baseload and linear supply paths. They think it crazy to shift to a system which is variable, flexible, distributed, with multiple interactions between investors, owners, operators and users. Some live in small towns and communities that are almost wholly dependent on these dying industries. The economic and social consequences for them will be dire and we need to work hard on a just transition where professionals and workers are re-skilled and new opportunities are provided. There are inspiring examples where this is being done in other countries; for example the recent deal with coal miners in Spain. Fortunately, work on a just transition is now also beginning in South Africa.

One thing is for sure, in the midst of an energy revolution, little remains the same. The only question now is whether policy, regulatory and institutional reforms will facilitate and hasten these changes, or whether the inexorable logic of economics will drag us belatedly into the future.