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Gridlocked

A long-term look at South Africa's electricity sector

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Summary

Electricity generation in South Africa is changing, but whether the electricity grid will be able to adapt to these changes is uncertain. This paper presents an alternative frame for the current electricity challenges by focusing on the electricity grid. Using the International Futures forecasting model, the African Futures Project has built three scenarios to 2050 to inform policymakers of the long-term implications of grid decisions. With coordinated planning, improved operational strategies and coherent policies, renewable energy can contribute significantly to the energy mix by 2050, help increase economic growth and benefit all South Africans. These interventions, however, will only be successful if there is a clear plan for the structure of the electricity sector.

OVER THE PAST year and a half, beginning in mid-2014, South Africans have lived with regular power cuts (also known as load shedding). Much emphasis during this electricity crisis thus far has been on how to increase supply and from which sources. In response to the deficit of electricity and the constraint this has placed on the economy, the South African Department of Energy (DoE) has been searching for ways to increase generating capacity. New coal-fired power plants are under construction, the procurement process for a number of new nuclear power plants has begun, and oil and gas production is being explored as a possible energy source – whether from offshore, imports or hydraulic fracturing (or 'fracking'). Independent power producers (IPPs) are contributing to electricity supply, and embedded generation – largely in the form of residential solar photovoltaics (PV) – is playing an increasingly important role in decreasing demand on the national grid.

Renewable energy, IPPs and small-scale embedded generation (SSEG) are changing the electricity sector in South Africa. Electricity generation is becoming more decentralised and intermittent, and the line between producer and consumer is becoming blurred. At the same time, the electricity sector is transitioning away from a monopolistic model, with various new actors taking on roles and responsibilities historically controlled by Eskom, and with the introduction of new market elements, like IPPs. It is unclear how the government will respond to these challenges. The government could either ignore these systemic changes, respond to them on an ad hoc basis, or embrace them through coordinated planning, investment in flexible capacity and clear policies regarding embedded generation.

This paper uses the International Futures (IFs) forecasting model to create three integrated and cohesive scenarios for South Africa's future energy system to frame the uncertainty regarding planning, operations, and policies.

The Current Path scenario is a continuation of current energy planning and policies, though not necessarily the most likely future scenario. Under this scenario, Eskom remains in control of the transmission grid and much of the generating capacity, though IPPs continue to be integrated into the energy mix. The roles of various government departments become increasingly blurred and a lack of clear roles and responsibilities among the various actors in the electricity sector, compounded by a lack of coordination between energy planning and grid planning, slows down the integration of IPPs. A lack of clear policies and regulations regarding embedded generation means that its potential to contribute to the grid is not unlocked and the benefits of private generation accrue only to those who can afford it. Furthermore, since many municipalities rely heavily on electricity sales for revenue, residential embedded generation has a negative impact on their finances.

> Electricity generation is becoming more decentralised and intermittent, and the line between producer and consumer is becoming blurred

In the Efficient Grid scenario, investments in electricity-generating capacity are accompanied by efforts to ensure the efficiency of the grid's transmission-and-distribution infrastructure. Although this scenario sees heavy investments in the electricity grid, grid planning is still not integrated into energy planning, and grid investments are made on an ad hoc basis. Like in the Current Path scenario, government does not take advantage of embedded generation, so SSEG benefits only the wealthy and municipal revenues are likewise potentially reduced. The overall result is a more efficient transmission and distribution of electricity but without the full integration of IPPs or embedded generation. Less generating capacity is required in this scenario compared to the Current Path because of greater efficiency in transmission and distribution. This reduces the cost of electricity compared to the Current Path. The lower relative cost, however, translates into a rebound effect of increased consumption, and both electricity and overall energy consumption increase. This leads to an overall increase in primary energy production, energy exports and carbon emissions compared to the Current Path.

Finally, in the Smarter Grid scenario, investments in generating capacity and the efficiency of the grid are accompanied by integrated energy and grid planning, more flexible generating capacity and advances in operational strategies that enable the integration of decentralised and intermittent electricity, together with policies to unlock SSEG. Under this scenario, the grid is able to effectively integrate renewable energy into the South African energy mix. In addition, because of policies and regulations surrounding embedded generation, the benefits are distributed among all citizens. Higher penetration of renewable energy benefits the South African economy and the environment.

In all of these scenarios, renewable energy increases its share of the energy mix over the time horizon. In the Smarter Grid scenario, however, the South African economy

90 GW

THE ESTIMATED GENERATING CAPACITY REQUIRED BY 2030 ACCORDING TO THE INTEGRATED RESOURCE PLAN is 0.3% larger by 2030 and 2.3% larger by 2050. This means that there would be nearly 100 000 fewer South Africans living in extreme poverty in the Smarter Grid scenario than in the Current Path scenario. In addition, because of the higher levels of renewable energy contributing to the energy mix, carbon emissions are lower in the Smarter Grid scenario than in the Current Path. Because thermo-electric power generation consumes a lot of water, water demand is also significantly lower in Smarter Grid.

These three scenarios are not the only possible future outcomes for the South African electricity sector. They are merely meant to show the effects of different policy responses to the changing nature of the grid. As the South African electricity sector transitions from a monopolistic model to include market-based elements, the policy response to the increasing complexity of the system will determine the level of uptake of renewable energy and the equitable distribution of its benefits.

Background

South Africa is facing an electricity crisis. South Africans have experienced load shedding on average every third day during the first four months of 2015.[1] The National Treasury's 2015 budget review stated that of the structural weaknesses in the South African economy, 'the low and unreliable levels of electricity supply are now the most binding constraint'.[2] The review lowered the economic growth forecast to 2% in 2015 because of, among other factors, the effects of the electricity constraint on manufacturing, mining, exports, and reduced investor and consumer confidence.

Current generating capacity is not enough to meet growing electricity demand – and demand is rising quickly. The Integrated Resource Plan (IRP), the government's official electricity plan, estimates that nearly 90 gigawatts (GW) of generating capacity will be required by 2030, about twice as much as current levels.

Eskom has not been and will not be able to keep up with demand and has been increasingly forced to rely on expensive gas-fired power plants to meet peak demand. To cover these costs, in May 2015 Eskom applied to the National Energy Regulator of South Africa (Nersa) to increase the electricity tariff by 12.61% (in addition to the 12.69% increase that Nersa had already granted in 2014) for the 2015/2016 financial year.[3] In June, Nersa rejected Eskom's revised proposal of a 9.58% increase.[4] Electricity has long been subsidised in South Africa, and this tariff increase would have brought the price of electricity closer to the actual cost, though the increases may have negative consequences for the economy as a whole and they will further incentivise grid defection.[5] And even if Eskom were to achieve the revenues it aims for through tariff increases, by its own admission, load shedding will continue.[6]

The lack of a reliable supply of electricity is not due to unforeseen circumstances. The problem is a lack planning and strategic foresight. The 1998 White Paper on the Energy Policy of the Republic of South Africa stated that 'Eskom's present generation capacity surplus will be fully utilized by 2007'.[7] In an attempt to incentivise private-sector participation, in 2001, the DoE placed a moratorium on Eskom to build new power plants. When private-sector participation failed to materialise and the moratorium was lifted in 2004, Eskom had lost four years of construction time, creating a backlog in generating capacity.[8]

Electricity planning and the IRP

Due to the long lead times in construction of power plants, long lifetimes of capital and long-term cross-sectoral effects, long-term energy planning is essential to ensure demand is met with reliable supply. Like many other countries, South Africa has embedded its electricity plan into a larger strategy, the IRP, which aims to meet forecasted demand in the most efficient ways while incorporating other developmental and environmental goals.

South Africa's first and only IRP, the Integrated Resource Plan for Electricity 2010–2030 (IRP 2010), was adopted in March 2011. The IRP is a subset of the Integrated Energy Plan, which looks at the national energy sector as a whole. The IRP 2010 sets out electricity demand forecasts and a proposed power generation fleet to meet this demand. While the IRP 2010 is the official national long-term energy plan for electricity, it is considered a 'living plan' and an update was published in November 2013 for public comments. The next full IRP will begin only after the next Integrated Energy Plan is released.

> South Africans have experienced load shedding on average every third day during the first four months of 2015

The IRP uses international best practices to plan capacity to meet growing electricity demand. The plan factors in environmental considerations, such as carbon emissions and water use. The 2013 update to the IRP builds on the strengths of the IRP 2010 and includes updated scenarios using revised assumptions, decision trees to inform policymakers and risk assessments of implementing the IRP. Although some issues are contentious, the IRP provides a good deal of flexibility and adaptability, necessary attributes of a living IRP.[9]

Despite these strengths, grid planning has not been incorporated into energy planning in the IRP. The 2010 IRP does not explicitly address the electricity grid. The 2013 update does, however, include an annex on the impact of the IRP on transmission and the need for new ‘transmission corridors’ to accommodate the changing location of electricity generation. Grid planning in South Africa has historically taken a back seat to energy planning. This is because load centres (i.e. areas of high demand) have overlapped quite well with capacity centres. This overlap will soon disappear, however, as the location of generation changes. Furthermore, renewable energy, IPPs and SSEG will challenge some of the assumptions used in the IRP and energy planning more broadly.

An integrated assessment approach

Energy and electricity are parts of a larger system. Changes in population, economics, health, education, government spending, infrastructure, agriculture and water will all have a direct impact on the energy system – and energy will affect everything else.

These relationships are integrated and dynamic, and the IFs model is the tool used in this paper to explore and understand them. IFs is a global, long-term, highly integrated model using more than 3 000 data series to forecast over 500 variables for 186 countries to the year 2100. IFs is housed at the Pardee Center for International Futures, at the University of Denver. The Pardee Center is in partnership with the ISS on the African Futures Project. The strength of IFs lies in its ability to analyse dynamic relationships across systems such as population, economics, health, education, agriculture, environment, infrastructure, governance and energy. IFs contains an electricity sub-module as part of its infrastructure module, which is integrated with the energy module.[10]

Forecasting energy supply and demand

Demand

Demand forecasts are the first steps in long-term energy planning. To ascertain the electrical-generating capacity needed, energy planners must first estimate current and future demand levels. There are different ways to forecast energy demand but the method used in the IRP relies on two direct drivers: the size of the economy and the energy intensity of the economy. If one knows the size of an economy in terms of gross domestic product (GDP) and how much energy it requires to produce one unit of GDP (energy intensity), then one can calculate total energy demand as follows:[11]

$$\text{GDP} * \frac{\text{Energy}}{\text{GDP}} = \text{Total energy demand}$$

Electricity demand forecasts used in the 2010 IRP and for the 2013 update were done by both the Council for Scientific and Industrial Research (CSIR) and Eskom’s System Operator (SO). This paper will not explain the details of the models; it focuses only on the economic growth and energy-intensity assumptions.[12]

Economic growth (GDP)

Both the CSIR and the SO have low, moderate and high economic-growth forecasts. The 2010 IRP used the SO’s moderate forecast for its final ‘policy-adjusted IRP’ scenario. That scenario assumes an average GDP growth rate of 4.51% over the period to 2030.

The Base Case in the 2013 IRP update uses the Green Shoots scenario developed by the CSIR. That forecast was based on the National Development Plan (NDP)’s

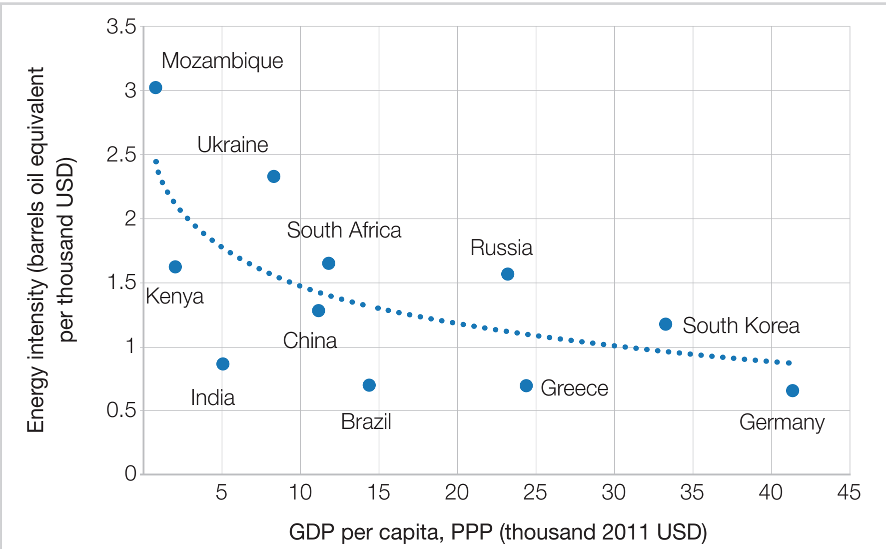
GRID PLANNING IN SOUTH AFRICA HAS HISTORICALLY TAKEN A BACK SEAT TO ENERGY PLANNING average 5.4% GDP growth rate to 2030 but also assumes significant shifts away from energy-intensive industries.[13]

Energy intensity

Both the SO and the CSIR models assume that the energy intensity of the South African economy will decrease over time. The SO electricity-demand model used for the 2010 IRP uses discrepancies between GDP growth and electricity-demand growth to forecast declining energy intensity over time. The CSIR model used for the 2013 update forecasts declining energy intensity indices for various mining and manufacturing sectors. The underlying logic behind both models used for both the 2010 IRP and the 2013 update is that South Africa is transitioning away from energy-intense industries, like mining and manufacturing, towards less energy-intense sectors, like services.

IFs forecasts the energy intensity of economies using GDP per capita as a driving variable. The assumption is that as countries develop and GDP per capita increases, the structure of the economy moves towards less energy-intense sectors, and energy efficiency increases in all sectors (see Figure 1).

Figure 1: Energy intensity of economies (energy consumption divided by GDP) vs GDP per capita at purchasing power parity (PPP)



Notes: As GDP per capita at PPP increases, we expect the energy intensity of the economy to decline following a logarithmic curve. South Africa's economy is quite energy-intense given the GDP per capita. For a full description of how energy demand is modelled in IFs see the help site, http://www.du.edu/ifs/help/understand/energy/equations/demand.html.

Sources: IFs version 7.09 using energy-consumption data from the World Bank, World Development Indicators.

Demographic drivers

To forecast GDP per capita, however, IFs must forecast population size. The relationships between economic growth, population growth and energy demand are not simple. GDP per capita and population size are intimately linked with energy demand. For example, increases in GDP per capita will increase electricity demand as more people gain access to electricity. But, all else being equal, as GDP per capita increases, since this is used as a proxy for development in IFs, the energy intensity of the economy decreases. However, as GDP per capita increases, overall GDP in the

SOUTH AFRICA IS TRANSITIONING AWAY FROM ENERGY-INTENSE INDUSTRIES LIKE MINING TO SECTORS REQUIRING LESS ENERGY, LIKE SERVICES country usually increases as well, meaning that even though the energy intensity of the country is decreasing, since the size of the economy is also growing, overall energy use increases. As these relationships demonstrate, population is of vital importance in forecasting energy demand.

The CSIR electricity demand forecasts for the 2010 IRP use the same population assumptions for all three scenarios discussed here. The model assumes the South African population will grow to 54.6 million by 2034.[14] The CSIR model then uses population as a driving variable for electricity demand in certain sectors: domestic, commercial and manufacturing.[15] Analysis done by the African Futures Project (AFP) indicates that this population forecast is quite low. The SO model does not explicitly include population as a driver of electricity demand.

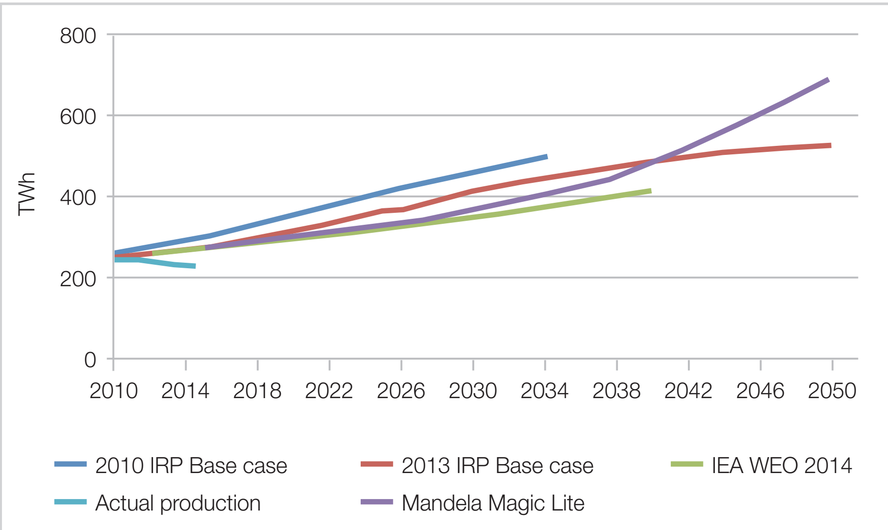
South Africa's demographic and economic trends

The 5.4% growth target set in the NDP and used for the IRP 2013 forecast is unlikely to be achieved. In August 2015, Jakkie Cilliers authored a paper, published by the ISS, titled 'South African Futures 2035: Can Bafana Bafana still score?' That research includes a more realistic growth forecast for South Africa. In the most likely scenario of that paper, 'Bafana Bafana Redux', South Africa grows at an average of 3.6% over the next 20 years. In a more optimistic scenario, Mandela Magic Lite, the South African economy grows at 4% over the next 20 years.

The August 2015 paper complemented earlier work done by the African Futures Project. In October 2013 the AFP published a series of population forecasts, with a particular emphasis on the uncertainty regarding migration.[16] The authors found that even their lowest population forecasts were still considerably higher than the population forecast in the NDP.

The scenarios for 'South African Futures 2035', updated demographic and health assumptions, using the latest mid-year census report from StatsSA, regarding life expectancy, infant mortality, HIV prevalence and migration rates.[17] After incorporating this data into the IFs model, Bafana Bafana Redux forecasts that the population in South Africa will reach 67.3 million by 2035.

Figure 2: South African electricity-demand forecasts in TWh



Sources: 2010 IRP, the 2013 update to the IRP, the International Energy Agency's World Energy Outlook 2014 (New Policies Scenario), and the Mandela Magic Lite Scenario from South African Futures 2035. Actual historical values of electricity demand (net sent-out) from StatsSA are also displayed.

IN THE MANDELA MAGIC LITE SCENARIO, ELECTRICITY DEMAND INCREASES TO 362 TERAWATT-HOURS (TWH) BY 2030 AND TO 673 TWH BY 2050

Figure 2 is a graph comparing electricity demand, as forecast in IFs, with the forecasts from the CSIR and the SO used in the previous IRPs, as well as a demand forecast from the International Energy Agency. In the Mandela Magic Lite scenario, electricity demand increases to 362 terawatt-hours (TWh) by 2030 and to 673 TWh by 2050.[18] In this scenario, electricity demand is lower than the forecasts in both the 2010 IRP and the 2013 update in the short to medium term, though it rises more towards the end of the time horizon. The rise in the long term is due to the larger population and optimistic economic growth in the Mandela Magic Lite scenario.

Self-fulfilling prophecy

Since electricity demand currently exceeds supply in South Africa, in some sense, true electricity demand is unknown. Consumption is constrained by supply; if supply were to increase, so would consumption. The degree to which consumption could rise if supply were to be increased is difficult to estimate, however.

> The cost of an oversupply of electricity is usually less than the cost of unserved energy

Because of the effects supply can have on demand, energy planners need to err on the side of optimism in their growth forecasts. As stated previously, one of the reasons for less-than-expected economic growth is electricity constraints. It is illogical to use economic growth forecasts that are constrained by electrical capacity to inform decisions regarding electrical capacity – if GDP is constrained by supply, then one cannot use GDP to forecast supply. Although an overly optimistic economic growth forecast could lead to an overinvestment in generating capacity, the cost of an oversupply of electricity is usually less than the cost of unserved energy (up to a point) – in other words, it is less costly to have too much energy than too little.[19]

Supply

Energy planners use demand forecasts to inform decisions on investment in capacity. For the 2010 IRP, demand profiles were forecast until 2030, using a time step of one hour. This type of granularity is necessary in energy planning, as demand can change drastically throughout the day, the week and the season. Once these demand profiles are created, energy planners can plan to build resources based on the cost, capacity factor, reliability and dispatchability of each capacity type.

Once electricity demand is forecast in gigawatt hours (GWh), energy planners need to translate this into required capacity measured in gigawatts. Since GWh is a unit of energy and GW is a unit of power, the translation from electricity demand to supply decisions is not trivial.

Making informed energy-planning decisions requires assumptions of:

- The cost of each type of capacity (dependent on run time, fuel costs, maintenance, etc.)
- The lifetime of each type of capacity
- Capacity factors of each type of capacity
- The reliability and dispatchability of each capacity type
- The efficiency of the transmission and distribution of electricity through the grid
- Demand profiles
- The potential for demand-side management

TRUE ELECTRICITY DEMAND IN SOUTH AFRICA IS UNKNOWN BECAUSE POTENTIAL CONSUMPTION IS CONSTRAINED BY CURRENT SUPPLY

The IRP used the most recent and reliable data to make assumptions and forecasts regarding each of these inputs.[20]

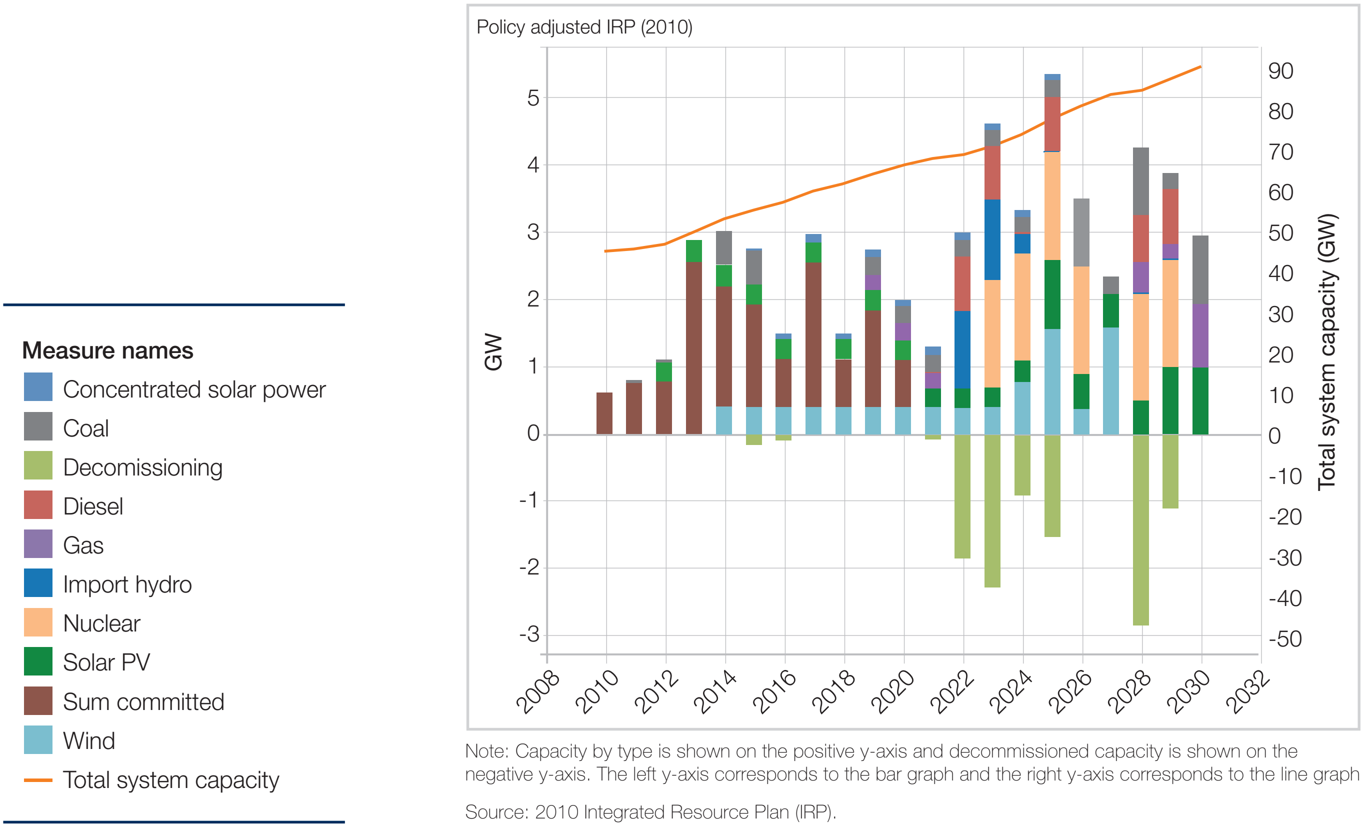
Once all of these assumptions are formalised, the model used to create the IRP can be run to find least-cost options for capacity building. Additionally, following public consultations, other policy requirements, such as environmental considerations, job creation, regional development and integration, and security of supply, are added to create the policy-adjusted IRP. Figure 3 shows the policy-adjusted scenario from the 2010 IRP.

Figure 3 includes the substantial amount of capacity that has already been committed, extending out to 2020. This is largely from the Medupi and Kusile coal-fired power plants still under construction. Wind and solar power is added consistently, reaching 8.4 gigawatts (GW) each by 2030. The first new nuclear build should come online in 2023 and increases by 1.6 GW in five of the following six years, totalling 9.6 GW by 2030. In addition, 3.3 GW of hydropower is imported from Mozambique and Zambia, and more diesel-, coal- and gas-fired power plants are built. In addition, many power plants will need to be decommissioned, starting in 2022.

The orange line in Figure 3 represents total system capacity over time. As capacity is decommissioned in 2022, new build increases to ensure that total system capacity continues to rise.

According to the policy-adjusted scenario in the 2010 IRP, total installed capacity will double by 2030 – from 44.5 GW to 89.5 GW. Of this new build, 29% will be coal-powered; 17% will be nuclear; 16.3% will be wind; and 14.9% will be solar PV (see Figure 4).

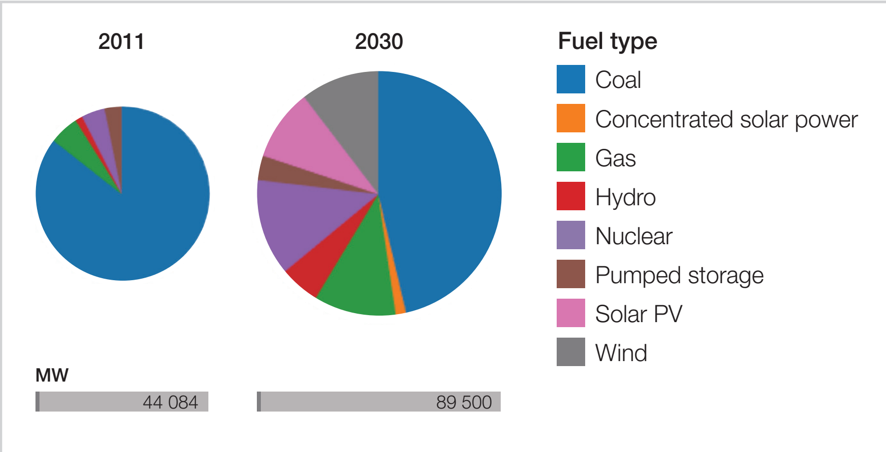
Figure 3: South Africa's total system capacity over time and by type



Note: Capacity by type is shown on the positive y-axis and decommissioned capacity is shown on the negative y-axis. The left y-axis corresponds to the bar graph and the right y-axis corresponds to the line graph.

Source: 2010 Integrated Resource Plan (IRP).

Figure 4: Total generating capacity in 2030 compared with 2011



Note: Most generating capacity is currently from coal-fired power plants; 29% of the new build in the 2010 IRP is from coal and 17% is from nuclear.

Source: 2011 data from **Eskom's generation plan mix**, (http://www.eskom.co.za/OurCompany/SustainableDevelopment/ClimateChangeCOP17/Documents/GenerationMix.pdf)

As other researchers have noted,[21] the 2010 IRP paid little attention to grid planning. The IRP clearly outlines exact levels and types of capacity over time but says nothing about where, geographically, this electricity comes from or who will produce it. Furthermore, the demand forecasts used to create the IRP are national demand forecasts and say nothing about the geographical location of demand. As much as supply capacity is important, grid planning is essential to ensure that energy can be transported from where it is produced to where it is consumed.

Rethinking capacity

The electricity system is changing, largely due to the penetration of renewable energy, the addition of independent power producers and increases in embedded generation. As a result, electricity generation is becoming decentralised and intermittent, and the line between consumer and producer is beginning to blur.

IPPs are edging in on production through the independent power-producer procurement programme. Likewise, many private citizens, frustrated by load shedding and the rising price of electricity, are installing their own electrical capacity. This SSEG is largely in the form of rooftop solar PV, which is becoming increasingly cost competitive with grid electricity.

Wind and solar electricity production is inherently intermittent. Wind farms are dependent on changing wind patterns and solar panels require sunlight. Production, in terms of wind and solar, is therefore not reliable. Wind energy is variable, changing drastically over time. Solar power is more certain, in that one can calculate the hours of sunlight, but production can fluctuate rapidly due to cloud cover.

Following the fourth round of bids, the Renewable Energy Independent Power-Producer Procurement Programme (REIPPPP) has facilitated the procurement of over 5.4 GW of privately owned renewable energy in just four years.[22] In addition to the 1.1 GW procured during the fourth round of bids, in April 2015 the energy minister, Tina Joemat-Pettersson, instructed her department to 'accelerate and expand the renewable energy IPP procurement programme'. This will be achieved by expanding

ACCORDING TO THE POLICY-ADJUSTED SCENARIO IN THE 2010 IRP, TOTAL INSTALLED CAPACITY WILL DOUBLE BY 2030 FROM 44.5 GW TO 89.5 GW the fourth round of bids, expediting another 1.8 GW of capacity and requesting that the REIPPPP be expanded to procure another 6.3 GW. In addition, the DoE will procure 3.1 GW from gas-fired IPPs; 2.5 GW from coal-fired IPPs; and 0.8 GW from co-generation IPPs. The minister went on to announce that the Small Projects Programme, which seeks to procure renewable energy from small-scale IPPs is under way.

Together, all of these IPPs could contribute 20 GW [23] of capacity. To put that in perspective, all power-generating capacity from all sources in South Africa in 2013 was equivalent to 45.7 GW.[24] Although, when combined, this is a lot of capacity, the

average size of each project from the first four rounds of the IPPPP is just 69 MW. Compare this with the six units, each with 800 MW capacity, being built as part of the Kusile coal-fired power station.[25]

> Driven by the increasing cost of grid electricity and the prevalence of load shedding, many South Africans are beginning to 'defect'

As evidenced by the minister's plans to expand the programme, the IPPPP has been successful in many ways. Not only have private power producers been willing to continually bid lower in each successive round of bids, but the renewable energy that has been built as a result of the programme has also significantly contributed to the South African economy. An independent study by the CSIR found that renewable energy in 2014 contributed a net R0.8 billion to the economy.[26] But there are a number of hurdles standing in the way of IPP integration.

Eskom has already expressed concern over the ability to integrate IPPs into the grid.[27] Eskom has connected 32 projects totalling 1.6 GW, but the general manager of grid planning, Mbulelo Kibido, said in October 2014 that it was becoming increasingly difficult and expensive to integrate IPPs, renewable or otherwise. Since the easiest projects to connect to the grid have already been selected during the first IPPPP bidding rounds, it is now likely to become more difficult to incorporate IPPs.

In addition to IPPs, private citizens are beginning to produce their own electricity. Driven by the increasing cost of grid electricity, the prevalence of load shedding and the decreasing cost of PV, many South Africans are beginning to 'defect'. The 2013 update to the IRP includes a forecast for SSEG using rooftop PV as a proxy. Based on assumptions regarding income, it forecasts that small-scale PV could account for 30 GW of electricity-generating capacity in South Africa by 2050.

If this seems unlikely, one need only look at Germany, where 48% (86 GW) of the country's total installed capacity is distributed. Not all of this is residential PV: Germany strongly encourages industry to produce its own electricity. Installed PV capacity in Germany grew from 1 GW to 32 GW between 2004 and 2012. Therefore, South Africa's forecast of 30 GW by 2050 is not unrealistic.[28]

The average capacity of rooftop PV is much smaller than even the Small Projects Programme of the IPPPP, however. The forecast in the 2013 IRP assumes an average installation capacity of 5 kilowatts (kW). This means the 30 GW of energy in 2050 would come from six million citizens.

As a way to curb peak demand, Eskom and some municipalities are beginning to implement time-of-use (ToU) tariffs.[29] ToU tariffs, or 'differential pricing', allow the electricity supplier to change the price of electricity throughout the day, depending on demand patterns. Feed-in tariffs (FITs), or 'standard offers', are policy options under which electricity producers (including private citizens) are compensated for the electricity they supply to the grid. Although ToU and FITs can and have been used globally to effectively integrate private production into the grid and manage demand curves, they also contribute to the increasing complexity of the system.

As a result of the changing locations of generating capacity and the decoupling of load centres from capacity centres, the flows of electricity are also changing. Electricity no longer flows in one direction from producer to consumer. FITs could turn every consumer with private generation into part-time producers, or 'prosumers'. A safe and reliable supply of electricity requires a system operator to coordinate supply and demand in real time, while avoiding fluctuations in the frequency of electricity.

> The changing locations of generating capacity and the decoupling of load centres from capacity centres are changing the flows of energy

What's more, since embedded generation occurs 'behind the meter', it cannot be directly controlled or billed by the municipality. Because much municipal revenue comes from electricity sales, if policies and regulations are not put in place, SSEG could lead to revenue losses for some municipalities.

Instead of a limited number of power stations owned and operated by one utility, South Africa may have millions of producers, each with their own unique production and consumption patterns, buying and selling electricity at changing prices throughout the day. Adapting to the increasing complexity of this kind of system would require the integration of grid planning (and all energy planning) into the IRP, clear roles and responsibilities for all electricity-sector actors, flexible generating capacity, and coherent regulations and policies regarding SSEG.

Grid response

The electricity grid was created in the image of the Industrial Revolution, modelled for centralised mass production to leverage economies of scale. Whereas telecommunications networks have evolved to accommodate modern technologies (e.g. cellphones, GPS, satellite TV and the Internet), electricity infrastructure has not changed significantly over time.

These changes to the grid will affect each actor in different ways. Table 1 outlines how the major trends affecting the electricity grid will have an impact on each actor. In the left-hand column are the major trends discussed above: decentralisation of generating capacity; intermittency of production from wind and solar power; bi-directional flows of electricity as citizens produce their own electricity; and embedded generation, with much private production occurring behind the meter. The column headings represent the various actors in the electricity sector who are affected by each of these trends. The bottom row of Table 1 represents the changes necessary to respond to the changing electricity sector – planning, grid operations and policies – and where they need to happen.

Table 1: Major trends affecting the electricity grid

	Energy planning	Grid planning	System operator	Grid operator	Municipality
Decentralised		X		X	
Intermittent	X		X	X	
Bi-directional				X	
Embedded					X
	Planning		Operations		Policies

Note: An 'X' marks the trend that affects an actor.

Source: Author's conceptualisation, with guidance from Dr Tobias Bischof-Niemz from the CSIR

Energy planners responsible for long-term capacity planning in the IRP are going to be increasingly affected by the intermittent nature of wind and solar power. Although 31% of new generating capacity will come from wind and solar power, according to the 2010 IRP, this capacity is fundamentally different from traditional coal-fired power plants. Assumptions regarding the reliability and dispatchability of capacity will be of increasing importance as renewable energy increases its share of the energy mix.

30 GW

THE POTENTIAL ELECTRICITY-GENERATING CAPACITY BY SMALL-SCALE PV IN SOUTH AFRICA BY 2050

Grid planners, who are responsible for planning the transmission grid, are going to be increasingly affected by the changing location of generating capacity. New solar and wind plants are likely to be located far from traditional centres of electricity production, meaning that new transmission lines will need to be built. Not only are locations of capacity changing, but, since much of this new capacity is coming from IPPs, grid planners also have limited information about the proposed locations of new build.

SOs are responsible for maintaining a balance of supply and demand over the grid in real time. Intermittent electricity production increases the complexity of the system that the SO must manage. Balancing supply and demand to maintain a stable frequency is more complicated when production is no longer under the operator's control.

> As electricity-generating capacity becomes more decentralised, grid planning must be incorporated into long-term energy plans from the beginning

Grid operators, who must manage the municipality distribution networks, face new challenges as production on a smaller scale is more decentralised and intermittent. Grid operators are responsible for maintaining the integrity of the grid on a local level and fluctuations in supply make this more difficult. In addition, the bi-directional flow of power means distribution capacity may need to be upgraded.

Municipalities often purchase electricity in bulk from Eskom and then distribute it to customers. As mentioned, embedded generation is power production that occurs 'behind' the meter – meaning that it cannot be sold, taxed or even directly documented. Electricity sales represent a large proportion of many municipalities' revenue and a reduction in electricity demand due to embedded generation could have an impact on municipal revenue. This leaves less revenue available to provide services to those who cannot afford to generate their own electricity. Further, private citizens who install their own capacity often push excess energy back into the grid (when their demand is low). While these 'prosumers' are at times supplying the grid with electricity, they are not being adequately compensated. This mode of new generation necessitates new policies that must be put in place to address these challenges.

Planning

As mentioned, grid planning in South Africa has taken a back seat to energy planning. This is largely because load centres (areas of high demand) have overlapped quite well with capacity centres. Most electricity comes from coal-fired power plants built near coal mines in the Mpumalanga province. Most demand is centralised in nearby Gauteng, the economic heartland of South Africa. Transmission lines take electricity to the other large load centres in the Western Cape and KwaZulu-Natal. With the decentralisation of generation capacity, however, South Africans will need to plan the electricity grid without the convenience of load centres overlapping resource centres.

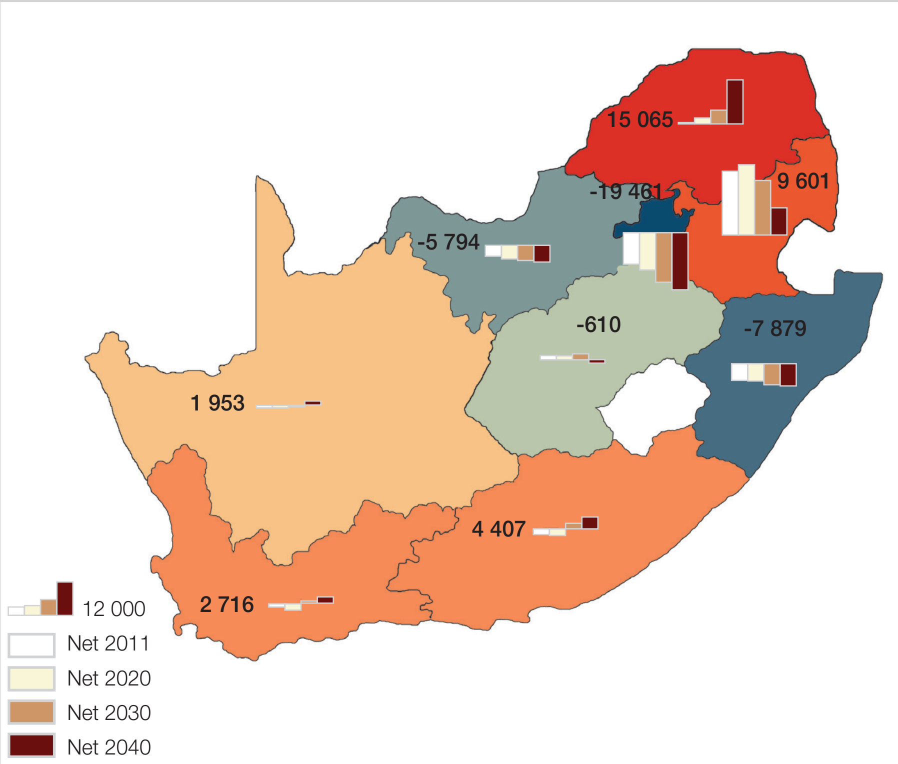
MOST ELECTRICITY COMES FROM COAL-FIRED POWER PLANTS BUILT NEAR COAL MINES IN MPUMALANGA

Following the release of the 2010 IRP, grid planners at Eskom released the Transmission Development Plan (TDP) 2011.[30] This 10-year plan is updated every year and the 2011 TDP included changes in the transmission grid needed to accommodate the plans of the IRP 2010. The 2013 update to the IRP has an annex titled 'Review of transmission impact of IRP update scenarios'. This includes much of the research done for the TDP. Due to the changing location of generating capacity, important changes to the transmission grid are now required. The 2013 update to the IRP identified five main 'transmission power corridors' that need to be developed.

Figure 5 is a map showing the changing balance between demand and generating capacity, as forecast in the Base Case scenario of the 2013 update to the IRP. Negative numbers represent a net electricity deficit; positive numbers represent a net electricity surplus. Currently, Mpumalanga is the largest net supplier and Gauteng is the largest net consumer of electricity. By 2040, Limpopo will be the largest net supplier owing to the planned expansion of coal-fired power plants there. The electricity deficit in Gauteng will increase by 2040.

Increases in gas and renewable capacity mean that all the Cape provinces will become net producers of electricity by 2040. This scenario does not include any increases in nuclear capacity, or large increases in gas imports, which would in all likelihood further drive production in the Cape. As the 2013 IRP explains, new transmission infrastructure will be required to evacuate excess power out of the Cape.

Figure 5: Changing balance of electricity demand and capacity (to 2040)



Notes: The map shows demand balance by 2040 for the Base Case scenario of the 2013 update to the IRP (allocated generation less maximum demand in MW). Although much new generating capacity is installed in the Northern Cape, demand is not expected to significantly increase there.

Source: Integrated Resource Plan for Electricity (IRP): 2010–2030. Update report 2013.

As electricity-generating capacity becomes more decentralised, grid planning must be incorporated into long-term energy plans from the beginning. Because of long lead times and the need for environmental impact assessments for each area of land the transmission line passes through, capacity may be planned for areas where transmission lines have yet to be built. Not only do new corridors need to be built, but energy planning also needs to be more flexible and better coordinated with grid planning to accommodate decentralised generation.

2040

LIMPOPO BECOMES THE LARGEST NET ENERGY SUPPLIER DUE TO PLANNED EXPANSION OF COAL-FIRED POWER PLANTS

Operations

Integrating decentralised and intermittent energy is not just an energy-planning problem – grid operations are changing as well. To ensure a safe and reliable supply of electricity, the frequency of the grid must be kept at exactly 50 hertz at all times. The job of the SO, an Eskom entity, is to balance electricity supply and demand in real time to maintain this frequency. To give an idea of the sensitivity of this balance, a one degree drop in temperature in Gauteng requires an additional 400 MW of supply.[31]

An inability to maintain this balance would result in a grid collapse, or a national blackout. Since South Africa does not have any neighbours with enough power to restart the system, it could take more than a week to fully restore power.[32] Load shedding is the SO's last resort to balance the system by manually decreasing demand.[33]

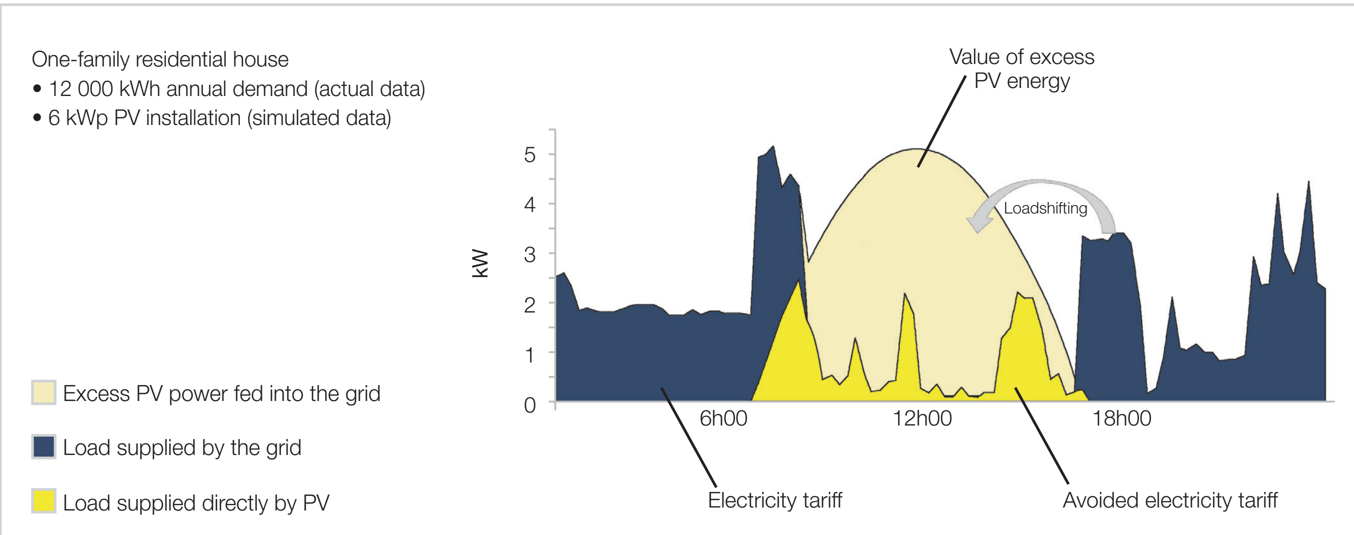
As wind and solar continue to increase their share of the energy mix, the difficulty in maintaining this balance will increase. The SO must be able to anticipate and react to changes in supply from intermittent power sources in real time. This requires greater flexibility in terms of power generation – power stations that are cheaper to ramp up or down will be more valuable. The growing complexity of supply will also require more flexibility on the part of the SO itself – new operational strategies, such as long-term wind forecasts, may be useful to ensure a safe and reliable supply of electricity.

Policies

Besides the technical advancements required to unlock SSEG potential, policies and regulations must be put in place so that municipalities are able to reap the benefits and redistribute the rewards effectively. If municipalities are not able to effectively regulate embedded generation, much of the potential benefits of this capacity will go to waste.

Figure 6 shows a typical demand profile for a residential household in winter. The electricity-generation profile of a 6 kW solar panel is simulated and overlaid in yellow. A typical residential household does not consume much electricity during the hours when solar power is most productive. An FIT is a policy mechanism where 'prosumers' are compensated for their excess and unused electricity (indicated in Figure 6).

Figure 6: Typical daily load profile for a residential household in winter



Source: Dr Tobias Bischof-Niemz, CSIR analysis, **How to stimulate the South African rooftop PV market without putting municipalities' financial stability at risk: A net feed-in tariff proposal,** June 2015.

Instead of harnessing the clean energy that the private sector is willing to install, without clear policies, only those who can afford it themselves may benefit. As energy analyst Dirk de Vos wrote in the *Daily Maverick*, 'Electricity could well go the way of health and education, where the top end of the market privatises and secures its own quality supply while the bottom end has to make do with what the state can provide.'[34]

> Instead of harnessing the clean energy that the private sector is willing to install, without clear policies, only those who can afford it themselves may benefit

However, electricity is different from health and education. Few private citizens truly defect, or go 'off-grid'. Most people who install their own PV systems become 'prosumers' – a combination of consumers and producers. Through clear and coherent policies, prosumers can be compensated for their excess energy when they are producers.

Scenarios

What follows in this section is a description of each of the three scenarios, as constructed in IFs; the implications of each scenario are also discussed. All scenarios in this paper use the Mandela Magic Lite scenario from "South African Futures 2035" as a foundation.[35] While this is not necessarily the most likely future for South Africa, as explained above, it is better to err on the side of economic optimism in energy planning. The scenarios in this paper also build on previous work done by the African Futures Project for the Western Cape provincial government, primarily the paper titled, "Green Cape 2040: Towards a Smarter Grid."[36]

The Current Path envisages a future situation that has no substantial changes in long-term energy planning or investments in the electricity grid. Efficient Grid is one where investments are made to upgrade the efficiency of the electricity grid substantially over the next 35 years, but the investments and improvements come on an ad hoc basis. Smarter Grid is a scenario where investments are made not just in the efficiency of the grid, but also in the 'smartness' of electricity planning, operations and policies. In Smarter Grid, the government and all electricity-sector actors anticipate and adapt to changes to the grid rather than reacting to changes. A smarter grid allows renewable energy to be integrated into the energy mix more effectively.

Due to the great uncertainty and long lead times associated with oil and gas production, increases in oil or gas production in South Africa are not included in any of these scenarios.[37]

Coal has been the main source of electricity and energy in South Africa for decades. It is likely to remain the main source of electricity in the future, even as power plants are decommissioned and a carbon tax is possibly introduced. The Current Path scenario has coal production peaking in the early 2030s as renewable energy begins to take off. South Africa has vast coal resources and reserves that will never be fully exploited owing to the economic viability of renewable energy.

The IRP includes plans to build a fleet of six nuclear power stations by 2029, together expected to contribute 9 600 MW to South Africa's generating capacity. This nuclear expansion has been taken into account in the three scenarios.

Current Path scenario

The resource profile in the Current Path roughly follows the 2010 IRP until 2030, and then the energy module and electricity sub-module of IFs complete the forecast to 2050.[38]

In the Current Path, energy planning continues along the same lines of the 2010 IRP and the 2013 update, without the integration of grid planning. Renewable energy is included in energy planning but the impact of the decentralised and intermittent nature of wind and solar on the grid occurs after the fact. Likewise, IPPs are implicitly included in the next IRP but the location of these private producers is not. This means grid planners struggle to connect IPPs to the grid, as it often takes less time to build capacity than to construct transmission cables. (As mentioned, constructing transmission cables requires long lead times to carry out environmental impact assessments.) Embedded generation continues to be implicitly included in the IRP – the IRP does not determine where and what size of capacity should be installed.

> Coal has been the main source of electricity and energy in South Africa, and is likely to remain the main source in future

The system operator struggles to keep up with the increasing complexity of uncertain and unreliable generation from an increasing number of IPPs in an increasing diversity of locations. Large-scale installed capacity makes it expensive to ramp production up and down to accommodate wind and solar.

Grid defection occurs at increasing rates as citizens become frustrated by load shedding and rising electricity prices. While grid defection lowers demand from the central producer, municipalities lose significant amounts of revenue.

In the Current Path, there is no significant overhaul of the grid, making it difficult to incorporate renewable energy into the mix. IPPs are not integrated to the degree that the government desires and embedded generation benefits only those who can afford to install it themselves. Those who can install their own generation are not compensated for the energy they supply to the grid however. Municipalities continue to lose revenue as residential PV uptake increases and it becomes increasingly difficult to provide electricity to those in need.

Efficient Grid scenario

Under the Efficient Grid scenario, large investments are made in electricity infrastructure in South Africa, leading to more efficient transmission and distribution of electricity. Energy efficiency can be a path to a less costly and a more environmentally-friendly energy sector. Increases in efficiency, however, do not always have direct impacts on demand reduction, lower capacity requirements or lower greenhouse-gas emissions.

To explore the effects of increasing the efficiency of the electricity sector, Efficient Grid is a scenario where transmission and distribution loss is reduced by 50% by 2050.[39] Reduction in loss means that less investment is required in electricity-generating capacity. Generating capacity increases from current levels of about 45 GW to over 139 GW by 2050 in the Current Path. In Efficient Grid this is reduced to 134.6 GW – a 3.2% reduction.

> The price of electricity may still increase in Efficient Grid, but not by as much as in a scenario where more electricity is lost through inefficient transmission and distribution

The relationship between efficiency gains and reduced capacity requirements is not linear – reducing transmission loss by 1 kWh does not translate to a 1 kWh reduction in required generation. Improvements in efficiency in transmission and distribution lead to increased electricity consumption: since electricity demand exceeds available supply in South Africa, then as more electricity becomes available, more electricity is consumed.

Furthermore, as electricity is delivered more efficiently, the cost of electricity decreases relative to the Current Path, which drives up demand. All else being equal, an increase in transmission and distribution efficiency should lead to lower electricity prices relative to the Current Path. The price of electricity may still increase in Efficient Grid, but not by as much as in a scenario where more electricity is lost through inefficient transmission and distribution. A lower electricity price will increase electricity consumption.

In the South African context, this rebound effect could happen in one of two pathways. The price of electricity that Eskom sells is determined by Nersa, through its multi-year price determination. According to the Electricity Regulation Act 2006 (Act 4 of 2006), Eskom is entitled 'to recover the full cost of its licensed activities, including a reasonable margin of return'.[40] As the cost of electricity transmission decreases, the price of electricity that Eskom sells will decrease, as determined by Nersa.

ENERGY EFFICIENCY CAN BE A PATH TO A LESS COSTLY AND A MORE ENVIRONMENTALLY FRIENDLY ENERGY SECTOR

The second way in which this rebound effect could occur in South Africa is in the municipalities. If the distribution of electricity within municipalities is more efficient, the cost of distribution will decrease. Should this cost reduction be translated into price reductions for private citizens, electricity demand will increase relative to the Current Path.

In Efficient Grid, electricity consumption increases by 0.8% by 2050. Therefore, Efficient Grid sees an overall reduction in required generating capacity while consumption increases slightly relative to the Current Path.

> Coal-fired power plants require large amounts of water for cooling, and increasing electricity demand will drive industrial water demand in South Africa

Although required generation capacity decreases over the time horizon, overall primary coal production increases. A more efficient electricity sector does not necessarily mean less coal is produced. Although less energy is required by the electricity sector, more energy is exported or used in other sectors, largely owing to the cheaper price of electricity. This leads to an overall increase in carbon emissions over this time horizon, relative to the Current Path.

Higher electricity demand increases economic growth slightly. The 0.8% increase in electricity consumption translates into a 1% increase in GDP by 2050. This slight increase means that 44 000 fewer South Africans will be living in extreme poverty by 2050.

One of the largest drivers of industrial water demand is thermo-electric power generation. In South Africa, coal-fired power plants require large amounts of water for cooling. Increasing electricity demand will drive industrial water demand in South Africa. In Efficient Grid, the reduction in required generating capacity reduces industrial water demand compared with the Current Path by a cumulative 2.2 cubic kilometres by 2035 (see Figure 7).[41]

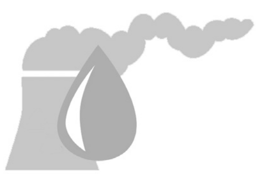
Although improvements in the efficiency of the grid lead to a reduction in required capacity, and therefore reduced industrial water demand, the rebound effects of increased energy demand offset the emissions benefits.

Smarter Grid scenario

A smarter grid is not simply a more efficient grid. As the nature of generation is changing – from centralised industrial distribution to decentralised and intermittent production – grid planning, operations and policies must become smarter to incorporate these new sources.

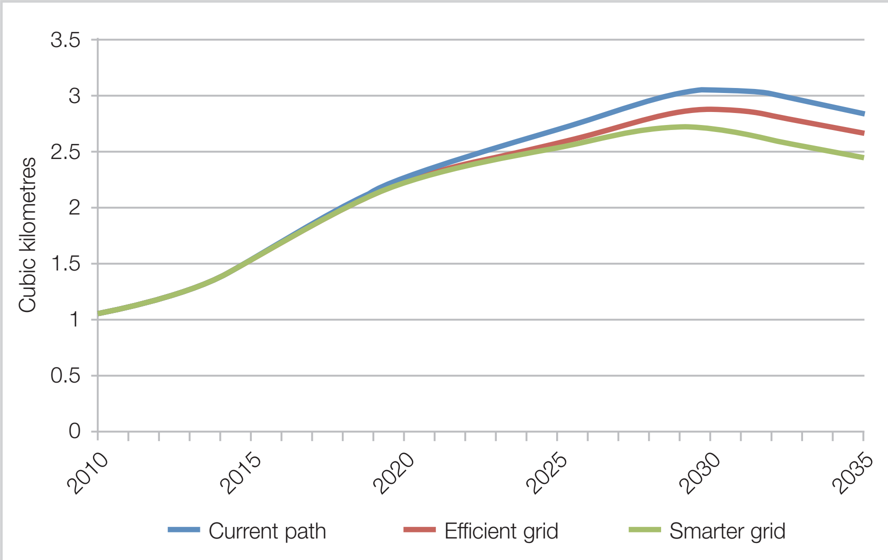
Smarter Grid scenario is a future where energy planning includes assumptions regarding the changing nature of capacity, systems operators are equipped with flexible physical capacity and adapt to the changing complexity of intermittent electricity using innovative operational strategies, and clear policies are put in place to unlock the potential of embedded generation.

Incorporating grid planning into energy planning allows IPPs to be integrated more rapidly. There are no delays between capacity construction and transmission construction, as the IRP and the TDP are coordinated. Likewise, incorporating



ONE OF THE LARGEST DRIVERS OF INDUSTRIAL WATER DEMAND IS THERMO-ELECTRIC POWER GENERATION

Figure 7: Industrial water use in the Current Path and Efficient Grid scenarios



Source: IFs version 7.15

embedded generation into energy planning provides municipalities and grid operators with a framework on how to approach potential revenue losses.

Generating capacity is more flexible, meaning it can be ramped up and down depending on the contribution from intermittent wind and solar production. New operational strategies, such as wind forecasts, are promoted to help the SO accommodate intermittent production.

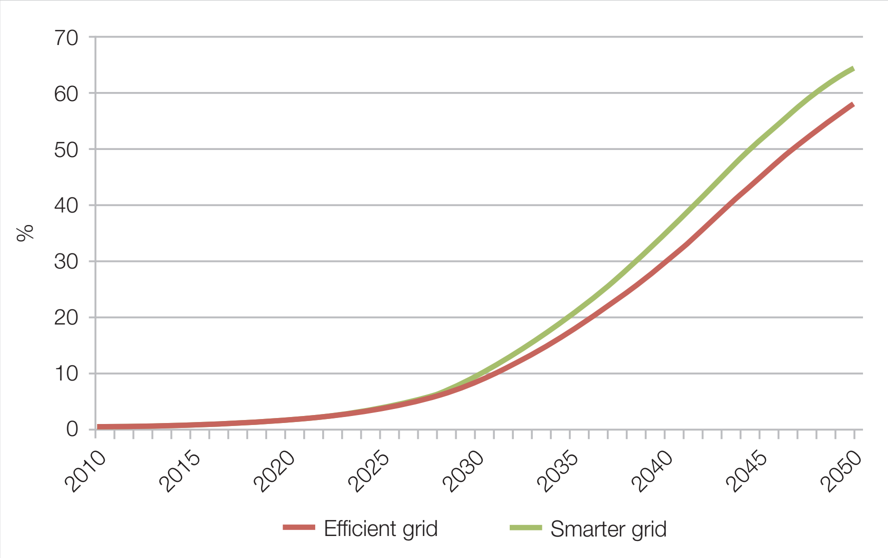
Policies and regulations regarding embedded generation are put in place to encourage private renewable energy production. This allows private citizens who can afford to install their own capacity to sell excess electricity back into the grid and municipalities do not become financially unstable. Unlocking the potential of embedded generation helps, rather than hinders, the municipality to provide a secure supply of electricity to all citizens.

IN THE SMARTER GRID SCENARIO, ELECTRICITY GENERATING CAPACITY IS MORE FLEXIBLE

This scenario, as modelled in IFs, is identical to the Efficient Grid scenario, except that, in addition to increases in efficiency, advances are made in the cost and output of renewable energy. The capital-output ratio for renewable energy (excluding hydro) is lower, representing improvements in planning, operations and policies. A reduction in the capital-output ratio represents the decreased cost of renewable energy capital as well as increased output. Incorporating grid planning with energy planning, and introducing clear policies regarding embedded generation lower the lifetime cost of renewable energy for both IPPs and private citizens. Successful administration of policies regarding embedded generation translate into an increase in compensated output per unit of capacity.[42] In this scenario, the capital-output ratio for renewable energy (excluding hydro) is reduced by 25% by 2050 compared with the Current Path.

Due to more efficient transmission and distribution of electricity, less capacity is required in Smarter Grid than in the Current Path. The increase in renewable energy production, however, means more total capacity is installed in Smarter Grid than in

Figure 8: Renewable energy production (excluding hydro) as a percent of total energy production



Source: IFs version 7.15 (pardee.du.edu)

Efficient Grid. As in Efficient Grid, more electricity is consumed in the Smarter Grid scenario compared with the Current Path – electricity consumption increases by nearly 2% by 2050 compared to the Current Path.

Unlike Efficient Grid, however, coal production decreases. Although total energy demand increases, renewable energy pushes down coal production, resulting in an overall decrease in carbon emissions relative to the Current Path. Reduction in the use of coal-fired power plants also reduces industrial water demand by 14% less than in the Current Path by 2035 and 8% less than in Efficient Grid (see Figure 7).

In Smarter Grid, renewable energy increases by 24% by 2050 compared to the Current Path, making up 64% of total energy production (see Figure 8).

This increase in renewable energy has environmental and economic benefits. Carbon emissions fall by 11% by 2050 in the Smarter Grid scenario, or a cumulative 3% reduction. As mentioned, fewer fossil-fuel-fired power stations compared to the Current Path means a considerable reduction in industrial water demand (see Figure 7). GDP grows by 2.3% by 2050 and GDP per capita (at purchasing power parity) increases by 2.3% by 2050. Although this figure may not seem substantial, in real terms the increase in income brings nearly 100 000 more people out of extreme poverty by 2050 than in the Current Path.

Implementing a smarter grid

Many of the problems associated with the current electricity crisis stem from the transition from a monopolistic electricity structure towards a more market-based model. Under a monopoly, coordination among actors is much easier and control over the system is complete. As different responsibilities are doled out to different actors, planning and coordination become more difficult. The management of a changing electricity sector would be difficult even with monopolistic power but as responsibilities are diffused, the complexity of coordination increases.

24%

INCREASE OF RENEWABLE ENERGY BY 2050 IN SMARTER GRID COMPARED TO CURRENT PATH

Before 1999, Eskom was responsible for all generation (except for a few IPPs), all transmission and all distribution (except for within large municipalities). Eskom created the energy and grid plans, and operated the transmission and distribution systems. As a public entity, it fell under the jurisdiction of the Department of Public Enterprises. The Department of Minerals and Energy was responsible for energy planning, allocation and procurement (in consultation with Nersa) for the country, though Eskom could control its own assets and planning.

After the NewGen regulations were put in place in 2009, the roles of the different actors in the electricity sector became more ambiguous.[43] Energy planning and the IRP, as discussed, are now the responsibility of the DoE. The Minister of Energy is responsible for awarding IPPs, in consultation with the Minister of Finance. As Eskom operates the transmission grid, however, it also acts as the buyer of all electricity from all producers. As Eskom owns much of the generating capacity, there is potential for conflicts of interest.

Because of this potential conflict of interest, there are now discussions over the role of the system operator and the ownership of the transmission grid. In his 2010 State of the Nation Address, President Jacob Zuma announced the establishment of an independent system and market operator, separate from Eskom. However, the proposed bill[44] was voted down in 2015.[45] This bill would have removed the SO, which procures supply to balance demand, from Eskom control.

Although there is the potential for a conflict of interest as long as the SO and the associated authorities remain in Eskom control, restructuring the electricity sector must be part of a long-term, coherent plan. If the government should decide to continue to move towards a market-based model with more private-sector participation, then an independent system and market operator, or at least an independent market operator, will be necessary to avoid conflicts of interest. Should the DoE instead decide to revert to an Eskom monopoly, then IPPs should be discontinued.[46] Either way, the direction of the electricity sector must be communicated through long-term planning, so that roles and responsibilities can be clear and actors can be held responsible.

> Restructuring the electricity sector must be part of a long-term, coherent plan

SOUTH AFRICA HAS ALREADY TAKEN STEPS TO BUILD A GRID CAPABLE OF ACCOMMODATING RENEWABLE ENERGY

South Africa is not the only country undergoing this sort of electricity-sector transition. Electricity grids worldwide are in the process of getting smarter and many are moving from a state-owned utility to include market elements. Incorporating renewable energy from private producers into the energy mix is part of this process and many of the steps taken towards achieving a grid that is capable of accommodating this capacity are already being implemented in South Africa. As stated previously, the IPP programme has been successful in many ways and embedded generation is increasingly being viewed as an opportunity rather than an inconvenience.

The 'Greencape 2040' paper, cited above, found that without standardised regulations and policies in place, and data-informed decisions regarding the grid, a feed-in tariff (FIT) could lead to even more gross-margin losses than in the Current Path. This is because the implementation of an FIT could incentivise further PV uptake. In February 2015, Nersa released a consultation paper asking for stakeholders to comment on the regulations governing SSEG.[47] Clarity on these regulations are necessary to unlock the potential of SSEG, distribute its benefits and ensure that residential PV uptake does not leave municipalities financially unstable.

In addition, there have been studies conducted by the CSIR on the costs, benefits and implications of various grid interventions, including the implementation of an FIT.[48] The CSIR has found that medium- and small-scale embedded generation can significantly contribute to the energy mix through the implementation of an FIT. The mechanism through which the FIT is administered in the CSIR research is that of a Central Power Purchasing Agency. This is an entity responsible for both compensating distributors (municipalities or Eskom distribution) for gross-margin losses, and for purchasing excess electricity from embedded generation. The research found that through this mechanism, between 2.0 and 2.5 GW of *additional* low-cost renewable energy could be implemented within the next few years.

Conclusion and recommendations

Due to the increasing prevalence of renewable energy, IPPs and SSEG, electricity production is becoming more decentralised and intermittent. Since embedded generation occurs behind meters, this adds another level of complexity for managing electricity sales. These trends are adding to the complexity of planning and operating the electricity sector. Each actor in the electricity sector will be affected in different ways. How they respond will determine the level of renewable-energy uptake in South Africa and the equitable distribution of its benefits.

Long-term energy planning is vital to the prosperity of South Africa. Aligning the IRP with the NDP and with long-term planning in other sectors is necessary to create cohesive and realistic scenarios for the future. Because energy is so closely tied to the water sector, the IRP and the National Water Resource Strategy should complement one another and contain integrated solutions. Likewise, grid planning can no longer take a back seat to energy planning – the strength of the grid is essential for South African growth. All stakeholders must be involved in the planning process, so that grid planners, the system operator, grid operators and municipalities do not have to respond on an ad hoc basis. Furthermore, the IRP must take into account the increase in SSEG 'behind meters'. The nature of capacity is fundamentally changing and the IRP model assumptions must reflect that.

The government must also stick to deadlines set for releases in energy plans and then adhere to the results of those plans. Important energy decisions with serious implications are being delayed in anticipation of energy plans that are consistently released months after their expected delivery. According to the 2010 IRP, 'At the very least, it is expected that the IRP should be revised by the Department of Energy (DoE) every two years, resulting in a revision in 2012.'[49] Three years later, the 2013 IRP update stated that the next IRP should be released only after the next Integrated Energy Plan is released. The latest Integrated Energy Plan was expected to be submitted to the Cabinet in the last quarter of 2014, but the status of the Integrated Energy Plan, and therefore of the IRP, still remains unknown to the general public.

> Electricity grids worldwide are getting smarter and many are moving from a state-owned utility to include market elements

Although the 2010 IRP remains the official government plan for new generating capacity, the 2013 update was intended to provide additional insight into 'critical changes for consideration on key decisions'.[50] One of the key factors about which the 2013 IRP provided critical insight was nuclear capacity. The 2013 IRP update provided a decision point regarding nuclear build based on 2014 electricity demand. As electricity demand was lower than 265 TWh in 2014, according to the 2013 IRP, nuclear procurement should not proceed.[51] The government continues to pursue nuclear power and continues to reference the 2010 IRP rather than the update.[52] The government must adhere to the results and recommendations of energy plans, otherwise they are of no use.

Maintaining a safe and reliable supply of electricity across the grid will become more complicated as renewable energy increases its share of the energy mix. The SO will be able to adapt better to the intermittency of wind and solar power with more flexibility in generating capacity. Capacity that can more easily be ramped up and down, depending on wind and solar levels, will become increasingly valuable. System and grid operations will become more difficult and operators will also require more advanced strategies to deal with these changes. Whether the SO remains an Eskom entity or becomes independent, the SO and the generating capacity will nevertheless need to be more flexible to integrate renewable energy.

The uptake in embedded generation could be to the significant detriment of municipal revenues. Ignoring the changing nature of capacity could lead to a future where wealthy citizens turn to private electricity alternatives while the rest are left with what the state can provide. Regulations and policies must be put in place to unlock the potential of embedded generation.

Investments in the efficiency of the grid could lead to a reduction in required generating capacity, as illustrated in the Efficient Grid scenario, but could also bring down the cost of electricity, leading to more overall energy production and higher carbon emissions. By moving not only towards a more efficient grid but also a smarter grid, renewable energy can be integrated into the energy mix and contribute to the benefit of all.

Implementing the Smarter Grid scenario is not necessarily about increasing the efficiency of the grid or its technological sophistication. It is about improving the planning process, the flexibility in operations and the policies regarding embedded generation. These interventions will be successful only with a clear plan regarding the future structure of the electricity sector. The government must make roles and responsibilities clear, and outline a strategic path for the future of the utility. Whether or not it chooses to continue to transition towards a more market-based electricity model, roles and responsibilities need to be made transparent so that actors can be held accountable.

Notes

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5 Explained in more detail below.

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7 Department of Minerals and Energy, White Paper on the Energy Policy of South Africa, December 1998, http://www.energy.gov.za/files/policies/whitepaper_energypolicy_1998.pdf, 53.

8 Gaylor Montmasson-Clair and Georgina Ryan, Repositioning electricity planning at the core: An evaluation of South Africa's Integrated Resource Plan, Trade & Industrial Policy Strategies, November 2014, 15.

9 For a full, detailed evaluation of the IRP, see Gaylor Montmasson-Clair and Georgina Ryan, Repositioning electricity planning at the core: An evaluation of South Africa's Integrated Resource Plan, Trade & Industrial Policy Strategies, November 2014.

10 For more information on IFs, visit the Pardee Center website, pardee.du.edu, and see the help site at du.edu/ifs/help.

11 These are only the direct drivers. There are obviously many distal drivers used to estimate and forecast the size and energy intensity of economies.

12 For a full description of the CSIR demand model, see Forecasts for electricity demand in South Africa (2010–2035) using the CSIR sectoral regression model, June 2010, http://www.doe-irp.co.za/IRPPrm/CSIR_model_IRP%20forecasts%202010_final_v2.pdf. For a full description of the System Operator demand forecast, see *IRP 2010 energy forecast revision 2 Report. Report prepared for IRP 2010 revision 2*. Systems Operations and Planning, July 2010, www.energy.gov.za/IRP/irp%20files/SO_IRP%202010%20Energy%20Forecast%20Final%20Report.pdf.

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About the African Futures Project

The African Futures Project is a collaboration between the Institute for Security Studies (ISS) and the Frederick S. Pardee Center for International Futures at the Josef Korbel School of International Studies, University of Denver. The African Futures Project uses the International Futures (IFs) model to produce forward-looking, policy-relevant analysis based on exploration of possible trajectories for human development, economic growth and socio-political change in Africa under varying policy environments over the next four decades.

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