WHY WE ARE HEADING FOR A FURTHER POWER CRISIS

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ABSTRACT

The Update to the Integrated Resource Plan 2010 [IRP2010 Update] has generally been well-received. In the light of evidence that the basis for the original IRP was too rigid, the Update is far more flexible in its approach. It has examined a wider range of scenarios. It has abandoned multi-criterion decision analysis, which had been the subject of much criticism on grounds of subjectivity, in favour of developing "a proposed path of least regret, incorporating the benefits of flexibility, and identify(ing) decision trees that consider the key determinants in decisions required and the proposed solutions under different outcomes of these determinants." However, it appears to suffer from a fatal flaw, namely that by focusing on capacity and the ability to meet the peak demand, it has overlooked the need to provide adequate energy to meet the day-to-day demands. The data provided in the Update are re-interpreted in terms of annual energy produced, and it is shown that each of the four primary scenarios which were considered leads in a drastic drop in the energy margin after 2020. Under some perfectly credible assumptions, the energy margin becomes negative in the mid-2020's. Because this is within the short-term planning horizon for the provision of power, it strongly suggests that decisions must be taken immediately to introduce at least another 500MW of generating capacity every year from 2018 to 2027. Failure to address this urgently means that our electricity supply will revert to a critical state in under ten years.

1.INTRODUCTION

In November 2013, the Department of Energy published a draft update of the Integrated Resource Plan 2010 [IRP2010] for public comment [1]. At the time of writing, Cabinet was due to consider the update in the light of the comments received.

The Update represents a considerable improvement in approach over the original IRP. First, it is much more flexible in its approach. Experience has convinced the planners that too much rigidity makes for plans that are too rapidly shown to be sub-optimal. Instead, it has developed a wider range of scenarios, and set up decision trees so that decision makers can easily see where the hard decisions that they have to make will lead them. The approach used originally was to employ a tool known as "multi-criterion decision analysis", which turned out to be a fancy name for guessing a set of weighting functions and using those guesses to inform decisions. It was a very subjective process, and almost certainly led to some less-than-reliable recommendations.

It also re-examined the likely demand, and reduced the projections quite drastically. Of course, in recent years demand has stalled. It is a moot point as to whether the drop in demand is caused by supply-side constraints or fundamental shifts in the nature of the economy. The Update seems to believe that much can be ascribed to changes in the economy. However, it could be argued that it was long predicted that demand would exceed supply by 2007, and that all that has happened since 2007 is that supply has inched up to relieve some new demand, and that fundamentally we face a constrained supply. Certainly processes such as Eskom paying large customers for power they volunteered not to use smacks strongly of limited supply.

Thus in this paper we return to the question of the future demand, based upon two models of growth of which South Africa appears to have followed one, and not the other; and check the adequacy of the proposed supply by converting the capacity changes used in the Update scenarios into energy supply. The reason for doing this is the gradual introduction of renewable energy sources into the supply. They have significantly lower generating capacity over a year than their installed capacity would suggest, unlike the fossil fuel or nuclear sources. Recent literature [2] has shown that it is essential to increase the spinning reserve to permit load following under conditions of fluctuating supply. The output of wind and PV systems can vary by as much as 50% within five minutes. Predictive tools are improving, which permit steps to be taken to mitigate the impact of such surges, but the only known means of ensuring system reliability is to increase the spinning reserve.

2. FUTURE DEMAND

The predictions of future consumption are given in Figure 1. They were based on an assessment of future economic growth, population growth and the energy intensity of the economy, and four primary scenarios were considered, as shown in Figure 1, with the original IRP prediction from the CSIR (other predictions from the original IRP were significantly higher)

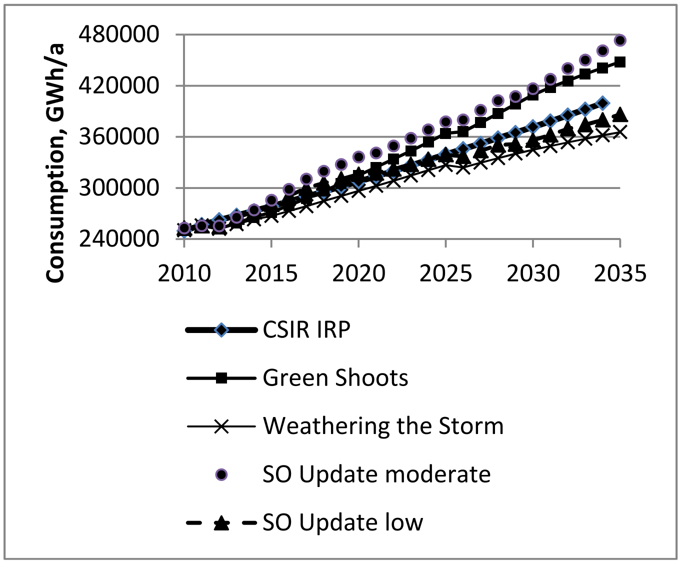

Figure 1. Predictions of consumption until 2035, from IRP2010 Update

No reasons are given for the shift in predicted consumption in 2025-6 in most scenarios. This appears to be an artefact. The actual consumption for the years 2010-2013 lies below all the predictions, reflecting a consensus that the lack of consumption is probably supply-constrained. The various scenarios were extended out to 2050, which is not shown in Figure 1 in the interests of clarity. The Green Shoots and SO Update moderate scenarios grow exponentially upwards over the period 2035-2050, while the growth in the SO Update low slows over this period. The result is a spread between 41 and 62TWh in the predicted consumption in 2050.

There is merit in considering whether other energy economies show growth patterns that could guide the selection of a consumption prediction for South Africa. The World Bank Development Indicators [3] give data on electricity generation over the past 40 years for most nations. Figure 2 shows a selection that includes South Africa.

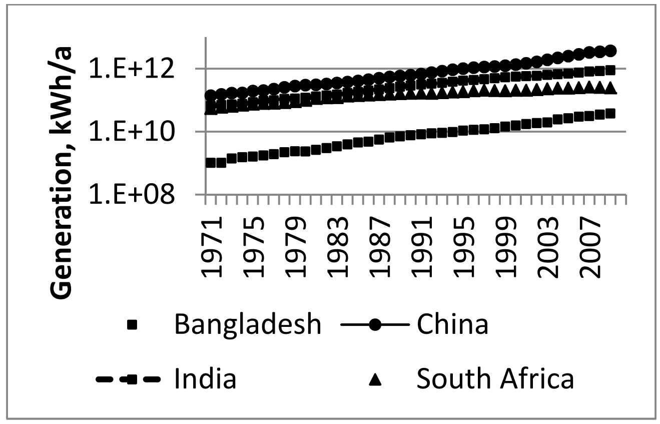

Figure 2 Growth in power generation, China, India, South Africa and Bangladesh (World Bank[3])

Note that the abscissa is logarithmic. The growth in generation is log-linear in China, India and Bangladesh, but in South Africa it starts by following India closely then deviates. In 1971, India generated 20% more power than South Africa; today it generates over four times more. The growth in power follows a similar log-linear pattern in many developing nations; South Africa is almost the odd man out.

However, it has company. Figure 3 shows how some countries follow a strictly linear growth in generation. Notice that the abscissa is is linear in this case. Growth has been almost identical in Australia and South Africa. It has been linear but the rate of growth lower in Belgium and Columbia.

It is not obvious why there should be such differences. It is reasonably certain that the exponential growth shown by Bangladesh, China and India in Figure 2 cannot continue for ever, even after persisting for 40 years. The linear pattern shown by Australia, Belgium, Columbia and South Africa seems more likely to be sustainable.

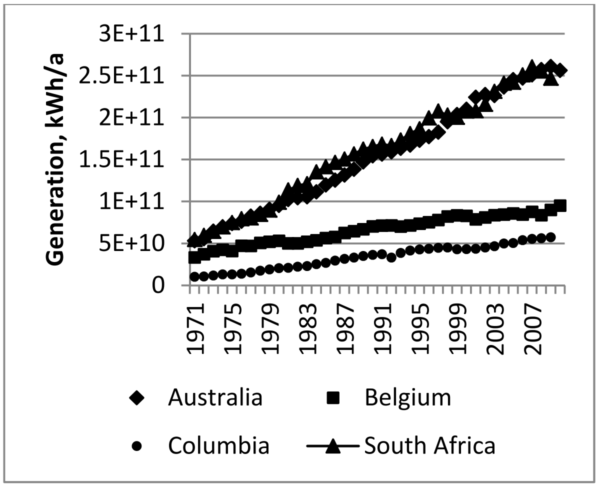

Figure 3. Growth in power generation in Australia, Belgium, Columbia and South Africa (World Bank [3])

If this is accepted, then it provides another basis for predicting future growth. On a linear basis, in 2035 the expected demand would be 4.05±0.09 E+11 kWh/a. The average of the four Update scenarios is 4.18 E+11 kWh/a, so a linear growth model based on past growth seems quite plausible.

This is an important conclusion, because it simplifies planning. South Africa needs to generate an extra 5.5GWh each passing year. There may, in the short term, be a need to add somewhat more than that to make up for recent shortfalls, but long-term, that is what we need.

The advantage of planning in this way is that there can be few surprises. If some surplus capacity arises, then new capacity can be cut back slightly. Equally, if there is a slight shortfall, than new capacity can be increased. Budgeting is simplified. The flexibility desired by the Update is inherently present.

With these thoughts in mind, it is now timeous to consider how well the proposed capacity increases given in the IRP2010 Update meet the predicted demand.

4. SUPPLY PLANS

A range of technology options was considered for each of the four scenarios in the Update. Some feeling for the range may be obtained from the data of Table 1 (Table 2 in the Update)

Table 1 Range of technology options considered in Update, and the installed capacity for 2030

Technology	IRP2010, MW	Green Shoots, MW
Existing Coal	34746	36230
New Coal	6250	2450
CCGT	2370	3550
OCGT/Gas Engines	7330	7680
Hydro Imports	4109	3000
Hydro Domestic	700	690
PS (incl Imports)	2912	2900
Nuclear	11400	6660
PV	8400	9770
CSP	1200	3300
Wind	9200	4360
Other	915	640
TOTAL	89532	81230[1]

The Update gives a total which for some reason is 120MW higher.

The reduction from 89.5 to 81.2GW is in line with the reduction in forecast demand from the original IRP2010. The Update suggests that this should meet the peak in the daily demand. Figure 4 shows the margins for the Green Shoots base case – the other scenario give similar results.

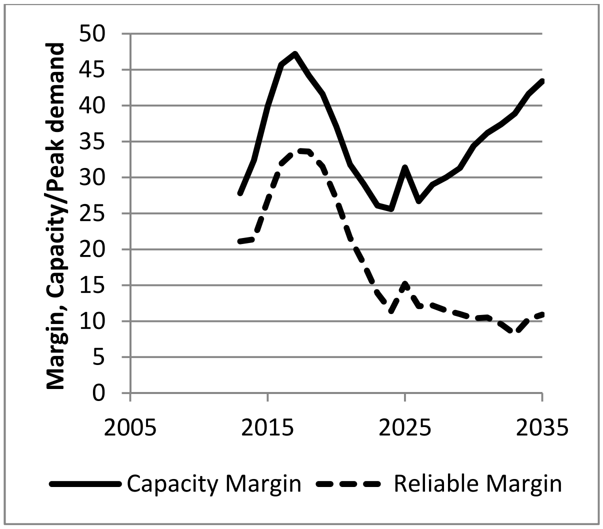

Figure 4. Margins for the Green Shoots scenario, IRP2010 Update

The Update has a small proportion of the total generating capacity in an undefined "Other" category.

Two margins are shown. The first, called here the "Capacity Margin", is the traditional definition of (Installed Capacity/Peak Demand) -1. However, during the 2010-2035 period, considerable renewable energy capacity will be installed, and that cannot be relied on to provide power when needed. Instead, therefore, the IRP2010 Update calculates what it terms "Reserve Margin (Reliable)", here called Reliable Margin. No definition is given, but it is believed that this is (Installed Reliable Capacity/Peak Demand)-1.

Note that the Reliable Margin drops rapidly until about 2024, and then drifts slowly downwards to below 10%. This seems unduly low. The margin is normally expected to exceed about 15%; there may be some hope that renewable energy will provide some supply during the peak hours, but this certainly cannot be guaranteed. Moreover, there is evidence that the reserve margin need to be **increased** as more and more renewable energy enters the supply, so that the normal 15% should be revised upwards.

This suggested that there needed to be an assessment of what might be called the Energy Margin, the ability of the generation system to provide the predicted amount of energy each year. Accordingly the technology choices made in each year for each scenario in the Update were converted from capacity into energy supply under the following assumptions:

1. The capacity factors, i.e. Annual kWh delivered/kWh deliverable at full power for 8766h/a, were 92% for nuclear; 85% for coal; 60% for local hydropower; 50% for combined-cycle gas-turbines (CCGT) and imported hydropower; 40% for concentrated solar power (CSP); 30% for wind and Other[2] sources of energy; 20% for photovoltaics (PV); and 5% for open-cycle gas-turbines (OCGT) and pumped storage (PS).
2. Base load was all nuclear and 70% of coal-fired energy; mid-merit was 30% coal, and 100% of CCGT and hydropower; peaking was 70% of CSP and 100% of OCGT and PS; and variable was 30% of CSP and all of wind and PV.

Figure 5 shows the makeup of the energy supply for the Green Shoots scenario, and Figure 6 compares the supply to the predicted demand, and gives the resultant energy margin, defined as (Supply/Demand)-1.

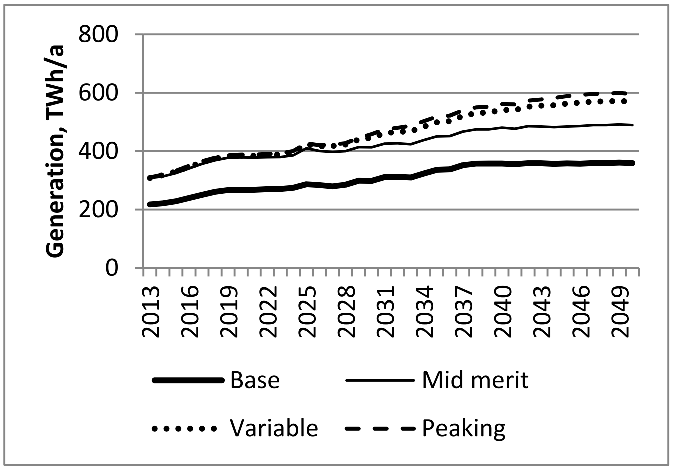

Figure 5. Makeup of the supply for the Green Shoots Scenario

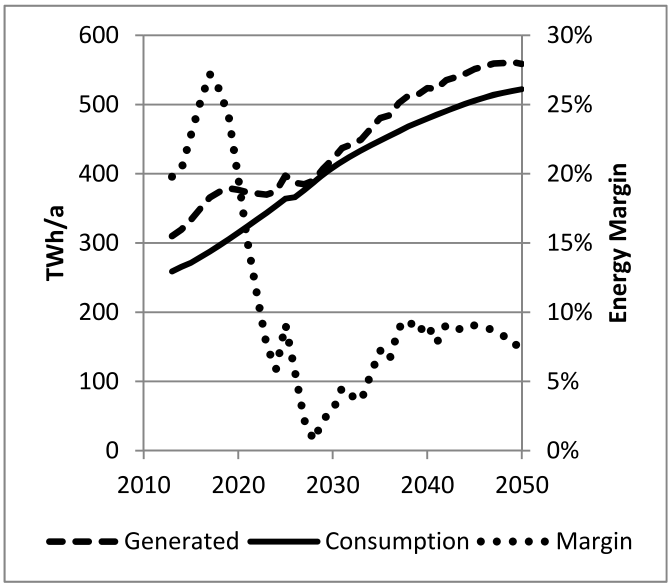

Figure 6. Comparison of energy generated and consumed for Green Shoots scenario, and the energy margin

The energy margin drops rapidly after 2015. The peak at 2025 is largely the result of the artefact in the demand prediction noted previously, so in fact the energy margin is probably below 5% 2025 until about 2033. It then recovers to around 8%, which may be too low.

Figure 7 shows the energy margin for the other three scenarios.

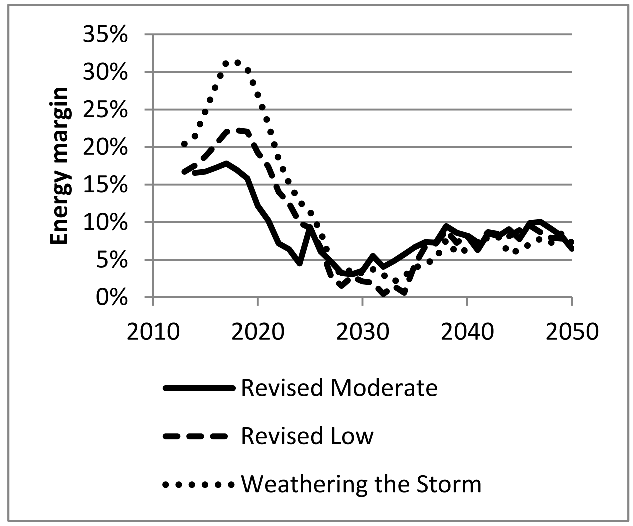

Figure 7. Energy margin for three scenarios

All show the same marked drop in energy margin after 2016; all show a low margin <5% in the period 2026-2033; and all have a margin of <10% from 2035-2050.

It should be recalled that the assumed capacity factors for coal and nuclear were 85% and 92% respectively. At present, Eskom's target is 80% for coal, and Koeberg has achieved closer to 85%. With this change in the basic assumptions, the three scenarios of Figure 7 change as shown in Figure 8. There are now definite shortages of energy in the period 2026-2033 and even after 2035 the margin of <5% appears insufficient.

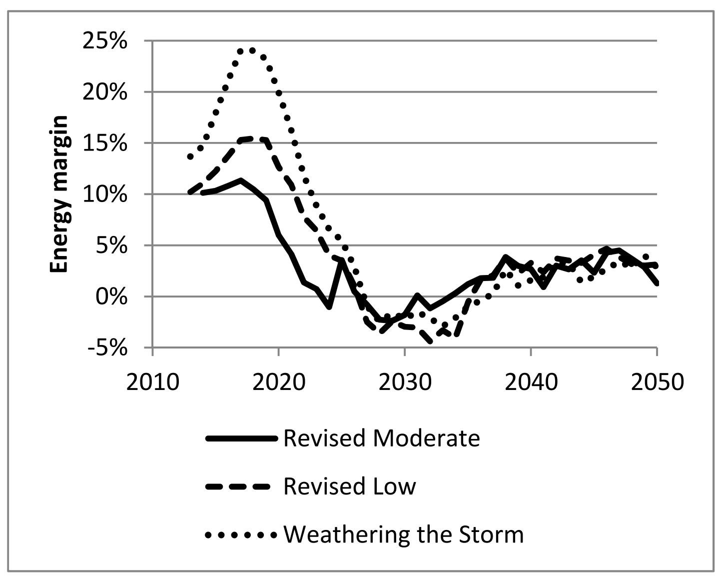

Figure 8. Energy margin for three scenarios with coal capacity 80% and nuclear 85%

To see what might be needed to avoid the risk of a shortage of power, the models were run with added power from 2018 to 2027. 500MW of new coal capacity was added each year – coal was chosen for convenience of calculation, but an equivalent capacity of any other form of primary energy could be chosen. The results for three scenarios are shown in Figure 9.

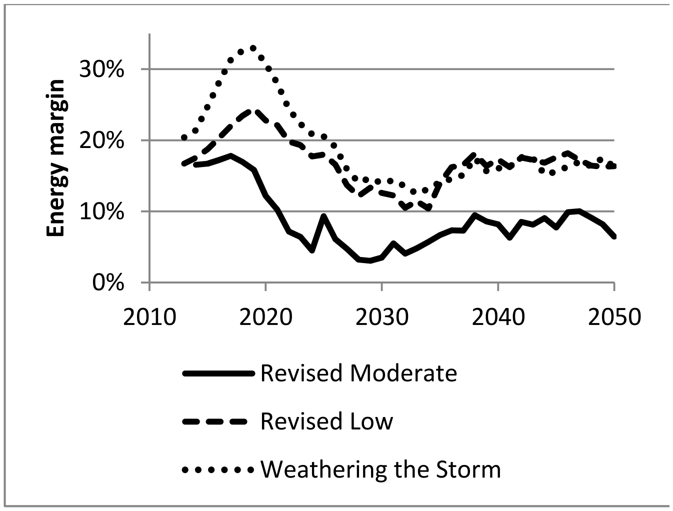

Figure 9. Energy margin for three scenarios with 500MW of new coal capacity added annually from 2018 to 2027

The "Revised Low" and "Weathering the Storm" scenarios both have a reasonable reserve of energy throughout the model period. The "Revised Moderate" scenario seems to require even more added power to ensure a secure system.

5. CONCLUSIONS

The proposals in the Update to IRP2010 are in many ways an advance on the original IRP2010, but the planners seems to have overlooked the need to meet the annual energy demand as well as meeting the peak demand. All the scenarios considered show a rapid drop in margin after 2018, and the energy margin falls to dangerously low levels between 2022 and 2025. This is true even with some relatively high availabilities for the base-load technologies. More conservative estimates of the availabilities shows that the system is at real risk of inadequate power supply.

The implication is that more capacity should be installed, and installed soon, if the risk of inadequacy is to be avoided ten years hence. The picture would look less gloomy if an additional 500MW of high-availability power were to be installed every year from 2018 to 2027. It is imperative that decisions be made in the very near future to create such additional capacity, without which our electricity future will remain precarious in spite of the new capacity already being created.

This analysis has of necessity been relatively unsophisticated. A deeper analysis by a modelling tool such as TIMES [4] would probably reveal additional features that this relatively crude approach has missed.

6.ACKNOWLEDGEMENTS

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7. REFERENCES

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7.AUTHOR

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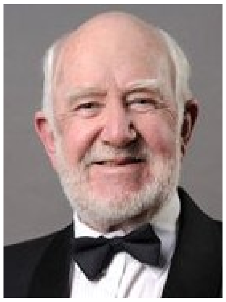

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