Comments on South Africa 2018 Integrated Resource Plan

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EXECUTIVE SUMMARY

In August 2018 the South Africa Department of Energy (the Department) published a draft 2018 Integrated Resource Plan (IRP). Synapse Energy Economics, Inc. (Synapse) reviewed the IRP, with a focus on the extent to which the draft complies with IRP best practices. We identified a number of flaws in the IRP, including:

- **An unreasonably high load forecast.** The IRP relies on an inappropriate load forecasting methodology that does not adequately consider important recent trends in electricity demand. The IRP thus repeats the mistakes made by the 2010 IRP, which over-forecasted 2016 electricity sales by nearly 18 percent. This could lead to South African consumers spending billions of dollars on unnecessary generating capacity.

- **Unreasonably high cost projections for renewables and battery storage.** The IRP does not sufficiently account for recent and projected declines in the costs of solar, wind, and battery storage resources. This results in the IRP overstating the future costs of these resources by up to 50 percent

- **Inadequate evaluation of existing generating units and planned unit additions.** The Department assumes that retirement dates for existing coal units and online dates for previously contracted generating units are locked in. Rather than fixing these dates, the Department should have allowed its model to determine economically optimal retirement dates and resource procurement decisions. This would have required fully accounting for all costs associated with continuing to operate existing power plants.

- **Poorly supported fuel price assumptions.** Most of the IRP scenarios assume that gas prices stay flat in real terms. The Department does not provide support for that assumption. Instead, the IRP should include base fuel price forecasts that are grounded in an independent market analysis and explore the impacts of fuel price sensitivities that are also tied to potential future market scenarios.

- **Unsupported renewable build limits.** The IRP sets arbitrary limits on annual renewable resource capacity additions without providing sufficient justification for these limits.

- **Inadequate consideration of environmental impacts.** The IRP does not incorporate a stringent carbon budget and it is unlikely that South Africa will achieve its emission reduction goals under the proposed resource plan. The IRP also fails to consider the relative impacts of alternative resources on water consumption and water quality.

- **Disconnect between modeling findings and resource plan.** The proposed resource plan calls for the addition of more than 6,500 megawatts (MW) of new coal capacity over the next six years, including 1,000 MW that has not already been contracted. Yet none of the optimized IRP modeling scenarios involve the construction of any coal capacity during the 2020s. This disconnect runs counter to the purpose of an IRP.

- **Limited public documentation of analysis.** Stakeholders typically have access to a broad array of relevant information during an IRP process. There are several types of data that are generally released during IRP processes that were not provided along with the draft

2018 South Africa IRP, including peak load forecasts, reserve margins, load and resource balances, and other modeling inputs and outputs. Lack of access to such information and data hinders the ability of interested stakeholders to fully evaluate the reasonableness and accuracy of the IRP.

We recommend that the Department promptly revisit the IRP to correct for these deficiencies and refrain from using the IRP as a basis for making resource procurement and retirement decisions until it has corrected these deficiencies.

1. INTRODUCTION

In August 2018 the South Africa Department of Energy published a draft 2018 national Integrated Resource Plan (IRP) and solicited comments on the IRP from interested persons and organizations.[1] These comments provide Synapse Energy Economics, Inc.'s (Synapse) assessment of the extent to which the draft IRP comports with IRP best practices. These comments are based on Synapse's examination of the IRP modeling framework, input assumptions, and conclusions. They draw on Synapse's extensive experience evaluating IRPs throughout the United States and elsewhere.[2]

These comments are organized as follows: First we provide a brief overview of IRP best practices. Next, we evaluate the extent to which various aspects of the South Africa IRP follow basic IRP standards. Finally, we conclude with our summary findings and recommendations.

2. IRP BEST PRACTICES

IRPs are intended to compare options for meeting customers' demand for electricity in a transparent way. Planners should consider costs, benefits, and risks of various resource portfolios over the long term. Typically, the goal of an IRP is to identify the resource plan that maintains reliability of the electric system at the lowest cost and lowest risk, while complying with all current and anticipated governmental policies. Decisions resulting from IRPs are long-term in nature, with implications that can be felt by consumers for decades. It is therefore important that any near-term resource procurements called for by an IRP help to mitigate long-term uncertainties.

It is critical that resource planners undergo a rigorous approach that includes several core steps. First is the development of key forecasts and input variables, including forecasted electricity demand (also known as the "load forecast") and commodity prices (such as coal and natural gas prices) as well as cost

[1] Republic of South Africa Department of Energy. August 2018. Integrated Resource Plan 2018. [Hereinafter "2018 IRP"].

[2] Appendix A provides a description of Synapse and the authors of this report.

trajectories and availability for supply- and demand-side resource options.[3] The second is the use of an industry-approved electric system model with both capacity expansion and production cost capabilities. Finally, the IRP process should include a meaningful stakeholder process with participation from a diverse group of interested parties.

The first of these steps is especially fundamental to an IRP. Electricity planners should begin their development of key input variables with a characterization of the existing electric system and generation fleet, as detailed here. Electricity demand is one of the key input variables in any resource planning analysis, and planners should assess current levels of distributed generation[4] and the magnitude and effectiveness of existing energy efficiency programs as a gauge of recent patterns in customer demand. On the supply side, there is a need to evaluate existing thermal generation units that may reach the end of their useful lives and/or become uneconomic to continue operating and therefore require decommissioning during the IRP analysis period. These units should be evaluated with respect to their longevity, utilization rates, ramping abilities, variable operating costs, emission rates, installed or needed environmental controls, and the amount of capital, maintenance, and other fixed costs needed to keep the units operating. The timing and duration of any power purchase agreements should be evaluated to determine their effect on the electric system. In addition, an IRP should address any transmission constraints that affect power flows.

The use of reasonable input assumptions is fundamental to a sound IRP. An IRP's central or "base" case should use the most likely, most defensible set of assumptions available at the time of analysis. In this way, the IRP is sure to determine an optimal plan under a most likely future scenario. Once the initial base case is constructed, the IRP should also evaluate alternative scenarios and sensitivities in which certain key inputs are varied. Particularly important input parameters include:

- **Load forecast**: The forecast of annual peak demand (typically, the largest quantity of electricity demanded over any hour interval) and energy demand (the total electricity needed over the course of a year) provides the basis for any energy planning process and plays a key role in determining the need for new resources.
- **Regulatory environment**: National and municipal policies and regulations regarding such issues as renewable energy penetration levels, energy efficiency, demand-side management, and environmental impacts can affect the operation of the electric system. Consideration of these types of policies within an IRP may result in the inclusion of emissions restrictions or an externality price, plans for the installation of pollution controls, or the procurement of alternative resources to meet projected demand.

[3] Supply-side resources refer to central power generation facilities such as coal-fired power plants. Demand-side resources include options for reducing customer electricity demand through demand response and energy efficiency programs, such as a program to install more energy efficient appliances in homes.

[4] Distributed generation refers to decentralized generation resources installed at or near the site of electricity consumption. Examples include rooftop solar and combined heat and power systems.

- **Commodity prices**: Future prices for fuel, emissions, and purchased electricity influence the variable operating costs of generating units and the economic value of demand-side resources, renewable technologies, and traditional thermal generators. These prices change over time—sometimes dramatically—and thus any price projections should be up-to-date and consistent with expert industry opinion.

- **Demand-side resources**: The level of consideration given to energy efficiency and other demand-side resources in integrated resource planning varies by jurisdiction. Best practices dictate that third-party studies of the potential energy and peak savings from demand-side resources be incorporated directly into resource planning processes and included in electricity simulation models. When possible, demand-side resources should be treated as supply options in capacity expansion modeling, such that they are selectable resources based on relative economics.

- **Supply options**: Capital and operating costs vary across resource types. The IRP process provides an opportunity to assess both supply- and demand-side options for meeting customer needs. IRP best practices suggest that all resources be examined with the same rigor and that limits not be placed on any alternative technologies without sufficient justification. Economic retirements of existing resources have also become an essential part of resource planning. It is critical to examine the possibility of retiring existing units and replacing them with either a single resource or a portfolio of resources.

- **Transmission and distribution**: Electricity is delivered to customers over a network of transmission and distribution lines. Resource planning should reflect any constraints in these existing systems that may limit the types of resources that can be sited at certain locations. To the extent that these constraints exist, resource planning may be focused on overcoming them through strategically placed generators, energy efficiency or other demand-side measures, and improvements to the system. Certain resources may also include additional costs if new interconnection infrastructure is required as part of their development.

These and other relevant variables should be input to an electric system model that is designed specifically to evaluate the ability of new and existing resources to meet expected loads and to provide operational details about individual generators. These models produce a single preferred resource portfolio to serve customer requirements, which may be evaluated under different policy scenarios or sensitivities to measure the uncertainty around specific input variables. Up-to-date forecasts of the variables listed above produce a more rigorous IRP that is reflective of conditions and expectations in the electric sector, helping the resource planner arrive at a least-cost portfolio that also scores well on metrics relating to environmental impact, fuel diversity, reliability, security of supply, and risk.

3. EVALUATION OF SOUTH AFRICA'S IRP

3.1. Load Forecast

The load forecast is a critical component of any IRP. Peak demand forecasts in particular drive decisions around investing in new resources. Under-forecasting load can lead to the need for the last-minute, expensive development of new generation resources or, worse yet, electric reliability problems. Over-forecasting load can result in the development of unnecessary new resources or the failure to shut down aging existing resources that are no longer needed. The costs associated with under- and over-forecasting load are ultimately borne by electricity consumers.[5] The evidence presented in South Africa's 2018 IRP indicates that it relies on a load forecast that is unreasonably high and is grounded in a load forecasting approach that has proven to be inadequate.

The IRP Load Forecast Relies on a Model that Consistently Over-Forecasts Load

The "moderate" base load forecast used in this IRP calls for average annual growth in electricity sales of 2.2 percent over the next decade and approximately 2.3 percent over the next five years.[6] This is quite similar to the steady growth forecasted under the "moderate" load projection presented in South Africa's 2010–2030 IRP.[7] As the 2018 IRP acknowledges, this previously forecasted load growth "did not realise."[8] In fact, electricity sales in South Africa *decreased* between 2010 and 2016.[9] As a result, the 2010–2030 IRP over-forecasted 2016 electricity sales by 18 percent.[10] This meant that electricity generation in South Africa in 2016 was more than 50 terawatt-hours (TWh) lower than forecasted. If its load forecast led South Africa to invest in new power plants to provide such a large amount of unneeded generation, it likely wasted tens of billions of dollars in capital costs.[11] Even if South Africa did not build

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[5] Documentation associated with the 2018 IRP indicates that the government of South Africa is aware of this risk. Republic of South Africa Department of Planning, Monitoring, and Evaluation. June 2018. Socio-Economic Impact Assessment: Draft Final Impact Assessment for Integrated Resource Plan Update. Pp. 14-15.

[6] Republic of South Africa Department of Energy. May 2017. Forecasts for Electricity Demand in South Africa (2017–2050) Using the CSIR Sectoral Regression Model for the Integrated Resource Plan of South Africa, pp. 16-17. We note that the forecast of "electricity sent out" presented in the main IRP document appears to indicate slightly lower growth rates of about 1.9 percent per year. 2018 IRP, p. 20.

[7] South Africa Integrated Resource Plan for Electricity 2010–2030. March 2011.Appendix D, p. 51.

[8] 2018 IRP, p. 16.

[9] *Ibid,* p. 17.

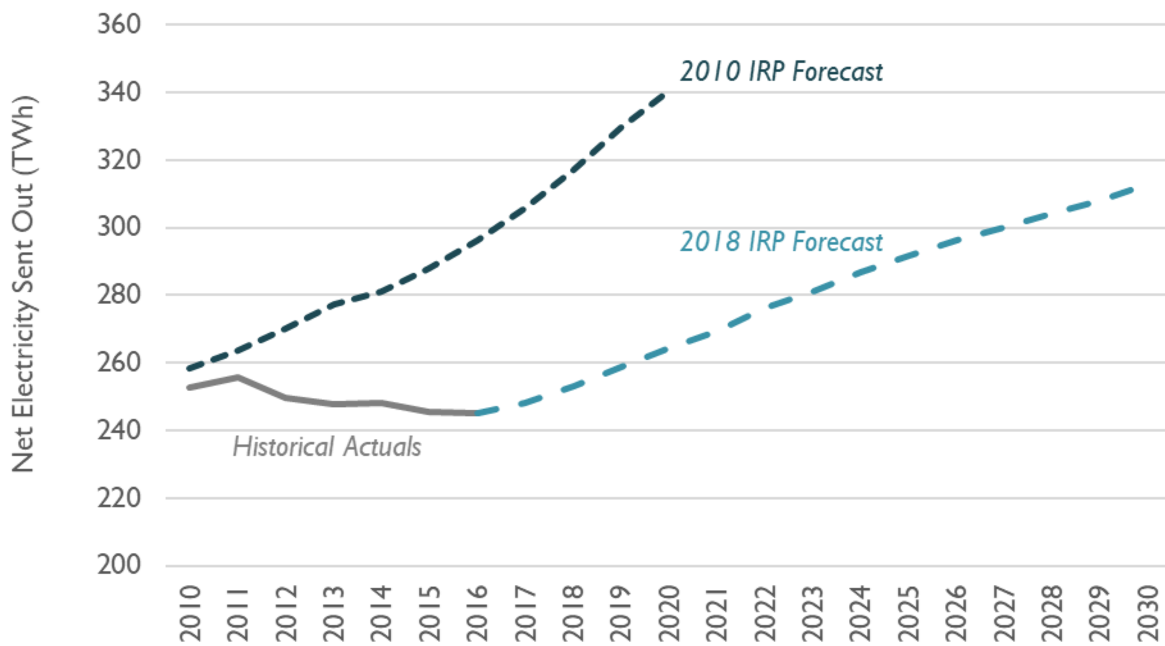
[10] *Ibid*, p. 18.

[11] Assuming the new capacity consisted of natural gas combined cycle plants with a typical capacity factor of 60 percent and cost of $1,000 per kilowatt (kW), we estimate the cost of the new capacity would amount to approximately $9.7 billion. If the new capacity included costlier and less efficient resources (such as coal plants), the unnecessary capital costs would be much higher, up to around $30 billion.

new capacity but instead unnecessarily maintained existing, aging coal units, the fixed costs for that maintenance likely added up to more than one billion dollars over the period from 2010 through 2016.[12]

Figure 1 indicates that the Department may be on the verge of repeating this costly mistake. It shows that the 2018 IRP relies on forecasted load growth similar to that projected back in 2010, despite the fact that none of the previously forecasted load growth has materialized.

Figure 1. Comparison of Historical Electricity Generation to 2010 and 2018 IRP Projections



Source: 2018 IRP, Figures 3 and 5, pp. 17, 20.

The 2018 IRP provides a variety of reasonable explanations for previous over-forecasts of load. Chief among these explanations are improved energy efficiency, fuel switching away from electricity, and a general decoupling of economic growth from growth in electricity sales.[13] Though it identifies the problems with its prior forecasts, this IRP does little to correct them, using the same load forecasting methodology as was used in the previous IRP without providing any indication that the same issues that

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[12] Assuming a capacity factor of 60 percent, ongoing capital costs of about $17 per kW, and fixed operations and maintenance costs of about $33 per kW. U.S. Energy Information Administration (EIA). January 2017. Assumptions to the Annual Energy Outlook 2016, page 114. Available at https://www.eia.gov/outlooks/aeo/assumptions/pdf/0554%282016%29.pdf; U.S. EIA. September 2015. Assumptions to the Annual Energy Outlook 2015, p. 105. Available at https://www.eia.gov/outlooks/aeo/assumptions/pdf/0554%282015%29.pdf.

[13] *Ibid*, pp. 16-18.

derailed the last forecast will not arise again.[14] The IRP's load forecast is rooted in sector-specific regression models based on historical data.[15] While this methodology has been adjusted to some degree to account for changes in the electricity intensity of the South African economy, it remains essentially grounded in past economic relationships. For example, domestic electricity use is forecasted solely based on its historical relationship to final consumption expenditures by households.[16] This presumes that the relationship between household expenditures and electricity use remains essentially unchanged, but this is not the case. Instead, the IRP makes clear that energy efficiency, fuel switching, and other factors have reduced the extent to which increased economic activity leads to increased electricity demand.

Rather than relying exclusively on regression models to forecast electricity demand, the IRP should ideally incorporate bottom-up models that directly forecast the number of future electricity customers, the types of electricity use associated with each customer type, and the quantity of consumption associated with each use. This approach to forecasting has become more common and more important as historical relationships between electricity demand and such traditional explanatory factors as economic growth have changed. At a minimum, South Africa's load forecast model should explicitly capture recent trends in electricity demand rather than relying on historical relationships that may no longer hold.

The IRP Does Not Adequately Support Its Load Forecast

The IRP tries to justify the load forecast's limited treatment of distributed generation, energy efficiency, and fuel switching by stating that these factors were "considered to be covered in the low-demand scenario."[17] This explanation is plainly inadequate. As an initial matter, such important and clear trends should be accounted for in a base scenario, rather than being limited to a "low-demand" sensitivity. Furthermore, even the low-demand scenario does not appear to sufficiently account for the various factors behind the recent delinking of economic growth from electricity demand. From 2010 to 2016, electricity sales declined despite South African gross domestic product (GDP) increasing at an average annual growth rate of greater than 2 percent.[18] Under the low-demand scenario presented in the IRP, GDP increases by only 1.33 percent per year—less than recent rates—yet electricity demand *increases* by 1.2 percent per year.[19] This association between GDP and electricity demand is not supported by recent evidence. In addition, the fact that the IRP does not even consider a low-demand case of zero or

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[14] Republic of South Africa Department of Energy. May 2017. Forecasts for Electricity Demand in South Africa (2017–2050) Using the CSIR Sectoral Regression Model for the Integrated Resource Plan of South Africa, p.1.

[15] *Ibid,* p. 7.

[16] *Ibid,* p. 8.

[17] 2018 IRP, pp. 21-22.

[18] *Ibid,* pp. 17-18.

[19] *Ibid,* p. 21.

negative load growth—in the face of a decade of flat to declining electricity demand—indicates that the IRP does not contemplate a reasonable range of load trajectories.

Similarly, there is little evidence to support the IRP's suggestion that a turnaround in economic growth will cause the forecasted change in the trajectory of electricity demand.[20] As discussed above, the recent decline in electricity demand came despite annual GDP growth of greater than 2 percent. This delinking of electricity demand and GDP growth is likely due to a variety of factors, ranging from fuel switching to increases in the efficiency of industrial processes. In any case, the IRP's central GDP forecast is likely overly optimistic. Under this scenario, annual GDP growth would increase to 3.5 percent by 2023.[21] The International Monetary Fund, on the other hand, forecasts that South African annual GDP growth rates will remain below 2 percent through 2023.[22]

Fundamentally, each of the load forecasts presented in the IRP projects an immediate break from recent history. This much is clear from Figure 8 of the IRP electric demand forecast report, reproduced as Figure 2 below.[23] This figure shows that electricity demand in South Africa increased steadily from 1970 through 2007 but has remained essentially flat for the past decade. All five load forecasts presented in the IRP—including the one labeled "Low"—call for steady growth over the next 30 years, often roughly on par with 20th century growth trends. For such forecasts to be credible, the IRP would need to present a clear explanation for the abrupt and ongoing forecasted departure from recent trends. The IRP fails to meet this burden.

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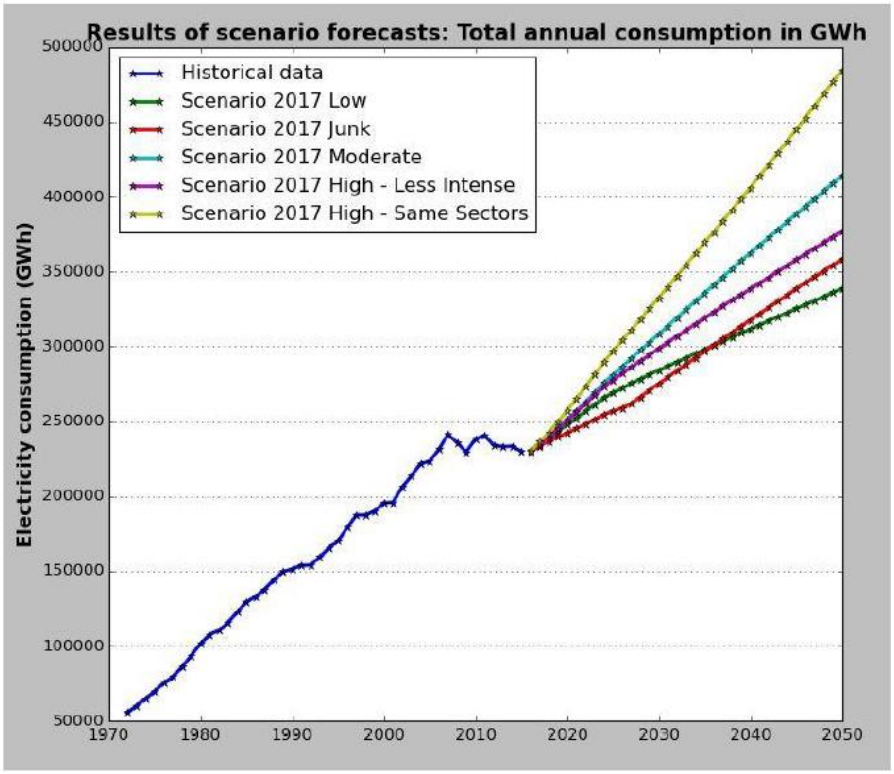
[20] *Ibid,* p. 16.

[21] Republic of South Africa Department of Energy. May 2017. Forecasts for Electricity Demand in South Africa (2017–2050) Using the CSIR Sectoral Regression Model for the Integrated Resource Plan of South Africa, pp. 11-12.

[22] International Monetary Fund. Real GDP Growth: Annual Percentage Change. Available at https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/ZAF.

[23] Republic of South Africa Department of Energy. May 2017. Forecasts for Electricity Demand in South Africa (2017–2050) Using the CSIR Sectoral Regression Model for the Integrated Resource Plan of South Africa, p. 18.

Figure 2. South Africa Historical and Forecasted Electricity Assumption, 2018 IRP Electricity Demand Report



Source: IRP Electricity Demand report, Figure 8

The Base IRP Load Forecast Should Represent a Most Likely Scenario

Interestingly, the IRP indicates that its authors are aware that the load forecast is too high. According to the IRP, "current indications are that demand is more likely to be lower than forecasted."[24] The Department proposes to mitigate this risk "by managing the pace and scale of new capacity implementation through regular reviews of the IRP."[25] We suggest that the management of the proper pace and scale of new capacity implementation should start now, with a reasonable load forecast.

Presumably, the Department would prefer to face the over-build risks associated with over-forecasted load rather than the energy supply risks associated with under-forecasting load. However, this sort of conservativism should be addressed directly and concretely in the IRP through such mechanisms as reserve margins and contingency plans,[26] rather than through a biased load forecast. The base load forecast itself should be as accurate as possible.

[24] 2018 IRP, p. 67.

[25] *Id.*

[26] Reserve margins constitute an extra amount of generation capacity maintained beyond expected peak demand and are generally expressed as a percentage of peak demand. Contingency plans may include options for rapid construction of

The Load Forecast Section of the IRP Lacks Important Details and Data

In addition to presenting an unreasonably high forecast of electricity sales, the load forecast section of the IRP is also lacking in its presentation of fundamental load forecast data. Most notably, neither the IRP nor the accompanying load forecast report provide any discussion of future peak demand levels. This is a glaring omission. Peak demand is often the primary driver of need (or lack thereof) for new generating capacity. It should be explicitly accounted for in IRP modeling and discussed within the IRP document.

In addition, there is no explicit accounting for any form of distributed energy resources, such as rooftop solar and energy efficiency. Typically, these resources are identified and incorporated within an IRP load forecast. If not, they are instead treated as options for meeting load requirements within a capacity expansion modeling framework. The 2018 South Africa IRP appears to include no explicit treatment of any of these resources on either a demand- or supply-side basis.

3.2. Reserves and Reliability

At its most basic, the IRP is a plan to meet a region's forecasted annual peak and energy demand, plus an established planning reserve margin, over a specified future period. The strategy used by the electric sector to maintain reliability, and keep the lights on, is a simple one: have more electricity supply available than is expected to be required.[27] The first step in executing this strategy requires a reasonable assessment of peak electric load and a determination of the single highest hourly load in each future year of the IRP analysis period. The additional capacity required above and beyond the expected peak load is referred to as the planning reserve, established via a set planning reserve margin. This reserve margin varies by region and by electric utility but is often between 12 and 18 percent of peak load. The forecasted peak demand plus the planning reserve margin indicates the total number of megawatts of supply- and demand-side resources that should be available in a given year to maintain reliability. This number, net of existing installed capacity, represents the total amount of capacity that a must be procured in a future year.

South Africa's 2018 IRP identifies a need for 39,730 MW of new generation capacity but provides no data about peak load or planning reserves to support this conclusion.[28] Neither the IRP nor its supporting electricity demand forecast document provide the methodology used to develop the peak load values found in the IRP. The IRP provides no information regarding South Africa's regional reserve margins, which should be applied to the peak load forecast to determine the necessary planning reserve. It also does not provide a capacity balance indicating the total capacity of new supply- and

battery storage resources, or plans to call on demand response programs, if electricity demand turns out to be higher than forecasted.

[27] United States Energy Information Administration. 2012. "Reserve electric generating capacity helps keep the lights on." Accessed on September 28, 2018 at: https://www.eia.gov/todayinenergy/detail.php?id=6510.

[28] 2018 IRP, p. 26.

demand-side resources needed to maintain reliability. Without this information, the IRP lacks a sound basis for determining the magnitude of capacity additions over the analysis period.

3.3. Treatment of Existing and Contracted Resources

Evaluation of Existing Units

Regulatory constraints and changes to capital and operating costs of different generation technologies can affect the economic competitiveness of various generating resource types. In recent years in the United States, increasing coal prices, declining gas prices, and required environmental retrofits to coal-fired units have combined to flip the relative economics of gas- and coal-fired generating units, with gas units often having lower operating costs than coal units. Similarly, increasing penetrations of renewable resources displace higher-cost fossil generation resources while lowering the marginal cost of energy and reducing overall system costs. Given these recent trends, many of which are of widespread and international relevance, it is important that a reasonable IRP evaluate the existing units in a generating fleet as well as future new-build options.

The PLEXOS electric simulation model used by South Africa in its IRP has the capability to optimally retire generating units during the analysis period. While Synapse did not have access to the PLEXOS IRP data, it appears that unit retirement dates for existing resources were hard-coded into the PLEXOS model instead of allowing the model to select the economic retirement date for each unit. The IRP states that "A number of Eskom power plants (Majuba, Tutuka, Duvha, Matla, Kriel and Grootvlei) require… extensive emission abatement retrofits to ensure compliance with the law."[29] IRP best practices suggest that any ongoing capital and operational costs associated with these types of retrofits be accurately represented alongside general maintenance costs within a capacity expansion model like PLEXOS and that the model be allowed to consider these costs to determine the economically optimal retirement dates for generating units. Using this endogenous retirement functionality can help the Department avoid sinking large amounts of money into aging power plants that cannot earn back such investments.

Committed and Contracted Capacity

The South Africa IRP also failed to allow PLEXOS to fairly evaluate the economics of committed and contracted capacity. Instead, the IRP assumed that the 18,000 MW of new generation capacity already committed to will begin operation.[30] This includes more than 5,000 MW of coal capacity to be built between 2019 and 2022.[31] Given the trends noted above related to increasing capital and operating costs for coal units, the PLEXOS model should have been used to evaluate whether this capacity continues to be cost-effective. This capacity should have been offered to the model in capacity expansion mode, letting the model make the decision as to whether this capacity is economic when compared to alternative resource options. If there is a cost associated with canceling capacity that is

[29] *Ibid*, p. 28.

[30] *Ibid*, p. 26.

[31] *Ibid*, p. 41, Table 7.

already under contract, the model is capable of incorporating that information as well. There is no need to assume that future new power plant operation dates are set in stone.

3.4. New Resource Costs and Operational Constraints

Sound and defensible resource cost and operational assumptions are a critical component of an IRP. The input cost assumptions used in the South Africa 2018 IRP are unreasonably high for future renewable energy and battery storage projects. Additionally, the IRP imposes annual build limits on renewable resources without providing resource potential studies or market analysis to justify those constraints.

Resource Costs

The IRP's assumed 2018 costs for solar and wind projects are high relative to external sources but are reasonably grounded in actual costs achieved by resources associated with South Africa's Renewable Energy Independent Power Producers Program (REIPPP).[32] Nonetheless, we note that the 2018 modeled costs are 15 percent higher for solar and 19 percent higher for wind than 2017 actual costs published by industry expert Lazard.[33] More concerning, the IRP's assumptions regarding the future costs of renewables are unjustifiably high. The IRP assumes that solar and wind costs will decline by only 20 percent between 2015 and 2050. Outside experts expect much more rapid declines. Bloomberg New Energy Finance projects that global solar costs will drop by 71 percent between 2018 and 2050 and that wind costs will drop by 58 percent over the same period.[34,35]

The IRP also relies on unreasonably high and out-of-date cost assumptions for battery storage resources. Batteries can serve as an important part of future resource portfolios, as evidenced by global trends showing an uptake in battery storage deployment. Bloomberg New Energy Finance projects that more than $500 billion will be invested in global battery storage capacity by 2050, including both grid-scale and behind-the-meter resources.[36] The International Renewable Energy Association (IRENA) projects that electricity storage capacity will triple in energy terms by 2030 in order to accommodate increased global renewable deployment.[37] In 2017, the United Kingdom installed 140 MW of battery storage

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[32] Assuming the REIPPP process was conducted in a fair and comprehensive manner, it is reasonable to rely on costs achieved in actual local power procurement processes.

[33] Lazard's Levelized Cost of Energy Analysis – Version 11.0.

[34] Bloomberg New Energy Finance, New Energy Outlook 2018. https://about.bnef.com/new-energy-outlook/.

[35] None of the resources cited here state explicitly whether costs are in real or nominal dollars. For the purposes of this report, it is assumed that costs are represented in nominal dollars.

[36] Bloomberg New Energy Finance. Annual Energy Outlook, 2018. Summary available at https://about.bnef.com/blog/batteries-boom-enables-world-get-half-electricity-wind-solar-2050/.

[37] International Renewable Energy Agency. Electricity Storage and Renewables: Costs and Markets to 2030. October 2017, p. 8.

capacity and Germany installed 75 MW. Across Europe, more than 1.1 gigawatts (GW) of new battery storage resources are in the pipeline for 2018.[38]

The IRP's battery storage cost assumptions were sourced from a 2015 vintage report by the Electric Power Research Institute (EPRI)[39] and were then escalated by 2.5 percent per year to arrive at an "updated" 2017 cost. In fact, battery storage costs have declined substantially since 2015 and are expected to continue to drop. The EPRI study actually states that battery costs are expected to decline by 30 percent or more over the next five years,[40] yet the IRP does not appear to incorporate any realistic cost decline assumptions for battery storage. IRENA finds that lithium ion battery storage costs fell by as much as 73 percent between 2010 and 2016 and projects that they will decline by another 60 percent between 2016 and 2030.[41]

The 2017 installed battery costs used in the IRP are significantly higher than levels indicated by Lazard's latest industry-standard Levelized Cost of Storage report but they do fall within the range of costs cited by IRENA[42] when evaluated against a different set of assumptions.[43] Given the lack of available regionally specific data on battery storage installation costs, the Department should have solicited quotes from battery storage project developers as part of the REIPPP or during the IRP process and should have modeled a variety of battery storage cost sensitivities to understand the value that battery storage can offer to the South Africa electric system.

Transmission Costs

It is reasonable to assign transmission costs to a new generation project if the project drives the need for specific system investments or upgrades. However, this principle should be applied evenly to all resources based on the individual project's impact on the grid.

The IRP states that "For [renewable energy] technologies (wind and solar PV), the transmission infrastructure costs entailed collector stations and the associated lines connecting to the main transmission station, as well as the transmission substation costs. For conventional technologies, the costs entailed only the main transmission substation costs."[44] This treatment is reasonable in theory;

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[38] Buchsbaum, L. 2018. "Renewable Energy Storage Takes Off in Europe." May 1, 2018. https://www.powermag.com/renewable-energy-storage-takes-off-in-europe/?pagenum=2.

[39] EPRI. April 2017. *Power Generation Technology Data for Integrated Resource Plan of South Africa: Technical Update.*

[40] It is unclear if this was written in 2015 and referencing the 2015–2020 timeframe, or if it was added as part of the update in 2017 and therefore referencing the 2017–2022 timeframe.

[41] International Renewable Energy Agency. 2017. Electricity Storage and Renewables: Costs and Markets to 2030, p. 12.

[42] *Ibid*, p. 67.

[43] Costs assumptions differ widely across sources for a variety of reasons, including the framework of the analysis (historical trend-focused or forward projection-focused), the scope and quality of the cost dataset, and the technical specifications and operational assumptions for the storage systems evaluated.

[44] 2018 IRP, p. 30.

however, accurate costing is site dependent. Average incremental transmission costs should be incorporated into the model based on the most representative new renewable connection sites, not simply based on average connection costs across the entire system. This requires identifying where solar and wind resources are most likely to be installed (based on resource potential, among other factors) and evaluating the costs to connect to the system only at those likely connection points.

Renewable Energy Build Constraints

The IRP states that the scenario without renewable energy annual build limits provides the least-cost option and that imposing annual build limits on renewable energy will restrict the cumulative renewable installed capacity. However, the plan selected in the IRP retains a 1,000 MW annual build limit for solar resources and a 1,600 MW annual build limit for wind, stating that the limits were retained to enable a "smooth roll out" of renewable energy that "will help sustain the industry."[45] While the IRP claims that these build limits do not affect the modeled energy mix until after 2030, this is clearly not the case.[46] By 2030, the scenario without build limits is already shown to have a distinct energy mix, and lower costs, compared to the Department's preferred resource plan.[47]

Build limits can be reasonable elements of an IRP analysis when used to simulate real-world constraints on annual build-out timelines and quantities. Factors that can legitimately limit incremental build schedules include availability of suitable land, constraints on the hardware supply chain, availability of qualified developers and installers, and transmission and distribution system upgrade needs. However, build limits need to be transparently developed and supported by resource potential studies, market data, and additional details on how the government anticipates these factors changing over time. The IRP provides no studies or analysis to support its enforced build limits. Such build limits are of particular concern when coupled with conservative cost decline assumptions. These cost assumptions can make renewables appear uneconomic in the short term, which delays renewable builds until the later years, at which point the renewable projects run up against the arbitrary build limits.

3.5. Fuel Prices

There are significant risks and costs associated with a resource portfolio that relies on a large quantity of coal- and gas-fired generation. The IRP acknowledges that there are risks associated with fuel price volatility, but these issues are only mentioned as risks that require future consideration. The IRP appears

[45] 2018 IRP, p. 39.

[46] *Ibid*, p. 11.

[47] *Ibid,* pp. 12, 48.

to rely on the EPRI report for its fuel cost assumptions, which assume that gas and coal prices increase at the rate of general inflation.[48] This is a faulty assumption and does not reflect IRP best practices.

Appendix E of the IRP states that in the past South Africa was locked into long-term contracts with the company Eskom that gave it access to coal priced below the global market price. However, the IRP states that, based on Eskom's coal procurement, indications are that this is no longer the case.[49] In the absence of a long-term contract, South Africa will be subject to global coal market fluctuations that could drive electricity prices upward. In 2017, global coal prices spiked due to carbon emission policies in China and miner strikes in India. This type of supply-side disruption could easily happen again.[50] While global prices are forecasted to drop and flatten out after 2020,[51] future supply-side disruptions could very well drive prices up again in the future.

The IRP also acknowledges that increased reliance on natural gas will expose the system to price fluctuations, among other risks.[52] There have been major offshore discoveries of natural gas in Tanzania and Mozambique, but demand in the region has been historically low. Therefore, infrastructure to transport the natural gas to consumers is currently limited. Pipelines can be built to bring gas from Mozambique to South Africa but there are high costs associated with building out such infrastructure. Further, there are significant security risks associated with reliance on physical pipelines. Additionally, natural gas is a global commodity, and East Africa's natural gas strategy is currently focused on growing markets in India (and elsewhere in Asia) and Europe.[53] While transportation costs to move natural gas within the region will be lower than costs to transport it to Europe and Asia, natural gas prices will largely be set by global markets, which can be volatile and subject to currency fluctuations.

Uncertainty around coal and gas prices should be incorporated into an IRP analysis by modeling price sensitivities. These sensitivities should explore the effects of deviations from base price forecasts that are derived from market analysis and prepared by market experts, rather than being simplistically tied to inflation. The IRP results show that system costs are very sensitive to fuel cost assumptions.[54] Therefore the Department should have evaluated additional gas and coal price sensitivities to understand the full risks associated with fuel cost volatility.[55]

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[48] Power Generation Technology Data for Integrated Resource Plan of South Africa. Technical update, April 2017. Prepared by EPRI. pp. 7-7, 9-13.

[49] 2018 IRP, p. 68.

[50] South Africa Data Portal. Coal Prices Forecast: Long Term, 2018 to 2030. http://southafrica.opendataforafrica.org/xfakeuc/coal-prices-forecast-long-term-2018-to-2030-data-and-charts.

[51] *Id.*

[52] 2018 IRP, p. 68.

[53] International Energy Agency. 2018. Outlook for Natural Gas, Except from World Energy Outlook 2017.

[54] 2018 IRP, p. 12.

[55] The IRP modeled a market-linked gas price scenario in which a market-linked increase in gas prices was assumed instead of an inflation-based increase. However, the IRP is not clear on what specific prices were modeled.

3.6. Environmental Costs and Constraints

Greenhouse Gas Emissions

South Africa has recognized the importance of addressing climate change and has pledged to contribute to mitigating global carbon dioxide (CO_2) emissions. The IRP accounts for constraints associated with current and future South African climate policy; however, South Africa's official pledge allows for future emissions to fall within a wide range. The target put forward in South Africa's Intended Nationally Determined Contribution (INDC) is for annual emissions to plateau between 398 and 614 million metric tons of CO_2 from 2025 to 2030.[56] The high end of this range is more than 50 percent higher than the low end and future electric sector emission constraints will depend on the target that the country decides to pursue.

The Paris Accord set a goal of limiting temperature increases to 2 degrees Celsius and aiming for temperature increases of less than 1.5 degrees. To meet these global climate change mitigation targets, South Africa will most likely need to achieve total emissions at the low end of its INDC. According to the World Resources Institute, which applauds some aspects of South Africa's INDC, limiting emissions to the low end of the target (roughly 400 million metric tons per year) would account for "a fairer share" of global emissions reductions.[57] Climate Action Tracker, a research project partially funded by the German Ministry for the Environment, Nature Conservation, and Nuclear Safety, considers South Africa's target to be "Highly Insufficient" due to its wide range.[58] However, Climate Action Tracker believes that if South Africa reduces its emissions to the lower end of its target, it will be contributing its fair share toward global carbon reductions. South Africa can take a leading role in responsibly reducing carbon emissions by aiming for the low end of its INDC.

To meet a 400 million metric ton emissions target, South Africa will likely need to reduce 2030 emissions from the power sector beyond what is planned in the IRP. South Africa's current goal is to achieve electric sector emissions of 275 million metric tons per year between 2025 and 2030, which would use up a large portion of the total 400 million metric ton target. For comparison, emissions from electricity generation and heating combined were 295 million metric tons in 2014, while total emissions were 527 million metric tons.[59] Additionally, it is more difficult to reduce emissions from some of the other high-emitting sectors. South Africa's IRP does not envision substantial transportation electrification, which suggests there will be minimal transportation sector decarbonization in the short term. Emissions reductions from the industrial sector, another major emitter, are more difficult and more expensive to

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[56] South Africa's Intended Nationally Determined Contribution (INDC), 2016, http://www4.unfccc.int/ndcregistry/PublishedDocuments/South%20Africa%20First/South%20Africa.pdf.

[57] Rich, D., E. Northrop, K. Mogelgaard. 2015. "South Africa Pledges to Peak its Greenhouse Gas Emissions by 2025." Available at https://www.wri.org/blog/2015/10/south-africa-pledges-peak-its-greenhouse-gas-emissions-2025.

[58] Climate Action Tracker. 2018. "South Africa." Available at https://climateactiontracker.org/countries/south-africa/.

[59] World Resources Institute CAIT Climate Data Explorer. Available at http://cait.wri.org/profile/South%20Africa.

achieve relative to those from other sectors.[60] It seems unlikely that South Africa can achieve emissions of 400 million metric tons per year while its power sector emits 275 million metric tons per year on its own.[61]

The IRP should incorporate a more stringent carbon budget than is included in any of its scenarios. At a minimum, it should include a more aggressive emissions reduction policy as a separately modeled policy scenario. Such a policy could be incorporated directly as a modeled cap on emissions or indirectly as a modeled emissions price. The emissions price under an aggressive carbon policy scenario could be based on an estimate of the social cost of carbon. Many such estimates are available. The U.S. government calculated the social cost of carbon to be roughly $40 per ton in 2016.[62] A National Bureau of Economic Research survey found that experts think the social cost of carbon is between $150 and $300 per metric ton.[63] The Department should consider choosing a well-documented social cost of carbon and including it in its IRP modeling.

Water Impacts

Another important environmental impact that receives little attention in the IRP is power sector water consumption. Given South Africa's forecasted shortage of 234 gigalitres of water in 2025, water consumption from the power sector should be reduced as much as possible.[64] Reducing power sector water consumption is particularly important because power plants are disproportionately located in water management areas with moderate or severe water shortages. For example, power generation consumes 37 percent of the water used in the Upper Olifants.[65]

Additionally, coal mining and coal-fired power generation impact water quality in surrounding areas, creating pollution that is expensive to clean up.[66] For example, the Kingston coal ash spill that occurred

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60 de Pee, A., et al., *Decarbonization of industrial sectors: the next frontier,* 2018. Available at www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability%20and%20resource%20productivity/our%20insights/how%20industry%20can%20move%20toward%20a%20low%20carbon%20future/decarbonization-of-industrial-sectors-the-next-frontier.a.

61 Note that these emission targets should account for upstream greenhouse gas emissions associated with gas production and distribution. If gas generation capacity is added, power plant emissions must be reduced further to meet overall emissions targets.

62 *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, 2016. Available at https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf.

63 Pindyck, R. S., *The Social Cost of Carbon Revisited*, 2016. Available at https://www.nber.org/papers/w22807.

64 Thopil, G.A., A. Pouris, 2016. "A 20 year forecast of water usage in electricity generation for South Africa amidst water scarce conditions." *Renewable and Sustainable Energy Reviews* 62. Available at https://repository.up.ac.za/bitstream/handle/2263/54430/Thopil_20_2016.pdf?sequence=1.

65 Centre for Environmental Rights. 2018. "Water impacts and externalities of coal power." Available at https://cer.org.za/wp-content/uploads/2018/07/Water-Impacts-and-Externalities-Report_LAC.pdf.

66 *Id*.

in the United States in 2008 cost $1.2 billion to clean up, according to the U.S. Environmental Protection Agency.[67] According to a *USA Today* affiliate, 30 of the people who worked on cleaning up the spill have since died, and another 200 are sick from illnesses linked to exposure to coal ash toxins.[68]

The impact of alternative power generation technologies on water consumption and water quality should be evaluated and at the least given qualitative consideration in the South Africa IRP. To the extent that future water shortages may affect generation costs and impose operational constraints, such effects should be modeled where possible. Even where quantification is difficult, policy consideration of the importance of water consumption and water quality to security and public health should be acknowledged and incorporated into decision-making processes.

3.7. Modeling Framework and Tools

The PLEXOS electric system model is a powerful tool that provides the user with information on new capacity investments, retirements of existing units, and hourly operational outputs when it is used appropriately. The 2018 IRP, however, fails to make use of certain key components of the PLEXOS model while ignoring several areas of uncertainty.

First, as mentioned previously, the PLEXOS model has the capability to endogenously determine capacity additions and retirements. Rather than allowing it to do this, however, the Department hardcoded the retirement dates for existing units as well as start dates for capacity that has been committed or contracted. The Department is thus unable to say with confidence that the resource portfolio selected by PLEXOS is truly least-cost. As mentioned in other sections of this report, the IRP places an unjustified cap on renewable capacity additions, warranting the same criticism.

Second, South Africa's IRP covers a 32-year analysis period, from 2019 to 2050. This is sufficiently long to capture the full operating lives of many new renewable and natural-gas fired generating units; however, any new coal and nuclear units selected by the model will have useful lives that are much longer than the analysis period. The IRP acknowledges that there is much greater uncertainty in the later years of the analysis and puts the focus on the time period through 2030, largely ignoring the fact that the IRP commits the country to certain expensive, long-lived resources that may not fare well under future regulatory and cost trends.

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[67] U.S. Environmental Protection Agency and Tennessee Valley Authority. Kingston Coal Ash Release Site Project Completion Fact Sheet, 2014. Available at https://semspub.epa.gov/work/04/11015836.pdf.

[68] Satterfield, J. 2018. "Worker death toll rises in Kingston coal ash spill; Roane County man latest victim," *Knoxville News Sentinel*. Available at https://www.knoxnews.com/story/news/crime/2018/09/20/kingston-coal-ash-spill-cleanup-worker-dies-lawsuit-hearing-nears/1344072002/.

3.8. Uncertainty and Risk

Risk assessment has an important role in an IRP. A risk assessment should be quantitatively grounded to the extent possible and otherwise should be rooted in thorough qualitative analysis. The 2018 IRP's discussion of grid stability risks posed by renewables does not meet these standards.[69]

Various jurisdictions around the world are already demonstrating that moderate levels of renewable generation can be reliably integrated into the grid. Denmark generated 46 percent of the electricity it consumed from wind and solar in 2017, with wind and solar accounting for more than 49 percent of installed capacity.[70] Other jurisdictions with their own synchronized grids have increased renewable generation despite having to maintain reliability without the help of neighbors. Ireland generated 26 percent of its electricity from wind power alone in 2017, according to the Irish Wind Energy Association.[71] That same year, Hawaii generated 16.7 percent of its electricity from solar and wind, which accounted for 26.7 percent of installed capacity by December.[72] The state has set a target of 100 percent renewable energy for 2045.[73] These jurisdictions have already tested moderate penetrations of intermittent renewable energy and have continued to run their grids reliably.

South Africa is right to check for potential technical challenges to achieving the least-cost scenario modeled. However, without annual renewable energy build limits, South Africa's modeling indicates that wind and solar will account for just 21 percent of generation in 2030. As more and more jurisdictions reach similar penetrations of renewables in the next decade, any technical challenges South Africa might face will have been addressed elsewhere by 2030. South Africa should not be overly concerned about near-term grid stability risks from renewables.

3.9. Valuing and Selecting Plans

Given the current shift in the energy sector away from coal (and nuclear, in certain jurisdictions) and toward gas, the default approach to integrated resource planning is often to rely on gas combined-cycle

[69] 2018 IRP, pp. 38, 68.

[70] Energinet. 2018. *Environmental Report 2018*. https://en.energinet.dk/About-our-reports/Reports/Environmental-Report-2018.

[71] Irish Wind Energy Association presentation to Join Oireachtas Committee on Communications, Climate Action and Environment, January 16, 2018. Available at https://webarchive.oireachtas.ie/parliament/media/committees/communicationsclimatechangenaturalresources/presentations/iwea-presentation-to-joint-oireachtas-committee-16012018.pdf.

[72] U.S. Energy Information Administration. *Electric Power Monthly*, February 2018, https://www.eia.gov/electricity/monthly/archive/february2018.pdf.

[73] Fialka, J. 2018. "As Hawaii Aims for 100% Renewable Energy, Other States Watching Closely." *Scientific American*. Available at https://www.scientificamerican.com/article/as-hawaii-aims-for-100-renewable-energy-other-states-watching-closely/.

and/or peaking plants[74] as the primary new supply resource option without fully considering energy efficiency, demand response, battery storage, and other alternatives. An alternative resource planning approach would include a comprehensive package of demand-side management measures, renewable technologies, and storage with gas generation on an "as needed" basis and may be more likely to result in the "least cost" to consumers.

As do many IRPs, South Africa's IRP emphasizes cost as its primary metric for evaluation. While cost is a deserving top criterion, IRP best practices also include strong evaluation of metrics such as risk, environmental impact, fuel diversity, and reliability. The Department does not fully evaluate the selected resource plan on these other metrics. It also makes the distinction between "financial cost" and "economic cost" without providing a sufficient definition of either term.[75] The Department claims that the preferred resource plan in the IRP has the lowest economic cost, but reviewers are unable to determine whether this is defined in a comprehensive way. If, for example, South Africa includes coal industry jobs as part of the economic costs but fails to include the health costs of burning fossil fuels and/or the economic benefits of renewable energy jobs, this metric would be a misleading one.

South Africa's IRP is heavily dependent on new additions of fossil-fuel generators and makes negative progress as it relates to environmental and climate impacts. An alternative portfolio featuring more renewables and demand-side resources would likely score better than a fossil-heavy resource portfolio on the alternative metrics mentioned above.

3.10. Near-Term Action Plan

Typically, IRPs include an action plan that identifies specific, near-term action items that the entity behind the IRP intends to pursue. Whereas the overall IRP provides a general sense of what the next several decades may hold, the action plan focuses on concrete next steps. These may include near-term plans for construction, retirements, or investigative analyses. However, the 2018 IRP does not contain any clear action plan.

To the extent that the near-term sections of the proposed resource plan effectively constitute an action plan, the proposed actions do not match up with the findings of the IRP modeling analysis. For example, the proposed plan calls for the construction of thousands of megawatts of coal in the 2020s, despite the IRP indicating that new coal capacity does not play a near-term role in a least-cost resource plan under *any* modeled scenario.[76] Such a disconnect between the IRP analysis and near-term procurement plan requires a much clearer and more credible explanation than is presented in the IRP.

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[74] Peaking plants are typically only run in hours of high demand for electricity. They tend to be less capital intensive to build but have high operating costs. They are thus more expensive to run and require a higher electricity price before they are dispatched.

[75] Republic of South Africa Department of Planning, Monitoring, and Evaluation. June 2018. Socio-Economic Impact Assessment: Draft Final Impact Assessment for Integrated Resource Plan Update, pp. 6, 8, and 22.

[76] 2018 IRP, pp. 41, 56.

3.11. Documentation and Stakeholder Process

Under most jurisdictions that undergo IRP processes, stakeholders have access to a broad array of information relevant to the IRP. This information typically includes several types of data and analyses that were not provided along with this IRP. These data include load and resource balances, peak load forecasts, assumed reserve margins, and other modeling inputs and outputs. Several jurisdictions within the United States assure access to all IRP supporting data, assumptions, and modeling files and provide the opportunity to solicit additional information through a formal discovery process. The broader provision of IRP materials improves transparency and enables more productive stakeholder engagement with the IRP process, giving participants the opportunity to spot issues ranging from data entry errors (which may have a large and significant effect) to major flaws in forecasts and assumptions, particularly in those not documented in the IRP itself. Without this transparent process, stakeholders are unable to provide the necessary and adequate review of an IRP.

4. SUMMARY AND CONCLUSIONS

The 2018 South Africa IRP marks an improvement from previous IRPs in certain respects. Importantly, this IRP accounts for some recent developments in technology costs and plant performance.[77] In addition, the IRP makes use of PLEXOS, a well-respected, industry-standard IRP model. However, there are many ways in which the 2018 IRP falls short of IRP best practices. Some of the IRP's most glaring flaws include:

- **An unreasonably high load forecast.** Rather than learning from previous experiences over-forecasting load, the Department relies on a flawed load forecasting methodology that ignores a variety of important recent trends in electricity demand. As a result, the IRP is likely to result in the procurement of unnecessary generating capacity that will be paid for by—but not useful to—electricity consumers.

- **Unreasonably high cost projections for renewables and battery storage.** The IRP does not adequately account for recent and projected declines in the costs of solar, wind, and battery storage resources. The overstated cost projections are particularly extreme for battery storage, a technology that continues to experience rapid cost declines.

- **Inadequate evaluation of existing units and planned unit additions.** The Department treats retirement dates for existing units and online dates for previously contracted units as fixed assumptions. Instead, it should have allowed its model to determine economically optimal retirement dates and resource procurements, based on the latest information available.

[77] 2018 IRP, p. 10.

- **Poorly supported fuel price assumptions.** Most of the IRP scenarios assume that gas prices stay flat in real terms, without providing any support for that assumption. Instead, the IRP should include base fuel price forecasts that are grounded in an independent market analysis and should explore the impacts of fuel price sensitivities that are also tied to potential future market scenarios.

- **Unsupported renewable build limits.** The IRP imposes poorly justified limits on the construction of new renewable resources.

- **Inadequate consideration of environmental impacts.** The IRP does not incorporate a sufficiently aggressive climate policy. The IRP also does not adequately consider the impacts of electricity generation resources on water consumption and water quality.

- **Disconnect between modeling findings and resource plan.** The proposed resource plan calls for the addition of more than 6,500 MW of new coal capacity over the next six years, including 1,000 MW that has not already been contracted. Yet none of the optimized IRP modeling scenarios involve the construction of any coal capacity during the 2020s. This remarkable, unexplained disconnect runs counter to the purpose of an IRP.

- **Limited public documentation of analysis.** Under most jurisdictions that undergo IRP processes, stakeholders have access to a broad array of information relevant to the IRP. This information typically includes several types of input and output data that were not provided along with the draft 2018 South Africa IRP.

We recommend that the Department promptly revisit the IRP to correct for these deficiencies and refrain from using the IRP as a basis for resource procurement and retirement decisions until it has corrected these flaws.

APPENDIX A: ABOUT THE AUTHORS

Synapse Energy Economics is a research and consulting firm specializing in energy, economic, and environmental topics. Since its inception in 1996, Synapse has grown to become a leader in providing rigorous analysis of the electric power and natural gas sectors for public interest and governmental clients. Synapse's staff of 30+ includes experts in energy and environmental economics, resource planning, electricity dispatch and economic modeling, all-sector emissions modeling, energy efficiency, renewable energy, transmission and distribution, rate design and cost allocation, risk management, cost-benefit analysis, environmental compliance, and both regulated and competitive electricity and natural gas markets. Synapse's staff has provided expert assistance on integrated resource planning proceedings in dozens of U.S. states and territories. In addition, Synapse has helped draft integrated resource planning rules on behalf of the Puerto Rico Public Service Commission and worked with the U.S. Environmental Protection Agency (EPA) to draft guidance on state planning processes for regulatory compliance. Synapse staff authored a highly-cited IRP Best Practices guide, as well as EPA's Guide to Action chapter on resource planning practices.

Avi Allison is a Senior Associate at Synapse, where he provides consulting and research services on a wide range of issues related to the electric industry. His work focuses on energy resource planning, economic impact analysis, rate design, and wholesale capacity markets. Mr. Allison has reviewed, analyzed, and commented upon electric resource planning proposals as part of regulatory proceedings in the states of Michigan, Washington, Oregon, Idaho, Wisconsin, Indiana, Ohio, and Arizona. His work on IRPs has included evaluation of load forecasts, fuel price assumptions, modeling frameworks, environmental compliance cost assumptions, existing plant economics, and future capital cost assumptions, among other issues. Prior to joining Synapse, Mr. Allison was a research assistant at the Yale Center for Environmental Law and Policy. Mr. Allison has a Master's in Environmental Management from Yale University and a Bachelor's degree in Economics from Columbia University.

Rachel Wilson is an energy policy and economics analyst with more than a decade of experience in both utility resource planning and energy systems modeling. Her work at Synapse focuses on evaluation of the need for new energy infrastructure, power plant economics, and compliance with environmental regulations. Ms. Wilson performs analyses of electric power systems using industry-standard optimization and electric dispatch models in support of a wide range of projects on topics relating to electric and gas utility resource planning and evaluation of the need for new electric and natural gas infrastructure. She has direct experience with many optimization and electricity dispatch models, including Strategist, PROMOD, PLEXOS, and EnCompass. She uses them to analyze regional energy markets and to evaluate the modeling analyses performed by utilities. Ms. Wilson has served as the primary modeling specialist in several recent Synapse projects and has testified as an expert witness on issues relating to resource planning and energy systems modeling before the public utilities commissions of Washington, Texas, Oklahoma, Missouri, Indiana, Wisconsin, Kentucky, and Minnesota. As part of her work on utility resource planning, Ms. Wilson co-authored the widely-cited Best Practices in Electric Utility Integrated Resource Planning: Examples of State Regulations and Recent Utility Plans, prepared for the Regulatory Assistance Project, and contributed to the chapter on resource planning in EPA's Guide to Action. She has also presented on integrated resource planning at the Institute of Public Utilities' Grid School, which is intended to educate state utility commissioners and their staff, in both 2017 and 2018. Ms. Wilson holds a Master of Environmental Management from Yale University and a Bachelor of Arts in Environment, Economics, and Politics from Claremont McKenna College.

Devi Glick provides research and consulting services on a wide range of energy and electricity issues. Her recent work includes modeling for resource planning using PLEXOS and EnCompass utility planning software and assessing the reasonableness of utility resource planning methodologies and assumptions. Prior to joining Synapse, Ms. Glick worked at Rocky Mountain Institute as a Senior Associate on its Electricity and Energy Access programs. As a member of the Energy Access program, she developed IRP modeling tools and carried out trainings for the utility and energy ministry in Rwanda on best practices for long-term resource planning in the electricity sector. Ms. Glick also led a project evaluating long-term utility resource planning trends in the United States. Ms. Glick holds a Master of Public Policy and a Master of Science in Environmental Science from the University of Michigan, and a Bachelor of Arts in Environmental Studies from Middlebury College.

Jason Frost recently joined Synapse as a Research Associate after earning his Bachelor of Science in Physics from Stanford University. While at Stanford, Mr. Frost modeled optimal charging of electric vehicles on campus. Additionally, he worked on academic projects related to the variation of Locational Marginal Pricing (LMP) for buses in California and the value of utilizing capacity markets. Mr. Frost spent three summers working on applied physics research, most recently at Lawrence Berkeley National Laboratory. At LBNL he modeled the movement of electrons in thermoelectric materials, which can convert heat into electricity. He has also conducted research in Stanford's Department of Electrical Engineering and at the MIT Kavli Institute for Astrophysics and Space Research.