MEDIUM-TERM SYSTEM ADEQUACY OUTLOOK 2022 - 2026

30 OCTOBER 2021

Generation System Adequacy for the Republic of South Africa

Image: National Control Centre

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CONTENTS

1 INTRODUCTION

The South African Grid Code (SAGC: System Operator Code August 2019) requires that the System Operator, on or before 30 October of each year, publish a review (*called the* ***Medium-Term System Adequacy Outlook*** *or* ***MTSAO***) of the adequacy of the integrated power system to meet the requirements of electricity consumers. The objective of the MTSAO is to assess, over a five-year period, in this case for the 2022 to 2026 calendar years, the electricity supply shortfall risks that may arise based on foreseeable trends in demand and generation capacity in South Africa.

In so doing, the System Operator is required to take into account:

- possible scenarios for growth in the demand of electricity consumers. The expected demand includes South Africa's demand plus exports to neighbouring countries;
- possible scenarios for growth and/or decline in generation resources available to meet the expected demand. This includes all the generation resources licensed by NERSA plus imports from neighbouring countries, demand-side management resources, and distributed generation;
- possible scenarios for new and committed generation projects; and
- any other information that the System Operator may reasonably deem appropriate.

The MTSAO report is meant to identify and trigger warnings when security of supply faces risks. In particular, the outcomes of the assessment inform:

- consumers of the depth of the risk, that is, the amount and nature of demand not served;
- consumers of the likely timing of supply risks, be it the time of day (based on whether the gap is baseload or peaking) or the time of year (winter or summer months);
- policymakers with foresight to procure sufficient generation resources, that is, when and how much additional capacity is required to meet expected demand; and
- consumers with the opportunity to prepare for possible interruption in supply.

However, the MTSAO does not optimise in terms of the type and timing of capacity required to close the supply gap, if any. This type of capacity planning is carried out by the Integrated Resource Plan process. Also, the MTSAO does not assess the adequacy needed to transport and distribute electricity; therefore, the detail of the location of any supply shortages that may be localised due to the pattern of supply loss and how it interacts with the transmission and/or distribution system is not assessed.

2 METHODOLOGY

Detailed input data is required to model South Africa's integrated power system for the purpose of adequacy assessment. The data and information used are collected from credible sources and are of good quality; however, some of the key input data such as unplanned outages, self-dispatchable generation resources, and energy demand forecast are the main parameters prone to stochastic volatility. These variable objects form the basis of stochastic modelling, with a defined number of samples to resemble their random nature.

The MTSAO stochastic simulation applies computerized mathematical techniques that allow the quantification risk based on the Monte Carlo principle, the outcome of which is the probability distribution of the expected values of reliability indices. The number of simulation samples is a balanced trade-off between simulation runtime, input-output convergence, and quality of results. The process methodology used in the adequacy assessment is shown in **Figure 1** below. Other uncertainties such as the likelihood of a certain event occurring are accounted for through scenario modelling and sensitivity analysis.

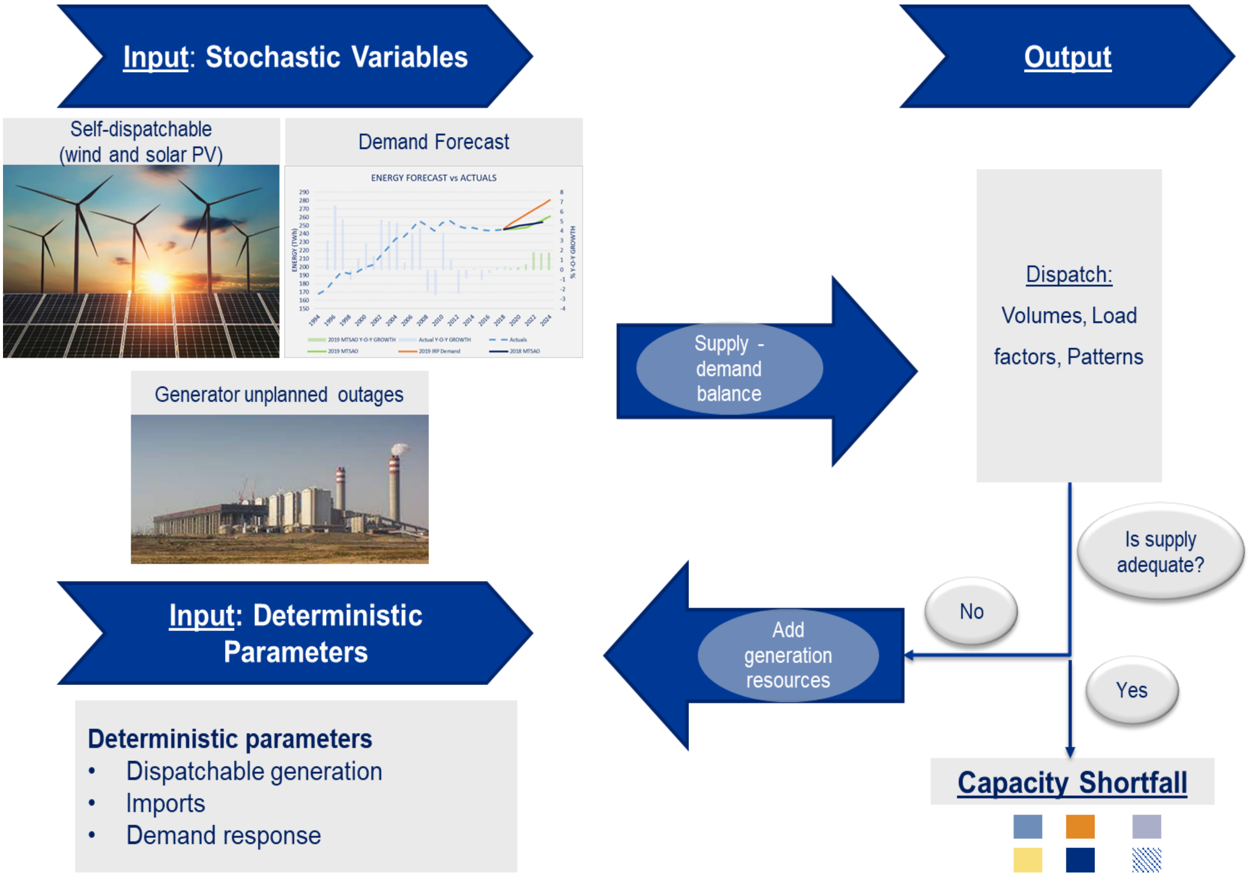


Figure 1: MTSAO methodology

In order to balance supply and demand, available supply resources are dispatched according to the merit order, subject to certain constraints. The outcome of this assessment is considered adequate when all three of the following metrics are met:

1) **Unserved energy** is less than 20 GW per year.
2) The capacity factor of a **contingency baseload station** is less than 50%.
3) The capacity factor of **open-cycle gas turbines** (OCGTs) is less than 6%.

In the event that any of the adequacy metrics are not met, additional capacity is added iteratively until all the adequacy metrics are met. The capacity options added to get to an adequate system are quantified per year and classified as baseload, mid-merit, or peaking capacity in MW, depending on the capacity factor required by the system for this resource.

3 KEY ASSUMPTIONS

This section details key assumptions used in the development of the MTSAO 2021. Due to the level of uncertainty surrounding both the demand-side and supply-side assumptions, a cone is provided, where possible, to assess a range of future realisations.

3.1 Electricity demand

3.1.1 Energy demand forecast

Three demand forecasts were developed for consideration in the MTSAO 2021, as shown below in **Figure 2**. The bottom line (yellow) is derived from Eskom's sales projections from customers as an input, taking into account volume and timing of potential extensions and/or shutdowns of customer operations. This demand is similar to the 2020 actual demand of 229 TWh reported by Statistics SA (Stats SA, 2020), and was thus deemed too low for the purposes of assessing the adequacy of a power system.

The other demand forecasts (dark and light blue) were derived within Eskom Transmission, based on GDP projections as inputs. The light blue line, termed "moderate demand", has an average annual growth rate (AAGR) of 0,7% from 2022 to 2026. The dark blue line, with an average annual growth rate of 1,4%, anticipates much higher recovery following the COVID-19 pandemic from 2023.

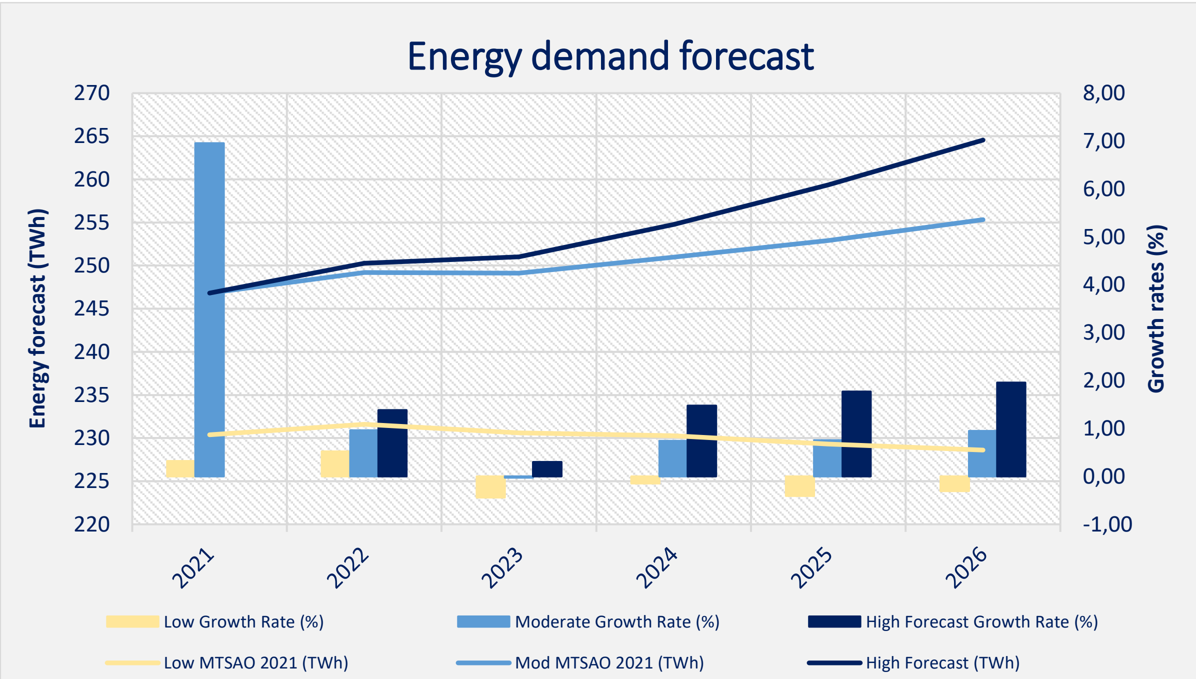


__Figure 2__: Possible energy demand forecasts

3.1.2 Impact of COVID lockdowns on electricity demand

Observation of the 2021 year-to-date (YTD) actuals shows a demand tracking 2019 actuals closely, suggesting a V-shaped bounce-back from the decline in 2020. This return to normal effect is also evident in the growth in GDP which suggests a positive outlook for the MTSAO period. It is for this reason that the MTSAO opted to study the moderate demand as a base. The higher demand provides a greater test for the adequacy of the power system and assumes much higher growth.

3.1.3 Impact of load reduction on electricity demand

Eskom defines load reduction as switching off electricity if an area experiences a surge in electricity demand beyond what the network is designed for. This is done in order to protect infrastructure from overloading, which may lead to explosions. Load reduction differs from load shedding and/or curtailment which is instructed by the System Operator due to a shortage in supply to meet demand. Load reduction operation is conducted at Distribution level but is currently not reported. However, considering how constrained the South African power system is, the possibility remains that, without load reduction, the System Operator may have resorted to increased load shedding to stabilise the grid. For now, consideration of the high demand forecast in the MTSAO 2021 is considered sufficient proxy for increased demand.

3.2 Plant performance

Historical trend analysis based on the Eskom Data Portal (2021) and depicted below in **Figure 3** shows steadily increasing unplanned outages from 2017, with stabilisation after the COVID-19 lockdown of 2020. This stabilisation in unplanned outages coincides with the expected delay in improved plant performance of 12 to 18 months after the Reliability Maintenance Recovery Programme was undertaken on some stations early in 2020. However, stabilisation in unplanned outages suggests that other units not yet maintained have dropped in performance. Eskom plant performance has been deteriorating at ~-2,1% per year since 2019 (-6% over the past three years).

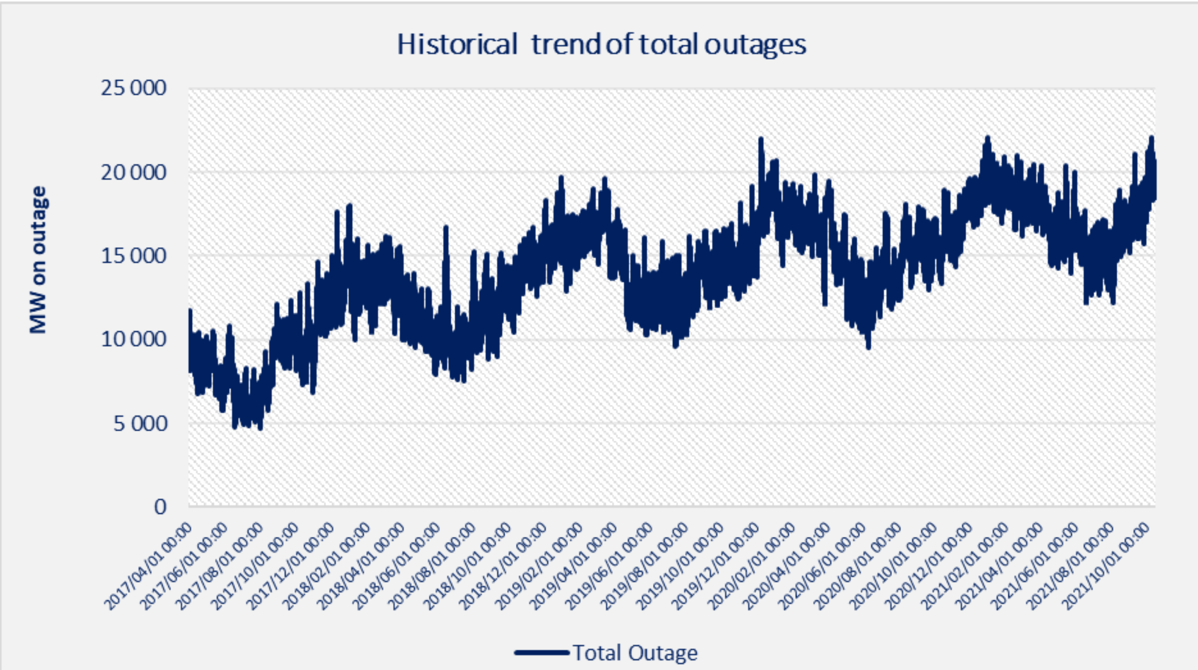


***Figure 3**: Five-year historical planned and unplanned maintenance*

The System Operator expects the downward trend in plant performance to continue in the medium term, fuelled by load losses and other heat-related incidences, particularly given that the current calendar YTD EAF was ~63% as at the week ending 10 October 2021. Therefore, a more likely low EAF, with an average of 63% for the MTSAO study period, is considered as the base case of the MTSAO 2021. A higher EAF, averaging 66%, that is aligned with Eskom Generation's plan was also considered for assessment, as shown in **Figure 4**. The EAF averaging 66% assumes that maintenance planned in the Reliability Maintenance Recovery Programme will be able to arrest decline in the plant performance.

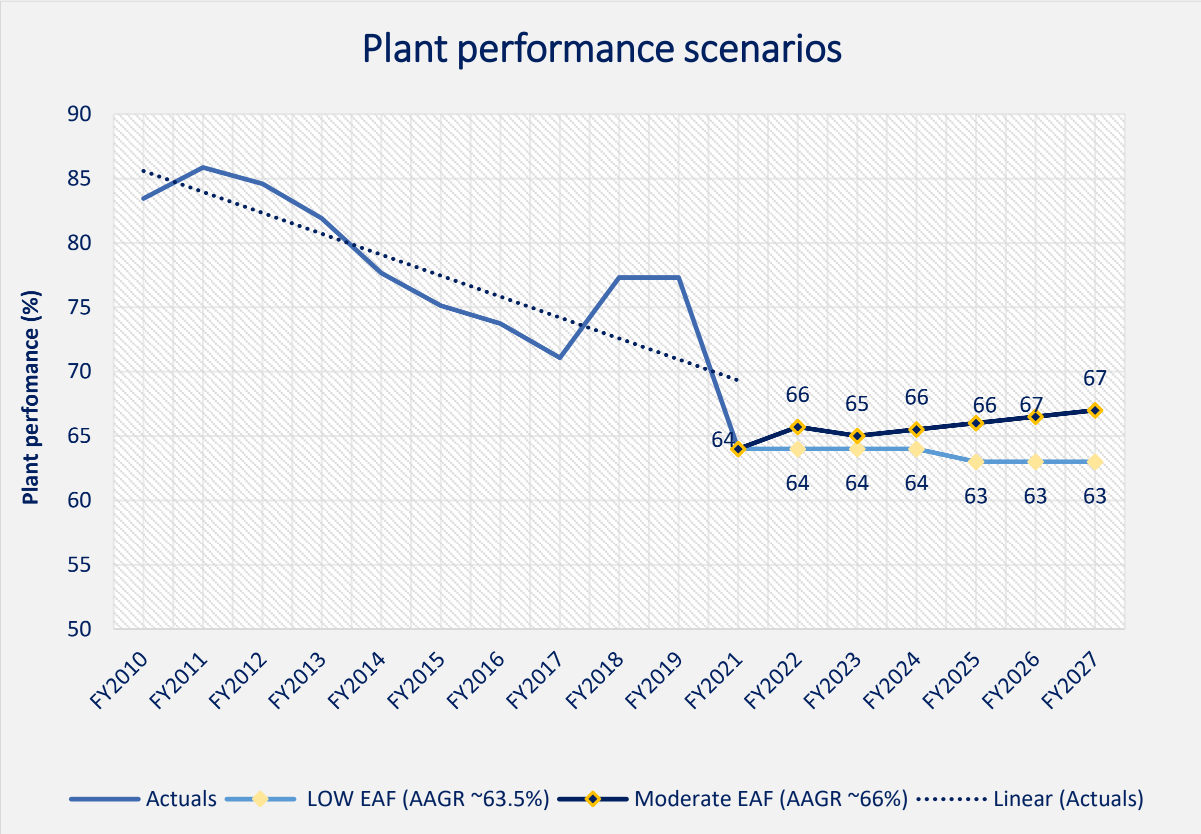


***Figure 4**: Eskom fleet energy availability factor (%)*

3.3 New build

Eskom new build capacity that has reached commercial operation since the last publication of MTSAO includes Kusile Unit 2, Kusile Unit 3, and Medupi Unit 1 in November 2020, April 2021, and August 2021, respectively. Although commercial operation of Medupi Unit 1 meant that the power station was fully operational, the MTSAO 2021 opted to reduce Medupi capacity with the recently damaged Unit 4 for the envisaged repair period of two years. The study assumed that this unit would return to operation in August 2023.

Additional units expected for commercial operation within the study horizon are three units of Kusile before the winter of 2024. The cumulative capacity from the remaining Kusile units and Medupi Unit 4 is shown in **Figure 5**.

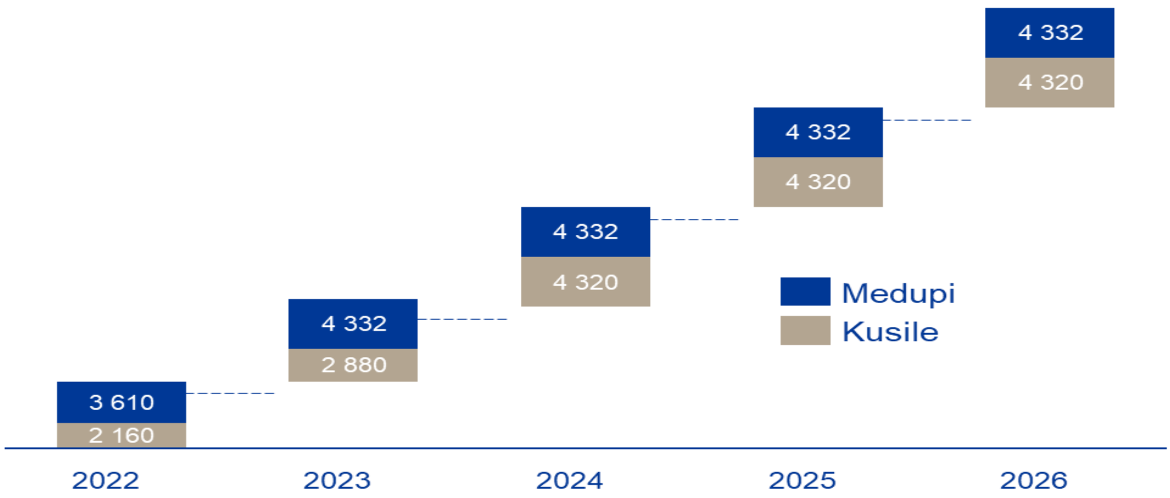


***Figure 5**: Committed new build cumulative capacity (MW)*

3.4 Plant retirements and shutdowns

The MTSAO 2020 assumed that units at Hendrina, Camden, Komati, and Grootvlei, as well as Arnot Unit 1, would shut down when reaching their turbine dead-stop dates (DSDs) and when it would no longer be economical to carry out the maintenance required in terms of the Occupational Health and Safety Act to keep them in service. However, statutory work has been carried out on some units to ensure operation of these units beyond their turbine dead-stop dates. **Figure 6** shows the assumed shutdown of units, with extension of dead-stop dates. In comparison to the MTSAO 2020, the MTSAO 2021 assumes that Arnot Unit 1 is scheduled to shut down beyond the study horizon instead of 2021. MTSAO 2020 assumed that Hendrina and Camden would remain with a single unit each by April 2023 (total 342 MW); the MTSAO 2021 assumes that 2 783 MW remains operational at the same time.

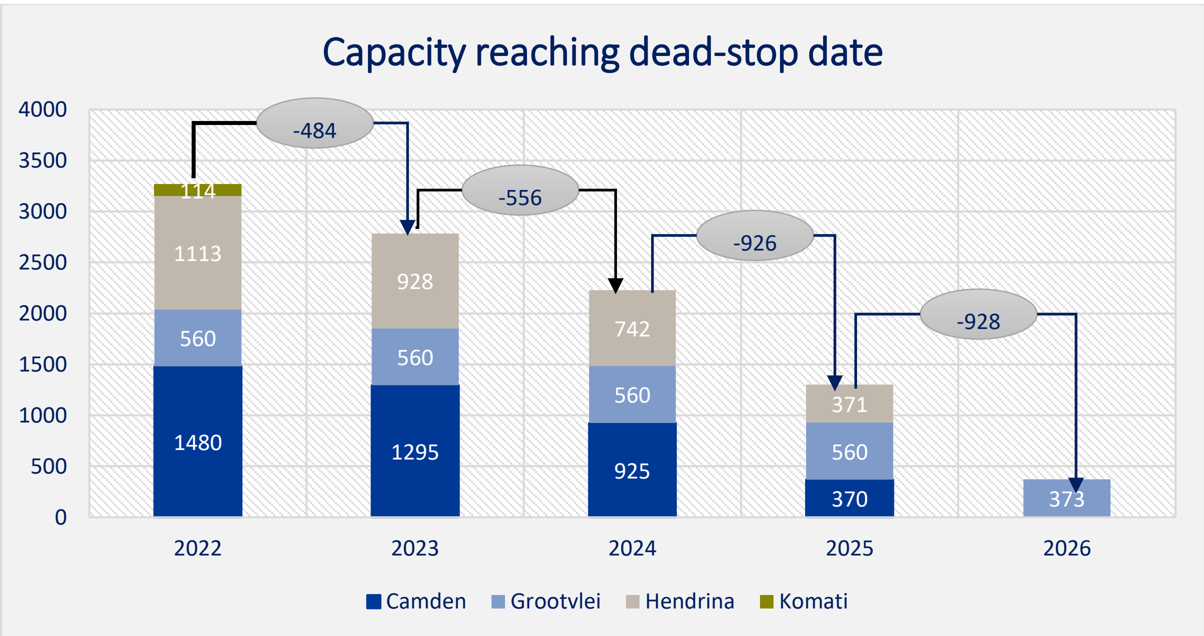


***Figure 6**: Capacity reaching dead-stop date (MW)*

Other coal-fired stations that are due for shutdown at 50-year life of plant during the MTSAO 2021 study period include Kriel Unit 1 in May 2026 and Arnot Units 2 and 3 by August 2026. The study also assumed that Duvha Unit 3 would remain unavailable throughout the study horizon.

Peaking power stations that reach end of life in this horizon are:

- Acacia, decommissioning between May and July 2026; and
- Port Rex, decommissioning between September and October 2026.

Koeberg Power Station would ordinarily reach its 40-year end of design life in 2024; however, in line with the IRP 2019, it is envisaged that all nuclear safety/regulatory licences and the steam generator replacement project will be expedited to extend Koeberg's life by an additional 20 years. No impact on the 1 860 MW capacity is assumed in the base case of MTSAO 2021. The potential delay in Koeberg life extension was considered as a risk and studied as a sensitivity.

3.5 Renewables from Independent Power Producer Programme

Committed capacity from the Renewable Energy Independent Power Producer Programme (REIPPP) up to Bid Window 4+ is considered as committed and is shown in **Figure 7** below. Indications are that commissioning of new renewable capacity as reported in the MTSAO of 2020 is on track to be realised by mid-2022.

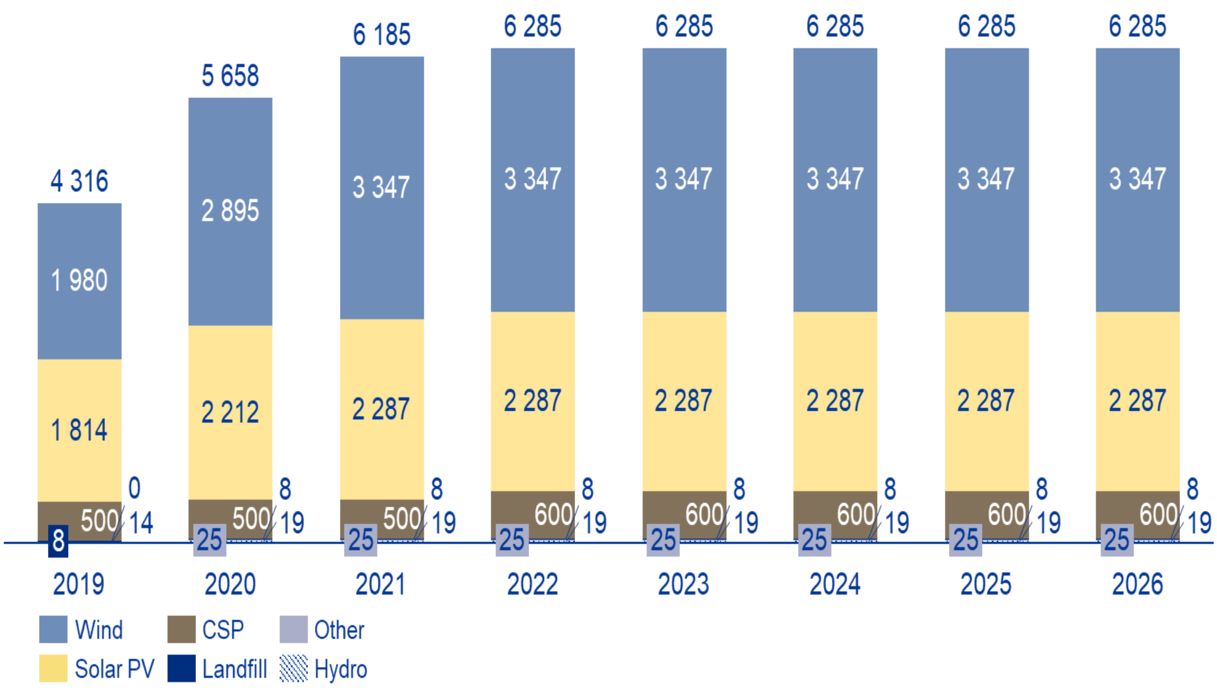


***Figure 7**: REIPPP cumulative committed capacity (MW)*

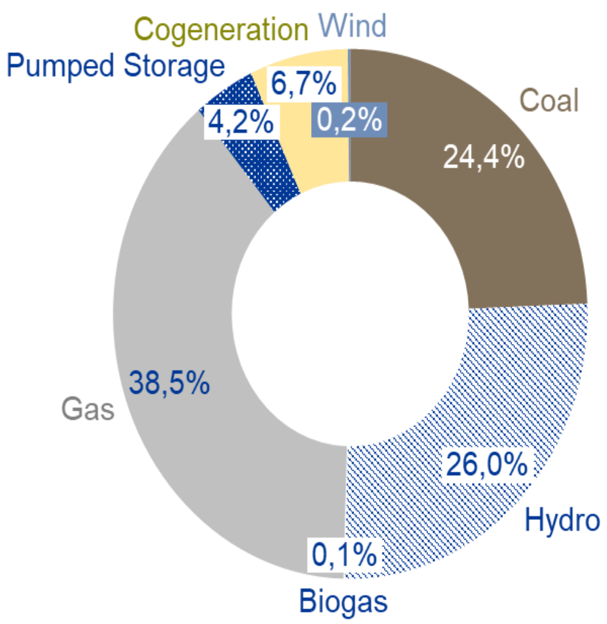
Additional determinations issued/to be issued by the Department of Mineral Resources and Energy in line with the gazetted IRP 2019 are not considered committed in the base case of the MTSAO 2021. However, these are considered as potential levers for identified supply shortages.

Existing renewable IPPs have a YTD energy production of 11.7 TWh as at week ending 10 October 2021 from an installed capacity of 5659 MW. It is envisaged that production from these resources could reach 15 TWh. When the current REIPPP installed capacity reaches 6285 MW, the programmes' energy output it is expected to reach 18 TWh per annum. Any unforeseen decline in this production will negatively impact power system adequacy.

Variable generation from wind and variable generation from solar PV plants were modelled as stochastic objects based on historical actuals. An aggregated regional profile was used for installations with a shorter operation period as well as for future installations.

3.6 Other NERSA licensees

Figure 8 below shows other generators connected to the grid, categorised by technology. The gas capacity includes 1 005 MW of DMRE IPP peaking plants at Dedisa and Avon, and the hydro capacity includes Cahora Bassa import. NERSA is currently processing applications for integration of ~200 MW from existing installations that seek to increase output. This is not finalised as yet, and NERSA agrees that the impact on the adequacy will not be significant.



Technology	Capacity (MW)
Coal	1052
Hydro	1121
Biogas	4
Gas	1661
Pumped Storage	180
Landfillgas	0
Cogeneration	289
Wind	7
Total	**4315**

***Figure 8**: Installed capacity of other non-Eskom generators*

The energy produced, excluding DMRE IPP gas peakers and Cahora Bassa import, was limited to ~11 TWh per annum throughout the study horizon based on historical trends. Due to the unavailability of data on plant performance of these generators, the MTSAO modelled typical plant performance based on plant of similar size and age. Given the tariff structure that typically applies to the self-generating entities, the study assumed high availability in the winter period. Any unforeseen decline in the production of these generators will have a negative impact on power system adequacy.

4 STUDY CASES

In its unpredictability, the South African power system is heavily sensitive to changes in the energy demand forecast and the Eskom plant performance. As a result, a combination of these parameters was studied, as shown in **Figure 9** below. The low demand forecast based on Eskom sales was considered too low to assess the power system adequacy. The high demand was studied against the moderate EAF, as this represents the best-case scenario from a demand-plant performance perspective.

The base case of the MTSAO 2021 is the most likely scenario, with low plant performance and moderate demand growth. This case was used to further assess adequacy over potential risks facing the power system. These risks are if Koeberg licence extension by the National Nuclear Regulator (NNR) is delayed (see Section 7.3) and if the coal stations that do not comply with the Air Quality Act are ordered to shut down (see Section 7.2).

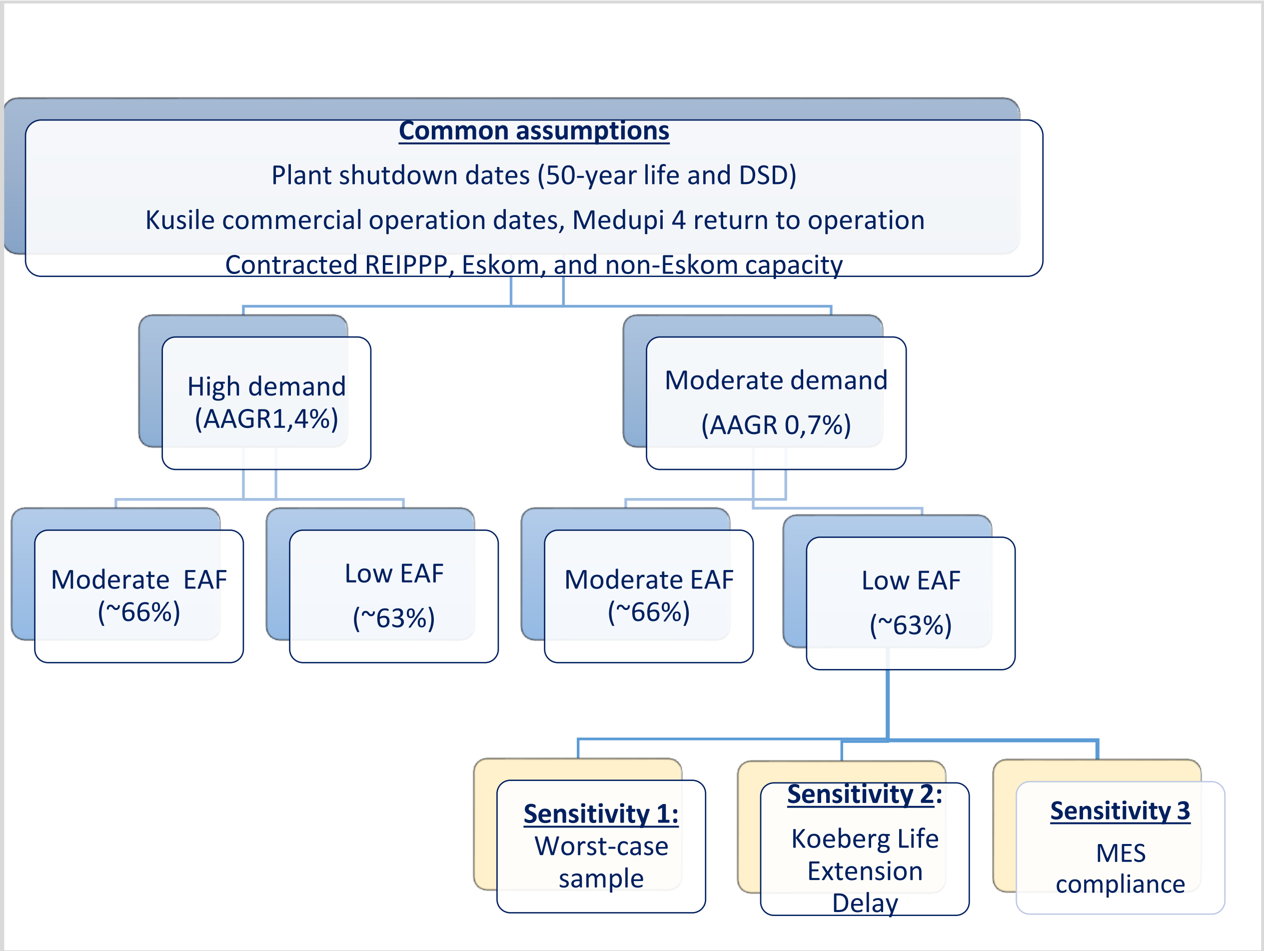


***Figure 9**: MTSAO 2021 study scenarios*

5 RESULTS

The results of the studied scenarios in **Figure 9** above are shown against the threshold for each adequacy metric in **Figure 10**, **Figure 11**, and **Figure 12** below.

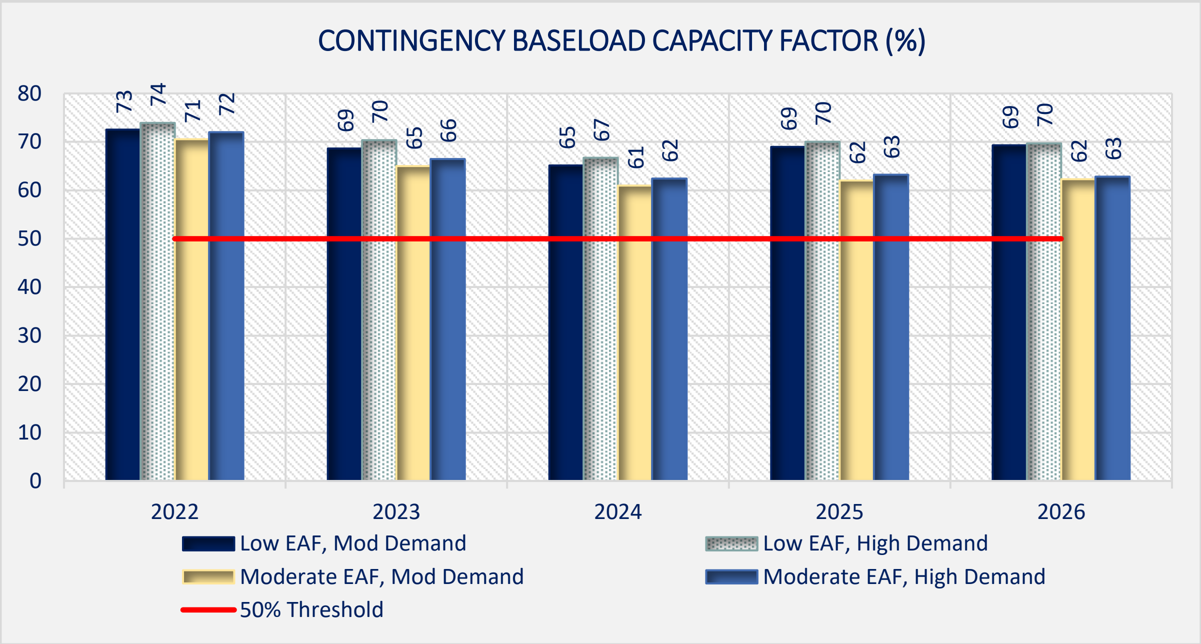


***Figure 10**: Base scenarios: contingency baseload capacity factor (%)*

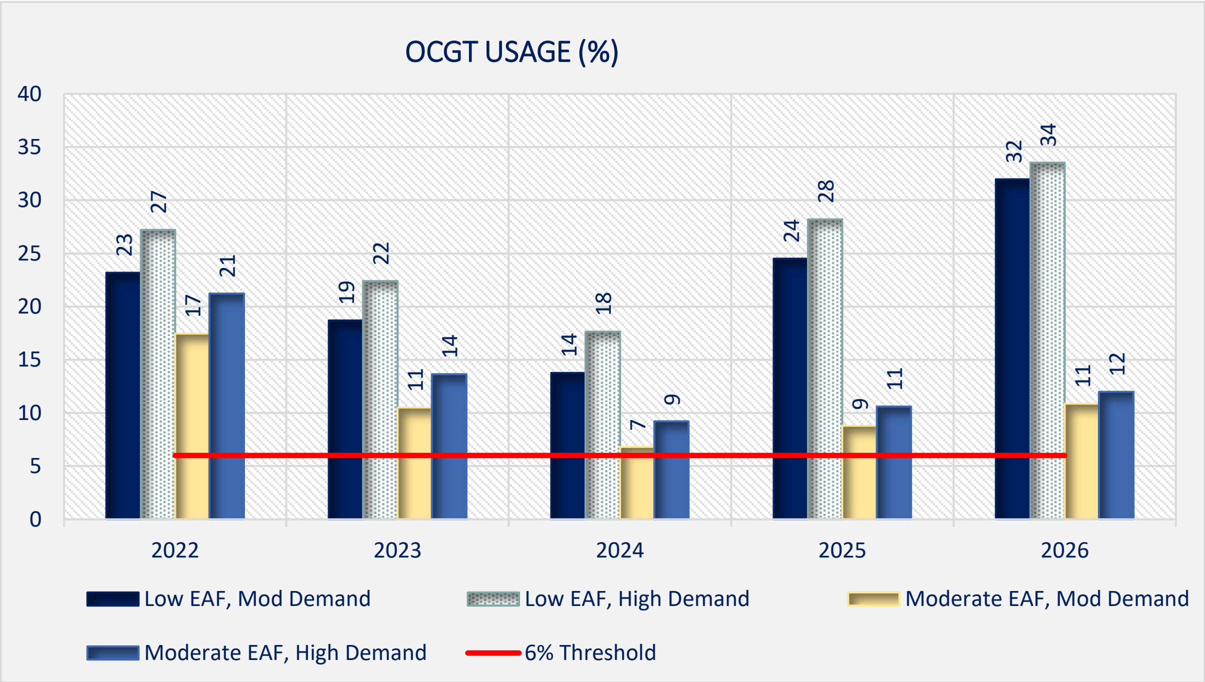


***Figure 11**: Base scenarios: OCGT capacity factor (%)*

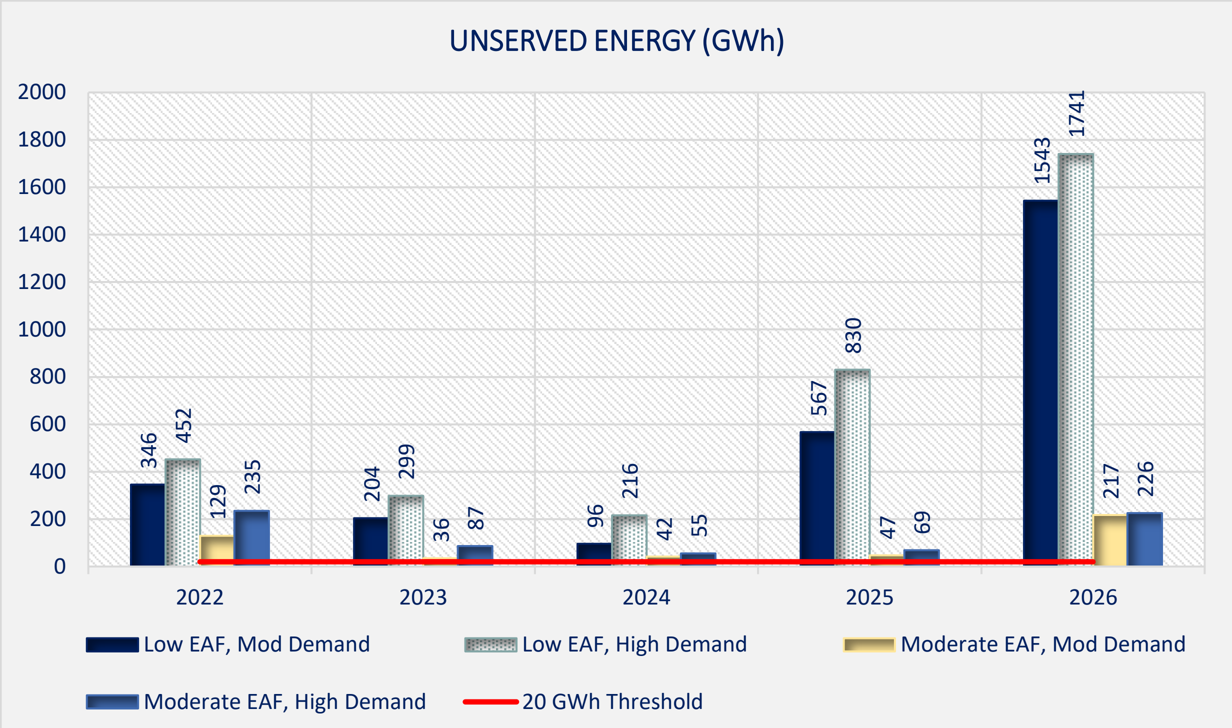


Figure 12*: Base scenarios: unserved energy (GWh)*

The results of the adequacy assessment show that, regardless of the scenario considered, the South African power system is severely constrained in the short to medium term, with all considered scenarios violating the baseload metric. This is to be expected considering that the current bouts of load shedding that the country is experiencing are not limited to the peaking period. Unserved energy and the OCGT capacity factor are also violated across the years, with expected improvement in year 2024 when additional capacity is commissioned. The last two years of study are more inadequate due to the shutdown of older coal-fired power stations while demand continues to grow, thus indicating a more pronounced requirement for new capacity.

It can, furthermore, be observed from the results that the system is more sensitive to changes in EAF than changes in demand growth. For instance, in 2026, a 9 TWh higher demand compared to moderate demand shows a marginal increase in inadequacy compared to an approximately 3,5% reduction in EAF between low and moderate sensitivities.

The study determined that only baseload capacity was required to restore the power system to adequacy for the moderate demand if the EAF were to follow the low or moderate trajectory. The magnitude of capacity required is depicted below in **Table 1**.

Table 1: *Baseload capacity requirement to close supply gap (MW)*

Scenario	2022	2023	2024	2025	2026
Moderate demand with low EAF	3 000	2 500	2 000	4 000	5 000
Moderate demand with moderate EAF	2 000	1 000	1 000	1 000	2 500

It can be observed that, at current EAF levels of 63% calendar year to date, capacity of between 2 000 MW and 3 000 MW is required between 2022 and 2024, while the last two years require capacity of between six and seven Medupi units. However, should the plant performance improve to an average of 66%, the requirement for additional baseload capacity can be reduced to no more than 2 500 MW. Any requirement for peaking capacity is insignificant and can be managed operationally by the System Operator.

6 POTENTIAL LEVERS TO CLOSE THE SUPPLY SHORTFALL

In closing the supply shortfall that was identified, the MTSAO 2021 assessed potential levers in the pipeline for development. In general, judgement on the expected commercial operation dates was applied based on up-to-date information from the IPP Office, Eskom's Single Buyer Office, Eskom's Project Development Department, and NERSA.

6.1 IRP 2019 determinations

The Bid Window 5 ministerial determinations (Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) Bid Window 5, 2021) were issued to the market in April 2021, in accordance with section 34 of the Electricity Regulation Act 4 of 2006. This process seeks to procure 2 600 MW of capacity, made up of 1 600 MW of onshore wind and 1 000 MW of solar photovoltaic. The DMRE expects to reach commercial close with preferred bidders by end 2021/beginning 2022, enabling a commercial operation date no later than 24 months after commercial close, or end 2023/beginning 2024. Thus, the MTSAO phased out the IRP 2019 capacity, assuming Bid Window 6 determinations would be issued such that commercial operation could occur in the year following Bid Window 5, in line with the gazetted IRP 2019.

Since the Bid Window 5 determinations do not make provision for storage, the 513 MW storage capacity in the IRP 2019 has been phased out. However, indications are that Eskom will procure 200 MW of battery storage, due for commissioning in 2024; IRP 2019 storage capacity was split to make provision for this. **Table 2** shows the phasing of the IRP 2019 capacity.

Table 2: *Phasing of IRP 2019 capacity (MW)*

Technology	2022	2023	2024	2025	2026
PV			1 000	1 000	
Wind			1 600	1 600	1 600
Battery			200		313

6.2 Risk Mitigation Independent Power Purchase Programme

In response to the short-term electricity supply gap identified by the IRP 2019 of approximately 2 000 MW between 2019 and 2022, the DMRE launched a Risk Mitigation Independent Power Producer Procurement Programme (RMIPPPP) to the market in August 2020 (Request for Information: Risk Mitigation Power Procurement Programme (RFIRMPPP), 2019). The System Operator stipulated that contracted capacity had to be dispatchable between 05:00 and 21:30 daily on instruction of the System Operator. In March 2021, preferred bidders were selected, and commercial close is expected in January 2022, previously September 2021.

Initial expectations were to connect to the grid at the latest by June 2022. However, the delays in the process have placed this date in jeopardy. In this regard, the MTSAO has categorised expected capacity as follows:

- *Gas Karpowerships, with a capacity totalling 1 220 MW.*

  These are self-contained floating power stations that operate on regasified liquified natural gas (LNG). Although they require much less time to deploy, the environmental impact assessment approvals are not in place. The commercial operation date was, therefore, moved out by six months to January 2023.

- *Hybrid technologies, with total capacity of 626 MW.*

  These technologies are similar to those that formed part of previous REIPPP bid windows; thus, similar timelines are expected. Taking into account the extension for commercial close, all 626 MW of this capacity is expected for commercial operation in June 2023.

- *Solar PV, with total capacity of 150 MW; selected a preferred bidder in June 2021.*

  Similar to the hybrid technologies, solar PV is expected to reach commercial operation in June 2023.

6.3 Self-generation: Estimated rooftop PV

Due to unavailability of centralised validated data, the extent to which rooftop PV is installed remains a challenge. There have been no revisions to the publications previously referenced. NERSA indicated that listing of installations on its database is lacking. It is for this reason that the MTSAO used the same estimations to assess the sensitivity of rooftop PV on system adequacy, that is, current installations based on AREP (2019) and future estimation based on the IRP 2019. The estimated capacity is shown in **Table 3** below.

***Table 3**: Estimated rooftop PV capacity (MW)*

Installed capacity (MW)	2022	2023	2024	2025	2026
SSEG rooftop projections	680	1 080	1 530	2 030	2 580

6.4 Impact of levers on adequacy

The impact on the adequacy metrics when levers are applied to the base case of the MTSAO is shown below in **Figure 15** for contingency baseload capacity factor, **Figure 14** for OCGT utilization and **Figure 15** for unserved energy.

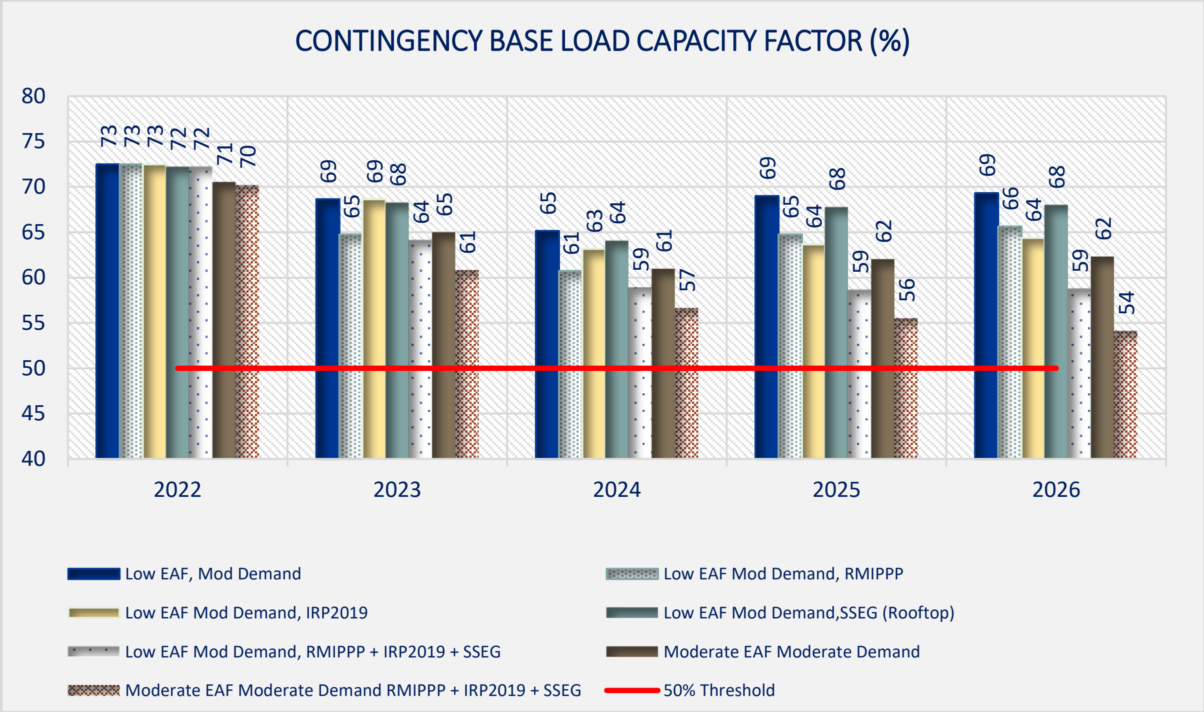


Figure 13*: Potential Levers: Contingency baseload capacity factor (%)*

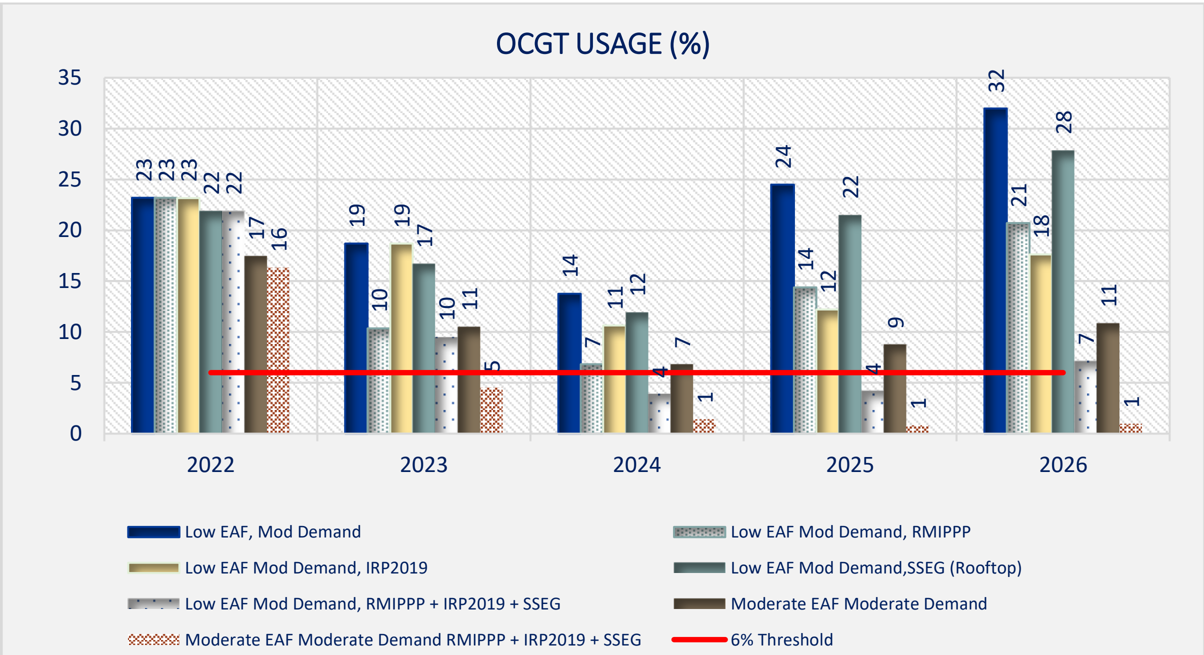


Figure 14*: Potential Levers: OCGT usage (%)*

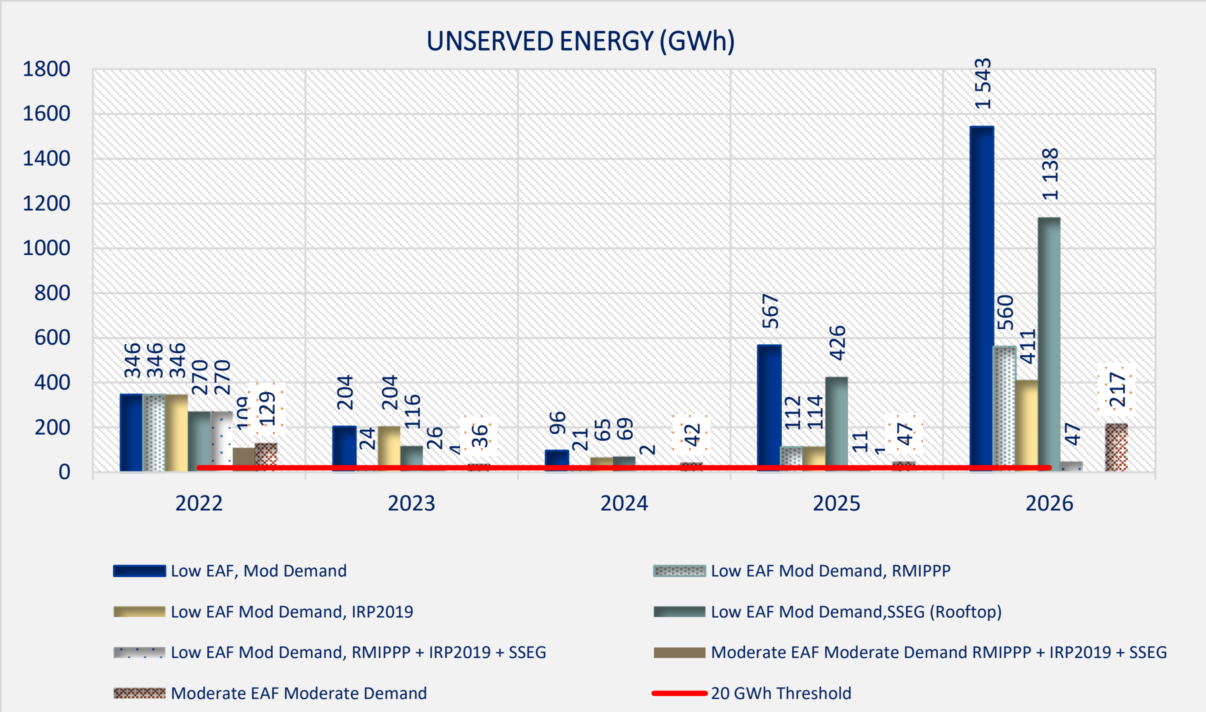


Figure 15: Potential Levers: unserved energy (GWh)

The results show that when each of the identified levers is applied individually, the impact on restoring the system inadequacy is insignificant. However, in the event that all levers materialise according to the assumed time frames, the unserved energy and OCGT usage metrics are reduced significantly. The baseload metric is still violated; this is to be expected, as none of these levers are of baseload type in nature.

Should a combination of all levers be realised, coupled with a 3% improvement in EAF, the baseload requirement is minimal while the unserved energy and OCGT usage metrics are not violated.

7 SENSITIVITIES

7.1 Worst-case sample

The results of Section 5 and 6 are based on the mean. Each sample is affected by variable parameters such outages, variable generation, and energy demand forecast. The mean outcome is the sum total of the results of all samples divided by the total number of samples. In analysing the worst probable case, the sample with the highest capacity on outage (planned and unplanned) is considered. Historical trends show total outages exceeding 20 GW in the last three years, as shown in **Figure 16** below. Indications are that this trend will continue into the future.

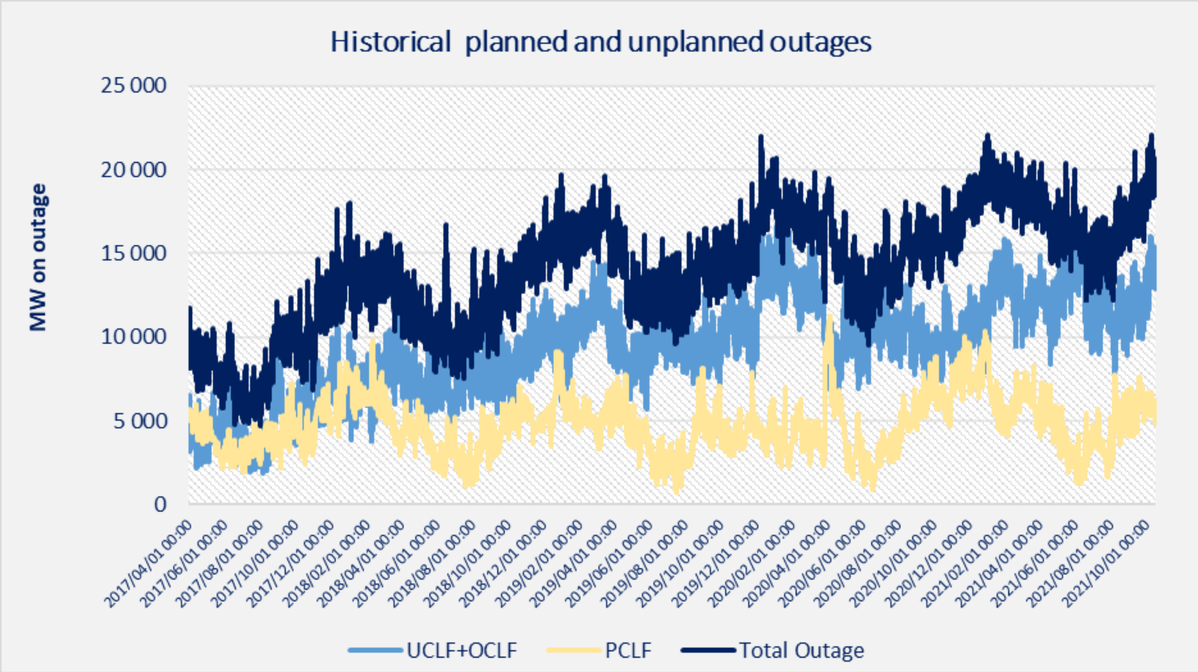
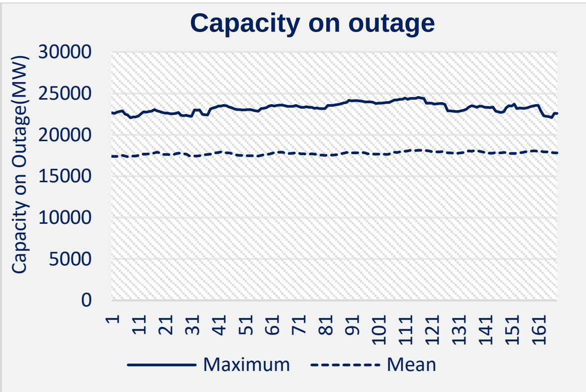
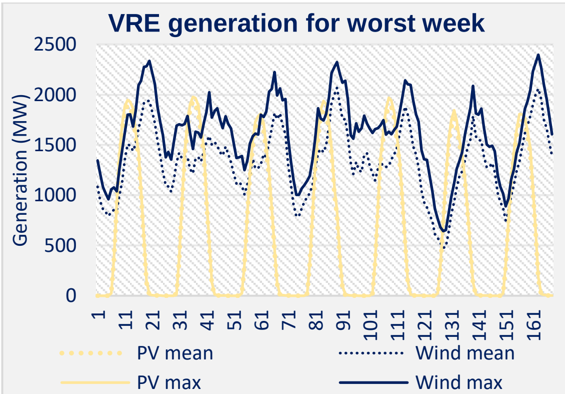


Figure 16*: Historical capacity on outage (MW), 2017 to 2021 YTD*

Figure 17 below depicts the three variable objects mentioned above for 168 hours of the worst week.





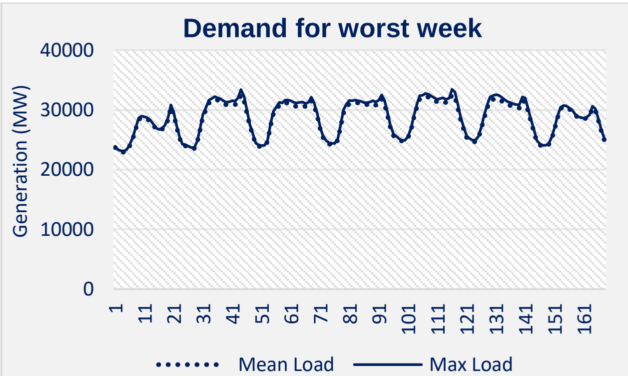


Figure 17*: Variable parameters during the worst week*

The demand forecast and solar PV show no variability compared to the mean. Wind generation is higher than the mean by no more than 800 MW, while the outages are up to 8 000 MW more than the mean. This indicates that variability of outages has a much bigger impact on the power system adequacy, as seen in the worst unserved energy shown in **Figure 18**. Higher outages are typically observed in summer months for Eskom plant because planned outages are scheduled during off-peak months, at which time there is a high likelihood of unplanned outages due to heat- and vacuum-related incidences.

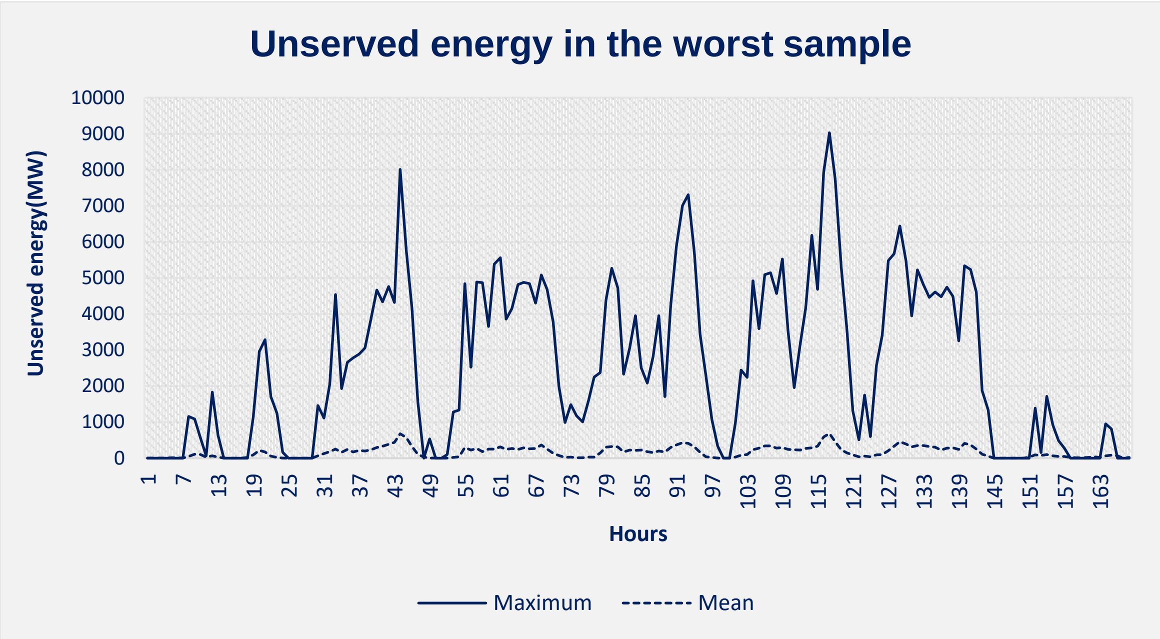


Figure 18*: Worst observed unserved energy for year 2022*

In case the events of the worst week materialise, the adequacy of the system will be severely affected, with a high likelihood and frequency of demand exceeding supply. This may result in a higher stage of load shedding.

7.2 Koeberg life extension

With regard to Koeberg Power Station, the IRP 2019 acknowledged that “it reaches end of design life in 2024. In order to avoid the demise of the nuclear power in the energy mix, South Africa has made a decision regarding its design life extension”. The IRP 2019, furthermore, recognised that Eskom was at an advanced stage with technical work required for the extension of the life of Koeberg plant, which would enable Eskom to apply for the necessary approvals to extend its nuclear operating licence with the National Nuclear Regulator (NNR). However, if Eskom’s preparations are significantly delayed such that the NNR submission deadline is delayed or if the NNR does not grant the nuclear licence to operate Koeberg beyond 2024 when the current operating licence expires due to insufficient resolution of preparatory issues, that will lead to a loss of at least 1 860 MW, resulting in a deficit in capacity and grid constraints. As a sensitivity, the MTSAO 2021 simulated a case without Koeberg for a period of two years, that is, Koeberg Unit 1 from July 2024 and Unit 2 from November 2025, returning to service beyond the study period.

The results shown in **Figure 19** indicate that the impact of Koeberg unavailability on the adequacy of the power system, benchmarked against the base case, is negative from 2024. This impact increases further in 2025 and is worse in 2026, where the base case was already heavily constrained. This is to be expected considering that Koeberg Power Station is a baseload station that performs well.

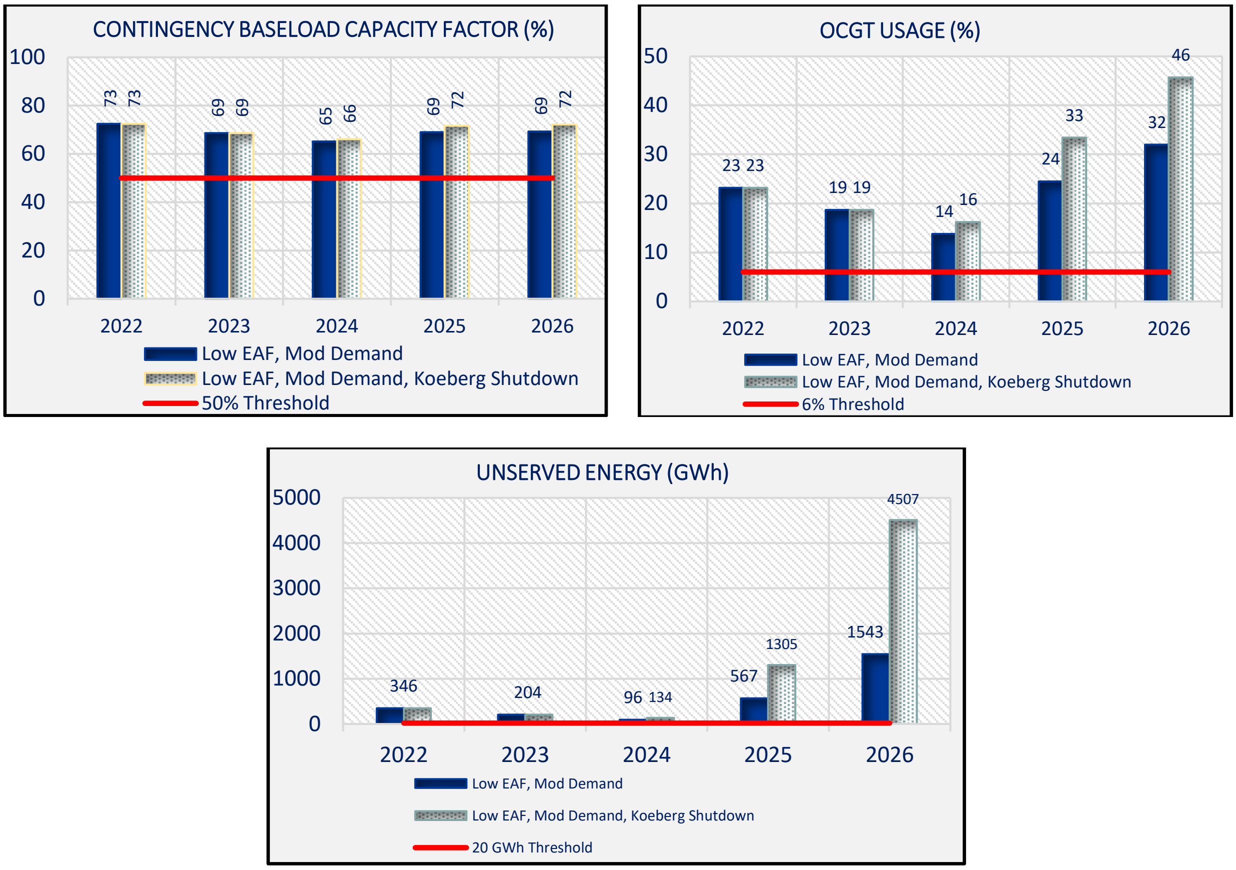


***Figure 19**: Impact of Koeberg shutdown on adequacy metrics*

7.3 Minimum emission standards

The MTSAO 2020 highlighted as a risk the likelihood that some Eskom power stations would not comply with the minimum emission standards (MES) required by the National Environmental Management: Air Quality Act (NEMAQA) 39 of 2004 (DFFE: NEMA, 2005). The NEMAQA gazette stipulated that all existing plants had to comply with the MES limits for new plant by 1 April 2020, unless granted a:

- **postponement**, limited to a maximum period of five years and/or up to 31 March 2025; or
- **suspension**, applicable only to existing plants due for decommissioning by 31 March 2030, and the application for suspension had to be made by 31 March 2019.

In its 2019 application to the Department of Forestry, Fisheries, and the Environment (DFFE), Eskom requested:

- suspensions for operations at Arnot, Camden, Grootvlei, Hendrina, and Komati that were due to be decommissioned before 2030. Subject to submission of decommissioning plans. Indications are that suspensions and alternative air quality limits will be granted at these power stations until decommissioning; and

- postponement and/or suspension at other power stations, based on cost-benefit analysis as well as realistic retrofit project scheduling. If these applications are not granted, Eskom will be non-compliant with:

    - NO_x, which requires complete shutdown of stations, and particulate matter (PM), which can be managed by operating the station below its maximum continuous rating (MCR). The immediate risk of such a decision is loss of ~18 GW baseload capacity, a 47% loss of the 38 GW installed coal capacity; and

    - SO_2 limits by 2025 at multiple stations. Since no station is able to meet the new SO_2 limits without flue gas desulphurisation (FGD), the practicality of such a decision is that only the older stations with MES exemptions until 2030 can operate after 2025 when standing MES postponements lapse, resulting in capacity losses of ~32 GW which is 80% of the ~40 GW envisaged installed coal capacity in 2025.

Realistically, projects to retrofit units for MES compliance are undertaken at intervals that coincide with general overhaul outages; thus, the risk of not retrofitting in time is unavoidable. Given that minimum generation from coal-fired stations in 2019 was 16 GW and about 14 GW in 2020 (during Covid-19 national lockdowns), the MTSAO 2021 did not model the impact of losing capacity in any of the potential eventualities as severe inadequacy can be inferred.

8 CONCLUSION

- The state of the power system is fragile and has been this way for a number of years. This study concludes that the power system will remain constrained for the foreseeable future due to the following:

    i) ***Poor performance***, particularly of coal-fired stations. While older stations are prone to failures that are a result of a prolonged poor maintenance regimen, new stations (Medupi and Kusile) suffer low reliability due to design defects. In addition to technical performance of the generating stations, there are other risks that could lead to loss of capacity, such as minimum emission standards and operating licences not being issued on time.

    ii) Lack of options with ***shorter lead times*** in the short to medium term. Although the licence threshold for generating facilities was lifted for those up to 100 MW, many uncertainties remain as to when these resources will be available to the national grid, if at all, in the period of assessment. It is also unlikely that these will sufficiently arrest the inadequacy of the power system, as the study determined that some form of baseload capacity was required in the short to medium term, regardless of the possible plant performance trend or demand forecast.

    iii) Lack of ***economical options*** to remedy the situation. Due to the magnitude of the supply gap and the urgency required to resolve the inadequacy, options available within these lead times are unlikely to be economical. A case in point is the minimum bid price above R1,40c/kWh from preferred bidders of the RMIPPPP announced in March 2021.

- If the trend of outages over the summer months continues to increase as observed in the historical data, the threat to security of supply is expected to be exacerbated. Improvement in the EAF remains the largest lever to restore system adequacy. Eskom continues to drive its Reliability Maintenance Recovery Programme on the coal-fired generation fleet to reduce the levels of unplanned maintenance. Although the impact is not seen across all units as yet, the drive is certainly a step in the right direction.
- Delays or failure to extend the life of Koeberg Power Station beyond its 40-year operating life will materially affect the adequacy of the power system. This is similarly true if coal power stations not compliant with the MES are shut down.
- The first two years of the study are expected to be severely constrained due to poor plant performance already experienced in recent years. There is an improvement in the year 2024 when Kusile Power Station becomes fully commercial, albeit the low EAF. The last two years of the study worsen due to around 3 000 MW of capacity of aging coal-fired stations being shut down, while demand continues to grow.

9 RECOMMENDATIONS

In order to minimise load shedding and restore power system adequacy in the medium term, the MTSAO 2021 recommends the following:

- Ensure that there are no delays in the commissioning of the new build programme and that the process to address design defects at Medupi and Kusile does not just continue as planned, but also yields improved performance.
- Improve plant performance of Eskom fleet, as this remains the largest lever to restore system adequacy by expediting the Reliability Maintenance Recovery Programme to improve predictability of performance in the future.
- Considering the lack of credible options in the short to medium term, place more emphasis on extending the life of Koeberg Power Station and on ensuring that compliance with the MES does not result in capacity shutdown.
- Expedite identified levers in the form of the IRP 2019 and RMIPPPP, and if possible, identify and implement more levers that are economically feasible.

10 RISKS OVER THE MEDIUM TERM

- *Dead stop dates*
  The MTSAO 2021 assumed that stations reaching their dead-stop dates would continue operating beyond this date. However, given the age of the affected stations and the intent to minimise maintenance expenditure with a view to redirecting the bulk of the funds to stations with much longer remaining life, there is a risk that those stations reaching their dead-stop dates may break down earlier than anticipated. **Figure 20** shows the impact of this eventuality, where more than 3 000 MW (blue bar) is shut down in March 2025 compared to that used in this study (red line). Although the capacity assumed in the MTSAO 2021 base case is slightly lower than the blue bar up to March 2025, the results of the MTSAO 2021 show that years 2025 and 2026 are severely constrained and that extension of the dead-stop dates assists in reducing the inadequacy.

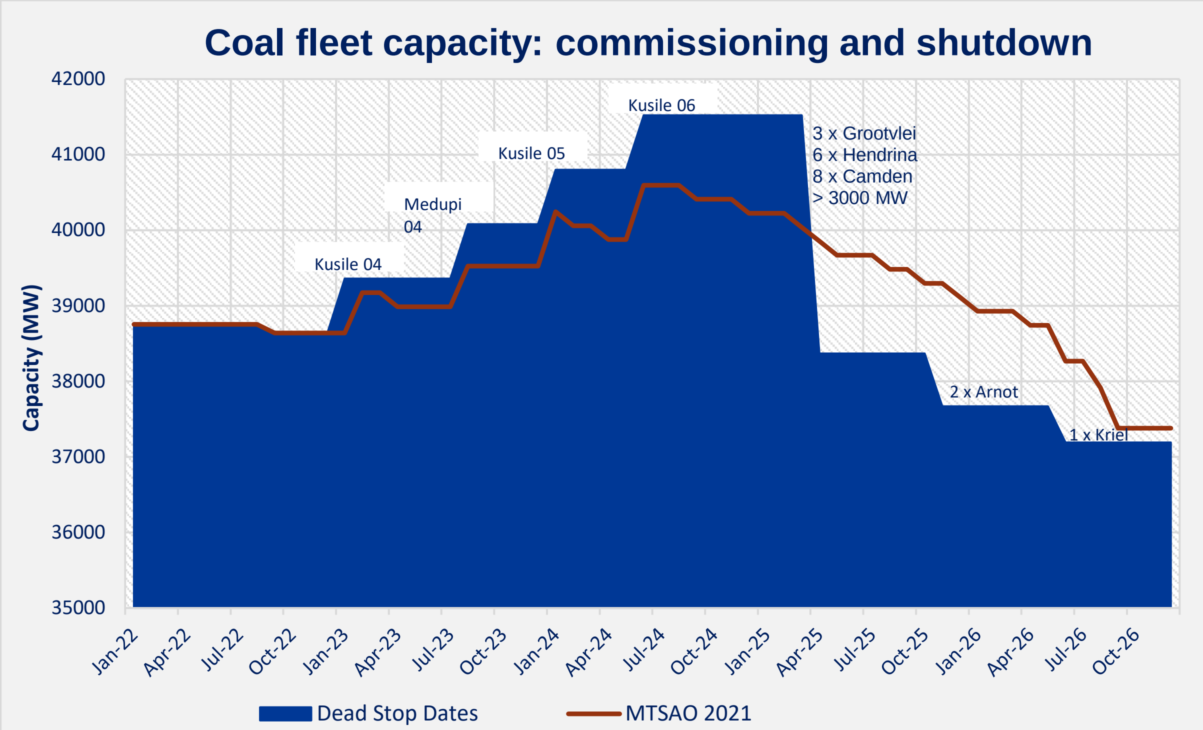


***Figure 20**: Potential shutdown scenarios*

- *Plant performance*
  The coincidence of planned and unplanned outages occurring at the same time, typically in the summer months when planned maintenance is ramped up and unplanned outages increase, remains a risk. Although the Reliability Maintenance Recovery Programme was undertaken in 2020, this did not extend to all stations. As a result, the overall improvement in EAF is insignificant.

- *Minimum emission standards*
  Some Eskom coal stations are non-compliant with the Air Quality Act and could be forced to shut down. Such an eventuality will have a severe impact on the power system, and indications are that no credible resources are available to replace this capacity. Refer to Section 7.2 for more details.

- *Koeberg life stations*
  Eskom's intentions and attempts to extend the life of Koeberg Power Station might face possible delays that might result in a loss of 1 860 MW of baseload capacity, negatively affecting the adequacy of the power system. More details are discussed in Section 7.3.

- *New capacity*
  Since the publication of the IRP 2019, the pace of procuring new capacity online has been marked by delays. The MTSAO 2021 shows the impact that this has on the adequacy of the power system. Any further delays to the RMIPPPP and Bid Window 5 will exacerbate the current supply constraints.

11 FUTURE WORK

11.1 Impact of Distributed Energy Generators on demand forecast

The current methodology used to derive a forecast expresses some level of sensitivity linked to the demand, such as GDP, demography, and economic sector growth rates, energy efficiency gains, etc. However, the impact from the supply side, such as from distributed generation, is not fully captured due to the lack of credible information. Since it is inevitable that the impact of distributed generation on the power system will be experienced by the System Operator sooner than previously anticipated, particularly following proclamation of the 100 MW licence exemption, it is, therefore, crucial to develop realistic high-level sensitivities regarding the aforementioned elements.

Although installation of these resources will add much-needed energy to assist in meeting the shortfall, it is likely that installations will comprise variable resources that require increased system flexibility to deal with steeper ramping requirements and likely increased requirements in withheld reserve provision.

11.2 Contingency analysis

(EPRI, 2021) states that supply disruptions across the world have evolved in recent years, categorised into “extreme weather events, cyber/physical security, and failures that reflect a combination of factors, potentially including human error, fuel supply constraints”. The paper stresses the need to assess correlation of events and their impact on power system adequacy, that is, the frequency and duration of the outage. Although quantifying events for analysis may prove challenging, the principle can accurately be assessed using contingency analysis.

The South African Grid Code: Preamble (2019) defines a credible multiple-unit contingency trip as a loss of three coal-fired units, or both Koeberg units, or the Cahora Bassa infeed. For energy adequacy assessment, the largest multiple contingency that can be studied is the loss of three Medupi units, resulting in a total loss of $3\,x\,722 = 2\,166\,MW$. Furthermore, a combination of the three multiple-unit contingency trips as in the South African Grid Code: Preamble (2019) can be studied, totalling $3\,x\,722 + 2\,x\,930 + 1\,100 = 5\,126\,MW$. This is roughly 10% of the installed firm capacity.

The loss will enable assessment of whether there are sufficient emergency reserves in the immediate term and whether the contingency baseload can restore adequacy for such prolonged outages.

11.3 Stochastic analysis

To gain confidence in the analysis and obtain a statistically significant result, it is believed that a large number of patterns are required to converge. From the analysis of the sample with the worst unserved energy, as discussed in Section 7.1, it is evident that the difference between the mean and the maximum is significant.

Both ENTSO-E (2021) and AEMO (2020) simulate 1 000 combinations of variables to assess sensitivity of the power system to extreme events. The next iteration of the MTSAO will attempt to increase the studied sample size, the exact number to be determined subject to software and hardware constraints.

12 SYSTEM OPERATOR STATISTICS

This section monitors and reports actual system reliability indices that are affected by the adequacy of a power system. The data reports trends from January 2017 to 2021 year to date as at 10 October 2021, with data available for retrieval from the Eskom Data Portal (2021).

12.1 OCGT utilisation

Gas peaking capacity dispatchable by the System Operator includes Eskom's Ankerlig (1 327 MW) and Gourikwa (740 MW) as well as the DMRE OCGTs at Dedisa (335 MW) and Avon (670 MW). Generation from these resources over the past five years is depicted in **Figure 21** below.

The usage of OCGTs to balance supply and demand has increased significantly from 2019, and the 2021 YTD utilisation is higher than the full year 2019, likely to increase further into the summer months.

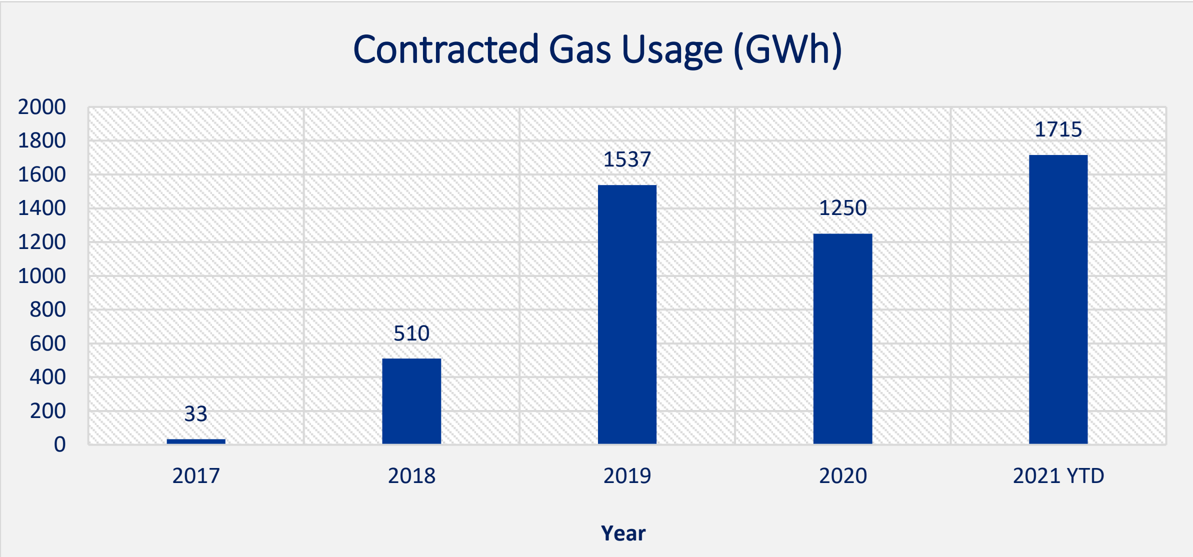


***Figure 21**: Actual OCGT utilisation 2017 to 2021 YTD*

12.2 Performance of reserves

The Eskom System Operator (SO: Ancillary Services, 2019) stipulates the type (instantaneous and regulating reserves) and capacity in MW required to restore system frequency to acceptable levels, depending on the drop in the level of frequency. Frequency incidents are correlated to performance of reserve deployment. Given the identified risk of reserve shortages due to underperformance of Eskom stations contracted to provide reserves, monitoring this index is critical in alerting the System Operator to an increasing trend in frequency incidents.

Although fewer generation trips led to frequency decay in 2020, the 49,5 < f < 49,7 Hz band experienced a total of 983 incidents, an increase compared to 848 in 2019 and 379 in 2020. The system also experienced a spike in over frequency in the 50,3 Hz band. The actual incidents for the period January to September 2021 are shown in **Figure 22** below. There were no incidences of frequency dropping below 49,2 Hz; such an incident would automatically activate underfrequency load shedding.

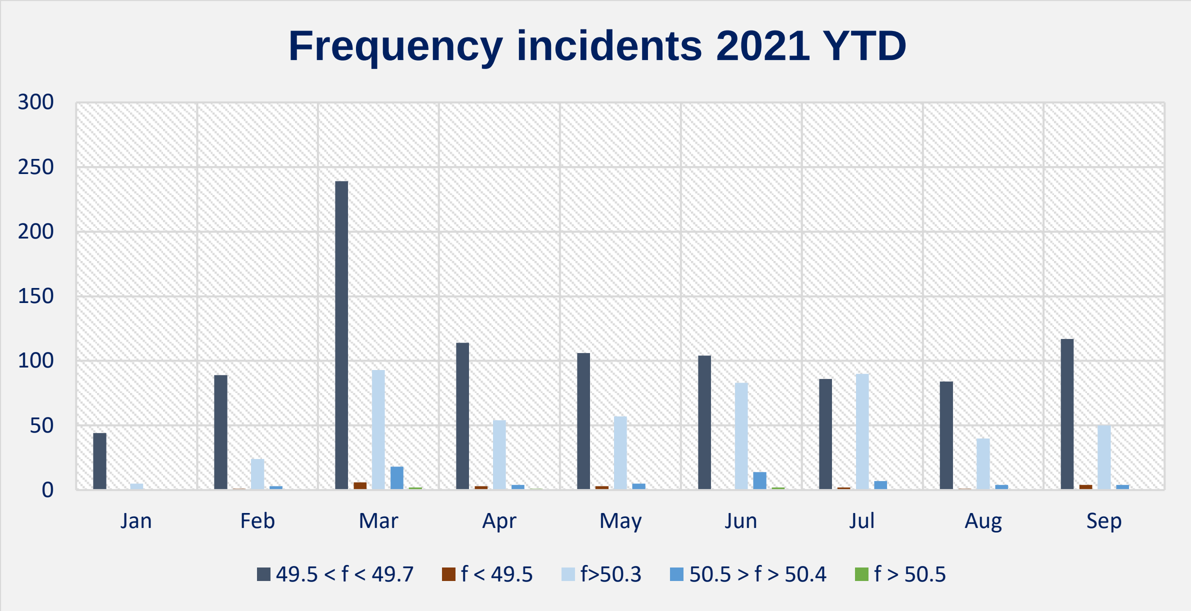


***Figure 22**: Actual frequency incidents 2021 YTD*

12.3 Unserved energy

Due to a shortage of supply, the System Operator implements load shedding and/or curtailment of demand to ensure a stable power system. **Figure 23** shows historical recorded energy not supplied due to emergency load reduction as 1,15 TWh for the current year to date. It can be observed that, even though 2020 was an unusual year, load reduction did not significantly decrease compared to 2019, signalling an inadequate system.

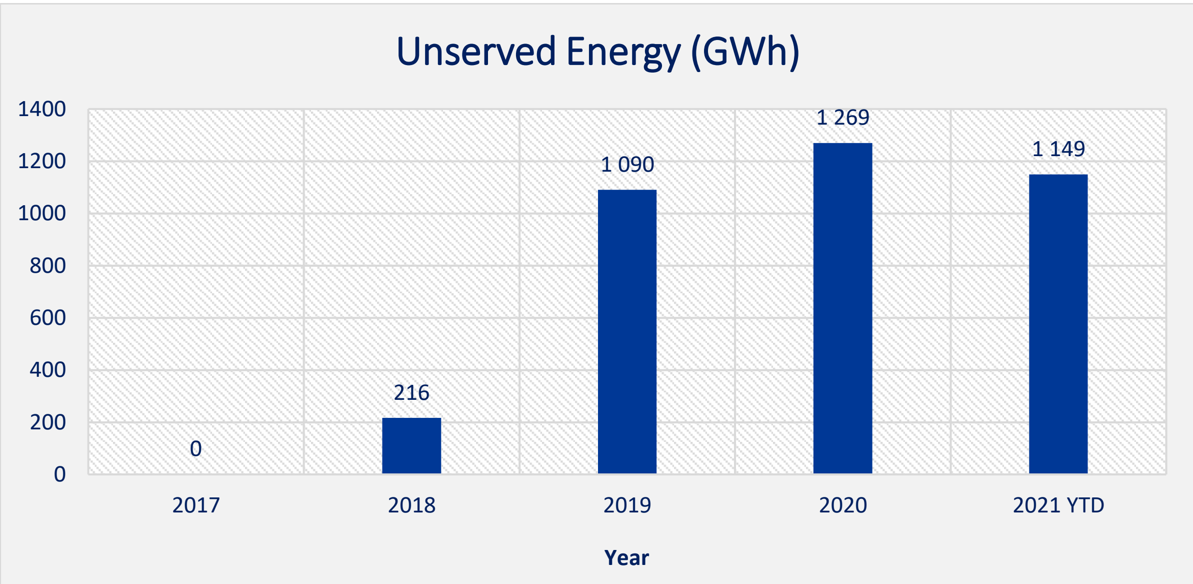


***Figure 23**: System Operator instructed load shedding for the calendar year 2017 to 2021 YTD*

The values include load shedding and load curtailment but exclude interruption of supply (IOS). IOS refers to all contracted and mandatory demand reductions to maintain system frequency and security of supply within acceptable bands.

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14 DEFINITIONS AND ABBREVIATIONS

Term/ Abbreviation	Definition
Capacity factor	Measures how hard the plant is running against its maximum possible output
DFFE	Department of Forestry, Fisheries, and the Environment
DMRE	Department of Mineral Resources and Energy
EAF	The energy availability factor of a plant is the percentage of the maximum energy that it can supply to the grid when not on planned or unplanned outage
Flue gas desulphurisation (FGD),	Technology used to remove sulfur dioxide from exhaust gases of fossil fuel power plants or processes
FOR	Forced outage rate – a combination of UCLF and OCLF
Integrated Resource Plan (IRP)	A generation capacity expansion plan based on least-cost electricity supply and demand balance in the long term
Manual load reduction (MLR)	An estimation of the demand that has been reduced due to load shedding and/or curtailment
Maximum continuous rating (MCR)	The capacity that a unit is rated to produce continuously under normal conditions
MTSAO	Medium Term System Adequacy Outlook
Minimum emission standards (MES)	Published under the National Environmental Management: Air Quality Act (NEMAQA) 39 of 2004
Multiple-unit trip	Two or more units of a power station that trip within one hour due to a common triggering event and whose total installed MCR capacity exceeds the largest single contingency limit
National Electricity Regulator (NERSA)	A regulatory authority established as a juristic person in terms of section 3 of the National Energy Regulator Act 40 of 2004
National Nuclear Regulator (NNR)	The legal entity established in terms of the National Nuclear Regulator Act 47 of 1999
OCGT	Open-cycle gas turbine
OCLF	Other capability load factor
PCLF	Planned capability load factor
REIPPP	Renewable Energy Independent Power Producer Programme
RMIPPP	Risk Mitigation Independent Power Producer Programme
SSEG	Small-scale embedded generation
System Operator (SO)	Entrusted with ensuring continuous and reliable delivery of electricity
UCLF	Unplanned capability load factor