RESOLVING THE POWER CRISIS: INSIGHTS FROM 2022

Meridian Economics

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All errors in this note remain those of the authors.

EXECUTIVE SUMMARY

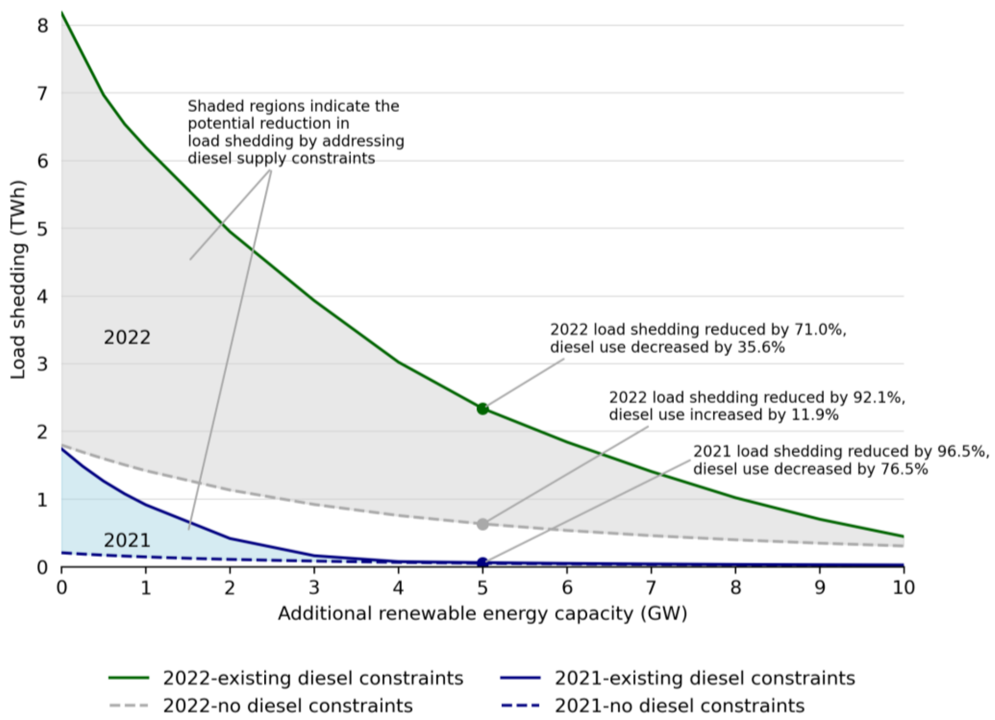
Load shedding in 2022 (8.1 TWh unserved) was more than four times greater than 2021 (1.8 TWh unserved). The crippling economic and social impact was far worse than this comparison would suggest, with South Africans for the first time feeling the real fallout from sustained stage 4 to 6 outages.

Our previous research[1] demonstrated that load shedding in 2021 would have essentially been eliminated by an additional 5 GW of Renewable Energy (RE) capacity – how much would renewables have helped in 2022? As shown in Figure 1, the same 5 GW of additional capacity would have eliminated the lion's share (between 71% and 92% depending on diesel supplied to OCGTs[2]) of the much larger load shedding experienced in 2022. This highlights the urgency of ensuring that all possible policy and regulatory steps have been taken to enable the rapid roll-out of renewables across the spectrum from small scale "roof-top" solar to utility scale wind and solar projects.

Logistical, financial and institutional issues hinder Eskom's use of the OCGTs – insufficient storage, high cost of diesel and equivocal support from NERSA and National Treasury create constraints, which if lifted would make a huge impact on load shedding. In concert with an additional 5 GW of RE capacity, lifting of the diesel supply constraints (as described above) does not equate to burning much more diesel, adding just 12% to the 2022 diesel budget, whilst resolving a further 20%[3] of loadshedding.

In the very short term, whilst renewable capacity is brought online, increased use of the OCGTs remains the only defence against higher levels of load shedding. Given that the economic consequences of load shedding far outweigh the direct cost of diesel, it remains rational to burn as much diesel as practically possible during this period to generate power.

Figure 1: Impact added renewables would have had on load shedding in 2021 and 2022



[1] *Meridian Economics, 2022. Resolving the Power Crisis Part A: Insights from 2021 – SA's Worst Load Shedding Year So Far.* *https://meridianeconomics.co.za/our-publications/resolving-load-shedding-part-a-2021-analysis-2/*

[2] *Open Cycle Gas Turbines – Ankerlig, Gourikwa, Avon and Dedisa with combined capacity of 3056 MW*

[3] *The difference between solving 71% and 92% of load shedding in 2022*

TABLE OF CONTENTS

ACKNOWLEDGEMENTS I
EXECUTIVE SUMMARY II
TABLE OF CONTENTS III
TABLE OF FIGURES III
1 INTRODUCTION 1
2 METHODOLOGY 2
3 RESULTS 3
3.1 Summary – additional renewables would have made a real difference in 2022 3
3.2 Diesel supply constraints are a critical limiting factor in addressing load shedding 3
3.3 PV or Wind? – A Mix is best but even 100% PV will dramatically reduce load shedding 5
4 CONCLUSIONS 7

TABLE OF FIGURES

Figure 1: Impact added renewables would have had on load shedding in 2021 and 2022 ii
Figure 2: Annual cumulative load shedding since 2019. Unserved energy in 2022 exceeded sum of all previous years. January 2023 exceeds all full years prior to 2022. 1
Figure 3: Distribution of load shedding hours per stage in 2021 and 2022. 2
Figure 4: 5 GW additional RE capacity would have reduced load shedding by 71% in 2022, which could be extended to 83.5% by doubling the diesel storage and refuelling capacity. 4
Figure 5: Addressing the diesel supply constraints would not significantly increase the annual diesel consumption in 2022 when combined with 5GW additional RE capacity. 4
Figure 6: A significant reduction in load shedding and diesel consumption can still be achieved, even when relying more on PV than wind. 6

1 INTRODUCTION

In June 2022 Meridian Economics published a two-part series of reports on Resolving the Power Crisis. In Part A of that series[1] we utilised Eskom's actual hourly data to quantify the impact that additional Renewable Energy (RE) generation capacity would have had on load shedding if it had been operational in 2021. The results of that study were startling – an additional 5 GW of wind and solar in the same proportion as the currently installed capacity, would have allowed Eskom to eliminate 96.5% of load shedding in 2021.

Since the publication of our previous work, load shedding has increased tremendously, with a total of 8.1 TWh of energy shed during 2022. This equates to a 355% (4.5-fold) increase on 2021 and is higher than all previous years of load shedding combined. Worryingly, as shown in Figure 2, most of the energy shed in 2022 was in the last quarter of the year. Sustained levels of stage 4 to 6 load shedding (see Figure 3) mark 2022 as being far worse in respect of economic impact than 2021. The high levels of load shedding have continued into 2023, and in January this year alone Eskom has already shed 2.1 TWh – more than the entire energy shed in 2021. If these high levels of load shedding continue, we are likely to see South Africa shedding more than 5% of its annual electricity demand, a thought that would have been unimaginable just a few years ago.

In this context of unprecedented levels of load shedding we have repeated our analysis of the published hourly Eskom data to determine the impact that additional RE capacity would have had on reducing load shedding in 2022. We focus our attention on both the impact of additional RE capacity and addressing constraints on diesel supply to the OCGTs, as available short-term measures to reduce load shedding.

Figure 2: Annual cumulative load shedding since 2019. Unserved energy in 2022 exceeded sum of all previous years. January 2023 exceeds all full years prior to 2022.

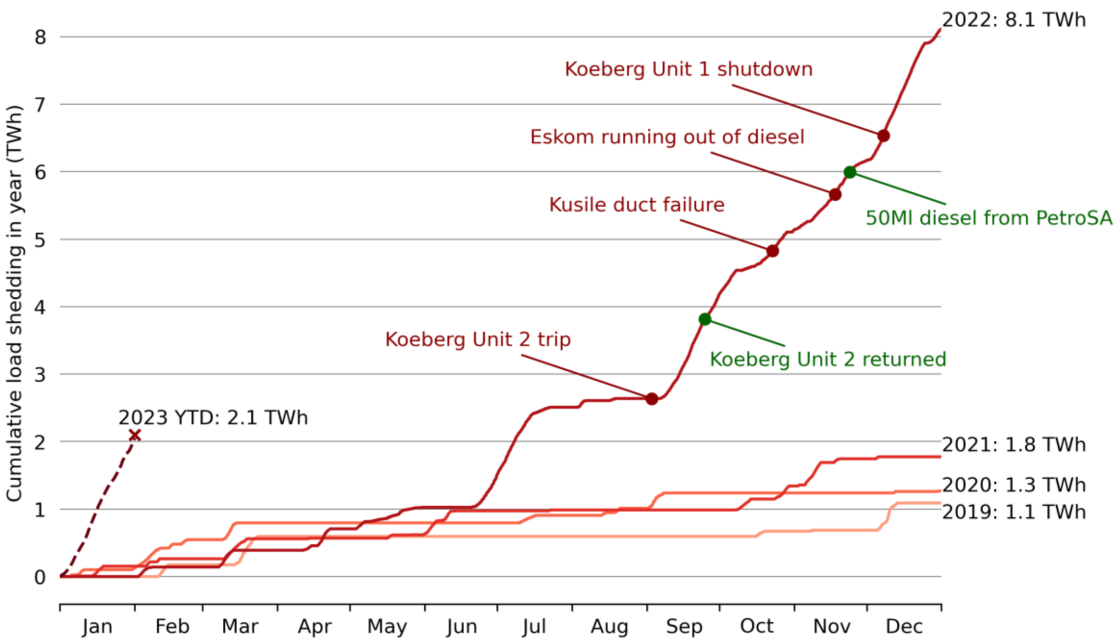
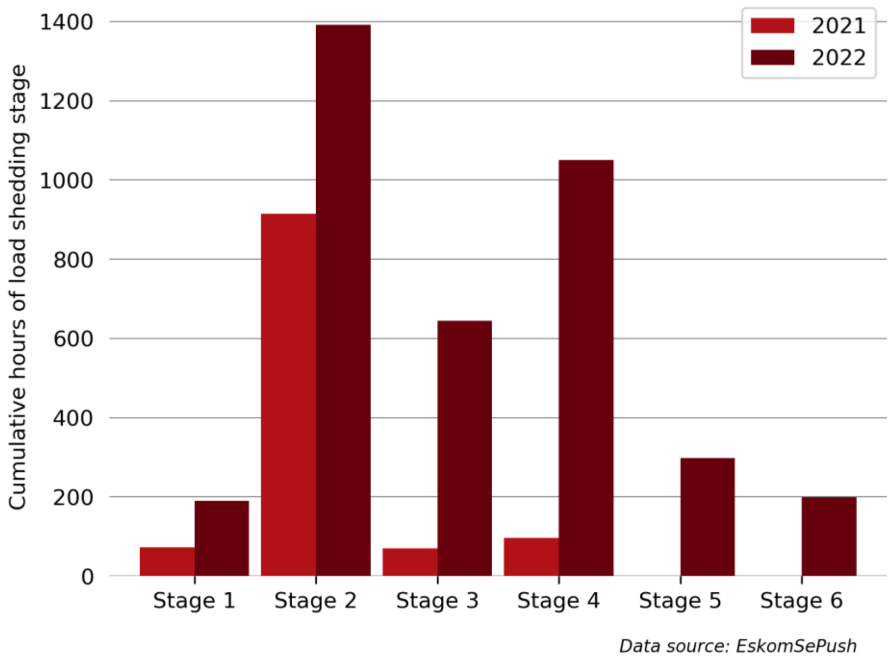


Figure 3: Distribution of load shedding hours per stage in 2021 and 2022.



2 METHODOLOGY

The methodology applied is consistent with our previous report for 2021 - using Eskom's data on the actual load shed[4] in each hour and assuming that, had additional energy been available to the grid to exceed the load shed in any hour, load shedding would have been entirely avoided for that hour[5]. In an hour where the additional energy from renewables was less than the load shed in that hour, the load shedding total for that hour would be reduced by the amount of additional energy available.

The primary metric we used to assess the impact of additional renewables on load shedding was the sum of remaining load shedding over the year – that is, the sum of the load shed over all 8 760 hours in the year – after subtracting the additional energy that would have been generated by the renewables in the load shedding hours. The actual load shed in 2022 was 8.1 TWh and percentage load shedding reductions quoted in this note are referenced against this figure.

As before, we conducted the analysis using two separate platforms – a spreadsheet model and a dedicated system modelling software tool that simulates hourly dispatch more accurately. The comparison of outcomes from the different platforms was used to verify the findings and confirm the credibility of results. The spreadsheet analysis is simple and provides an intuitive basis for demonstrating the 'direct impact' of additional renewable energy, and the extent to which this energy reduces diesel usage and cycling of the pumped storage facilities[6].

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[4] Eskom discloses load shed in its data as "Manual Load Reduction" or MLR – it is an estimation of the demand that has been reduced due to load shedding under the national load shedding schedule and/or curtailment. Whilst the MLR in any hour is lower than the load shedding stage number multiplied by 1 000 MW we have used MLR as a measure of actual load shed to be representative of the true extent of the problem.

[5] This assumes that the system operator would have been able to rely on forecasts of renewable generation for the hour in question – which is not an unreasonable assumption given a geographically diverse renewables portfolio and the accurate weather forecasting now available – and thereby determine that load shedding is not necessary. Hourly generation from renewable resources is known to a high degree of accuracy at least 24 hours in advance, allowing an adequately capacitated power system to prepare alternative generation to supplement any shortfall between supply and demand.

[6] For a detailed explanation of the 'direct impact' and 'knock-on impact' please see https://meridianeconomics.co.za/our-publications/resolving-load-shedding-part-a-2021-analysis-2/.

The more sophisticated system dispatch model is necessary to assess the further 'knock-on' impact on load shedding reduction that could be gained by using the OCGT and pumped storage assets in concert with the additional energy on the system. This provides a more realistic view of how the system would actually be run by the system operator, yielding more realistic estimates of the load shedding reduction and the cost to achieve this.

In our analysis we consider a range of additional RE from 0GW to 10GW. As with our previous report, we focus on an amount of 5GW, which would have reduced load shedding by 96.5% in 2021. We assume the additional RE capacity to be both wind and solar in the same ratio as existing (i.e. 60% wind and 40% solar PV), but also run further scenarios to examine implications of a predominantly solar mix for new capacity. Additionally, we investigate further measures to address load shedding, with a focus on the OCGTs.

3 RESULTS

3.1 SUMMARY - ADDITIONAL RENEWABLES WOULD HAVE MADE A REAL DIFFERENCE IN 2022

An additional 5 GW of RE capacity, operating within current diesel supply constraints[7], would have reduced load shedding in 2022 by 71% (i.e. eliminated 5.8 TWh of the 8.1 TWh total). As shown in Figure 4, a 61.7% reduction is achieved as a 'direct impact' of RE generation offsetting load shedding during the hours that the RE is available. Re-optimising the dispatch of the pumped storage and OCGT plant (peaking plant) in the context of the additional renewable energy would have had a 'knock-on' effect of further reducing load shedding by 9.3%.

Under the existing diesel supply constraints, in excess of 10 GW of additional RE capacity would have been required to reduce load shedding in 2022 by 95%. However, in the absence of constraints on diesel supply (i.e. if the OCGT capacity could be used whenever it was required) – more than 90% of the 2022 loadshedding would have been eliminated with only 5 GW of additional RE capacity (see the grey dashed line in Figure 4). Significantly, this reduction in load shedding would have required only a modest increase in the actual quantity of diesel burned for the reasons explained below – about 12% more than was actually used in 2022 (see the grey dot in Figure 5).

3.2 DIESEL SUPPLY CONSTRAINTS ARE A CRITICAL LIMITING FACTOR IN ADDRESSING LOAD SHEDDING

Eskom currently faces both financial and logistical constraints in operating the OCGTs at higher capacity factors. As shown in the shaded grey region of Figure 5, addressing the constraints on diesel supply can greatly reduce load shedding, especially when there is limited additional RE capacity available (for example in the very short term whilst new RE capacity is under construction). In the extreme scenario of removing all diesel supply constraints, the OCGTs would be able to operate at full power when needed (unless capacity is allocated for operating reserves)[8]. This not only directly reduces load shedding, but also allows for more energy to be stored using the pumped storage during times when there is no load shedding, thereby increasing the potential for further peaking power.

[7] *The annual capacity factor (and therefore total diesel burned) of the OCGTs in the model is constrained to match the actual 2022 Eskom data.*

[8] *We currently include operating reserves in the model, resulting in some OCGT capacity being reserved. However, we do not currently model planned and unplanned outages for the OCGTs.*

Figure 4: 5 GW additional RE capacity would have reduced load shedding by 71% in 2022, which could be extended to 83.5% by doubling the diesel storage and refuelling capacity.

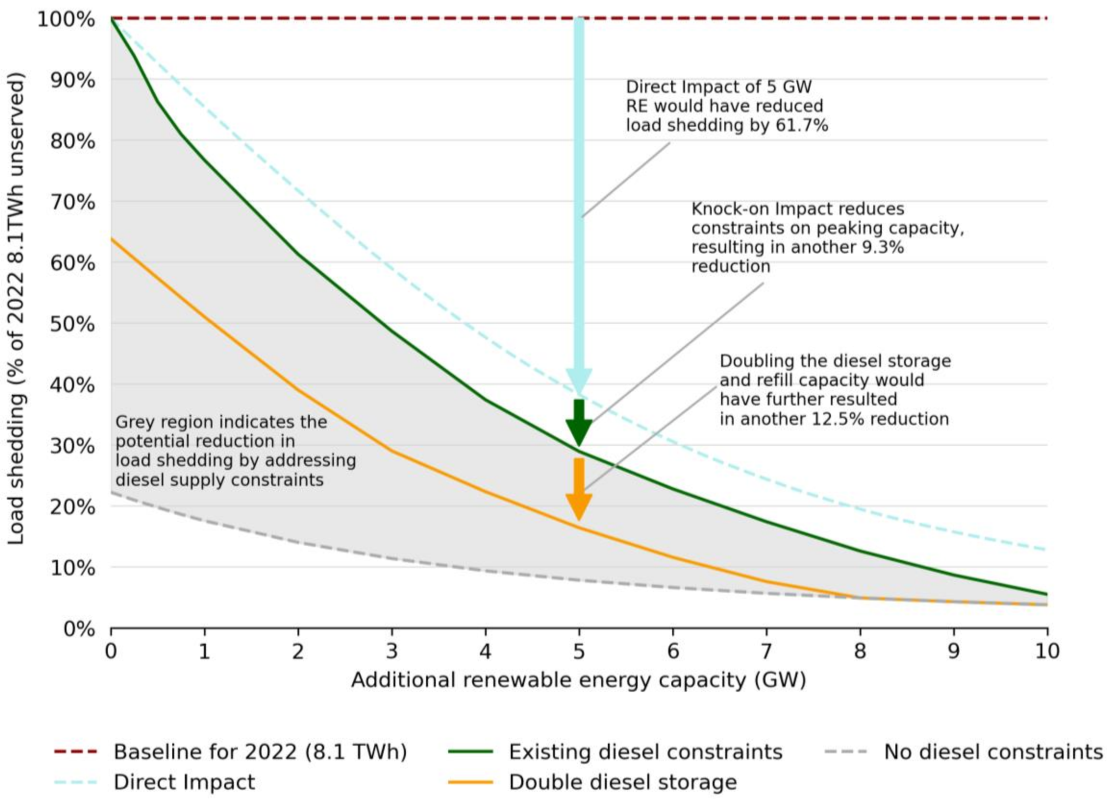
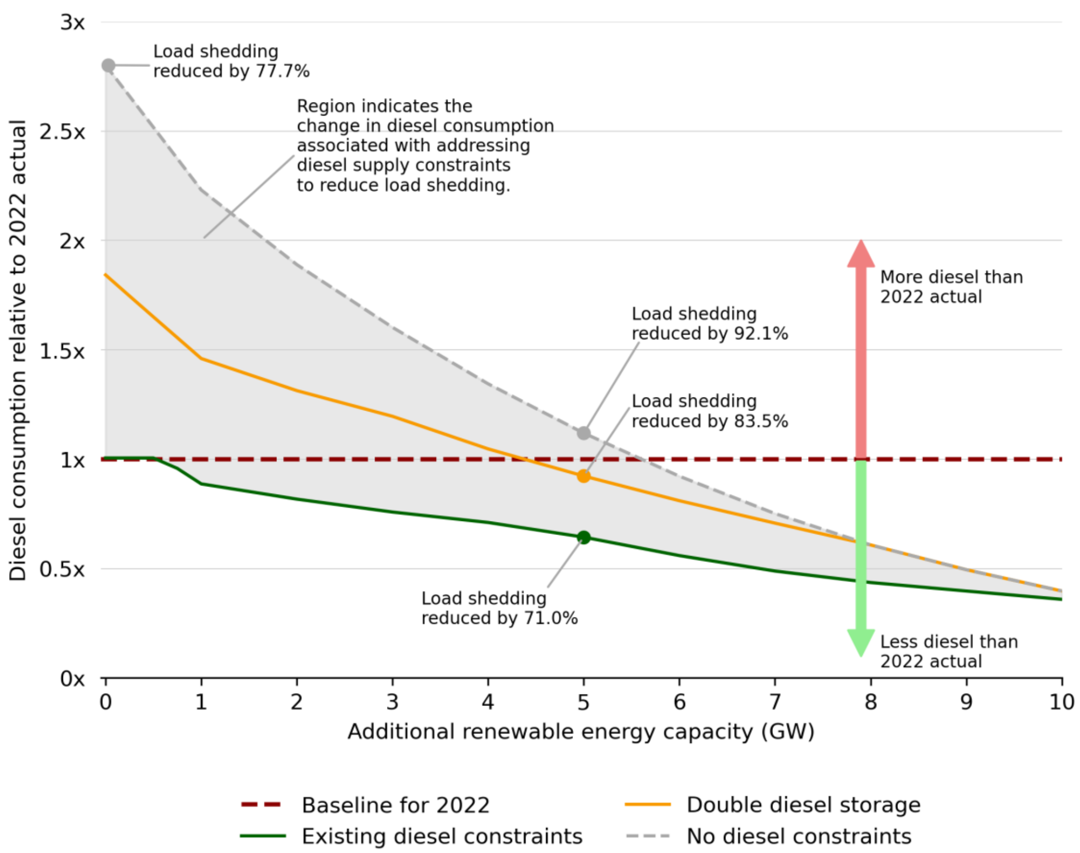


Figure 5: Addressing the diesel supply constraints would not significantly increase the annual diesel consumption in 2022 when combined with 5GW additional RE capacity.



Various estimates place the economic cost of load shedding between R10/kWh and R85/kWh[9,10]. The cost for Eskom to generate power using OCGTs is in the order of R7/kWh[11]. From a macro-economic perspective, it is thus always rational to increase spending on diesel to reduce load shedding whenever possible. This is particularly relevant in the short-term whilst the installed capacity of renewables ramps up.

Fully unconstrained operation of the OCGTs is likely impractical, however doubling onsite diesel storage and peak refuelling rates[12], could be an implementable solution. This scenario is described by the orange curve in Figure 4 and Figure 5. The results show that the addition of 5 GW of RE capacity combined with doubling the diesel supply capacity would have reduced load shedding by 83.5%, without burning more diesel than Eskom did in 2022.

Figure 5 illustrates diesel consumption relative to the quantity Eskom burned in 2022 for the scenarios described in Figure 4. The green curve represents the scenario where existing diesel supply constraints remain unaddressed. In this case, the system is unable to burn more diesel than the actual 2022 quantity (i.e. 100%). Note that this scenario actually burns *less* diesel than 2022. This is because as additional RE capacity is added, it reduces the need for OCGTs to be used during some hours of the day, freeing up the plants to be used during peak (or other) hours. But even when OCGTs are run as hard as they can during these other hours, existing diesel storage and re-filling logistics constrain their ability to reduce the need for load shedding.

In the absence of diesel supply constraints (see the grey dashed curve in Figure 5) and with no additional RE capacity, increased use of the OCGTs would have resulted in a 77.7% reduction in load shedding but at treble the cost of the actual diesel burned in 2022. As additional RE capacity is added to the system, the required diesel usage declines rapidly, and at 5GW of RE significant reductions in load shedding could be achieved by burning the same or less diesel than was actually used in 2022.

This illustrates that once additional RE capacity is available, improvements in diesel supply logistics are not used to increase overall diesel consumption, but rather to provide enough diesel to ensure continuous supply for shorter intense usage periods.

3.3 PV OR WIND? - A MIX IS BEST BUT EVEN 100% PV WILL DRAMATICALLY REDUCE LOAD SHEDDING

The power production profiles of wind and PV plants are complementary in nature, which when combined result in a more effective energy mix than either technology on its own. At the end of 2022 the ratio of installed PV capacity to wind was approximately 40/60. However, the solar resource is more evenly spread across the country than the wind resource which is more concentrated in areas such as the Eastern and Western Cape. Due

[9] *Nova Economics, 2020. 'Estimating the economic cost of load shedding in South Africa' , https://www.novaeconomics.co.za/our-work/estimating-the-economic-cost-of-load-shedding-in-south-africa*

[10] *CSIR, 2017. 'Formal comments on the Integrated Resource Plan (IRP) Update Assumptions, Base Case and Observations 2016', https://www.csir.co.za/sites/default/files/Documents/20170331CSIR_EC_DOE.pdf*

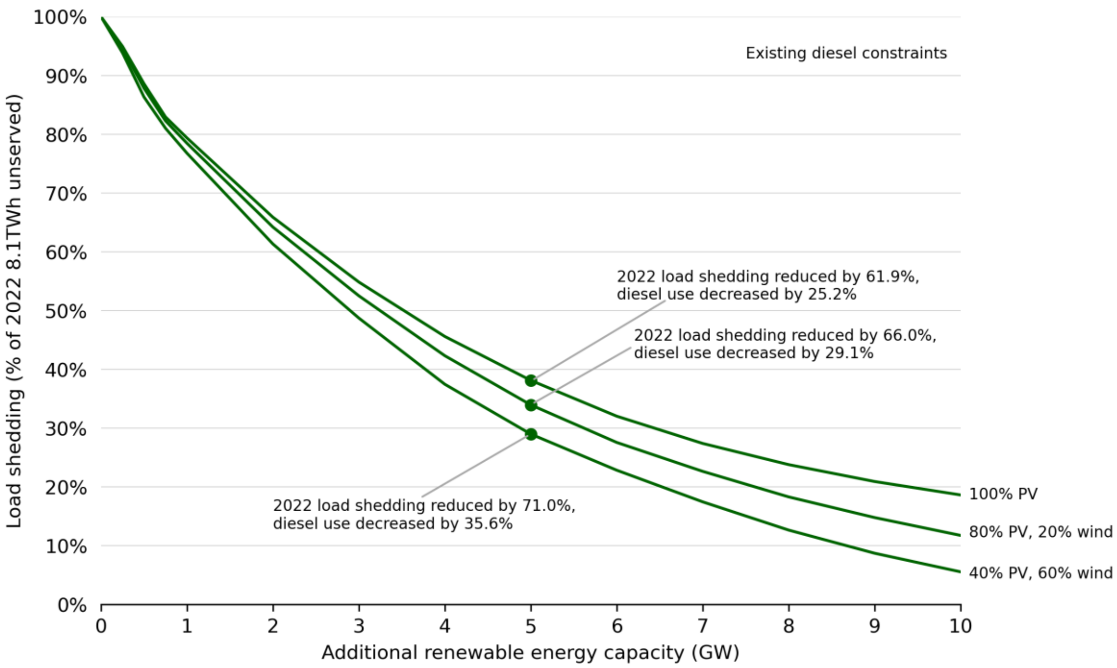
[11] *OCGT operating costs estimated at R7/kWh based on increasing the R4.7/kWh available from Eskom for FY2021/22 by the average change in wholesale diesel price.*

[12] *Doubling the storage and refuelling does not directly equate to doubling the diesel consumption. It is simply a mechanism to ensure enough diesel supply is available for periods of high demand.*

to grid constraints in these regions the ability to rapidly build new wind capacity will be limited in the short-to-medium term. Wind farms also have longer project development and construction lead times than PV plants.

In contrast, PV plants can be rapidly deployed at scales ranging from residential rooftop systems (<10 kW), up to large utility scale plants (>100 MW). For example, Vietnam was able to install a record 9.3 GW of rooftop solar PV in 2020, driven by an attractive feed-in tariff[13]. We further used our modelling tools to evaluate the effect on load shedding if the additional RE capacity was predominantly PV. The results, shown in Figure 6, indicate that even in the case of adding only solar PV capacity, load shedding in 2022 could still have been dramatically reduced by 62% (vs 71% from a 40/60 PV/wind mix) in 2022[14]. Incentivising residential, commercial, and industrial customers to invest in distributed PV generation can clearly have a profound impact on reducing load shedding. Based on international experience, this can also be achieved in the shortest space of time compared to other new generation interventions.

Figure 6: A significant reduction in load shedding and diesel consumption can still be achieved, even when relying more on PV than wind.



[13] *BloombergNEF, 2021. 'Vietnam Was Likely the Third-Largest Solar Market in 2020', https://about.bnef.com/blog/vietnam-was-likely-the-third-largest-solar-market-in-2020/*

[14] *Note the installed capacity of utility scale PV plants refers to AC maximum export capacity. These plants are located in high solar resource regions and typically use panels that track the movement of the sun to increase energy generation. Rooftop PV systems are typically specified on a kW peak basis (kWp) on the DC side. Therefore up to 8 GWp of rooftop systems would be required to generate the equivalent energy of 5 GW_{ac} of utility PV capacity.*

4 CONCLUSIONS

Analysis of hourly Eskom data from 2022 clearly demonstrates the following:

1. Despite load shedding being catastrophically worse in 2022 compared to 2021, 5GW of additional RE would have eliminated between 71%-92% of load shedding, depending on supplementary measures to relieve diesel supply constraints.
2. Deployment of rooftop PV – achievable rapidly at scale with appropriate incentives - will have almost as much impact on load shedding as a more optimal mix that includes wind. Rooftop and distributed PV has both the shortest lead time and is immune from any constraints posed by the transmission network.
3. Logistical supply constraints hindering the ability for OCGTs to burn diesel when necessary remain a critical cause of loadshedding. Even without increasing diesel consumption, load shedding can be significantly mitigated by improving the ability to burn diesel when necessary – primarily by at least doubling the available diesel storage at the OCGT plants.
4. In the very short term (next 6 months), burning large volumes of diesel when required is the only means to address the current crisis and is economically rational given that the economic, social and political consequences of load shedding far outweigh the cost of diesel.
5. Beyond the very short term, as more renewable capacity is rapidly added to South Africa's power system, improved diesel logistics are not used to increase overall diesel consumption, but rather to provide enough diesel to ensure continuous supply to the OCGTs for shorter intense usage periods.