RESOLVING THE POWER CRISIS

Insights From Detailed Power System Modelling & Technical Analysis

17 APRIL 2023
MERIDIAN ECONOMICS

CONTENTS

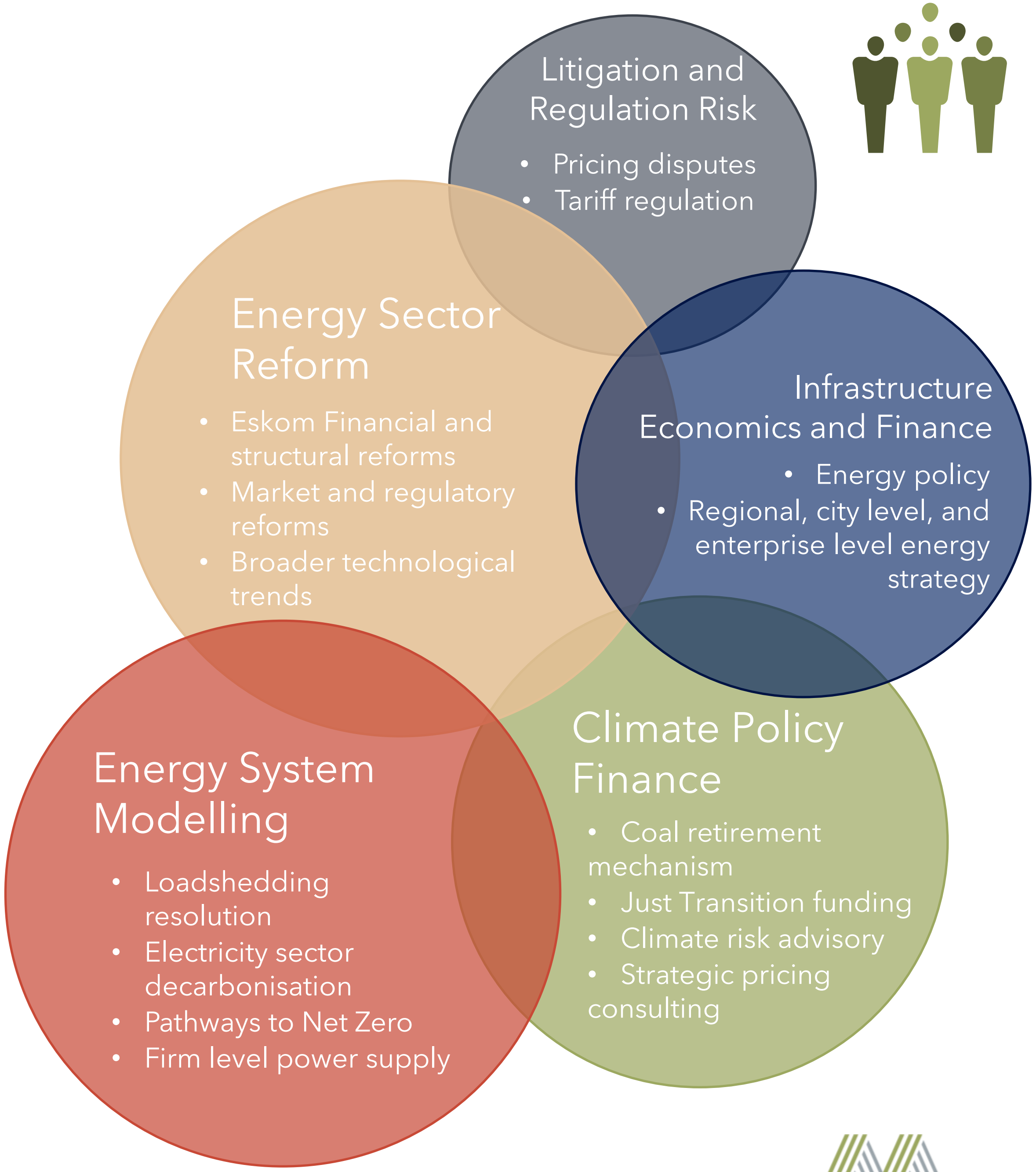
- Introduction to Meridian Economics
- The current load shedding predicament
- Insights from load shedding in 2021 and 2022
- Analysing the potential impact additional renewables would have made on load shedding in 2021 and 2022
- Our game plan to resolve the power crisis

01

INTRODUCTION TO MERIDIAN ECONOMICS

WHO WE ARE

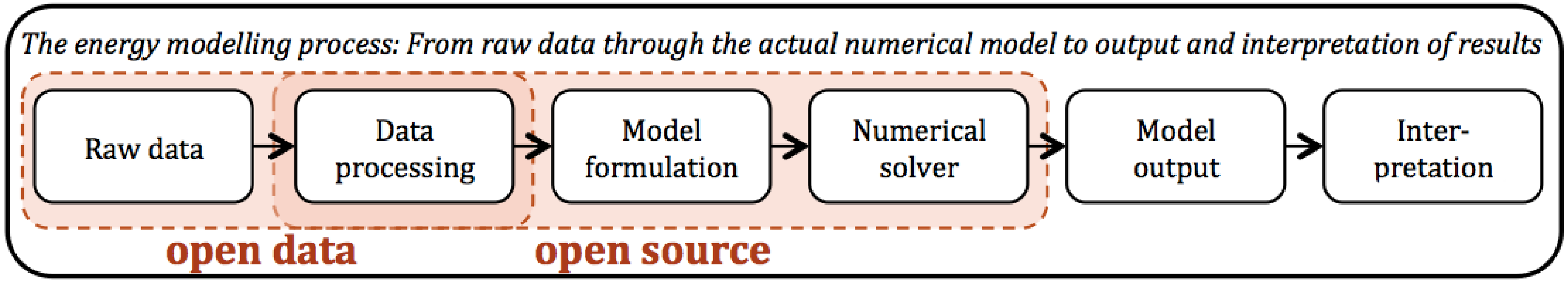
- Meridian Economics is a specialized energy and climate economics consultancy and think tank that provides executive level decision support, strategic advice and analytics capabilities.
- We work at the intersection of economics, energy regulation, finance, and climate change policy.
- We are networked and engaged at a high level of policy making, with insights based on rigorous analysis.
- We pride ourselves on bringing our quantitative capabilities – including rigorous financial analysis and modelling skills to bear on the questions faced by our clients.
- Our team includes highly skilled senior financial and power system analysts, and regulatory, energy and climate economists active in the South African energy space since the early 1990s, and the climate space domestically and internationally since the early 2000s.
- Most of our team have a background in engineering or science (MS or PhD)



GIVEN THE HIGHLY CONTESTED NATURE OF THE POWER SECTOR WE FULLY BELIEVE IN OPEN MODELLING AND OPEN DATA

“IN GOD WE TRUST. ALL OTHERS MUST BRING DATA.” – W.E. DEMMING

- Historically, commercial tools have been extensively utilised by both governments and utilities to develop power system capacity expansion plans.
- In the South African context, the modelling conducted by (or for) the Department of Mineral Resources and Energy (DMRE) for the Integrated Resource Plan (IRP) has been based in the commercial software PLEXOS.
- One of the challenges of utilising commercial tools to support transparent energy policy is the closed nature of the models, which are essentially a ‘black-box’ for external parties. For this reason, open modelling initiatives are gaining traction globally, with the goal of creating platforms that are based on open-source software as well as open data, which will lower the barriers to entry to create a broader active modelling community in South Africa.

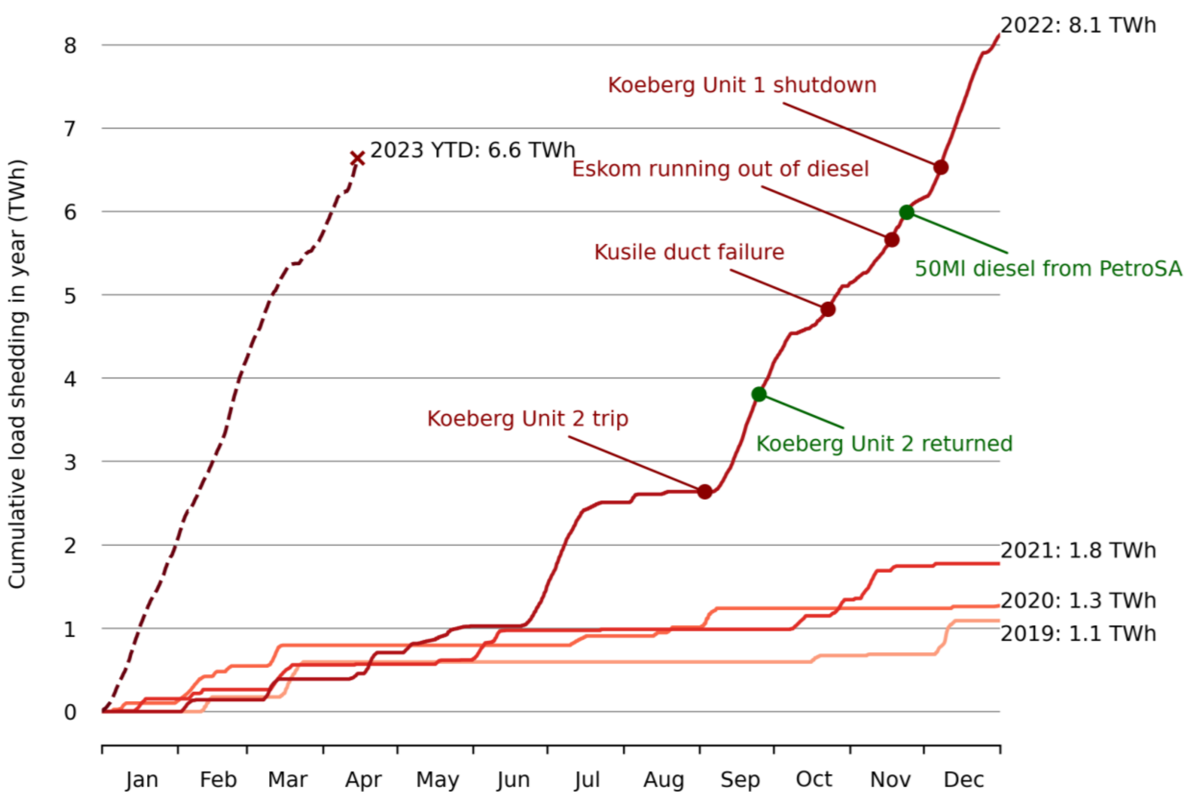


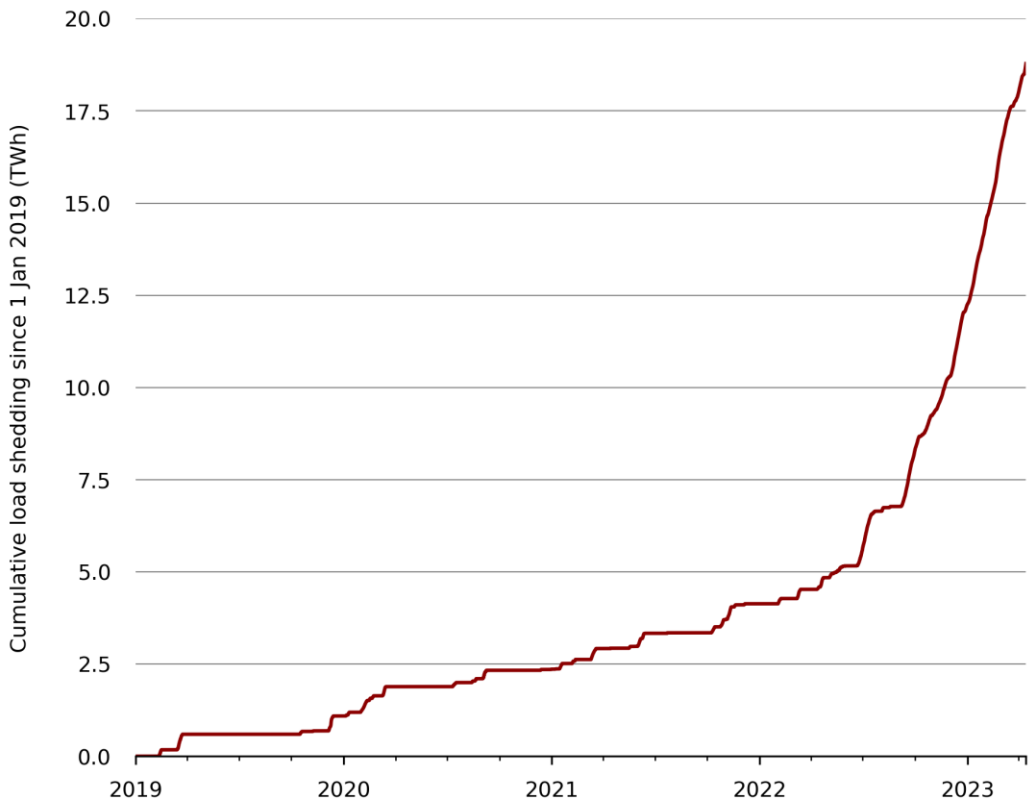
https://openmod-initiative.org/

02

OVERVIEW OF LOAD SHEDDING DATA TO DATE

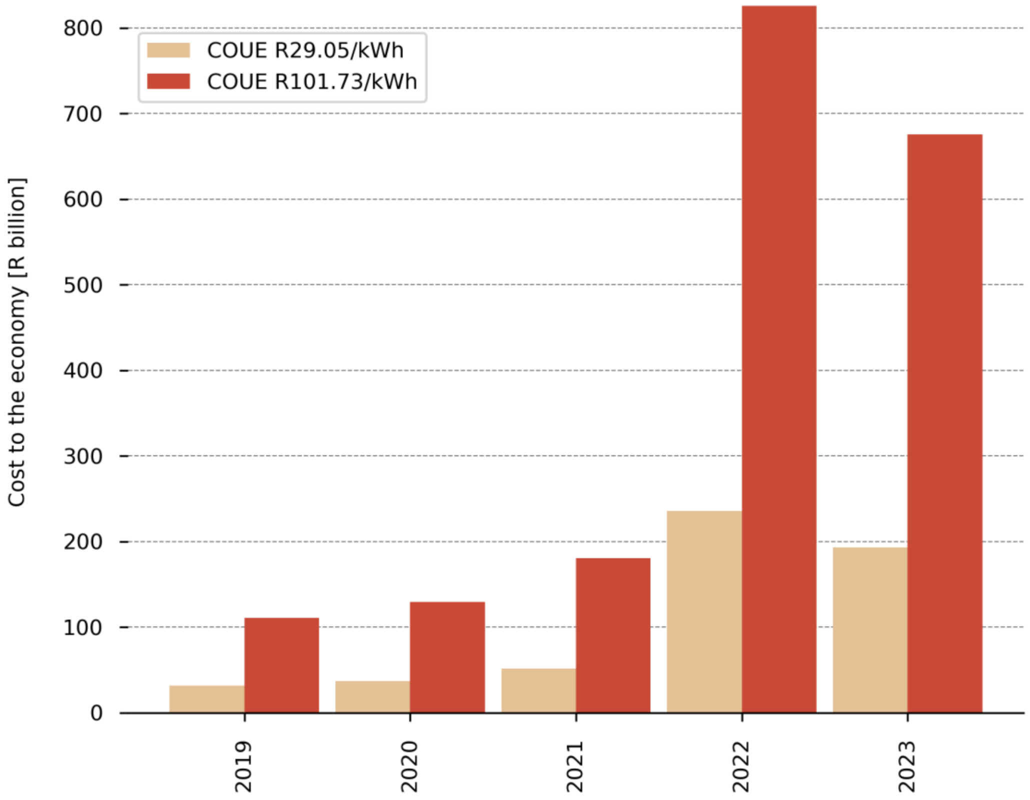
6.6 TWH OF LOAD HAS ALREADY BEEN SHED YEAR TO DATE IN 2023





ECONOMIC COST OF LOAD SHEDDING IS SUBSTANTIAL

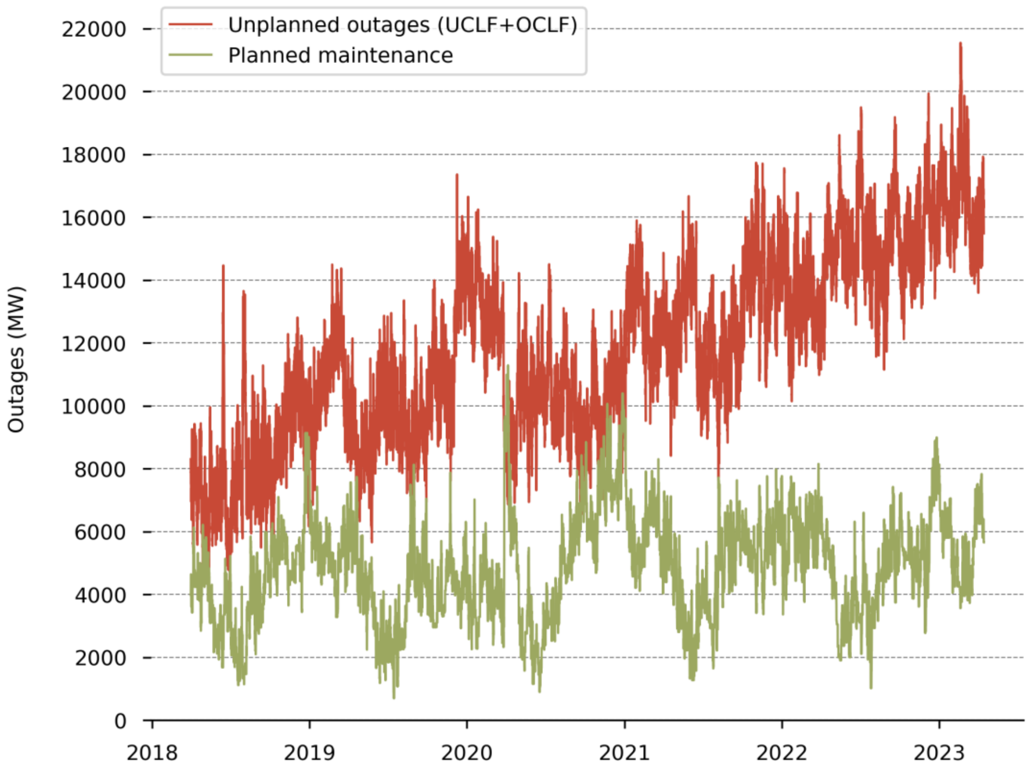
LEADING TO LOST PRODUCTIVITY, INCREASED EXPENSES, AND REDUCED GROWTH IN SOUTH AFRICA

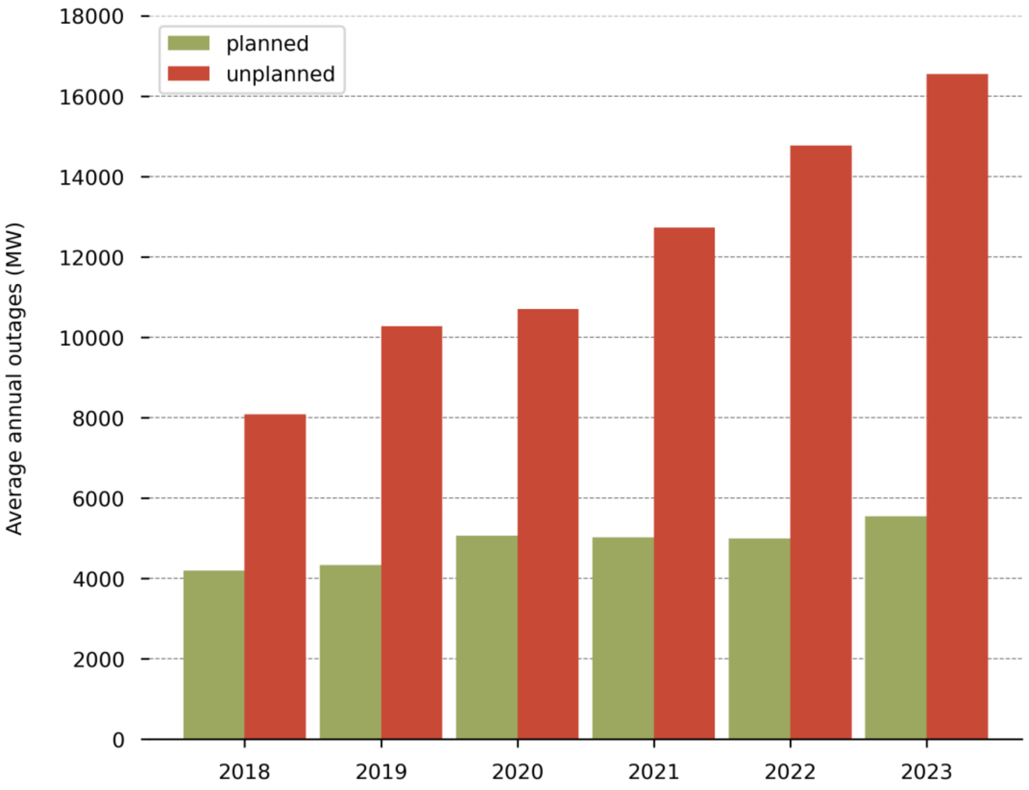


- Quantifying the broader economic cost of daily disruptions is challenging, with ongoing debates on the exact GDP impact, which includes lost production, investment, deindustrialization, increased unemployment, and declining livelihoods.
- Graph is based on Eskom submission to NERSA on cost of load shedding
  - Direct effect R29.05(GVA)/kWh
  - Total effect including long term damage to the economy R101.73(GVA)/kWh

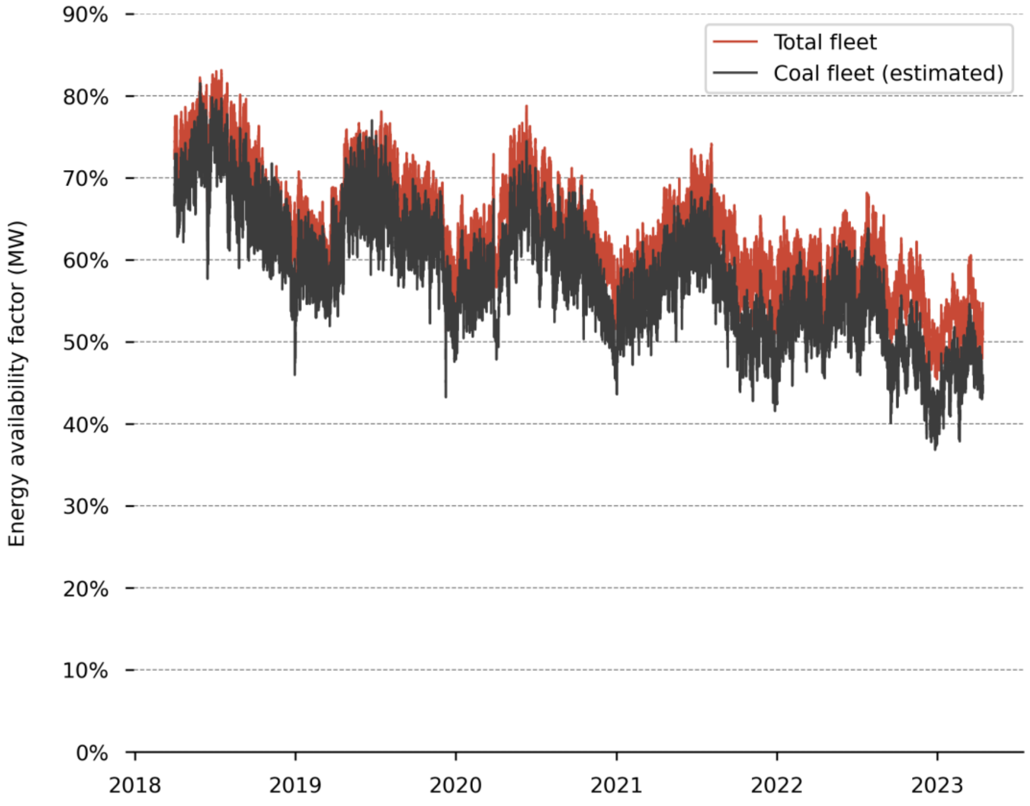
Source of COUE: Eskom RT&D

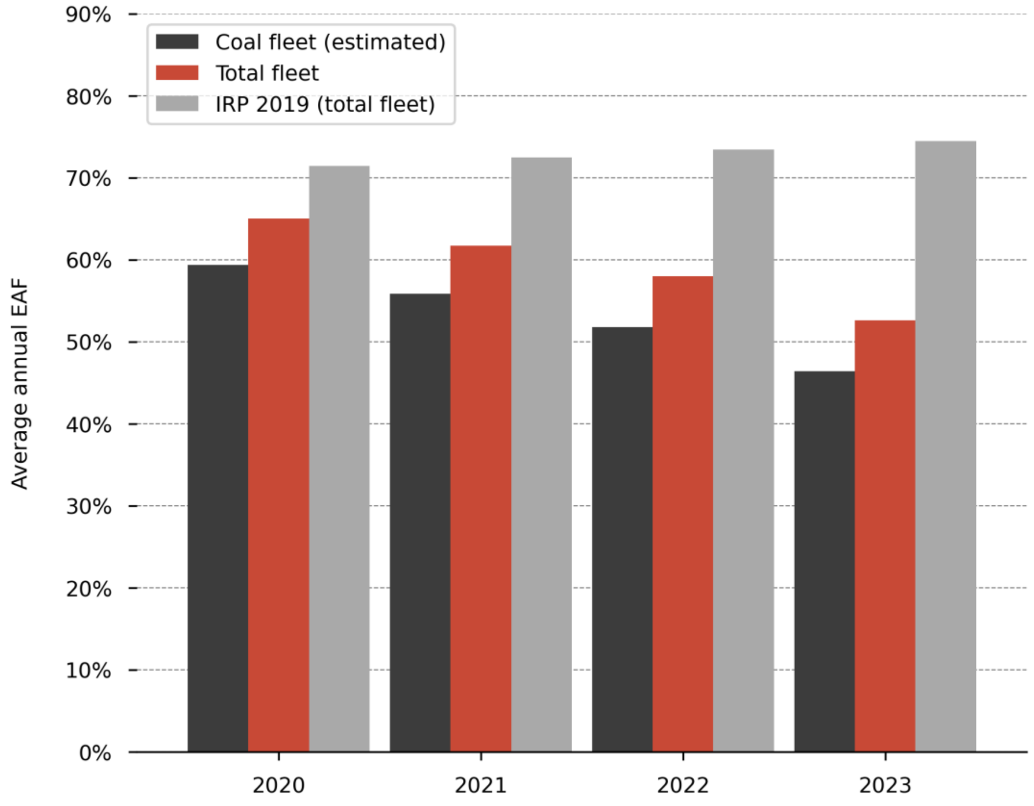
INCREASING PLANNED MAINTENANCE HAS NOT BEEN ABLE TO REVERSE THE TREND OF GROWING UNPLANNED OUTAGES



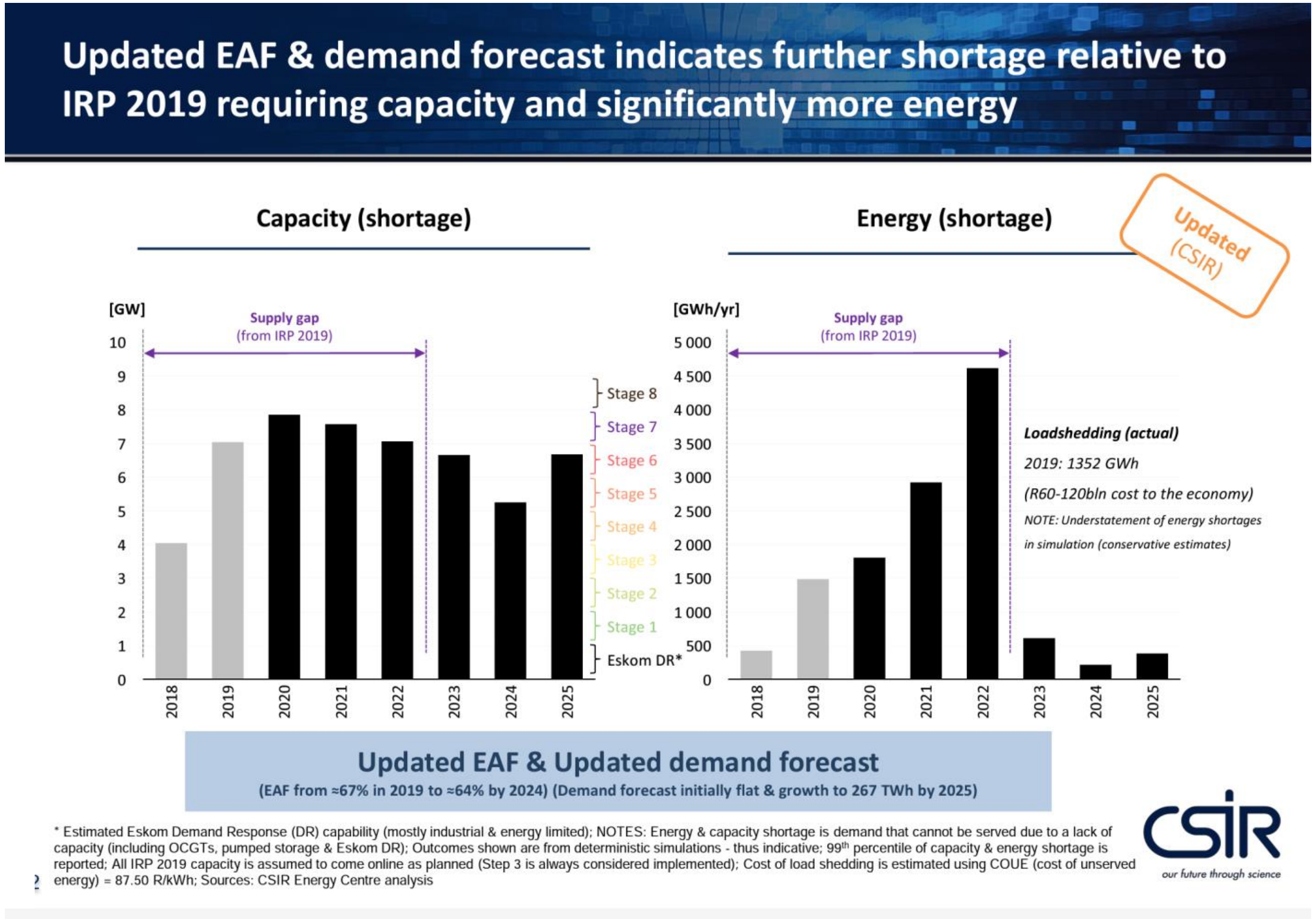


OUTDATED ENERGY POLICY ASSUMES AN EAF RECOVERY TO 75.5% BY 2024, RESULTING IN A WIDENING ENERGY GAP BETWEEN ENERGY PLANNING POLICY AND REALITY





THE CURRENT ENERGY CRISIS WAS FORESEEABLE WITH CSIR WARNING BACK IN 2020 THAT LOAD SHEDDING WOULD INCREASE DRASTICALLY WITHOUT RAPID INTERVENTIONS

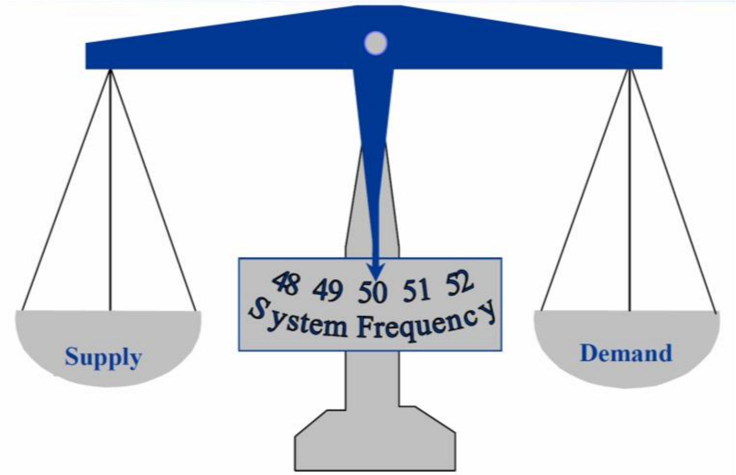


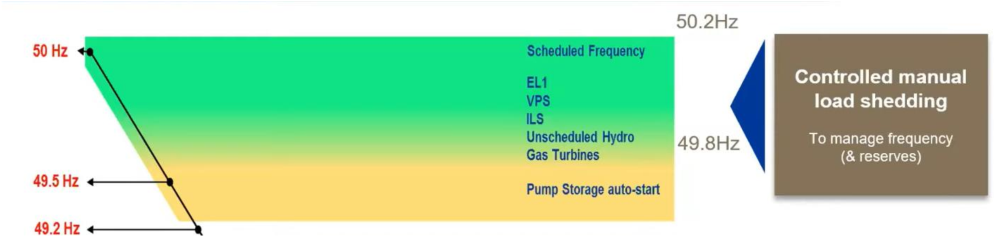
- Warnings by Eskom in various MTSAOs should have been heeded and actioned into an updated IRP.
- Effective energy planning cannot rely on best-case scenarios in terms of the Eskom performance.
- Eskom has not been able to attain EAF targets for their fleet and this is shown in their most recent System Status Outlook Briefing released in October 2022 when plant availability was at 58.53% versus a 65% target at year end for FY23.

03

INSIGHTS FROM LOAD SHEDDING IN 2021 AND 2022

ESKOM SYSTEM OPERATIONS ARE CONSTANTLY BALANCING SUPPLY AND DEMAND IN ORDER TO MAINTAIN THE GRID FREQUENCY WITH THE RANGE OF 49-51 Hz





Below 49.2 Hz, additional automatic load shedding systems activate which can shed up to 50% of load in (<1s) if needed

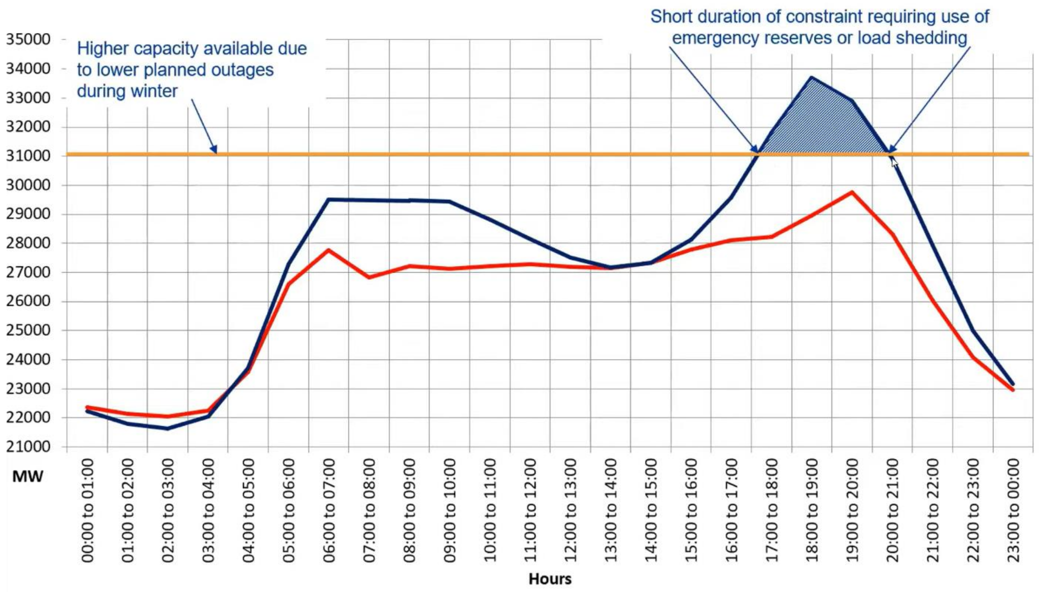
Resource	Capacity	Constraint
Pumped storage: Drakensberg Ingula Palmiet	2 732 MW 1 000 MW 1 332 MW 400 MW	 90 UH, 22.5 SH 54 UH, 13.5 SH 58 UH, 29 SH
OCGT: Ankerlig Gourikwa Avon Dedisa	3 080 MW 1 326 MW 740 MW 680 MW 334 MW	 326 UH, 36.2 SH 221 UH, 44.2 SH 210 UH, 52.5 SH 134 UH, 67 SH
GT: Accacia Port Rex	342 MW 171 MW 171 MW	 27 UH, 9 SH 46 UH, 15.3 SH
ILS	2 024 MW	120 minutes per week
VPS	0 – 500 MW	4 days a week of 120 minutes 40 – 150 MW in winter Up to 500 MW in summer
Critical peak day	~27 MW	Pilot project

OCGTs, GTs and pumped storage make up 6 000 MW of dispatchable generation. If the fuel for these generators is depleted it will add 6 stages of load shedding.

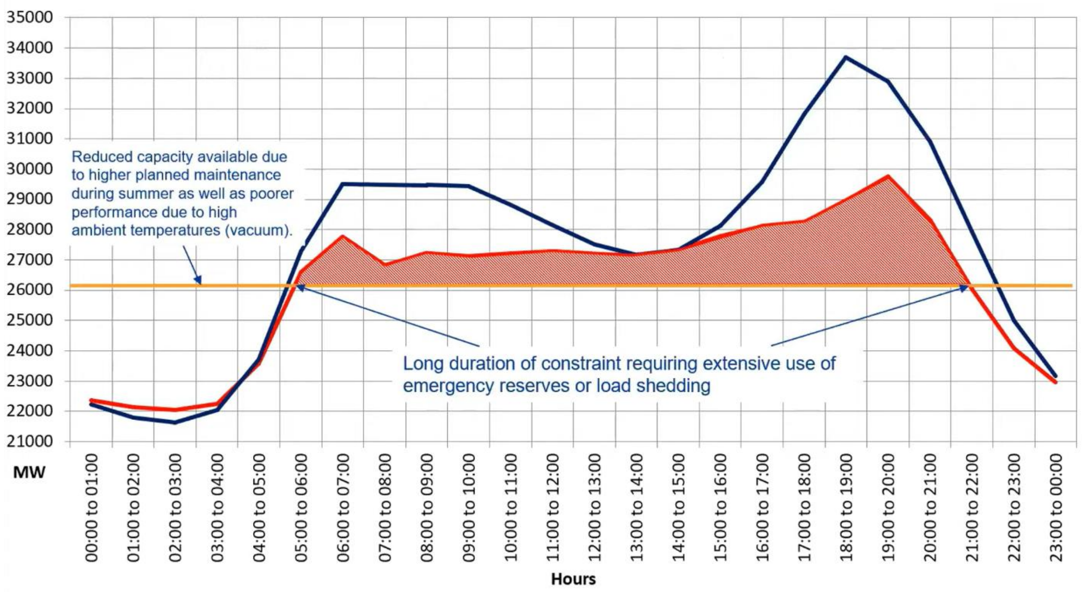
Source: Gavin Hurford Eskom System Operator, 2021. Why is load shedding necessary presentation

IT IS IMPORTANT TO DISTINGUISH BETWEEN BEING CAPACITY CONSTRAINED FOR SHORT PERIODS OF TIME IN THE EVENING PEAK AND BEING ENERGY CONSTRAINED ACROSS THE DAY

Example of load shedding for short duration evening peak (high plant availability, but high demand typical of winter)



Example of load shedding throughout the day (low plant availability, despite lower demand typical of summer)



Source: Eskom

Blue line is typical winter demand profile

Red line is typical summer demand profile

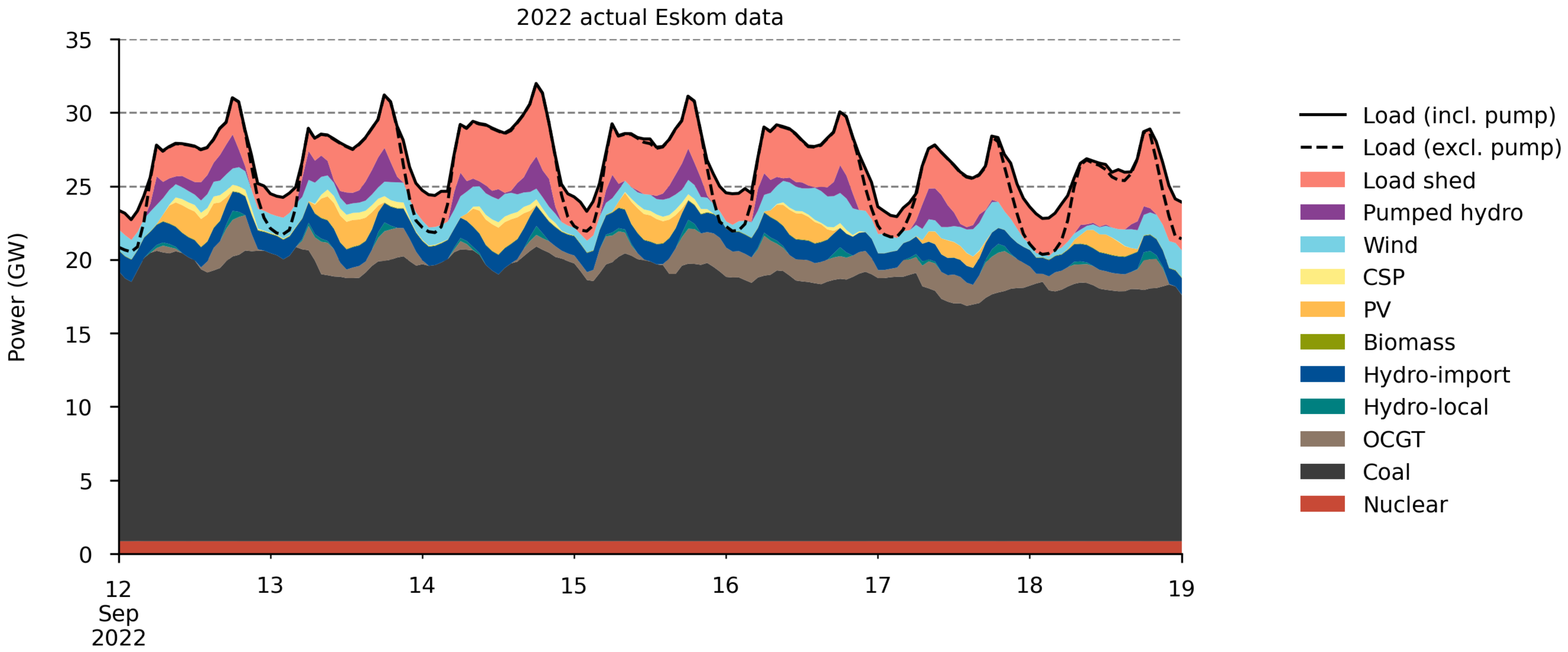
PUMPED HYDRO STORAGE AND OCGTS ARE KEY RESERVES TO MAINTAIN SYSTEM STABILITY

HOWEVER, BOTH RESOURCES ARE ENERGY CONSTRAINED AND CANNOT BE UTILISED FOR LONG PERIODS AT HIGH LOAD FACTORS WITHOUT BEING REPLENISHED.

Image source: www.polity.org.za

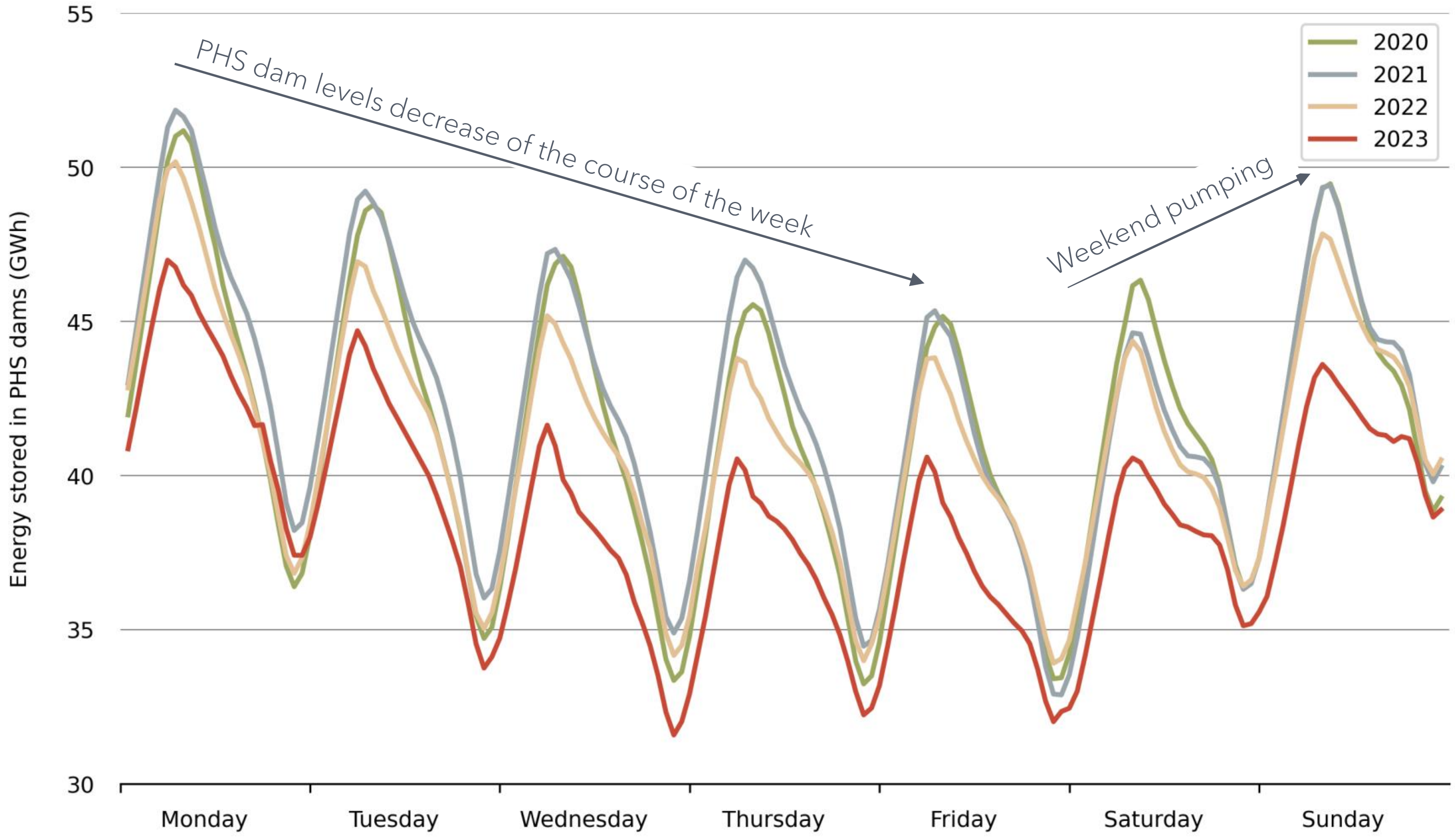
Image source: Engineering News

ACTUAL ESKOM SYSTEM DISPATCH FOR A WEEK INCLUDING STAGE 4-6 LOAD SHEDDING

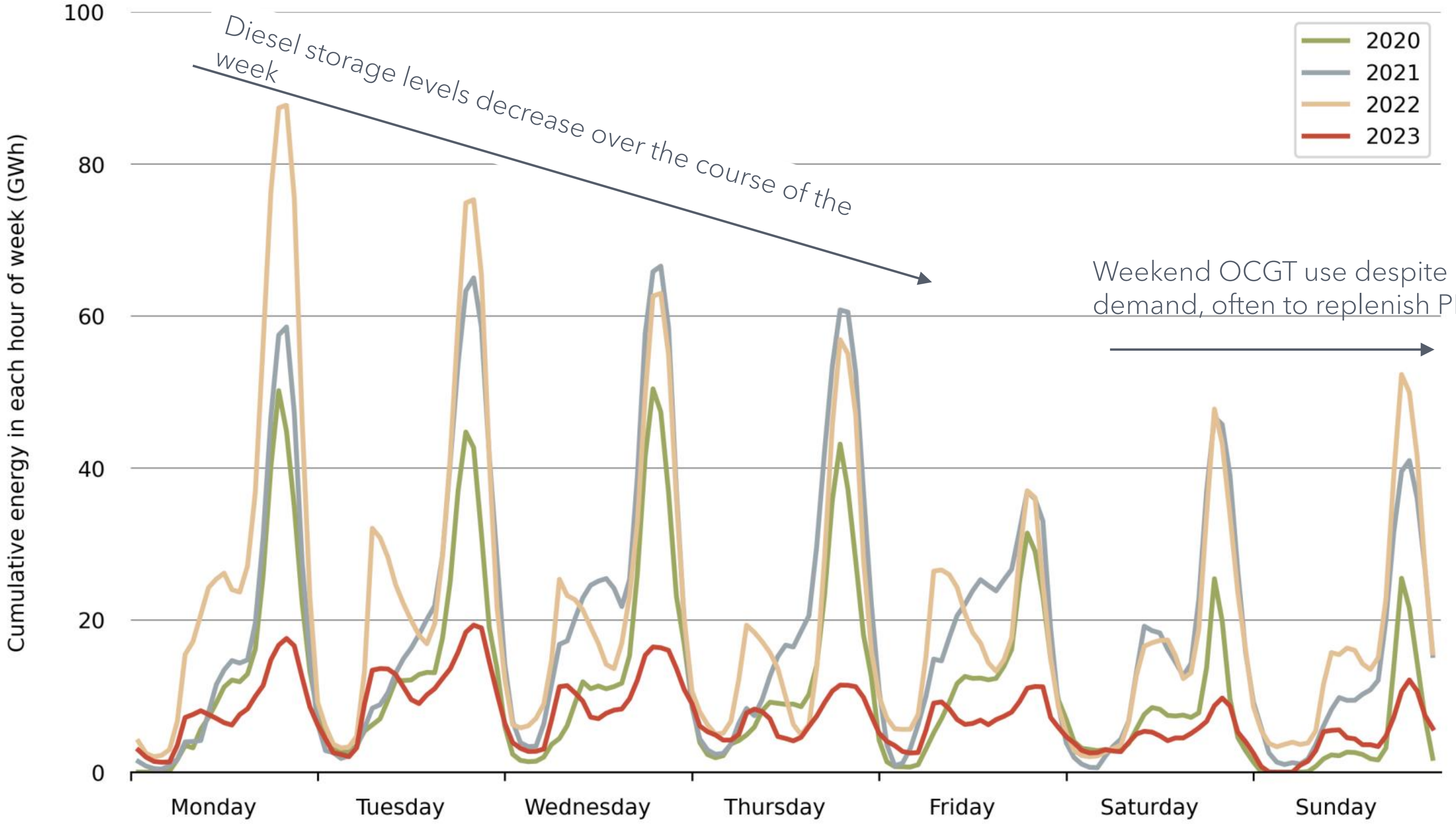


PUMPED HYDRO TYPICALLY OPERATES ON A 168H CYCLE

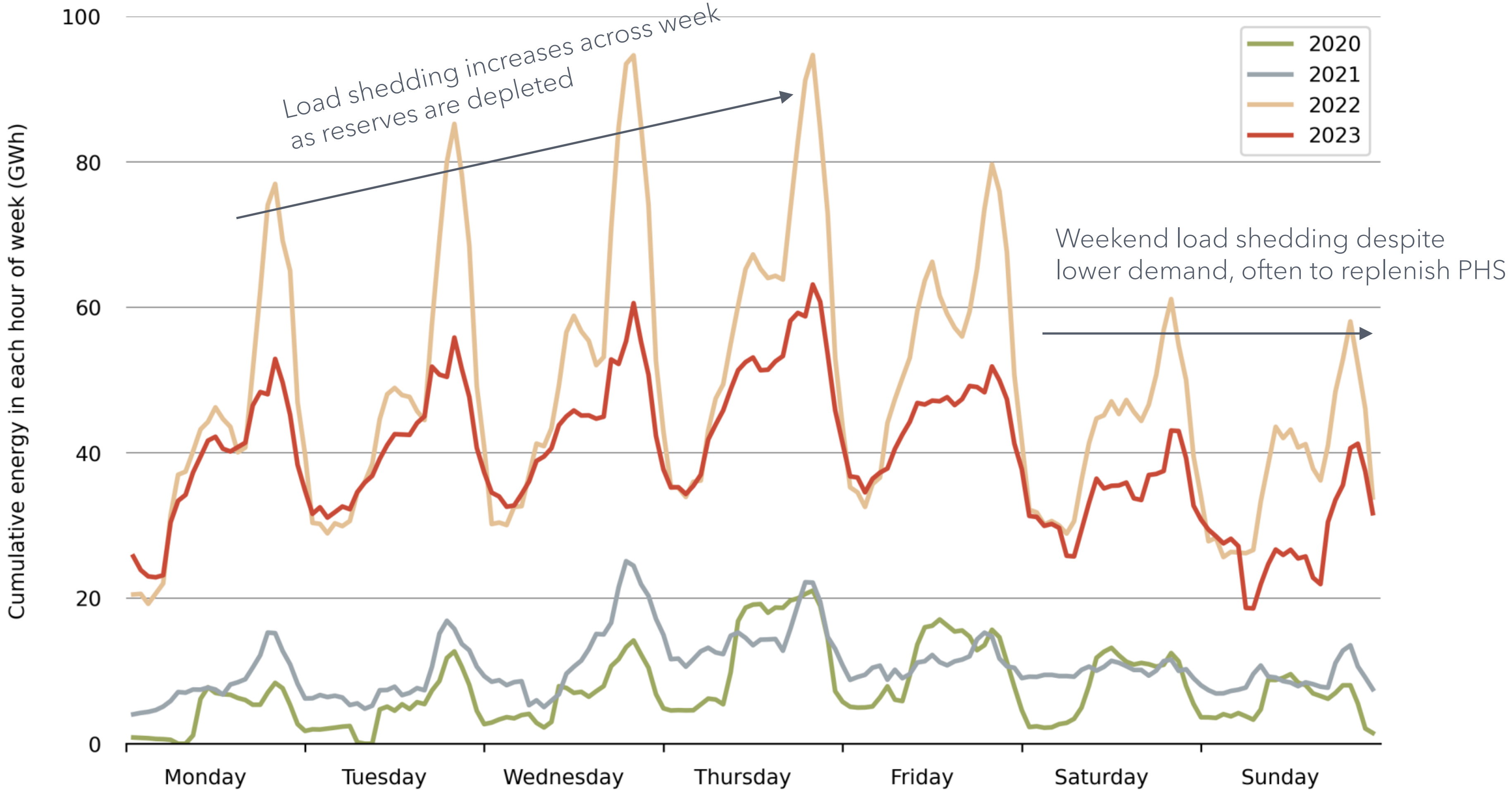
STORAGE DAMS ARE FULL ON MONDAY AND EMPTY ON FRIDAY EVENING – THEREFORE EFFECTIVENESS TO MANAGE LOAD SHEDDING REDUCES LATER IN THE WEEK



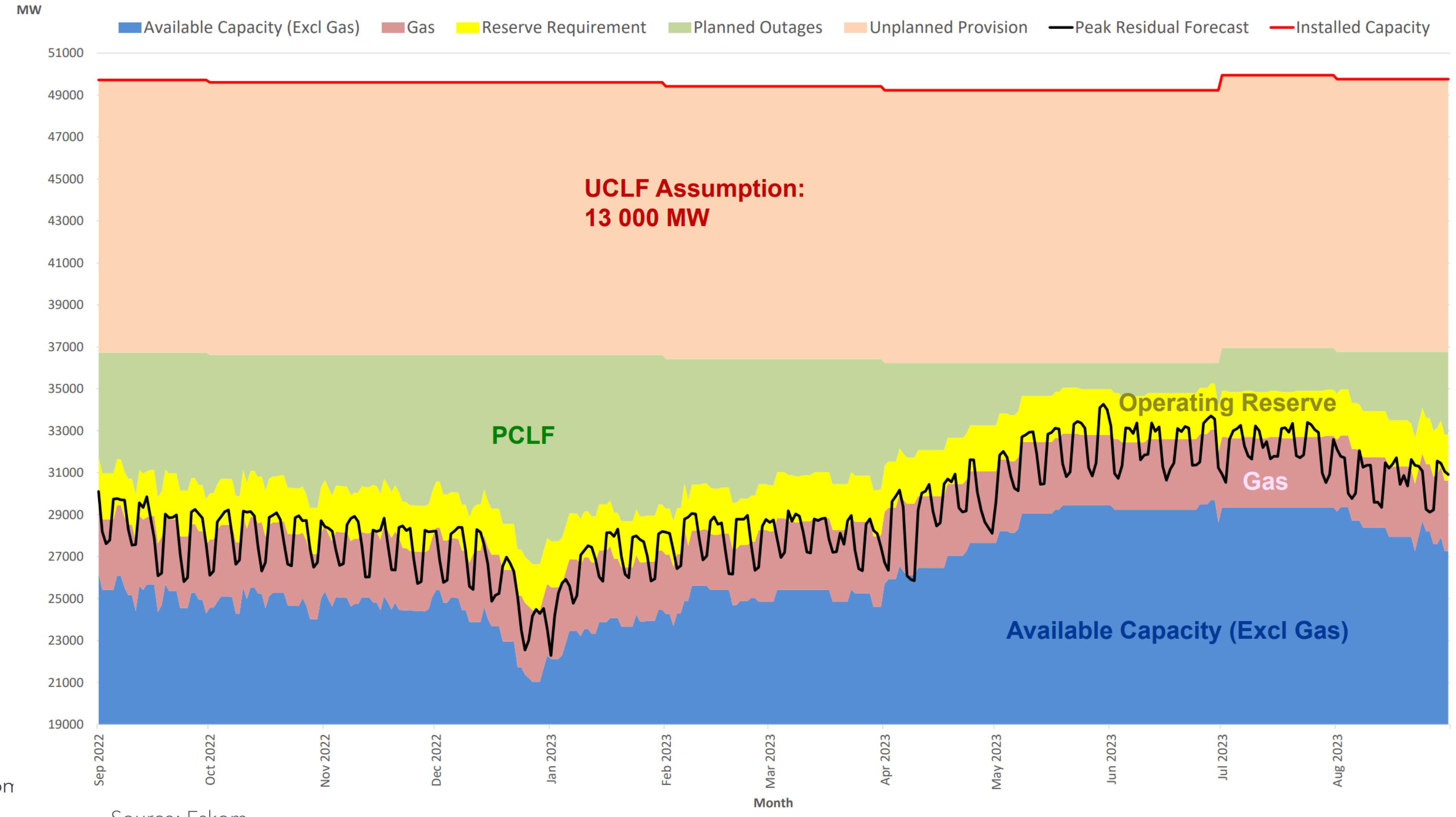
ENERGY PROVIDED BY OCGTS IS PRIMARILY IN THE EVENING PEAK, BUT CONTRIBUTION THROUGHOUT THE DAY IS INCREASING AS THE SYSTEM BECOMES MORE CONSTRAINED



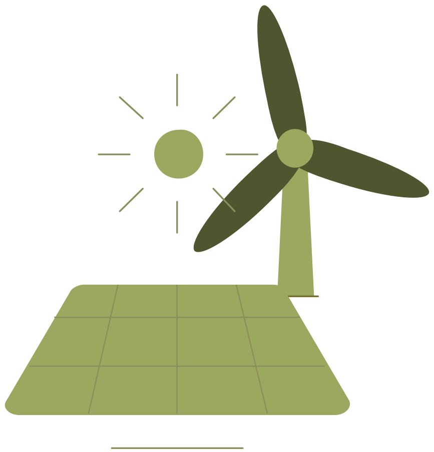
IN 2022 AND 2023 (YTD) THE SYSTEM WAS SO SHORT OF ENERGY THAT LOAD WAS CONSISTENTLY SHED ACROSS ALL HOURS OF THE WEEK, WITH HIGHER PEAKS IN THE EVENING



SYSTEM OPERATOR CAPACITY OUTLOOK FOR THE NEXT 12 MONTHS



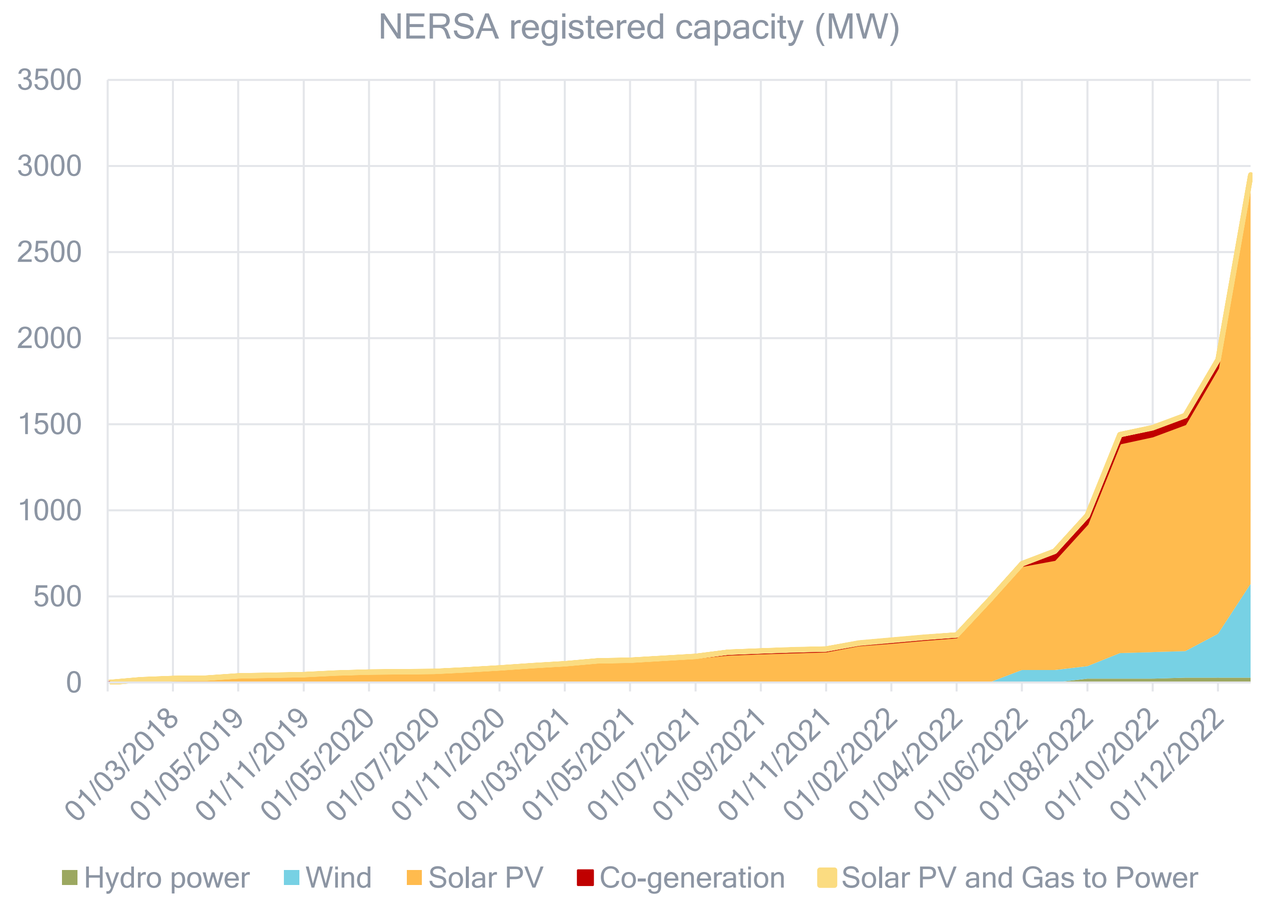
Source: Eskom

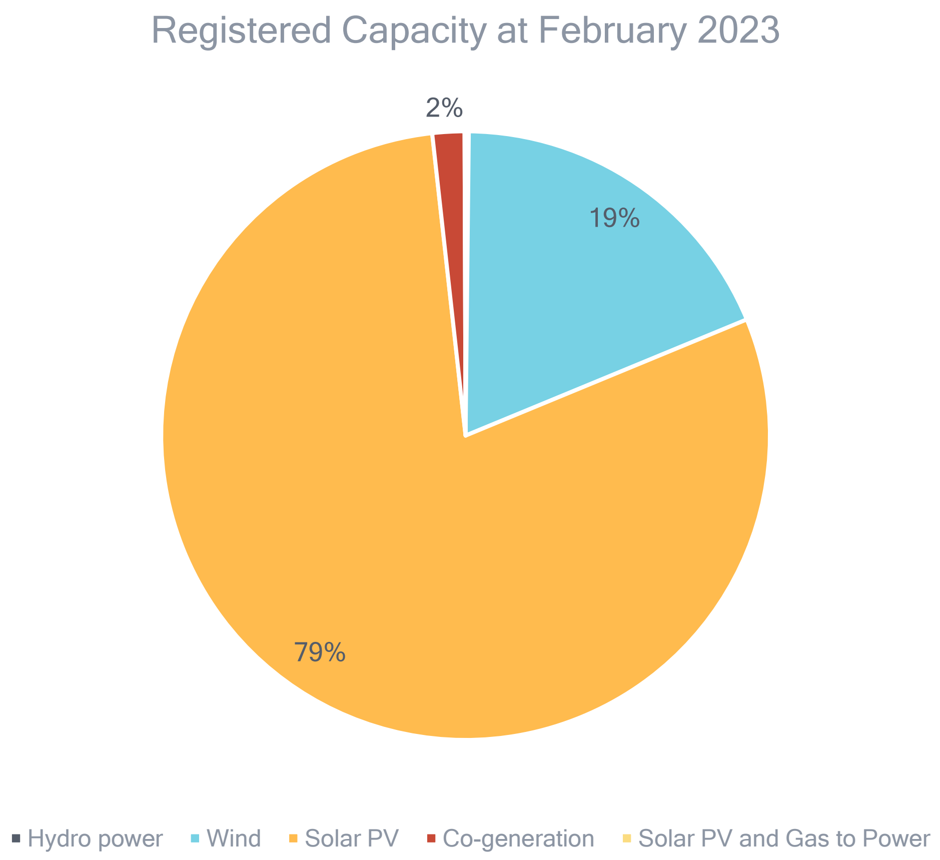


04

ANALYSING THE POTENTIAL IMPACT ADDITIONAL RENEWABLES WOULD HAVE MADE ON LOAD SHEDDING IN 2021 AND 2022

RAPID EXPANSION OF PRIVATE SECTOR SOLAR PV PROJECTS DUE TO THE LIFTING OF LICENSING RESTRICTIONS

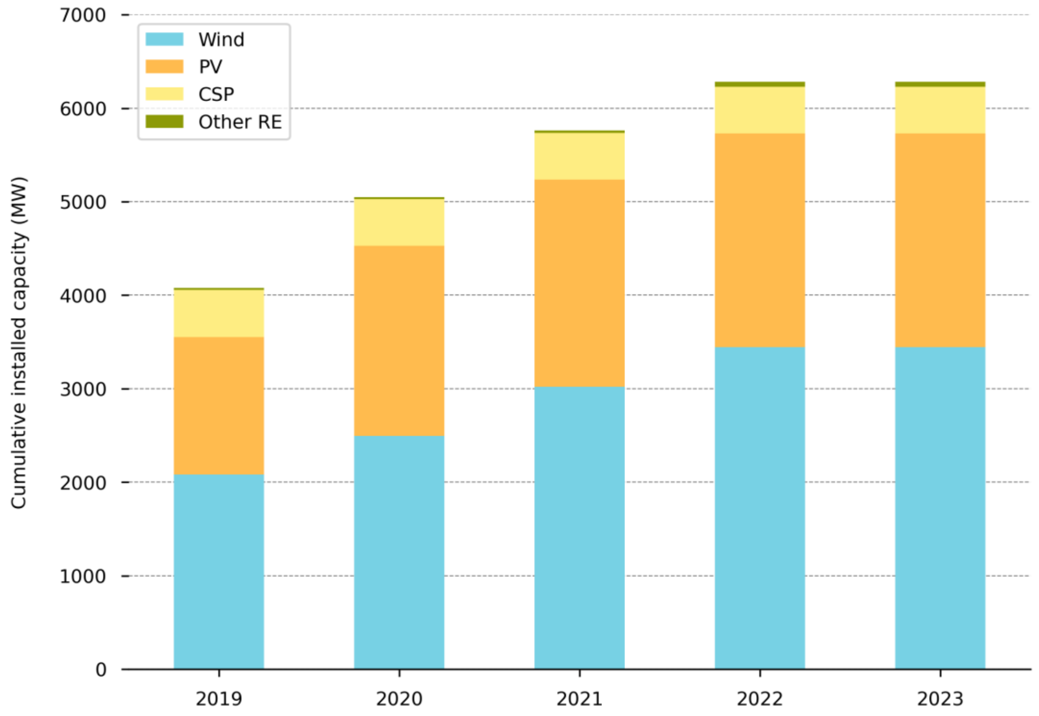


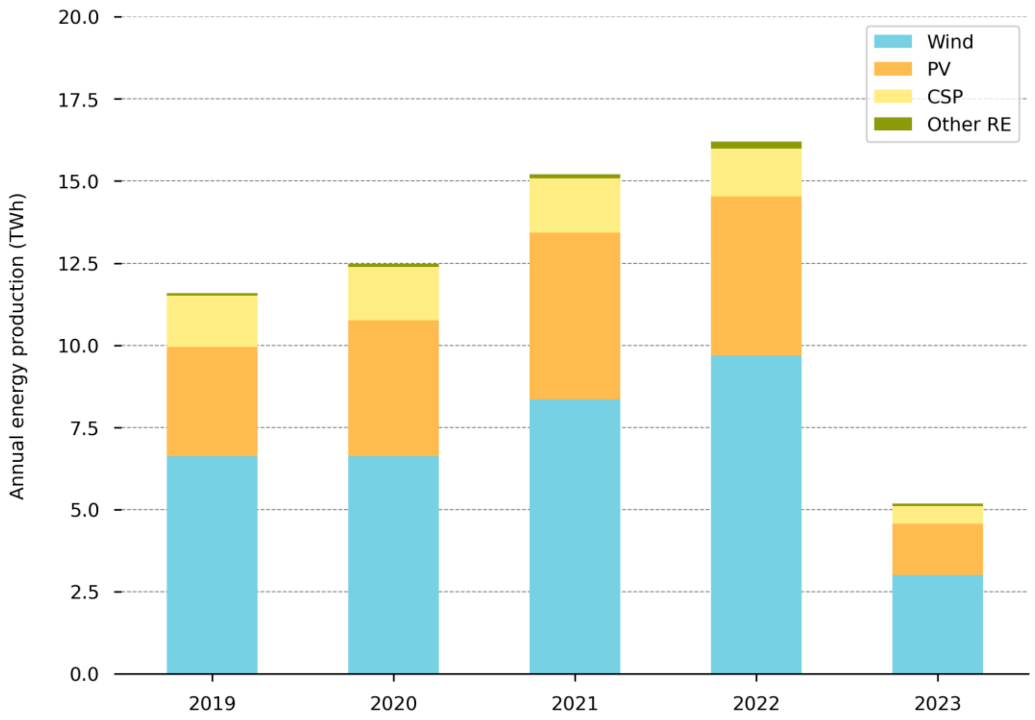


Data from [NERSA registered Generation facilities]

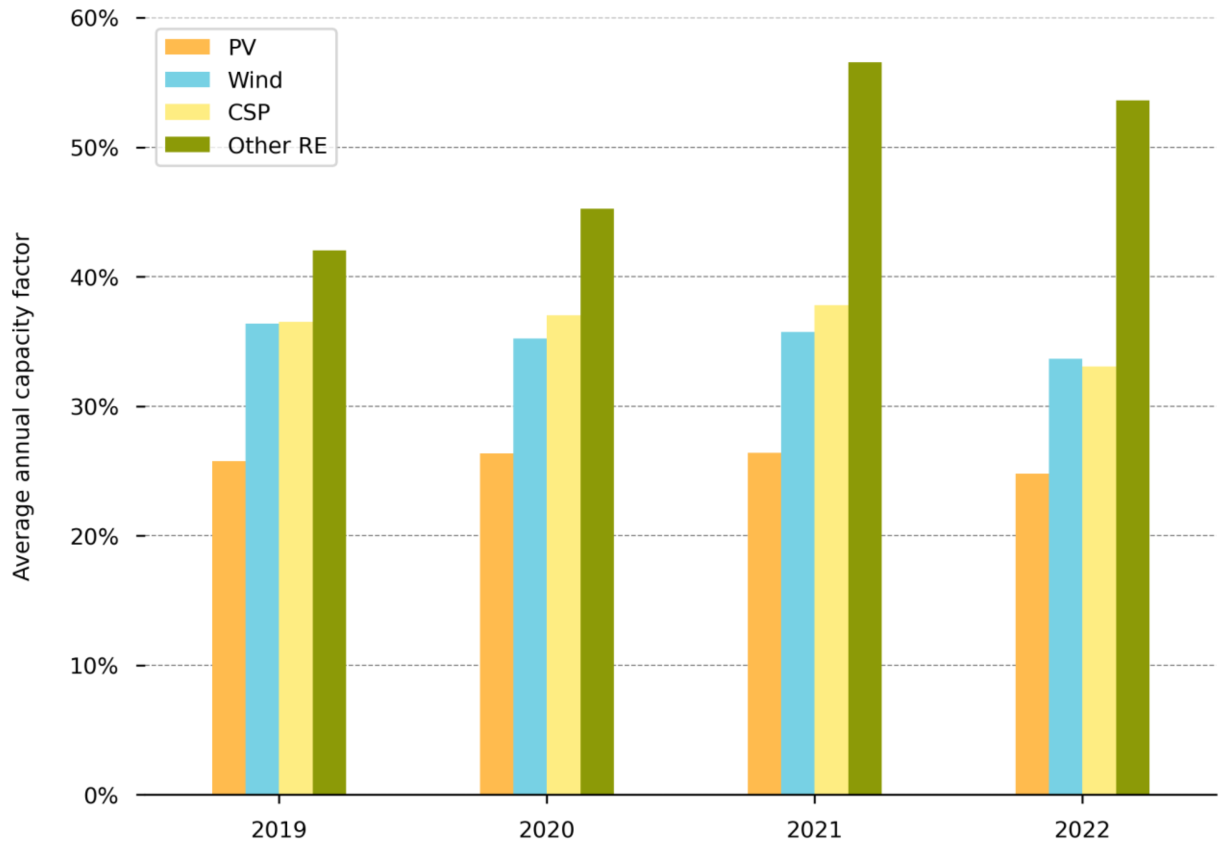
CURRENT RE CONTEXT:

THE CURRENT INSTALLED CAPACITY OF RENEWABLES IS 6280 MW, PRODUCING 16.2 TWH IN 2022





CURRENT RE CONTEXT:
THE CAPACITY FACTORS ACROSS RE TECHNOLOGIES HAS REMAINED CONSISTENT



WE RECENTLY COMPLETED STUDIES TO MODEL DIFFERENT SCENARIOS TO RESOLVE THE POWER CRISIS

- Last year, we published a two-part series on exploring a feasible strategy to resolve the load shedding crisis:
  - In Part A, we utilised Eskom's actual data to investigate the impact that additional generation capacity would have had on load shedding if it had been in operation in 2021, focusing on the shortest lead-time and cheapest sources of power generation. Using two separate modelling platforms, we demonstrated how avoidable the load shedding crisis would have been resolved, whilst enabling more efficient operation of our power system and associated cost saving.
  - Part B outlines a Game Plan of critical interventions to end load shedding and emphasizes how applying a laser focus to implementing strategic policy levers, government can establish high confidence that the problem will be resolved expeditiously.
- In February, we repeated our analysis done in Part A using updated Eskom data from 2022, where we experienced four times more load shedding than in 2021.

FLOW DIAGRAM SHOWING METHODOLOGY TO CALCULATE THE DIRECT IMPACT OF ADDITIONAL RENEWABLE ENERGY

Additional Renewable Energy (RE) is calculated in each hour based on Eskom actual generation data

Any load shedding in an hour is offset by the additional RE available

If RE exceeds load shedding, the remaining energy offsets OCGT generation and diesel is saved for later use

If RE exceeds load shedding and OCGT generation, the remaining energy offsets PHS generation and water is left in the upper dam (reduces pumping need in evening)

Any remaining RE offsets coal generation

DIFFERENT TYPES OF ENERGY SYSTEM MODELS ARE USED TO ADDRESS DIFFERENT PROBLEM TYPES

Decades

Capacity expansion planning
(Generation and transmission investments)

Production cost/resource adequacy
(System operational costs and impacts)

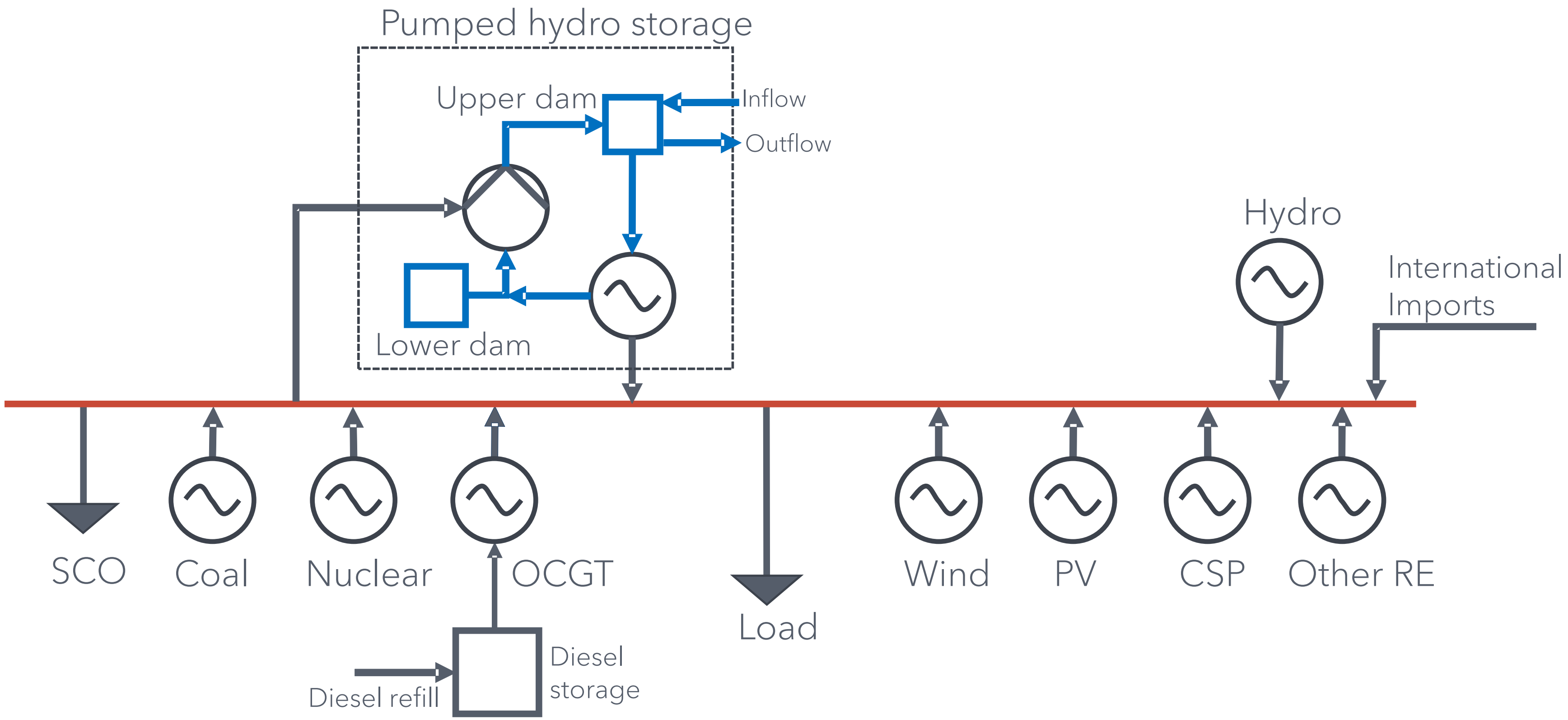
Power flow modelling
(Transmission planning and reliability)

Transient stability modelling
(Reliability and transient analysis)

Seconds

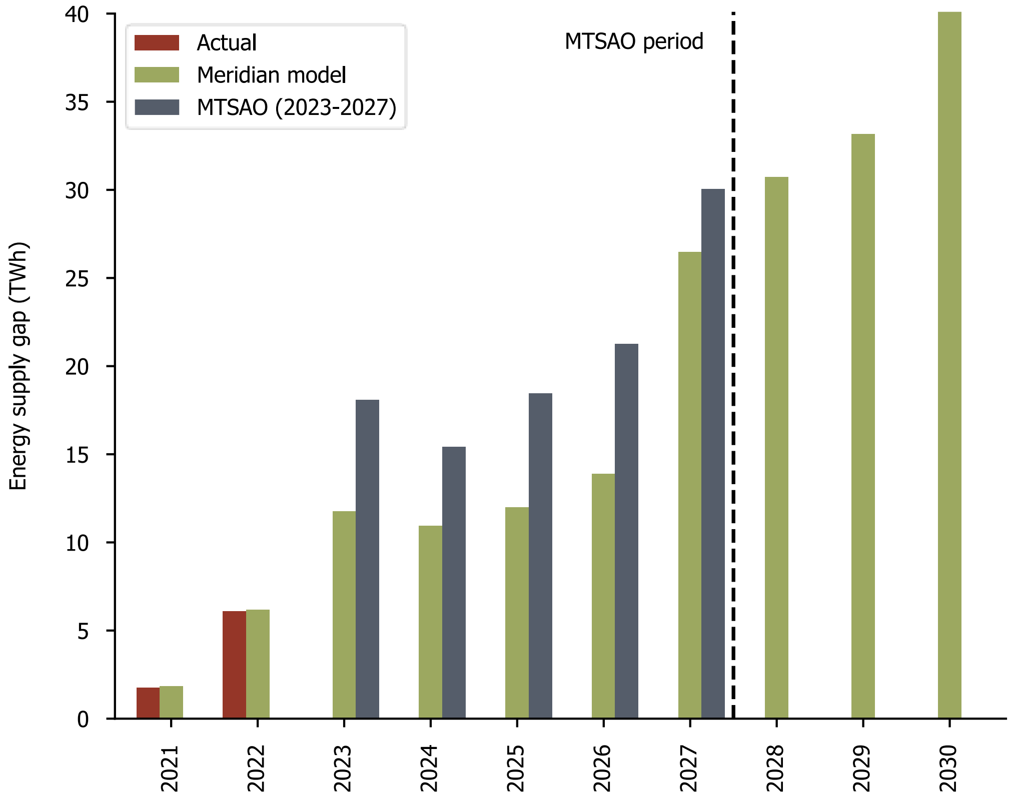
Modified from Mileva, Deshmukh. (2020) The GridPath Electricity Modelling Platform

WE ALSO USED A POWER SYSTEM DISPATCH MODEL TO SIMULATE HOW THE SO MIGHT HAVE RE-DISPATCHED PEAKING ASSETS HAD MORE RE BEEN AVAILABLE IN 2021 AND 2022

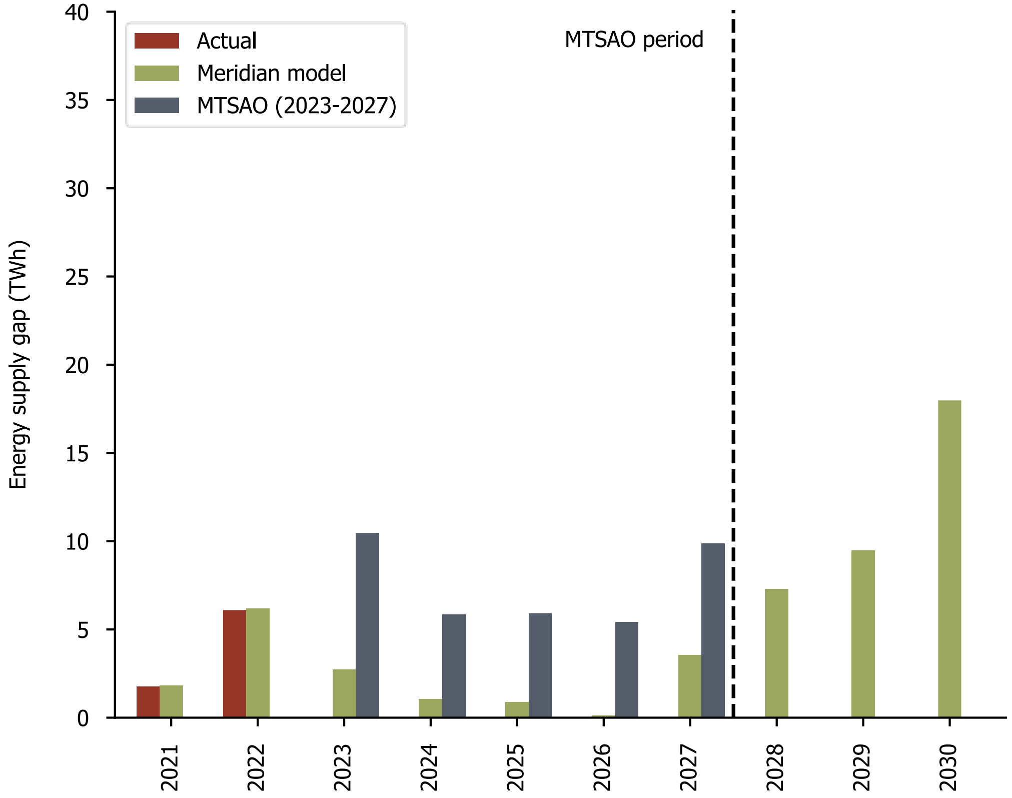


WE HAVE USED OUR POWER SYSTEM MODEL TO RECREATE THE MTSAO 2023-2027 SCENARIOS AND THE RESULTS ARE COMPARABLE WITH THE ESKOM MODELLING

Low EAF and high demand



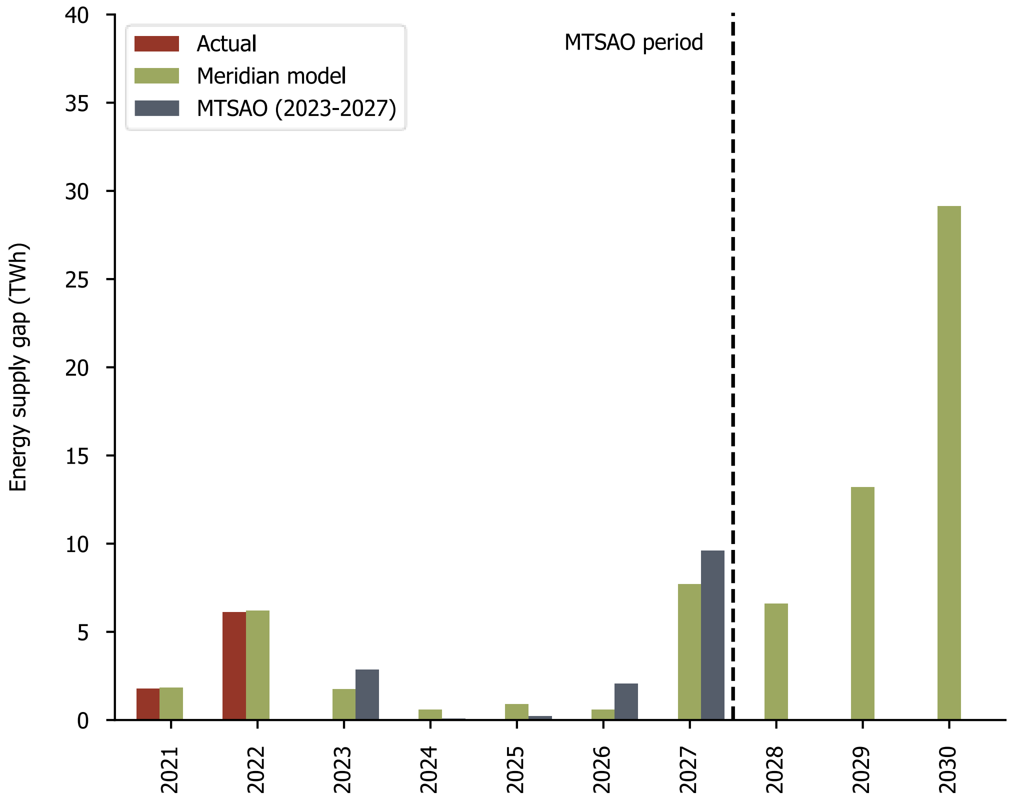
Low EAF and low demand



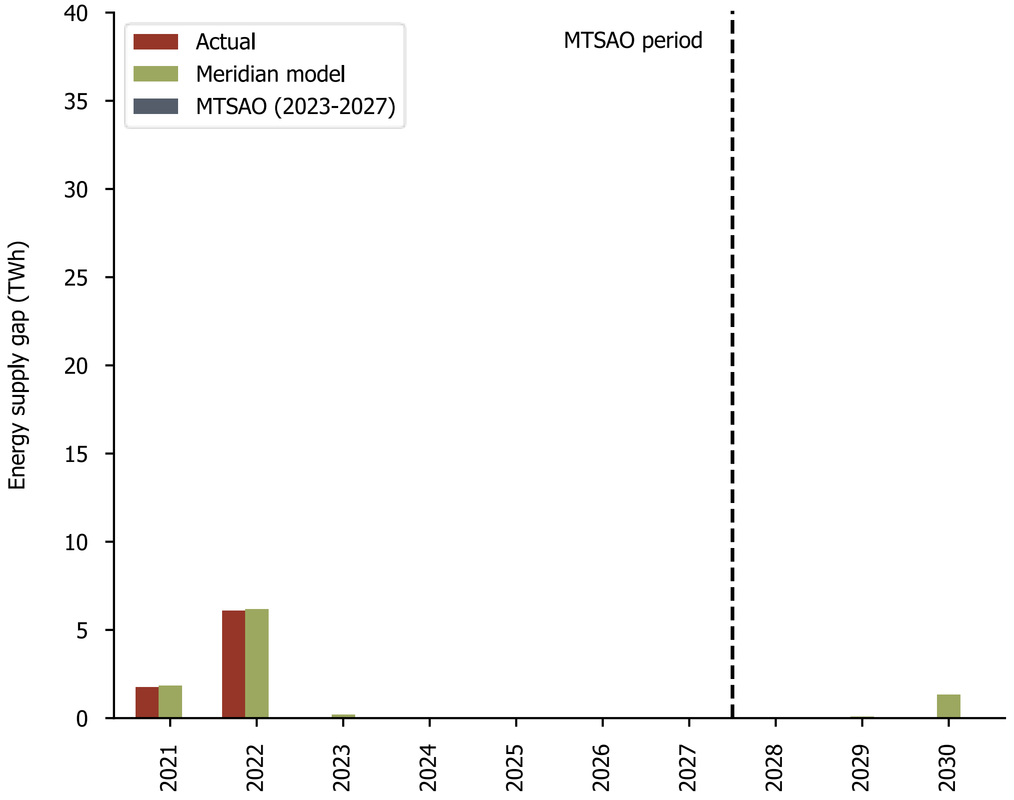
Based on only capacity installed to date, validation was completed in Oct 2022, so not all of 2022 was modelled

WE HAVE USED OUR POWER SYSTEM MODEL TO RECREATE THE MTSAO 2023-2027 SCENARIOS AND THE RESULTS ARE COMPARABLE WITH THE ESKOM MODELLING

High EAF and high demand

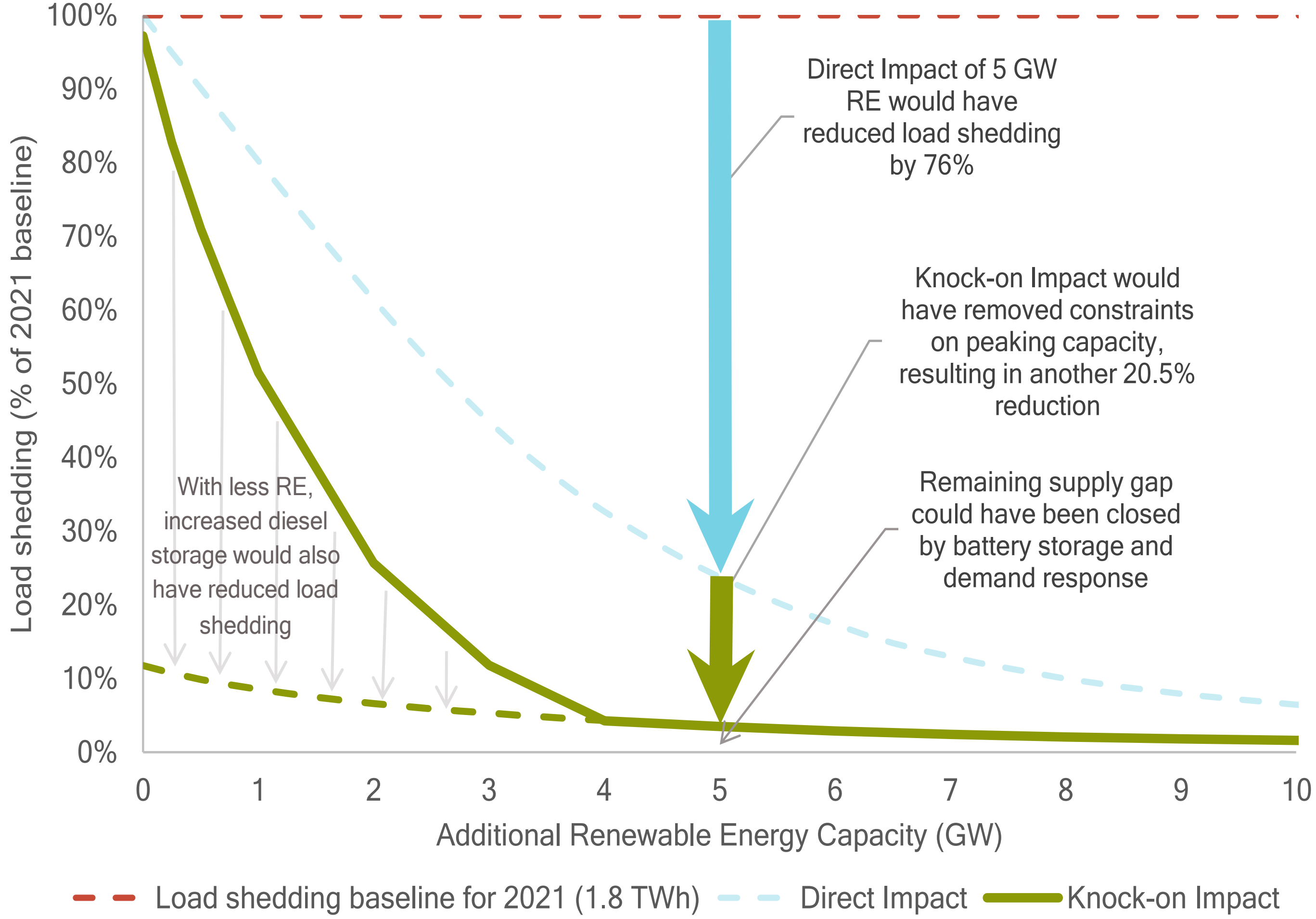


High EAF and low demand



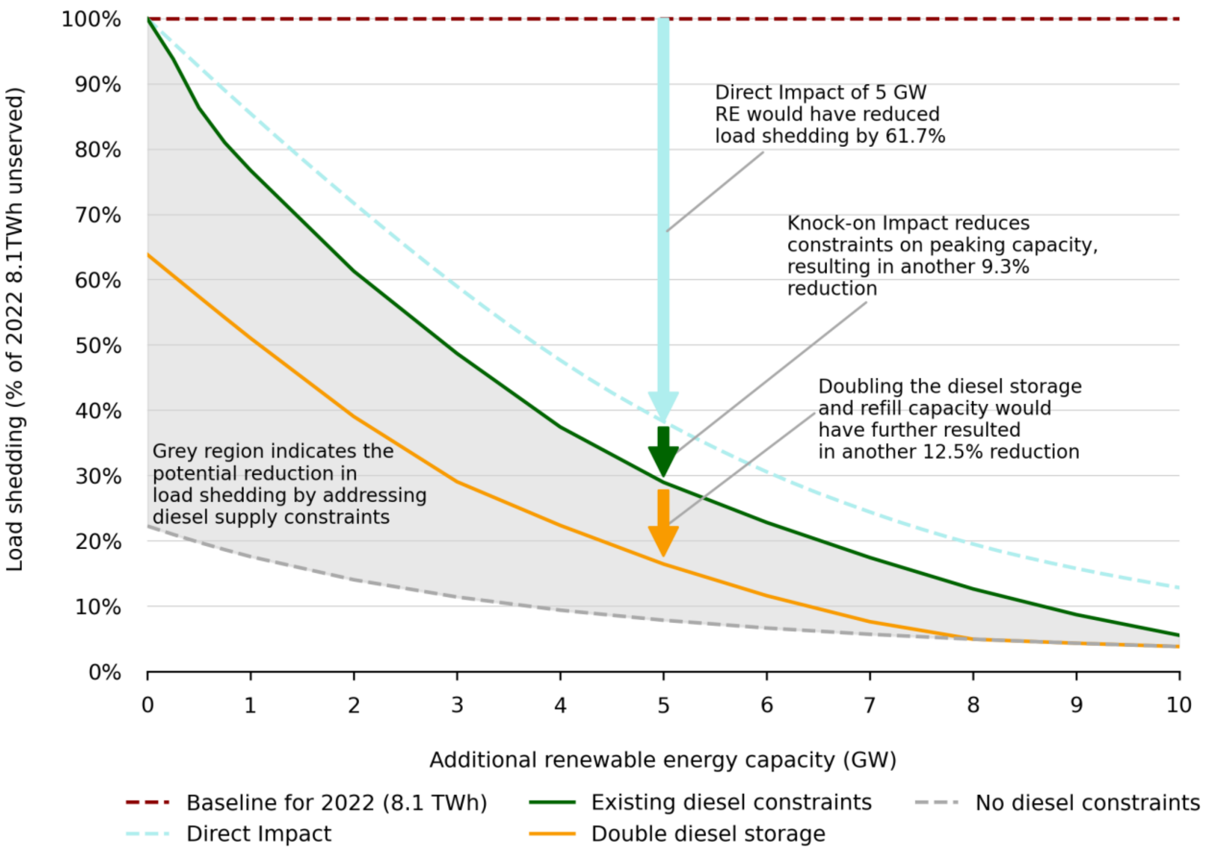
INSIGHTS BASED ON ACTUAL ESKOM LOAD SHEDDING DATA:

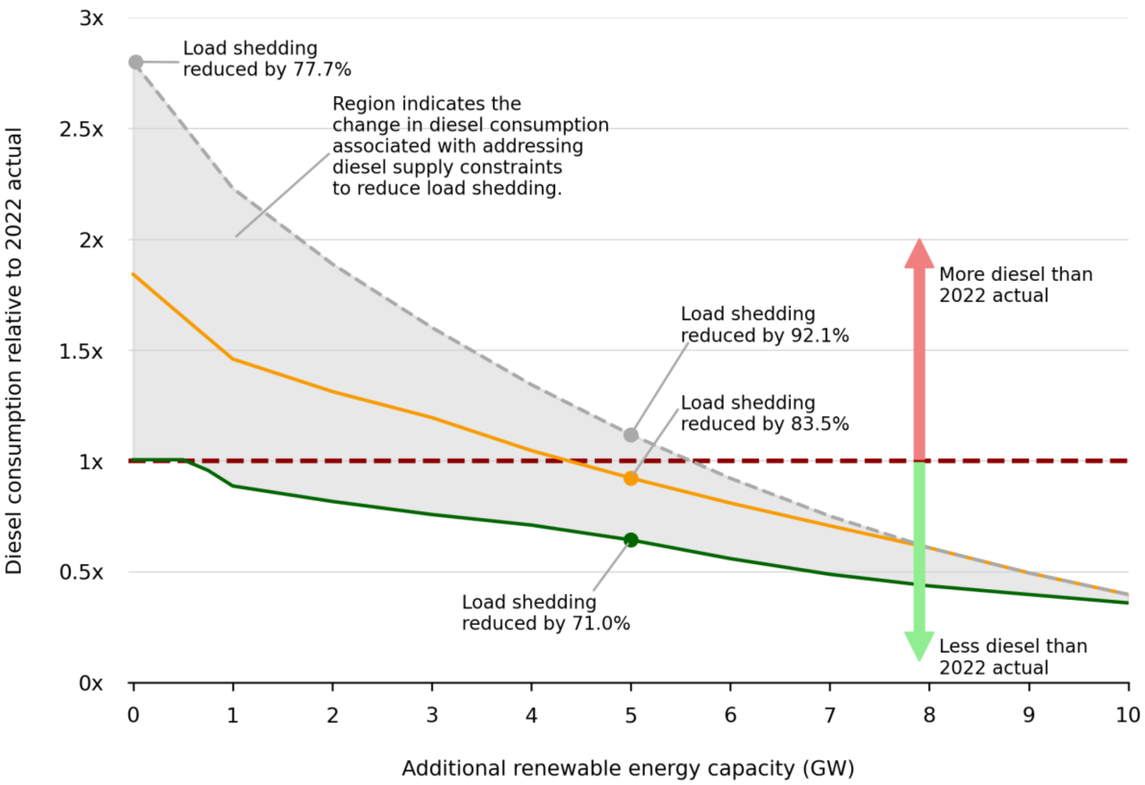
5GW OF ADDITIONAL RENEWABLES WOULD HAVE REDUCED LOAD SHEDDING BY 96.5% IN 2021 WHICH REACHED 1.8 TWH (MLR)



INSIGHTS BASED ON ACTUAL ESKOM LOAD SHEDDING DATA:

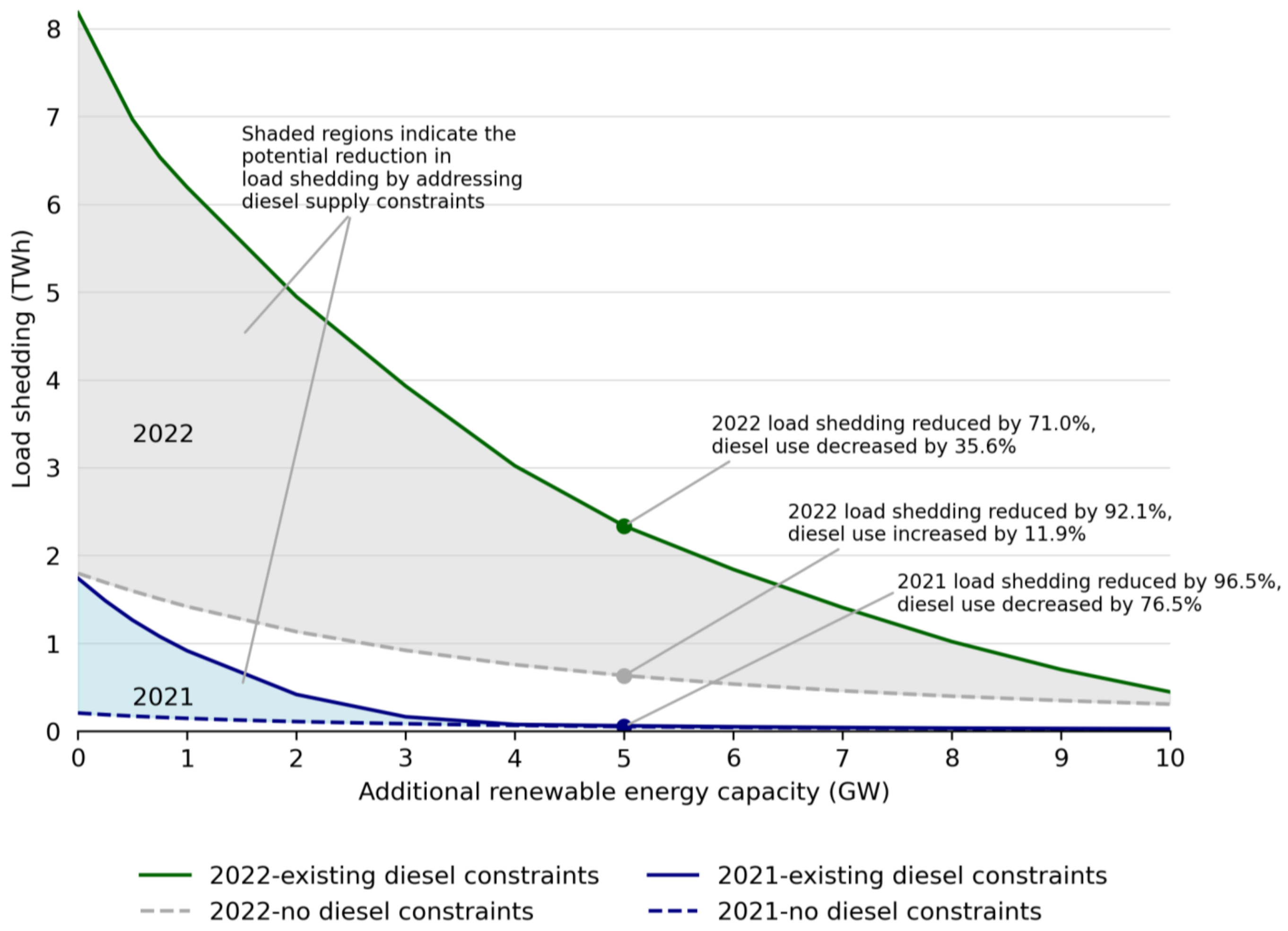
5GW OF ADDITIONAL RENEWABLES WOULD HAVE REDUCED LOAD SHEDDING BY 71% IN 2022, WHICH COULD HAVE BEEN FURTHER EXTENDED BY RELAXING DIESEL SUPPLY CONSTRAINTS, WITHOUT BURNING MORE DIESEL OVERALL



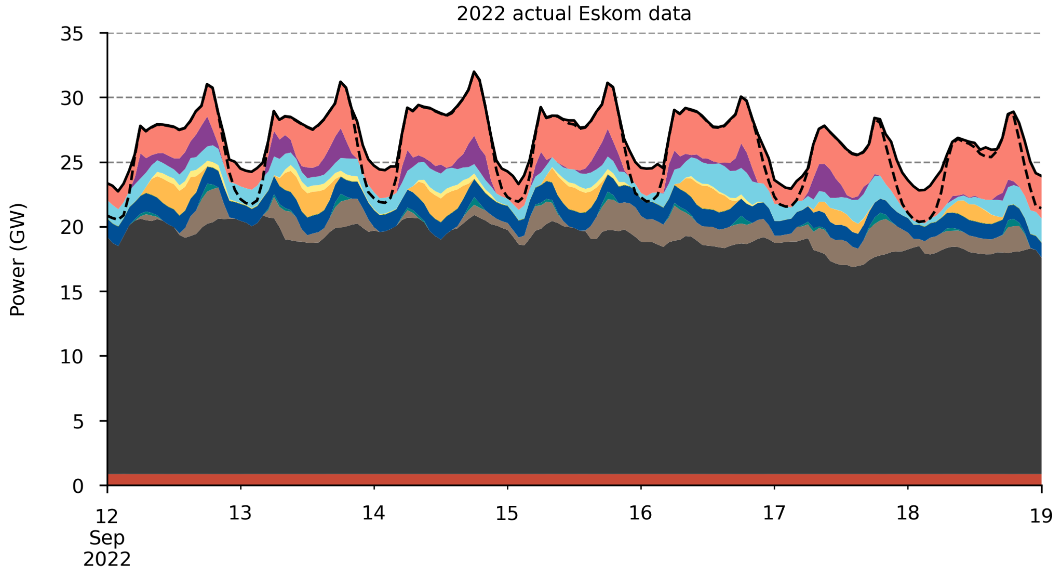


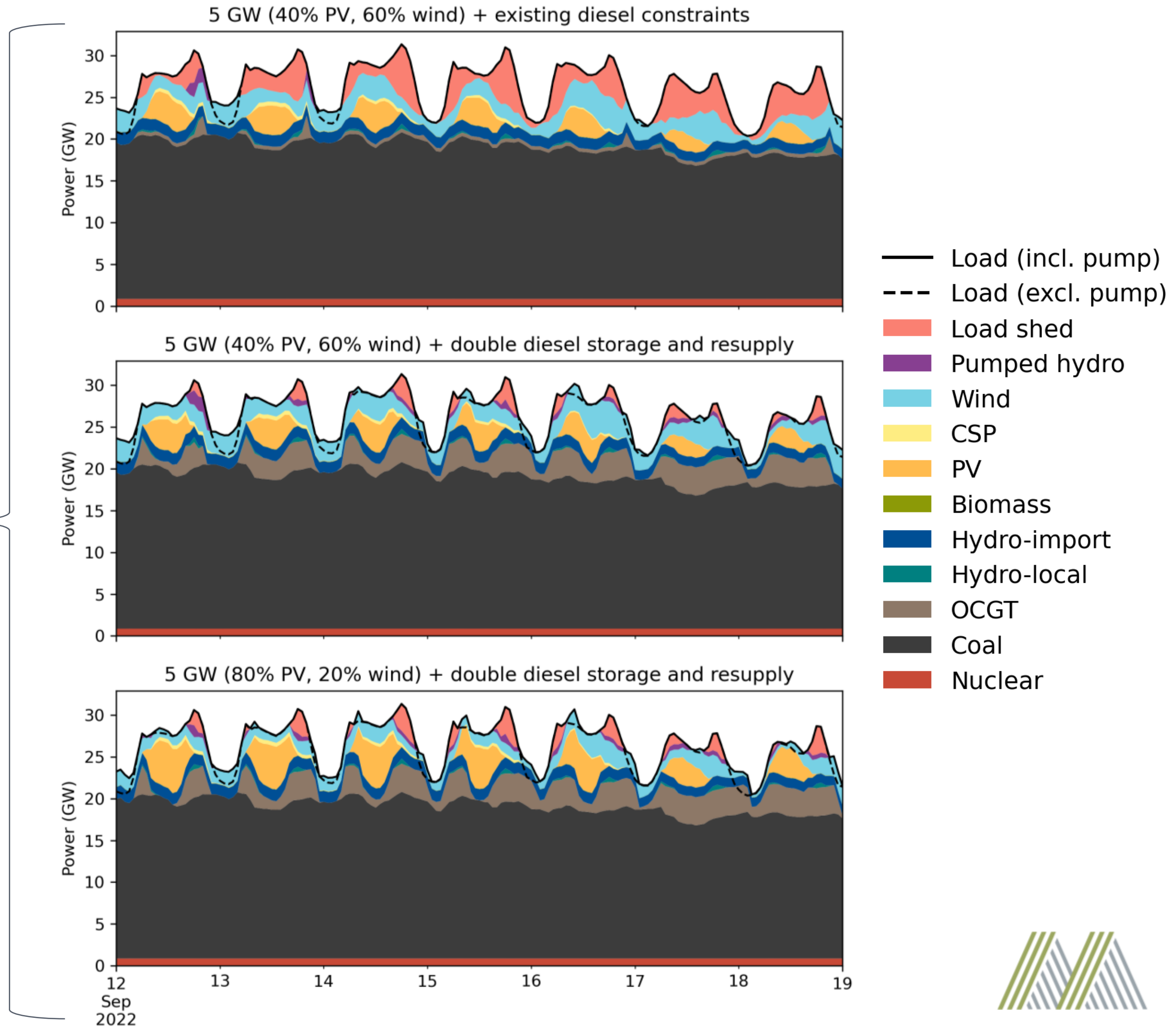
INSIGHTS BASED ON ACTUAL ESKOM LOAD SHEDDING DATA:

5GW OF ADDITIONAL RENEWABLES WOULD HAVE REDUCED LOAD SHEDDING BY 71% IN 2022 AND BY 96.5% IN 2021, DEPENDING ON DIESEL SUPPLY CONSTRAINTS

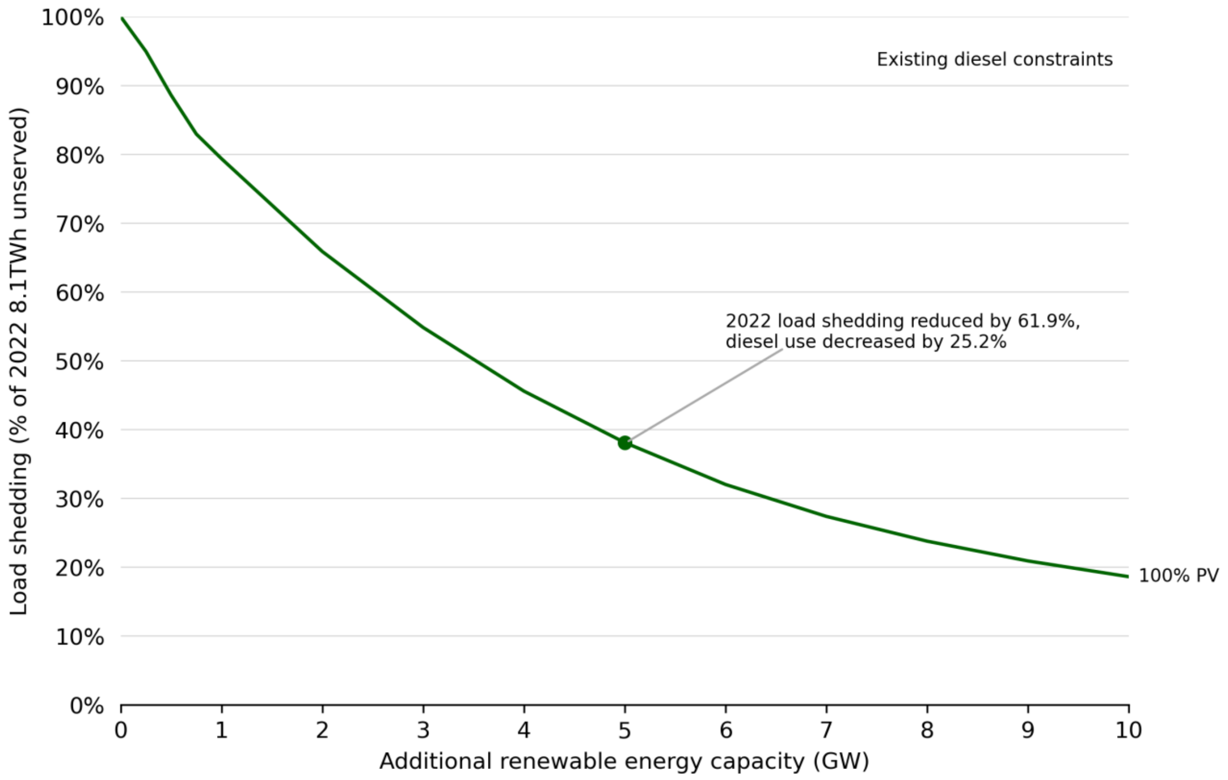


EXAMPLE OF SYSTEM DISPATCH WITH ADDITIONAL RE AVAILABILITY





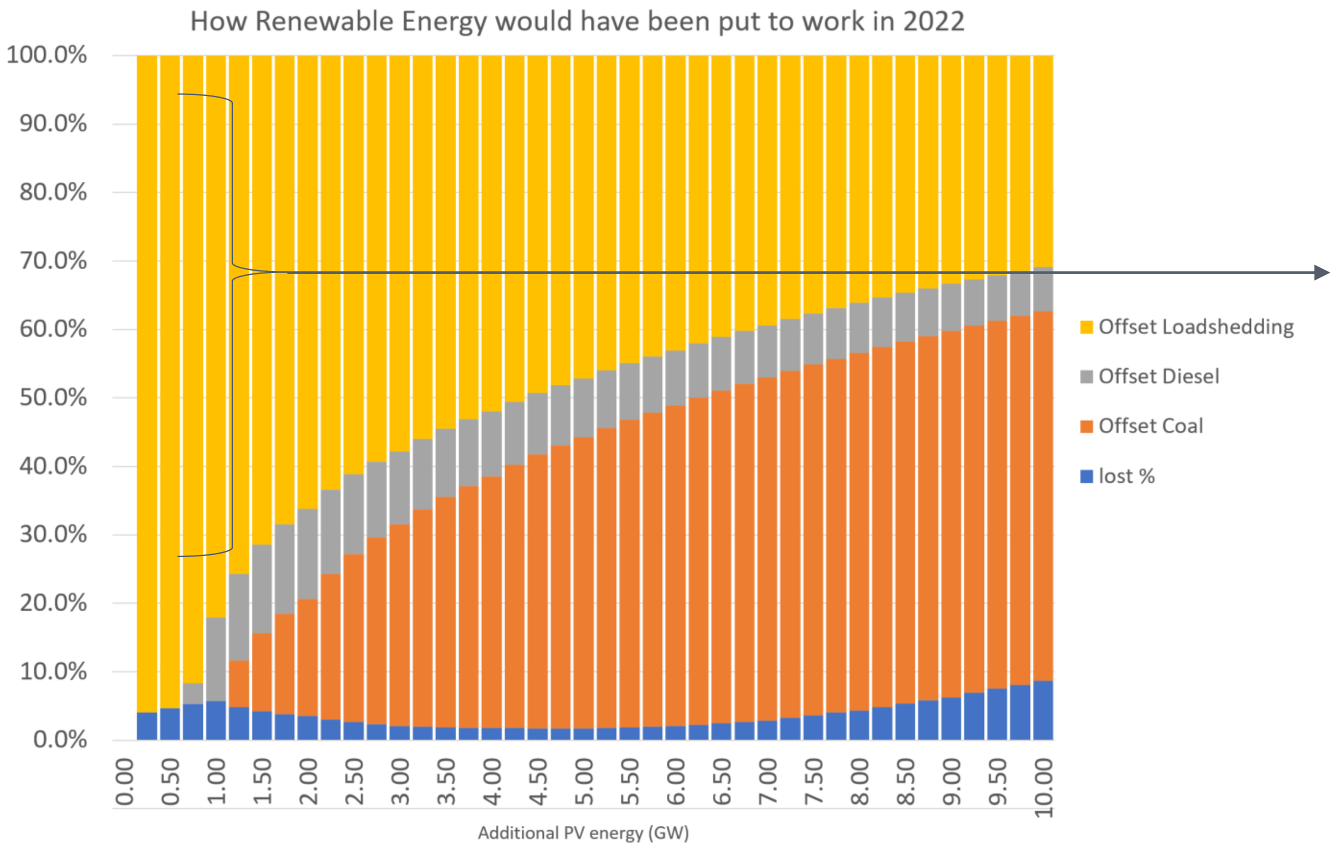
EVEN WHEN RELYING ON ONLY PV DUE TO GRID CONSTRAINTS LOAD SHEDDING IS SIGNIFICANTLY REDUCED



[1]Utility plants typically use single axis tracking to increase energy yield. kWp refers to the installed capacity on the DC side under standard conditions, whilst utility scale is maximum export AC

- Adding additional PV generation at the start of 2022 would have significantly reduced load shedding.
- For 5GW of utility scale PV load shedding in 2022 would have been 62% lower, whilst saving 25% on diesel costs.
- 5 GW of utility scale PV is equivalent to roughly 8 GWp of rooftop PV generation[1].
- Using our system dispatch modelling, we are able to quantify the avoided costs in terms of load shedding, diesel and coal consumption.

THE SYSTEM SAVINGS ARE DETERMINED BY THE AMOUNT OF LOAD SHEDDING, DIESEL AND COAL CONSUMPTION THAT ARE OFFSET THROUGH THE ADDITIONAL PV ENERGY (2022 EXAMPLE)

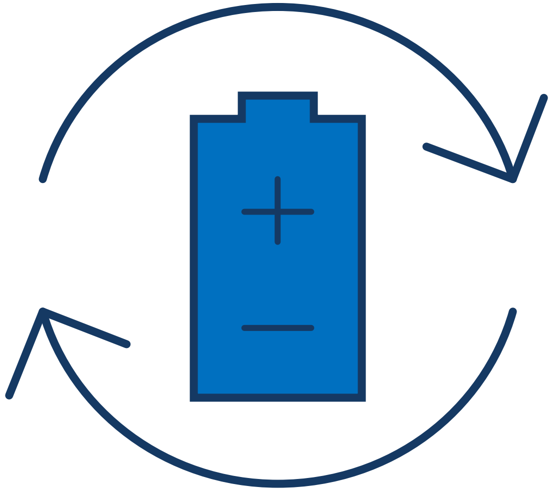


- Loadshedding will always be offset first by additional PV energy when possible, followed by diesel and then coal.
- Virtually all energy from additional PV capacity, up to 1GW, goes directly into offsetting load shedding. shedding.
- As more PV is installed above 1GW the share that goes towards load shedding reduces but remains above 30% even at 10GW
- At 5GW of additional PV energy
  - 47% offsets load shedding
  - 9% offsets diesel
  - 43% offsets coal
  - 1% is lost through pumped hydro losses

DEPLOYMENT OF SOLAR PV AND RELIEVING DIESEL SUPPLY CONSTRAINTS ARE CRITICAL SHORT-TERM SOLUTIONS

- 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 have the shortest lead time and is immune from transmission network constraints
- In the very short term, burning large volumes of diesel when required is the only means to address the current crisis and is economically rational.
- One of the main causes of load shedding is existing logistical supply constraints that hinder the ability for OCGTs to burn diesel when necessary
  - Doubling the available diesel storage at the OCGT plants can enhance diesel usage and further mitigate load shedding.
- Beyond the very short term, as more RE is rapidly added to South Africa's power system, improved diesel logistics can provide enough diesel to ensure continuous supply to the OCGTs for shorter intense usage periods

03



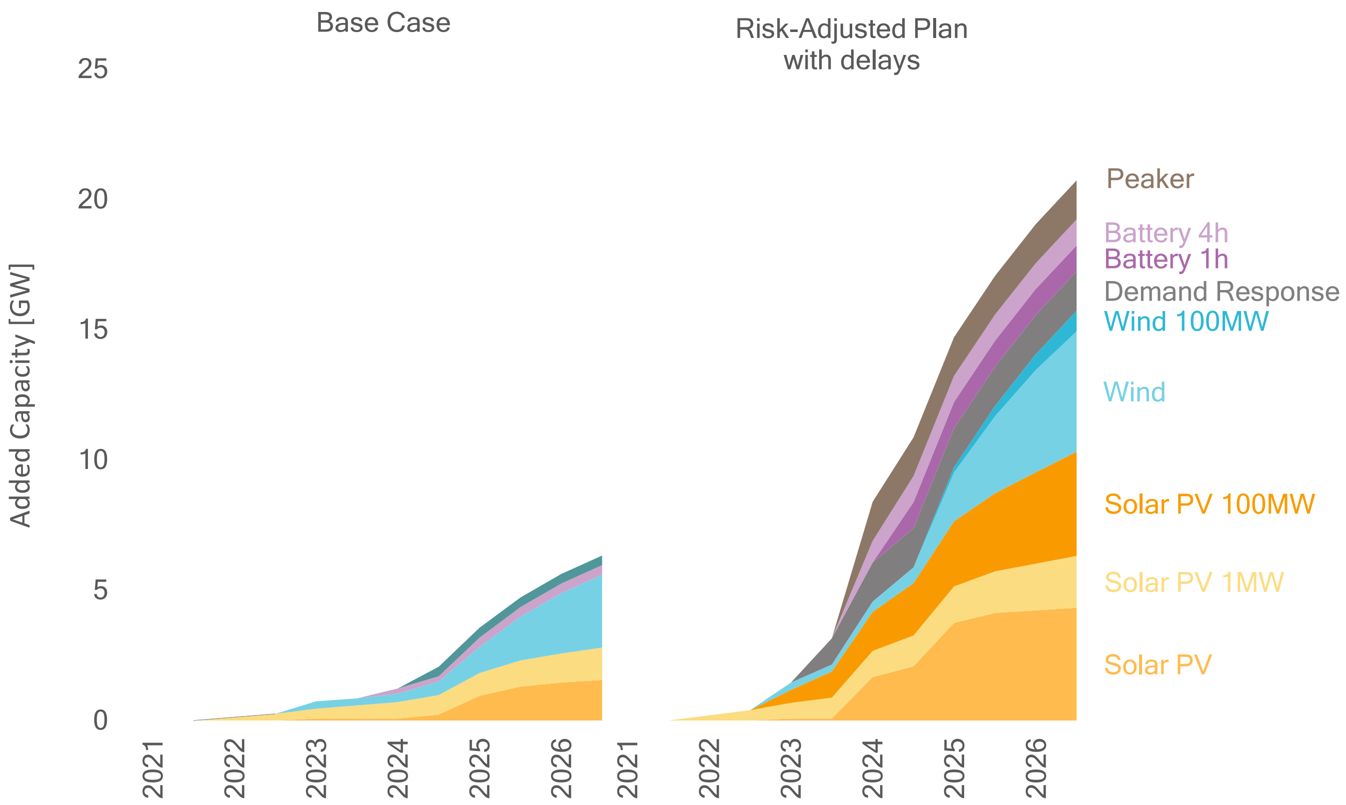
OUR GAME PLAN TO RESOLVE THE POWER CRISIS

THE GAME PLAN

RAPIDLY INCREASING ENERGY RESOURCES IN LINE WITH A 'RISK ADJUSTED RESOURCE PLAN' IS REQUIRED TO RESOLVE LOAD SHEDDING IN 2-3 YEARS

These include to:

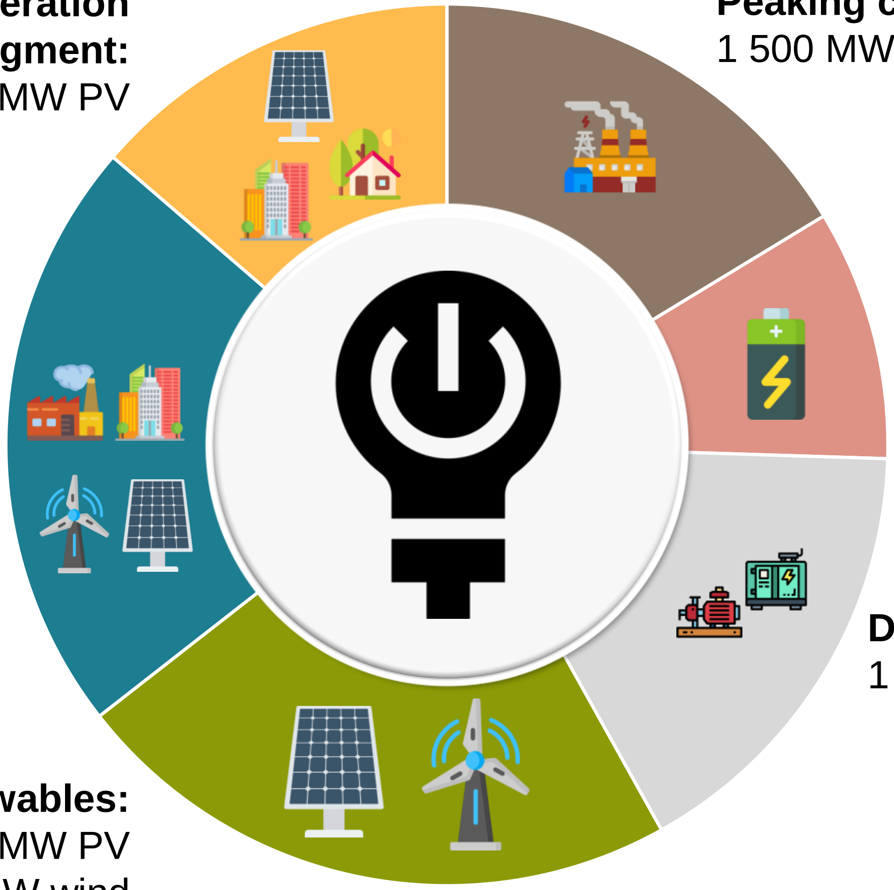
- Get as much capacity as possible online from the **RMIPPPP and REIPPPP BW5 projects** through increasing the likelihood that these projects can close, and minimise further PPA signature delays;
- **Expand REIPPPP BW6** by more than double and strengthen incentives for earlier connection;
- Rapidly accelerate the **uptake of <1 MW and 100MW** projects by increasing market incentives;
- Obtain **additional energy** from the multitude of existing and new projects (big and small) that are distributed throughout the grid;
- Urgently install **additional thermal peaking capacity** and expanded diesel storage at existing peakers;
- Procure a large amount of **Demand Response (DR) capacity** from DR aggregators and a large amount of **additional battery storage.**



THE SUITE OF ADDITIONAL ENERGY RESOURCES REQUIRED BY 2024 IN A 'RISK ADJUSTED RESOURCE PLAN'

Distributed generation in < 1 MW segment:
1250 MW PV

Peaking capacity:
1 500 MW



Battery storage:
840 MW

Distributed generation in 100 MW segment:
2000 MW PV

Demand Response:
1 500 MW

Utility scale renewables:
1 671 MW PV
389 MW wind
100 MW CSP

CONTACT US

name.surname@meridianeconomics.co.za
www.meridianeconomics.co.za

Suite EB04, Tannery Park,
23 Belmont Road, Rondebosch, 7700
+27 21 200 5857