
FLEXIBLE GAS:
AN ENABLER OF
SOUTH AFRICA'S
ENERGY
TRANSITION

CONTENT

ABSTRACT

South Africa is currently experiencing a severe power crisis with the country plunged into daily black-outs (or 'loadshedding') largely due to a lack of new capacity coming online to replace the ageing coal fleet. As of late, announcements from the President have been made outlining a myriad of interventions to be undertaken to resolve the current crisis, many of which would support a significant growth in renewable energy onto the system.

This paper looks at both the adequacy of South Africa's proposed energy crisis mitigation measures and the role that Gas Power plays in this context along with providing a view on how Gas Power can support South Africa's energy transition to 100% renewables. Taking a completely transparent and participative approach to the power system modelling, we simulated the least cost power system up to 2032 under three scenarios, namely; "Perfect World" where the model has no restrictions on how to optimize the system; "Planned World" where we identify eighteen announced crisis mitigation measures (and IRP additions) that are successfully executed and; "Reality Check" where a view is taken on how such measures may be delayed, over-estimated, or not realised at all.

By comparing parameters including annual new-build capacity; unserved energy levels; reserve provider allocations; renewable penetration and curtailment; total system costs; and total system emissions; we can observe how far our planned mitigation measures are from the ideal world and what would happen if these measures don't go according to plan. The results show that our Planned World is sufficient to alleviate the energy crisis but Reality Check will mean an exponential increase in the amount of load shedding we can anticipate.

Gas power is shown to play an important role in all three scenarios by providing dual dispatch functions we term "Flexible Peaking" and "System Contingency Reserves". Under ideal conditions, preferably in the form of flexible Gas Engine power plants, provides combined energy and operational reserves which translate into capacity factors of 1-30% in ideal circumstances but which increases up to 60% under system contingency scenarios. The Perfect World, which requires the addition of 9 GW of flexible gas, 7 GW of energy storage systems, and 40 GW of combined wind and PV by 2032, enables a 26% ($26B) cumulative cost saving and a 17% cumulative emissions reduction when compared to the Reality Check. And when testing for a scenario where no new fossil fuel plants are built, we observe an unrealistically high battery new build requirement of at least 3 GW / 24 GWh per year; a 55% system cost premium; and a <1% emissions reductions being achieved when compared to Perfect World with new fossil fuels.

Recommendations are made, which are grounded in real life project examples, to implement distributed 100-400 MW Engine based power plants which will:

- Provide the much needed power to the grid with short construction times;
- Provide more localized reserve and flexibility advantages to key areas in the grid;
- Enable the realization of multiple new gas energy sources in South Africa; and
- Allow one to address key fuel supply risks using multi-fuel technologies.

INTRODUCTION

South Africa is currently faced with the immense challenge of addressing their immediate energy crisis in the context of meeting their emissions targets as a signatory of the Paris Agreement. And these challenges sit on the shoulders of an ageing coal fleet which today still produces >80% of the country’s energy needs (Eskom, 2021). Eskom estimates that 6 GW of capacity is needed today to restore the power system however, with an estimated 1 GW of baseload coal likely to be removed through decommissioning and unavailability each year over the next 30 years, it is clear that significant capacity beyond the 6 GW will be required to ensure long term system stability (Colloquium, 2022). From the consumer’s perspective, the country is currently experiencing up to level 6 load shedding[1)] and whilst Eskom predicts level 3 until the end of 2023, the risk of maintaining higher levels for the short term to medium term is a very real possibility (Eskom, 2022).

In fact, the situation has become so severe that the President himself made an exhaustive address outlining a number of initiatives that will be taken to try alleviate the crisis (South African Government, 2022). Some of these initiatives include:

- improving the coal fleet availability;
- fast tracking the implementation of upcoming renewable/gas/energy storage independent power producer programmes;
- removing the capacity size cap on private generation;
- entering into temporary Power Purchase Agreement’s with existing generators;
- reducing license and Environmental Impact Assessment processing for renewable and transmission infrastructure; and
- increasing the international power imports.

It is clearly apparent that addressing the current crisis requires a multi-pronged solution at all levels of the energy value chain. For purposes of this paper, we limit our focus to currently identified new-build capacity initiatives ranging from rooftop PV to large-scale utility projects as fully described in Section 3 MODELLING APPROACH.

Gas-fired power generation (“Gas Power”) is often featured as a key theme within discussions around energy security, a topic which as quoted by the Minister of Mineral Resources and Energy is “a priority for the government and our preoccupation as the Department of Mineral Resources and Energy” (Department of Mineral Resources and Energy, 2022). A market scan of over 15 expert opinions and studies related to the role of gas indicates that the majority views gas as a transitionary energy source in supporting South Africa’s path to net-zero with a third of the opinions either indicating that “big gas”[2)] or no gas is needed for the South African system[3)] (see breakdown in Figure 1).

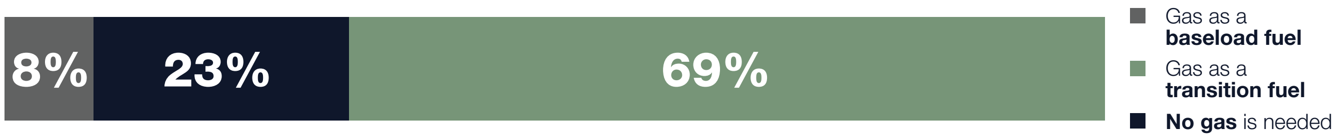

Figure 1: Poll on the role of gas for South Africa

1) Load shedding schedules go from level 1 (least worst) to level 8 (worst). Each level represents how many GW’s is short in the grid which needs to be supplemented through cutting off consumers for a few hours at a time.

2) When referring to Big Gas, we take guidance from how it has been defined by Meridian Economics (Meridian Economics, 2022). It refers to gas-to-power plants that are operated at high capacity factors and utilize large gas volumes, for example, Combined Cycle Gas Turbines.

3) Sources for this survey includes Wits Business School; National Business Initiative; BUSA; Eskom; Eurasia Group; Shell; DMRE; Standard Bank; CSIR; Africa International Advisors; Amabhungane; Department of Mineral Resources and Energy; International Institute for Sustainable Development; Presendent Cyril Ramaphosa and Independent Analyst, Clyde Mallinson.

In this study, we attempt to draw comparisons with some of the analysis already done by credible organizations, namely, Meridian Economics in their study “Resolving the Power Crisis Part B: An Achievable Game Plan to end Load Shedding” and National Business Initiative (NBI) in their study “Climate Pathways and a Just Transition for South Africa: The role of gas in South Africa’s path to net-zero” (Meridian Economics, 2022) (National Business Initiative, 2022). Both have used sophisticated power system modelling software and well researched analysis to come to their conclusions but with slightly varying opinions on the role of Gas Power. Meridian proposes the immediate addition of 1.4 GW of peaking thermal (questioning whether gas should be considered instead of diesel due to the questionable economics to bring in LNG) and describes the role of gas as a “peaking and insurance provider”. They also show that in the case of the coal Energy Availability Factor (EAF) dropping by 2% per year, then the diesel fired peaking plant would experience up to 20% capacity factors up until 2026 (no further data beyond this date is provided). NBI states that “gas can, if affordably supplied, play a key role as a transition fuel to replace more emissions-intensive fossil fuels like coal and diesel, and provide flexible capacity to enable a rapid scale-up of renewables” (National Business Initiative, 2022). Their modelling shows that gas capacity factors of 10% on gas plants should be anticipated but with more mid-merit levels of 30% reached whilst the large coal-fired plants are decommissioned.

Both these studies provide valuable insights into the role of Gas Power but we believe that further analysis regarding exactly how gas plants would be used in the current context of South Africa is warranted.

For example:

- How will the capacity factor change in the event of an extended system contingency occurring?[4)]
- Does gas play a role in providing reserves to the system?
- Which gas technology is most suitable for South Africa’s needs and are the current plans for Gas Power sufficient to meet our energy crisis needs?

By understanding the power system requirements for Gas Power as our starting point, we can then start to look at how such projects may look like considering other factors such as gas supply options and grid location preferences. Addressing such questions would go a long way in aiding the thinking of future gas infrastructure developments which will have the maximum impact and least regret.

[4)] A system contingency could be any unplanned event which affects the systems supply/demand balance. In the context of this discussion, it is considered as more larger and longer term events such as an abnormal weather phenomenon; major transmission line failure; geo-political events which impact fuel prices; and a catastrophic failure of a coal plant.

OBJECTIVES

The objectives of this study are to:

1. Evaluate the adequacy of the currently planned energy crisis alleviation projects related to the addition of MW's onto the grid; and
2. Define the roles; technology; and envelope of operations that Gas Power should provide to the South African power system and discuss the associated benefits and risks associated with this along with presenting a conceptual solution.

MODELLING APPROACH

Model Overview

Power modelling software from Energy Exemplar called Plexos® was used for this analysis. Plexos® is a techno-economic modelling software that uses mathematically based optimisation techniques for energy market analysis, widely used by system operators, energy planning departments, and consultants.

A long-term capacity expansion optimisation approach was applied in this study. Capacity expansion modelling finds the least cost generation capacity mix for a power system to meet electricity demand in the future whilst respecting any given constraints. Plexos® selects new generation capacity additions from several potential technologies. Available options: solar, wind, battery storage (LiIon and Vanadium Redox batteries), Open Cycle Gas Turbines (OCGT), Combined Cycle Gas Turbines (CCGT), Internal Combustion Engines (ICE), nuclear, coal, hydro pump-storage, and technologies to produce synthetic fuels (P2H). Plexos® solves the hourly (2 hr in this case) dispatch of power plants throughout the studied period, which is years 2023-2032, whilst making new capacity additions that will enable the least cost energy for the system. By taking this chronological modelling approach, i.e., the variability and seasonality of renewable generation and load need to be balanced hour-by-hour in the model, and modelling the operational reserve requirements of the system, we can identify accurate flexibility and storage capacity requirements which would be overlooked in more conventional and overly simplified 'load duration curve' or 'merit order' modelling approaches.

Model Inputs

Like any model, the quality of the outputs is only as good as the quality of the inputs and for this reason, we adopted a transparent approach to the modelling which allowed other subject matter experts to provide their inputs and suggestions into our proposed set of inputs and assumptions. Our baseline data was derived from publicly available, and generally acknowledged to be reputable, sources as far as practicable. Any information that was not publicly available was provided by the Wärtsilä modelling experts based on their experience of similar models around the world.

To solicit inputs into our baseline inputs, Wärtsilä undertook a public participation process whereby key industry bodies and stakeholders were given the opportunity to comment on the input assumptions used in our model. Annexure A contains the Invitation Letter along with the respective list of all the key inputs and references that were used in the model. This invitation was distributed to approximately 6,000 energy sector stakeholders through various WhatsApp energy groups and email. Interested parties were then allowed one month to provide comments and attend a "introduction to modelling" webinar to have a better understanding of the modelling approach.

A total of seventeen people expressed an interest in the process however, zero changes to the inputs as put forward by Wärtsilä were volunteered (which was viewed as positive confirmation on the legitimacy and credibility of the proposed baseline modelling inputs).

Further to the exhaustive list provided in Annexure A, Annexure B contains a brief description on the approaches and assumptions we have taken on the key inputs.[5)]

Scenario Descriptions

In defining the scenarios, the objective was to test the role of gas under extreme circumstances that may be realized in the South African power system. These extreme cases, labelled as "Planned World" and "Reality Check", enable us to gain insight into the operational envelope for Gas Power generation. As the name suggests, the Planned World scenario considers a system where all the recognized capacity addition measures are realized to their full potential and in line with their scheduled timeframes. The Reality Check scenario then takes a view on how each of those measures could either be delayed and/or reduced in capacity based on historical experience and/or anticipated behaviors' going forward. These 'unplanned' events are what we refer to in this paper as system contingencies.

A third, and final, scenario, titled "Perfect World", is one whereby we allow the model to determine the optimal capacity mix without imposing any of the known new capacity addition opportunities and/or restrictions. This Perfect World scenario allows us to benchmark our Planned World and Reality Check scenario in terms of achieving the lowest system tariff and reducing CO2 emissions.

Planned World	Considers a system where all the recognized capacity addition measures are realized to their full potential and in line with their scheduled timeframes.
Reality Check	Takes a view on how each of those measures could either be delayed and/or reduced in capacity based on historical experience and/or anticipated behaviors' going forward.
Perfect World	Allow the model to determine the optimal capacity mix without imposing any of the known new capacity addition opportunities and/or restrictions.

5) It is well known that Plexos® has the capability to integrate a large amount of system variables however, based on our experience with system modelling, we have only listed here the inputs which we believe will have a material impact on the modelling results. Other inputs not listed here have either been integrated with 'industry norms' type of values.

A summary of the amount of MW's added for each initiative is summarized in the image below.

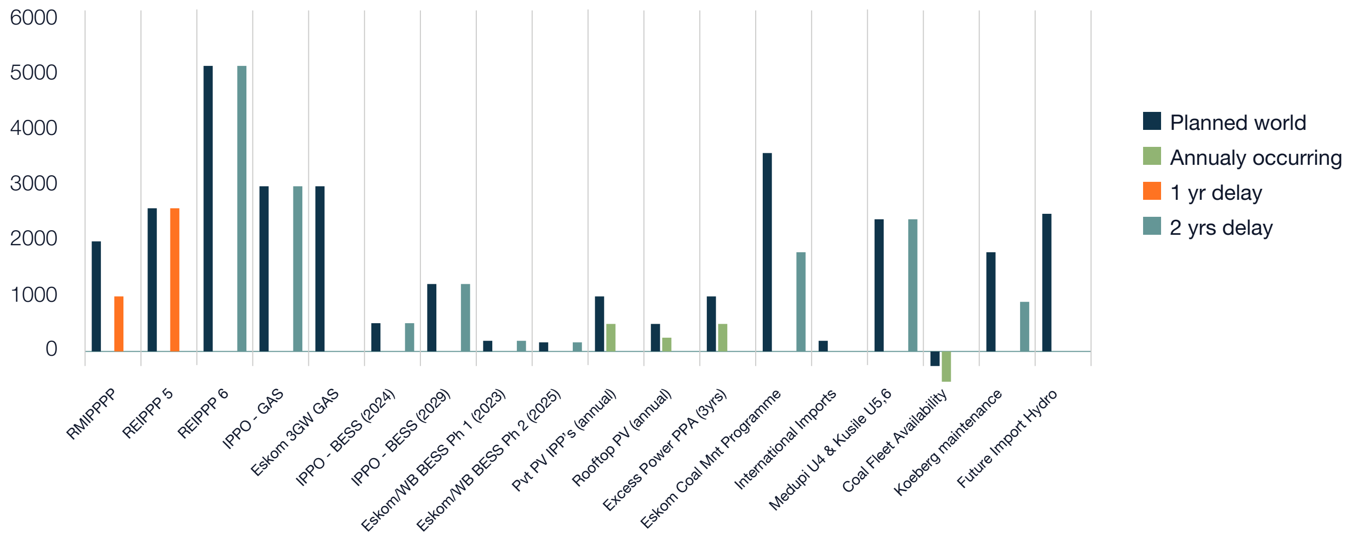

Figure 2: Treatment of how the impacted planned initiatives were either delayed or reduced in the Reality Check scenario

A more detailed description outlining the rationale for the delay and/or reduced MW's available under each initiative is provided in Annexure C.

In addition to the main scenarios as outlined above, further sensitivities to address related, and commonly discussed, topics have been undertaken which includes:

- Impact of not allowing for any new fossil fuel power plant to be built ("No Fossil Fuel");
- Impact of 'forcing' baseload CCGT's into the Planned and Reality Check scenarios[6)] ("Big Gas"); and
- Looking at the role of gas should the gas price reflect a domestic supply being available ("Dom Gas").

[6)] A concept often discussed is to replace/repurpose the current baseload coal fleet with baseload gas. We therefore impose a 70% minimum capacity factor for the CCGT's in this option and also reduce the gas price from \$15/GJ to \$12/GJ in recognition of the high volumes and stable offtake potential with this approach.

MODELLING RESULTS

New Capacity Additions

The table below adopts an 'IRP style' visualization comparing all three scenarios. The changes are based on the inputs and approaches as outlined in Annexure A and Annexure B with a full exhaustive list of associated installed capacity; new build capacity; and energy share graphs contained in Annexure D.

	COAL (MEDUPI/KUSILE ADDITIONS AND MAINTENANCE INCREASES)			AVAILABLE COAL CAPACITY (DECOMMISSIONING + REDUCED EAF)			NUCLEAR (+EXTENDED OUTAGE)			HYDRO AND PUMP STORAGE			BATTERY STORAGE		
	38773 (Eskom: 37149 + IPP: 1624)						1860			2100			2912		
	Planned	Perfect	Reality	Planned (1,5% EAF decline)	Perfect (no EAF decline)	Reality (3% EAF decline)	Planned	Perfect	Reality	Planned	Perfect	Reality	Planned	Perfect	Reality
2023	1600			-312		-633			-930				200	1652	
2024	800			-307		-614			-930				514	660	
2025	1800		1600	-3008	-2706	-3219							160	554	200
2026	1800		800	-315	-57	-553								589	514
2027			900	-252		-482								559	160
2028			900	-1643	-1394	-1759								886	
2029				-224		-415							1231	627	
2030				-221		-402				2500				465	
2031				-217		-390								464	1231
2032				-1803	-1589	-1762								621	
TOTAL NEW CAPACITY BY 2032 (MW)	6000	0	4200	-8301	-5746	-10228	0	0	0	2500	0	0	2105	7077	2105
TOTAL INSTALLED CAPACITY (% OF MW)	33,3	26,1	37				2,1	1,8	2,3	2,6	2	2,6	2,4	6,7	2,6
ANNUAL ENERGY CONTRIBUTION (% OF MW)	46,76	36,33	44,67				4,23	4,13	4,29	4,27	3,73	3,88	1,04	2,7	1,04

	PV (INCLUDES IPP'S + ROOFTOP)			WIND			CSP (INSTALLED BASE ALREADY INCLUDES CURRENT BUILD)			GAS & DIESEL			OTHER (RMIPPPP, P2H)		
	1474			1980			600			3830			499		
	Planned	Perfect	Reality	Planned	Perfect	Reality	Planned	Perfect	Reality	Planned	Perfect	Reality	Planned	Perfect	Reality
2023	500	2700	250		2502						850			150	
2024	500	1098	250		2562						11		1995		
2025	2500	1123	750	1600	2621						3235				1000
2026	3500	1149	750	3200	2681					3000	160				
2027	1500	1175	1750	1600	2741	1600					15				
2028	1500	1200	2750	1600	2801	3200				3000	1642	3000			
2029	1500	1226	1750	1600	2861	1600					224			262	
2030	1500	1252	1750	1600	2921	1600					251			726	
2031	500	1277	1750	1600	2981	1600					249			434	
2032	500	1303	1750	1600	3040	1600					2308				
TOTAL NEW CAPACITY BY 2032 (MW)	14000	13503	13500	14400	27711	11200	0	0	0	6000	8945	3000	1995	1572	1000
TOTAL INSTALLED CAPACITY (% OF MW)	18,3	13,6	19,7	20,2	30	18,4	0,7	0,6	0,8	10,3	12,6	7,7	2,3	1,4	1,3
ANNUAL ENERGY CONTRIBUTION (% OF MW)	13,2	11,28	13	17,23	33,25	15,4	0,71	0,69	0,72	2,02	3	8,63	4,34	<0	2,2

Table 1: IRP styled new build and energy share overview for each scenario

Coal

The addition of the Kusile Units 5 and 6 and the repair to Medupi Unit 4 would provide a significant amount of energy to the system along with the increased capacity that is claimed to be possible through increased maintenance (deRuyter E. -A., 2022). It was questioned whether these additions should be committed into the Perfect World as there is already a significant sunk cost into these projects but arguably, in a perfect world, there could be scope to divert those funds to other projects. In which case, we see that no new coal is built in the Perfect World nor any capex is spent to improve the performance of the current fleet.[7)]

Observing the effective lost coal capacity through decommissioning and reduced EAF, in Reality Check, which has a 3% annual EAF reduction, we see that over 10 GW is lost within 9 years. And the picture is only slightly improved in the Planned world where 8.3 GW is lost over 9 years.

The total energy share of coal by 2032 is 36% in the Perfect World (which is a significant drop from our current 80% level!).

[7)] It was assumed that the cost for existing plant performance improvements would be the equivalent to a new build capex cost. This however should be investigated further.

Nuclear

No new nuclear is recommended largely due to the high capital costs considered.

Hydro and Pump Storage

Apart from the 2.5 GW hydro that already exists in the current IRP (and which is premised on the realisation of a regional hydro project), no new hydro nor pump-storage is built.

Storage

There is 5 GW more storage proposed in the Perfect World than the current Planned and Reality Check scenarios. 2 GW of which is immediately required followed by an annual, and steadily increasing, contribution to align with the growth in renewables. Whilst both LiIon and flow batteries were modelled, only LiIon batteries were selected but it should be noted that this preference is highly susceptible to the technology learning rates and should not be taken as a firm view that LiIon is better than alternate emerging battery technologies.

The model opts to build predominantly 1hr and 2hr batteries in the first 2 years thereafter, it builds predominantly 4hr batteries until 2031 wherein some 8hr batteries are then built.

Solar PV, Wind, and Concentrated Solar Power

Solar PV (Photovoltaic) and Wind is built at huge scale up to the imposed limit in the model which was taken to be 10% of the peak demand[8)] (with a preference give to Wind as the cheaper renewable technology option). Collectively, their energy contribution in the Perfect World is 45% in 2032. No new Concentrated Solar Power is built.

Gas & Diesel

In terms of converting the existing diesel fired OCGT's to gas, we only see this conversion taking place in the Reality Check across the years 2023 to 2026. No conversions are suggested in both the Perfect World and the Planned World as the capacity factors are just too low to warrant such a conversion.

In terms of new build gas capacity, here we see a significant increase in the MW's required from 3 GW in Reality Check to 9 GW in Perfect World. Most of the additions are within the 100-300 MW range with the exception of a few larger 'chunks' which get addition at the same time that there is coal plant being decommissioned. And even though they make up over 12% of the installed base, there is a much smaller energy share contribution of 3% in the Perfect World. This is not the case though in Reality Check where they are only 8% of the installed capacity by 9% of the energy share.

Other

'Other' in the IRP2019 (Department of Mineral Resources and Energy, 2019) contains an annual build of 500 MW however, we took that view that it is more likely that other would be dominated by private+rooftop solar which already falls under the 'PV' category in the model. The only 'Other' consideration we have then is the projects under the RMIPPP and P2H projects. P2H only appears after 2029 in the Perfect World.

8) Whilst it must be acknowledged that there is some practical limit as to how much renewable energy can be built on an annual basis, what that limit is not easy to determine as it is impacted by many unknown factors. We, however, have used a value of 10% of the peak demand as this is what Wartsila has experienced in other jurisdictions and in our view represents a fair but achievable annual new build limit.

'No Fossil Fuels' sensitivity

In the sensitivity where we don't allow for any new fossil fuel power plant to be built, the model opts to build batteries with a small portion of CSP in 2028 and a 1.7 GW nuclear power plant in 2032 (note: a 10 year new build time for Nuclear has been considered). Whenever there is a drop in coal through decommissioning, this capacity is replaced with GW's of 8hr duration batteries with the installed battery capacity amounting to 27 GW / 216 GWh by 2032, which is 20 GW more than the Perfect World scenario! This means, that on average, South Africa should be building 3 GW / 24 GWh of batteries every year, a target we do not believe is realistically viable given the global supply capacity limitations and competition from more mature competing markets. The graph below indicates the new built technologies in the absence of fossil fuels.

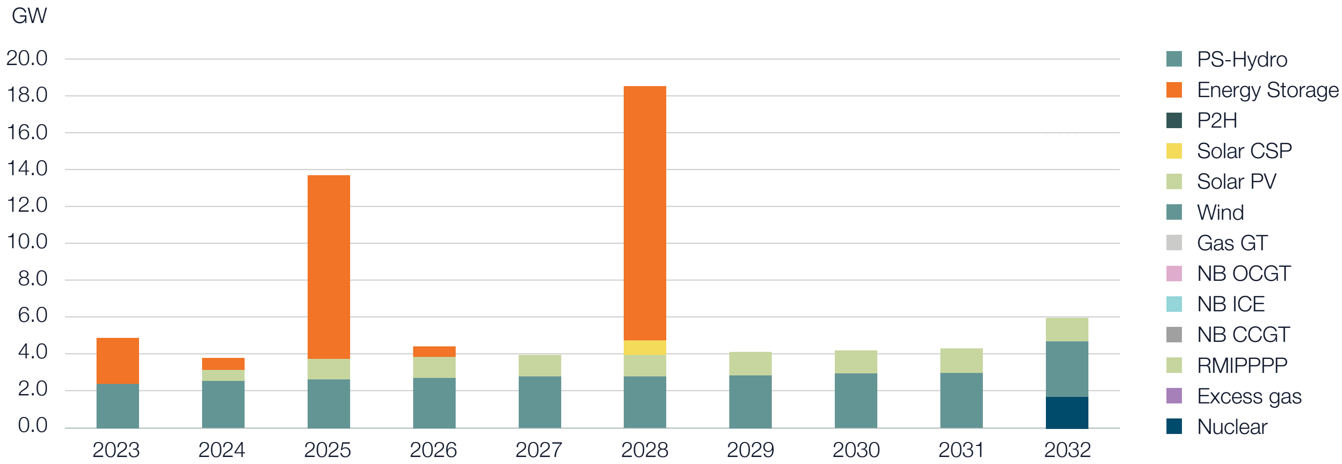

Figure 3: New build capacities when no fossil fuels are allowed to be built in the Perfect World.

Key Gas Power Observations

Gas Technologies

Despite the model automatically having the option to select between CCGT's; OCGT's; and ICE technologies, the preferred technology to support a least cost system is the ICE option which makes up >95% of all the new build gas across all three scenarios.

The model selects engines as the least cost Gas Power technology primarily due to its ability to provide flexibility at low cost to the power system. This is achieved through the following key characteristics:

- High efficiency is available at all plant dispatch levels
- No costs incurred for starting up[9)]
- Low capex
- Able to provide non-spinning operational reserves due to the fast ramp-up rates

On the other hand, CCGT's only make a small appearance with 670 MW in Perfect World in 2025 and 280 MW in 2028 when there is a temporary raised capacity factor required due to coal being decommissioned in those years.

9) Unlike gas turbines, engine (ICE) technology does not incur any additional start-up cost nor require additional starting fuel (Wartsila, 2022). Furthermore, the fact that there is no limitation on the number of starts means that the model can rely on engines for a large portion of its flexibility requirements without adding significant costs.

Gas Dispatch Requirements

In this section, we explore in more detail how Gas Power is used in the power system under the varying scenarios. What will become abundantly clear through these results is that it is not sufficient to merely label gas as 'peaking' or 'mid-merit' as this overly-simplifies what in reality is far broader and more dynamic.

Gas power players a significant role as both an energy provider and an operational reserves provider to the system.[10] And depending on the scenario considered, the requirement for each function varies.

Energy Provider

If we look at the energy provider function, we notice that the energy capacity factor for Planned World and Perfect World are similar with annual capacity factor ranges of 3-12% (which aligns well with the NBI and Meridian studies views). This picture however changes significantly in the Reality Check scenario where gas starts from 36% in 2028 (i.e. when the first Gas Power is commissioned) and increases to 58% in 2032. This is primarily due to the rapid decrease in coal capacity and availability.

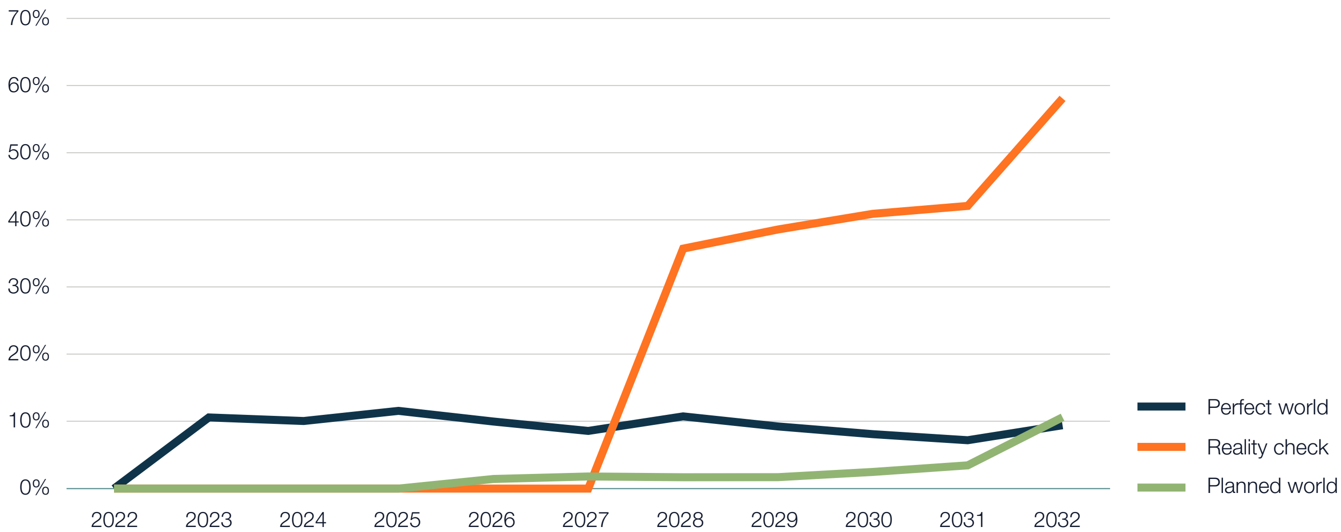

Figure 4: Gas Power Energy Capacity Factors per year fo each scenario

[10] If a technology provides energy to the system, that means that is required to generate power according to the day/week/month/year ahead energy dispatch forecasts. If a technology is a reserves provider, it only requires the technology to be available to provide energy to the system in the event that there is a supply/demand mismatch or frequency deviation on the grid (as defined in the Grid Code).

When looking at the intra-annual dispatch patterns of these gas plants, it is apparent that there are large variations in capacity factors at hourly; daily; weekly; monthly; and seasonal timeframe. At the hourly and daily level, the “Peaking” application as seen under Perfect and Planned Worlds exhibits peaks of varying sizes sometimes occurring twice a day or even no times for a few days. Similarly, the Reality Check dispatch sometimes has baseload characteristics and peaking characteristics within a single week.

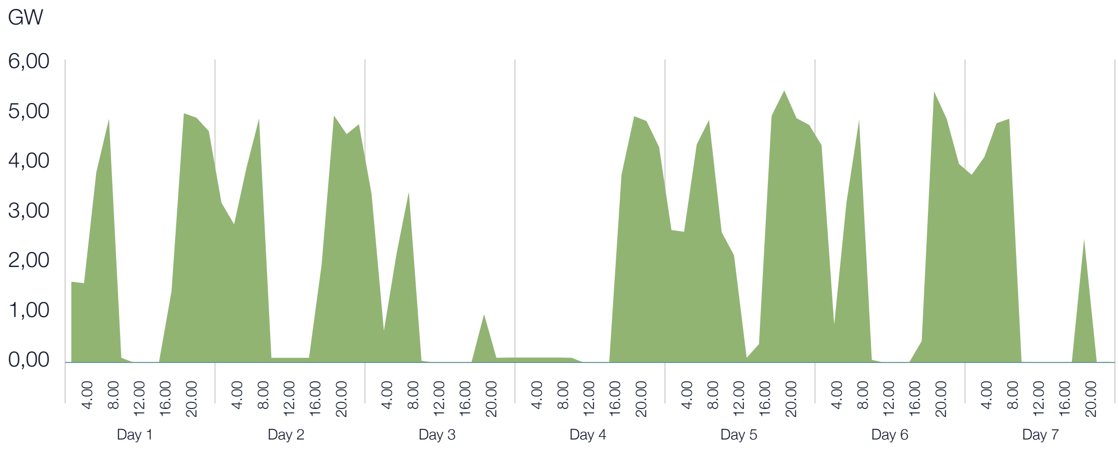

Figure 5: Typical weekly Gas Power dispatch profile for 2032 in the Planned World.

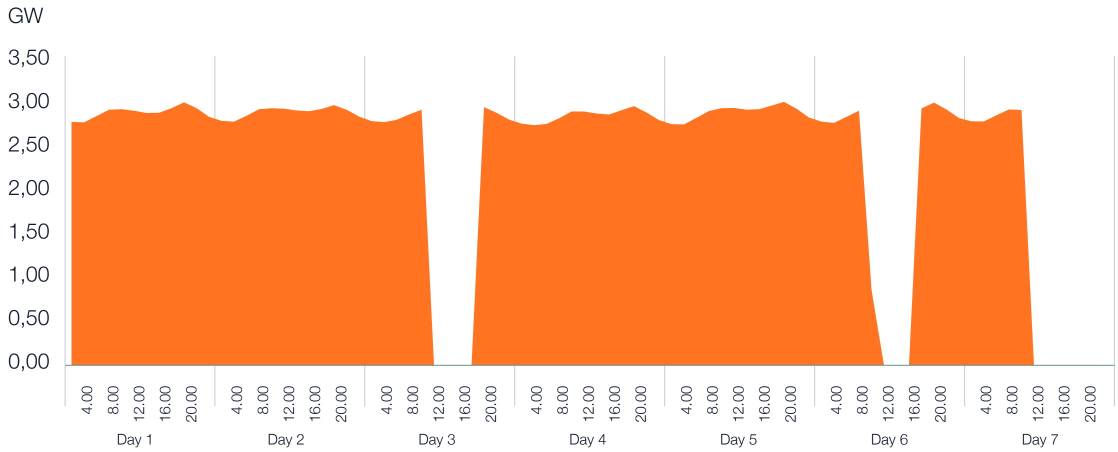

Figure 6: Typical weekly Gas Power dispatch profile for 2032 in the Reality Check.

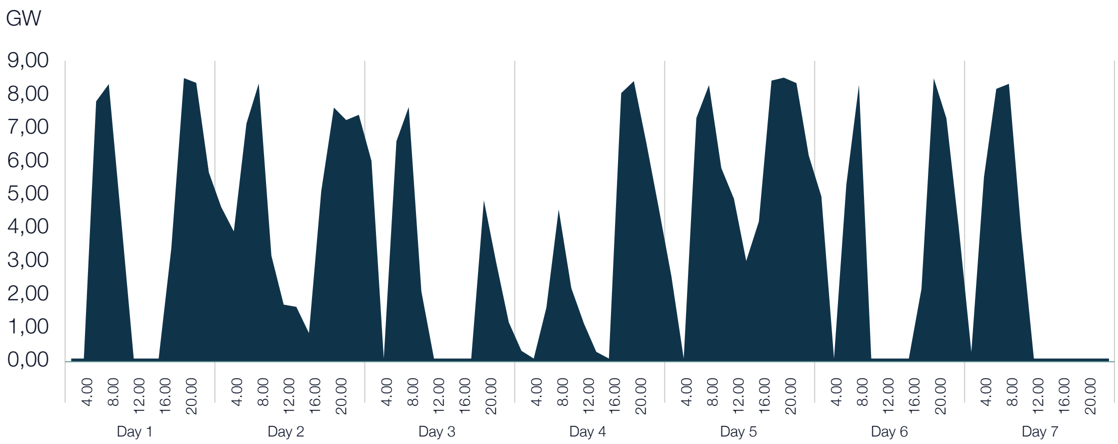

Figure 7: Typical weekly Gas Power dispatch profile for 2032 in the Perfect World.

At the weekly and monthly level, there is significant weekly variation in the energy dispatch with jumps of up to 30% capacity factor between consecutive weeks experienced for the Perfect and Planned World and 50% for the Reality Check with a peak weekly capacity factor of 89% being reached! This is largely due to the provision of both a traditional peaking application along with providing a renewable energy balancing function. Lastly, at the monthly and seasonal level, we notice a clear increase in the dispatch over the Winter months vs the summer months where anything from 40-54% of the total Gas Power is produced during May through August.[11)]

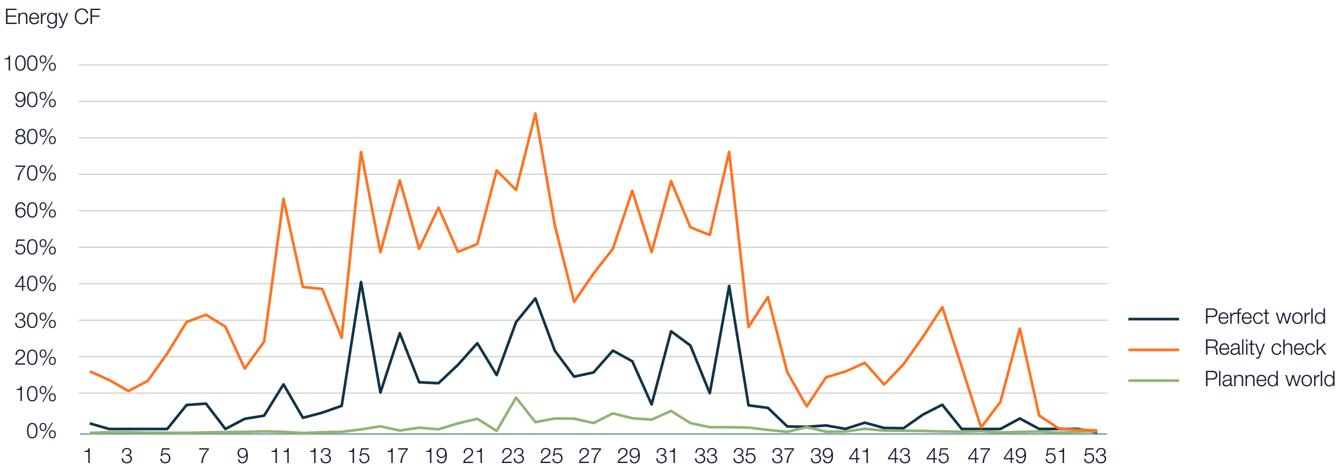

Figure 8: Weekly capacity factors for Gas Power in 2028.

Taking the observations around variability one step further, we also highlight the daily and annual gas consumption encountered for each scenario as depicted in the Figure 8. Naturally, the variability follows that of the Gas Power variability but in terms of total consumed gas, a summary of the gas consumption for 2028 is provided in Table 2.

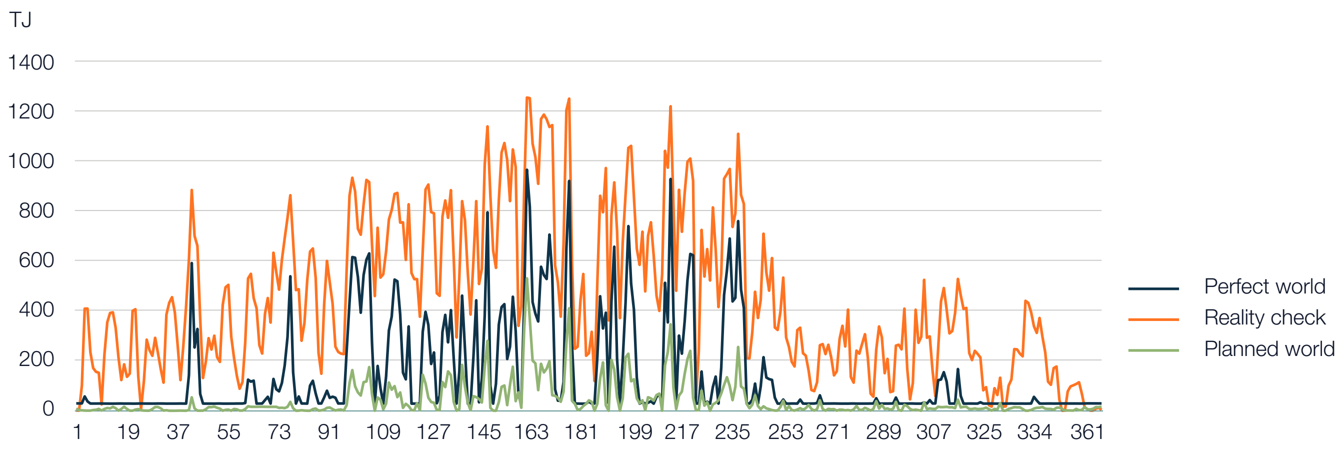

Figure 9: Daily gas consumption profiles for each scenario in 2028

	Perfect World	Planned World	Reality Check
Installed Gas MW's in 2028	**8 GW**	**6 GW**	**3 GW**
Annual Gas Consumption[12)]	**53 PJ**	**15 PJ**	**167 PJ**

Table 2: Summary of total gas capacity and gas consumption in 2028.

11) It is recognized that through shifting of the coal fleet maintenance into the summer months, this seasonal imbalance in Gas Power demand could be improved (or flattened). Our approach in this model was to assume that 7% of the planned maintenance for the coal fleet could be shifted towards the Summer months.

12) Note that these values do not include the consumption from the RMIPPP gas projects as it is assumed that these projects do not have an 'open access' possibility. It also does not include the gas that would be required for providing operating reserves to the system but it does include the gas consumed in the converted existing OCGT's.

Reserves Provider

We now focus the discussion on Gas Power as a reserves provider where we see each scenario taking a slightly varying view on who the reserve providers are for the system.

In the Perfect World, we see that all the system reserves are supplied through a combination of BESS (15-20%); Diesel OCGT (23%-37%); and ICE (41%-63%). This outcome resonates well as BESS is ideal to provide the instantaneous and regulating reserve support whereas the current diesel OCGT's and new gas ICE is able to provide cost effective non-spinning reserves to contribute to the regulating and 10-min reserve requirements of the system.

This balance changes slightly in the Planned World whereby we still see coal (which has traditionally been the main reserve provider to the system) providing some reserves to the system (10%-23%); BESS and ICE making their contributions but diesel OCGT still providing the majority of reserves (25%-50%).

Lastly, in the Reality Check world, there is a significant deficit in the available reserves and as a result, the model relies on 'load shedding' to provide system reserves in addition to BESS; diesel OCGT's; gas converted OCGT's; and new build ICE when it comes available. The respective share of the reserve providers for each scenario is shown in Figure 10, Figure 11, and Figure 12.

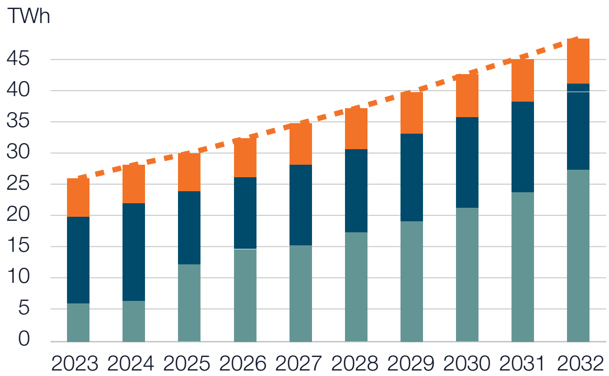

Figure 10: Share of reserve providers in the Perfect World

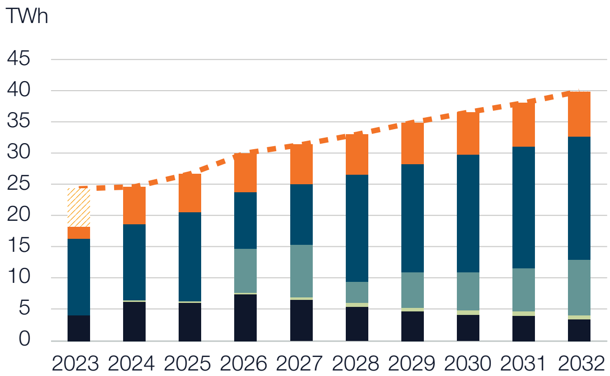

Figure 11: Share of reserve providers in the Planned World.

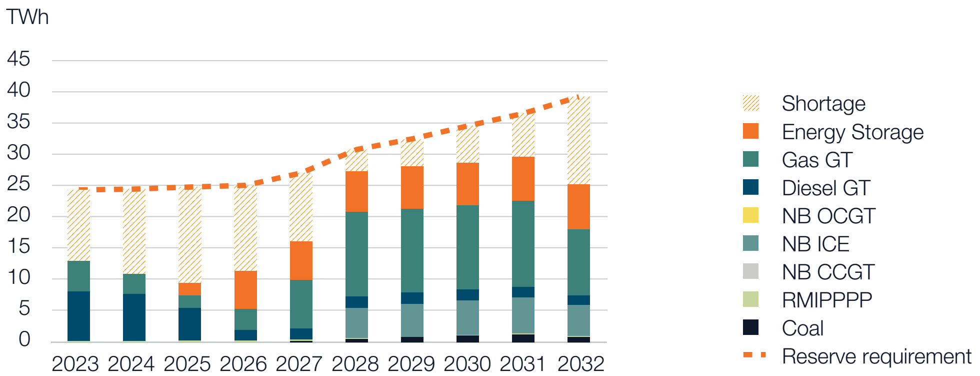

Figure 12: Share of reserve providers in Reality Check.

Focusing on Gas Power reserve provisions, in the Perfect and Planned Worlds, Gas Power as a reserve provider trumps that of its energy supply function with reserve capacities of 10-50% being assigned to this function. The reverse is true in the Reality Check scenario whereby there is more energy provisions allocation from the ICE capacity than reserve provisions allocation which ranges from 20-30% of the gas capacity. The system however does continue to rely on the converted OCGT's to play a significant role in providing reserves to the system.

When looking at the type of reserves that each technology contributes to, considering the Perfect World, the approximate ratio is that spinning reserves is made up of 50% from BESS and 50% from ICE whereas non-spinning reserves is made from 40% ICE and 60% OCGT.

What is abundantly clear from these results is that Gas Power has an equally significant role to play as both an energy and a reserves provider and that the traditional approach of assigning a small portion of the plant capacity to provide reserves (as seen in the current coal fleet) would be a gross underutilization of the flexibility advantages Gas Power can provide to the system.

Gas Price Sensitivity

All the simulations undertaken have considered a gas price of $15 / GJ (see section 3.c). Additional simulations considering $10 / GJ and $6 / GJ were then modelled and virtually no difference in both the Gas Power capacity installed and the Gas Power capacity factor observed. The same outcome will be true for higher gas prices until the gas price exceeds the diesel cost which has been set at $20 / GJ (as concurred by NBI's findings (National Business Initiative, 2022)). And even if today we are seeing >$20 / GJ LNG pricing, as there is some correlation between diesel and LNG pricing indices, it is unlikely that LNG would ever exceed a diesel supply cost (CME Group, 2022).

This demonstrates that Gas Power is relatively insensitive to gas price as it exists within a wide merit order price window (for dispatchable capacity) between coal and diesel OCGT's.

If, however, we wish to explore the opportunities should a low cost domestic supply of gas is available, considering a gas price of $3 / GJ, it is likely that we will see a significantly different role of gas as more a mid-merit/baseload energy provider to the system. At this price, the following gas technologies and capacity factors appear:

- Perfect World: 5.4 GW of ICE with 20-30% capacity factors and 4.9 GW CCGT with 80% capacity factor;
- Planned World: 5.1 GW of ICE with 30-40% capacity factors and 800 MW of CCGT with 70-80% capacity factors
- Reality Check: 3 GW of ICE with 60-70% capacity factors.

It is interesting to note that when comparing the original Perfect World scenario to the Domestic Gas Perfect World scenario, there is virtually no difference in the total installed gas capacity, only that capacity factors increase.

In order to achieve such a low domestic gas price, we believe that South Africa must undergo a radical gas revolution similar to what was experienced in the US through the discovery of shale gas which created a <$3 / GJ market.

Other Key Observations

System Costs

Unsurprisingly, given that the model optimizes for the least cost of energy, the Perfect World presents the lowest cost to the consumer with Planned World and Reality Check scenarios exhibiting 13% and 26% higher costs respectively when comparing the cumulative costs up to 2032. The cumulative difference between the Perfect World and Reality Check is $26B up until 2032.

Figure 13 shows the annual system costs for each scenario.

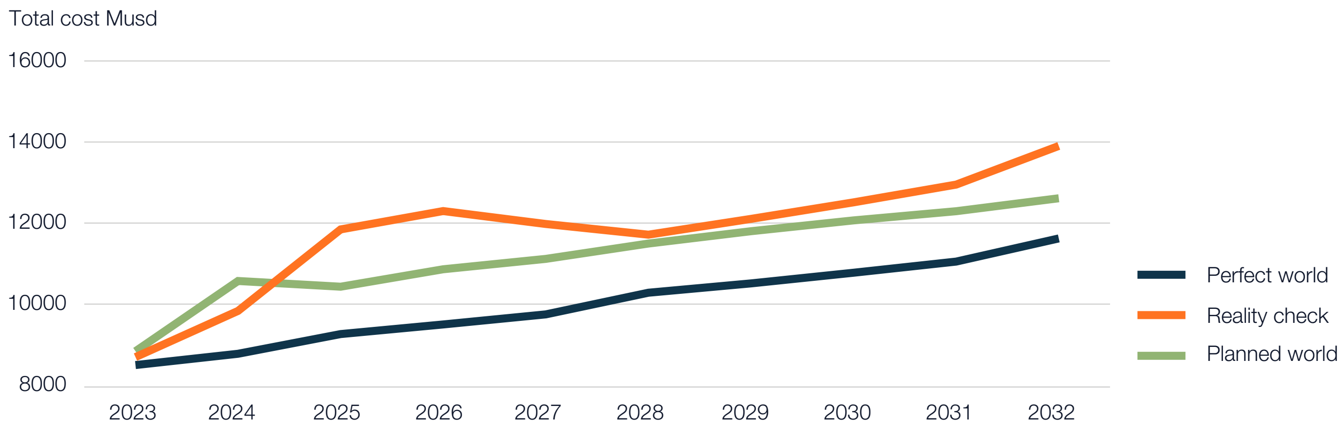

Figure 13: Annual power system cost for each scenario

If we also extend our system cost observations for the No Fossil Fuel and Big Gas sensitivities, the results clearly indicate a material cost premium associated with these two sensitivities when compared all three original Perfect World; Planned World; and Reality Check scenarios (refer to Table 3). The Big Gas sensitivities carry an approximate 20% premium, despite the lower gas price of $12 / GJ considered achievable with a high stable offtake, and the No Fossil Fuels has an approximate 55% premium largely due to the large capital outlay required for the significant battery additions and Nuclear addition.

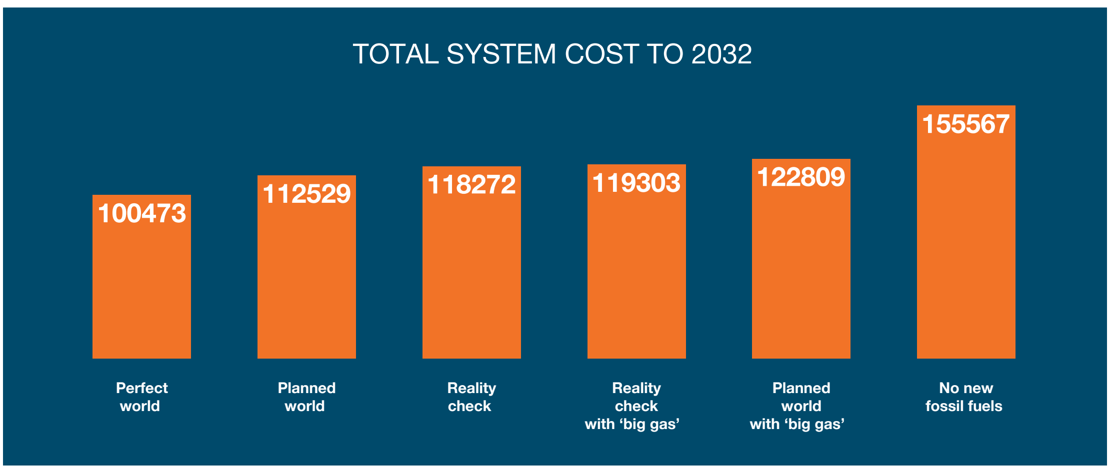

Table 3: Total System costs for the baseline scenarios; Big Gas; and No Fossil Fuels scenarios and sensitivities

Unserved Energy

By extracting the unserved energy parameter (or "load shedding"), we not only determine the relative accuracy of our model but also the risk of not meeting the Planned World objectives which is to eliminate load shedding.

In the Planned World, we don't see any significant load shedding appearing largely due to the timeous addition of the Medupi and Kusile coal units and the coming online and the RMIPPPP projects. The picture, however, does not look promising in the Reality Check scenario whereby there is already 0.4 TWh of load shedding in 2023 which triples in 2024; increases five fold by 2025 and ten fold by 2026 as shown in Figure 14.

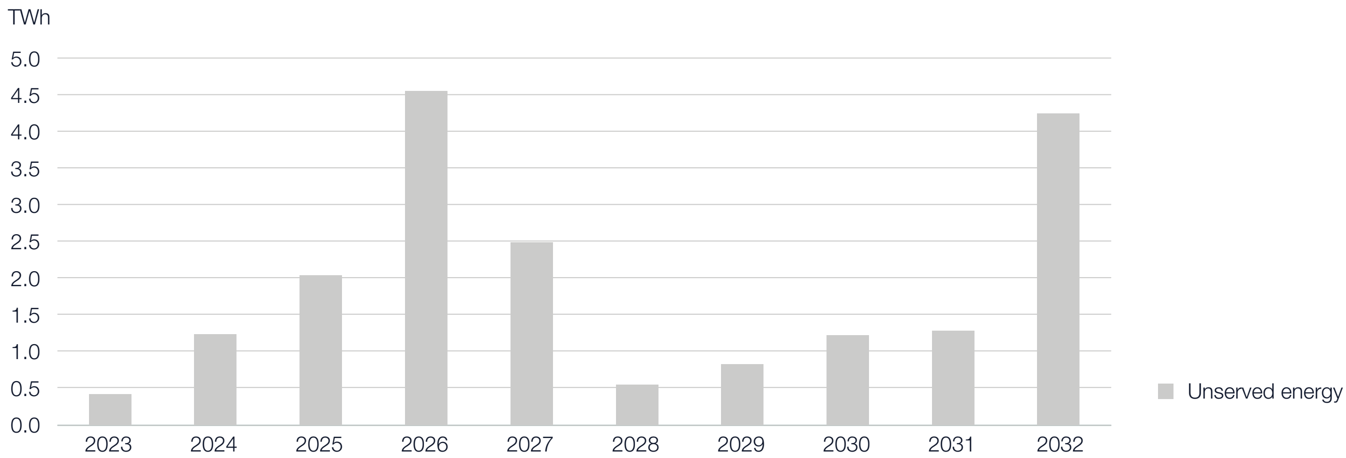

Figure 14: Annual amount of unserved energy in the Reality Check scenario.

When comparing to the latest load shedding statistics, considering that the amount of load shedding in 2022 up until June is 2.2 TWh, if we conservatively assume it continues unchanged for the remainder of the year, it means that our model would have under-estimated the load shedding by a factor of ten. Whilst there is a material difference between reality and the model in this regard, it must be stressed that the amount of load shedding is extremely sensitive to all the parameters and there will inevitably be some 'reality' inputs that are not practical to model.[13)] This result is also not unique for this model as when comparing to Eskom's predictions of unserved energy in 2022, the 'worst case scenario' predicts only 0.45 TWh which is very closely aligned with our current modelling predictions (Eskom, 2022).

Despite the difference in the starting point, the exponential increasing trend up to 2026 and the persistence thereafter in the Reality Check means that the continued roll-out of the Planned Initiatives (and new initiatives) needs to be considered as soon as possible. It can also be argued that with such high levels of load shedding, that the country growth, and subsequently energy demand, could be arrested thus artificially decreasing the amount of load shedding the country will experience.[14)]

One area which should also be recognized is that this study only looks at load shedding caused by a lack of generation capacity however, as most of the country relies on aged transmission and distribution infrastructure, there has been, and will likely be, a marked increase in the rate of failure at both transmission and distribution levels resulting in further effective load shedding.

[13)] For example, the unexpected outage of a single 600 MW coal unit for a few months could easily account for this difference between the model and reality.

[14)] In a media statement released by BUSA on the Eskom load shedding, they claim that the 0.7% decline in the economy during the 2022 second quarter was caused by the continued blackouts (Business Unity South Africa, 2022)

Emissions

Contrary to what would be expected, the Reality Check scenario, despite its lack of new build capacity, actually results in the largest amount of CO2 emissions compared to Perfect and Planned Worlds. This is primarily due to the continued reliance on coal and diesel to balance the system which both have higher emission factors than Gas Power.[15)]

The Planned World closely follows the emissions reduction trajectory of Perfect World up until 2027 whereafter it plateaus due to the continued reliance on coal and diesel in the absence of any new gas power. Even though the Perfect World continues to add Gas Power up until 2032, and the Planned World has no thermal (in the form of gas; coal; or diesel) additions beyond 2028, the cumulative emissions is lowest in the Perfect World by 7% compared to the Planned World. Reasons for this is that Gas Power, combined with the increased renewable energy, is able to displace more coal and diesel energy and therefore result in a significant net emissions reduction of 300 Mt (or 17%) when comparing Perfect World and Reality Check scenarios.

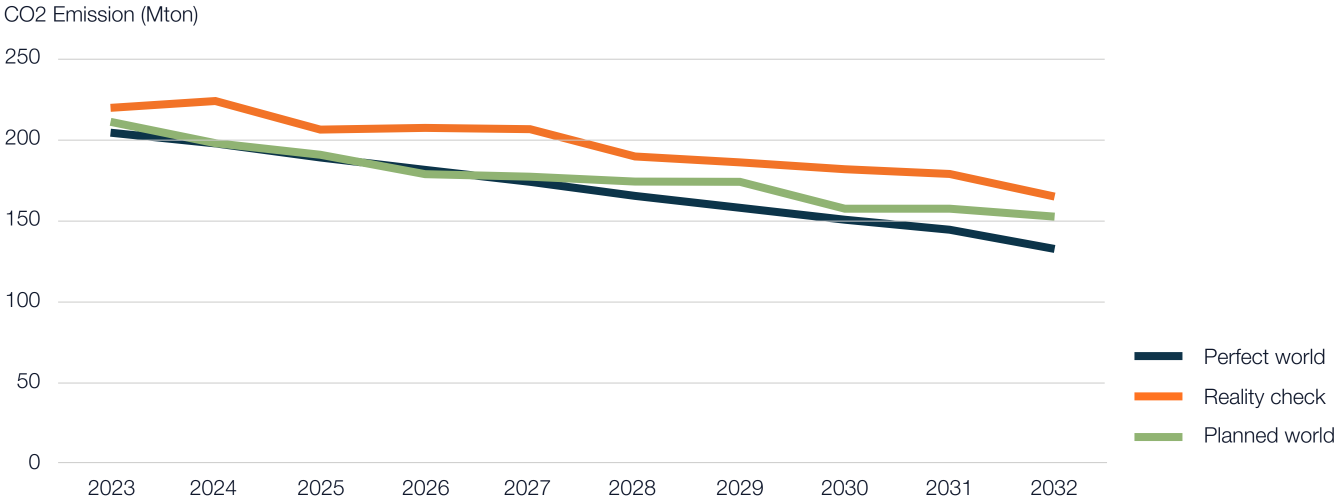

Figure 15: Annual CO2 emission trajectories for each scenario.

An encouraging outcome is that without imposing or forcing any specific emission reduction targets or constraints, the Perfect World naturally results in a trajectory which if continued to 2050, would enable South Africa to reach their net-zero targets.

Extending our emissions observations to include the No Fossil Fuel sensitivity, when comparing the baseline Planned; Perfect; and Reality Check Scenarios and the No Fossil Fuel versions, there is less than 1% decrease in system emissions achieved by not building new fossil fuel plants. This is largely due to the fact that we will continue to heavily rely on our existing coal and diesel fleet to provide such flexibility (in addition to the large amount of batteries added to the system) which has an emissions premium associated with it thereby offsetting any increases that would be realized through new, predominantly gas fired, power plants.

15) The following emission factors have been used in the model: Coal – 96.1kg/GJ; Diesel – 63.1kg/GJ; and LNG – 56.1kg/GJ.

Enabling Renewables

Between the three scenarios, we see a material difference in how renewables (wind and solar) is supported in the system by observing the amount of curtailment and penetration as depicted in Figure 16 below.

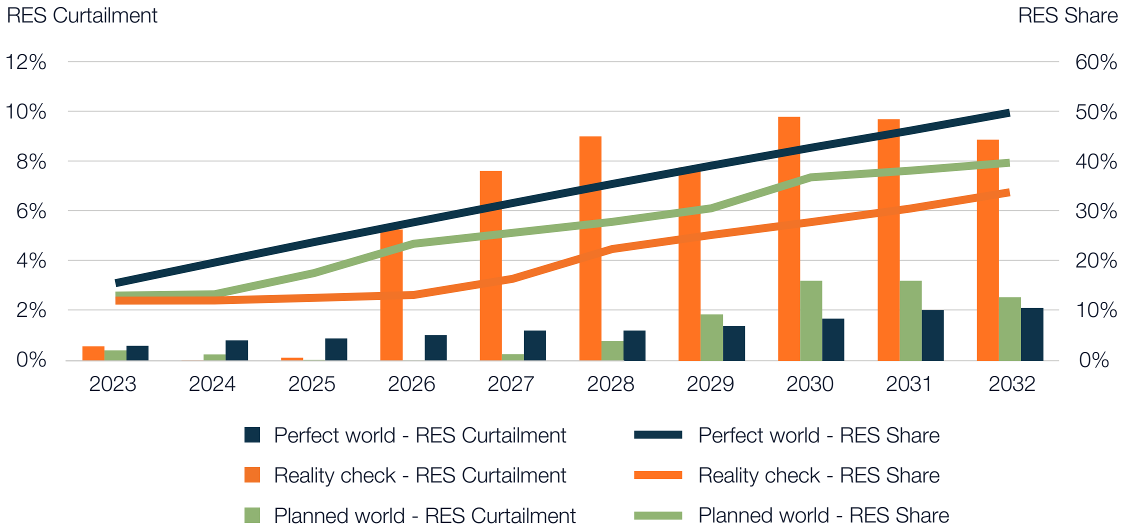

Figure 16: Annual renewable energy share and curtailment levels for each scenario.

Comparing the Perfect and Planned World, despite there being ~40-50% more renewable penetration in the Perfect World, there is never more than 2% curtailment whereas Planned world goes up to 10% curtailment in 2032. The Reality Check however, does not experience as much curtailment as the penetration of renewables is significantly lower than the Perfect World case.

This dramatic difference between the Perfect World and the Planned World highlights the importance of having not only a sufficient amount of flexibility but also the right 'mix' of flexible generators in order for renewables to reach their full potential.

For example, having the 8 GW of flexible gas in the Perfect World in 2028 versus only having 6 GW in the Planned World means that there is an increase of 6.7% renewable curtailment due to the lack of flexibility available in the system.

Power-to-Hydrogen

Power-to-Hydrogen (P2H) makes an appearance in the Perfect World through the addition of ~1.4 GW between 2029 and 2032 and is primarily used for energy balancing during the Winter months (very low load factors). During the modelling process, it was found that the inclusion of P2H was highly susceptible to the competing capex price of energy storage (8hr) which indicates that recognition for this technology is largely dependent on the long term capex reduction forecasts for electrolyzers and energy storage in form of batteries.

An additional variable which would have a material impact on the feasibility of P2H is that of Hydrogen storage technology (not included in the model). Considering that P2H is largely used to provide energy during the winter months, H2 would require significant storage capacity to allow for H2 production year round but consumption for only a portion of the year. There are a number of ways in which H2 can be stored such as the construction of conventional cooled H2 tanks or even storing H2 in unused mines. For purposes of this study, due to the lack of information available on this, storage has not been considered.

Despite the uncertainty around long term predictions for P2H, we do believe it potentially could play a role in the future (i.e. >2029) energy mix especially considering that any new build Gas Power has a 20-30 year lifespan meaning that at some point, there will likely be business case for blending of H2 into the gas supply mix.[16)] It should also be noted that when referring to Hydrogen as a possible fuel source for power generation, it would also encompass other Hydrogen based options such as Ammonia and Methanol as these fuels are more suitable for ICE technology.[17)]

[16)] This must be subject as well to the technical limitations associated with each technology. Today, ICE can blend up to 25% of H2 in their gas engines but research and developments in this area is ongoing (Wartsila, 2022).

[17)] In fact, Methanol ICE is already a commercial available product for the marine industry and Ammonia as a fuel source for ICE is at an advanced stage of development also for the marine sector (Wartsila, 2022) (Wartsila, 2022).

DISCUSSION

The Roles of Gas Power

As shown from the modelling results, it would be misleading to restrict the defined role of Gas Power to a single dispatch pattern such as peaking or mid-merit due to its wide range of anticipated energy and reserve capacity factors. And whilst the study undertaken by Meridian does principally identify this range by stating that gas provides peaking and insurance functionality, this description entices one perceives that it would operate in a peaking mode except for the rare occasion of backing up the system if required (like one would claim from your car insurance). However, the reality is that Gas Power is likely to play a far more significant role in building resilience into the power system by acting as the 'power safety net' in any system contingency event which can (and will likely) happen. In this study, we have identified eighteen possible system contingencies, but the reality is that there are many more factors that may result in the need for Gas Power to step in and maintain system stability. And the chances of all South Africa's planned energy crisis mitigation measures been undertaken successfully is arguably very low given the historical performance of many of these initiatives. As a result, one can very much anticipate a world whereby Gas Power operates at above peaking capacity factors for extended periods of time (5 years+) until South Africa can achieve their 'ideal' power system mix. And when we do reach this 'ideal' state, a pure peaking function would be more aptly described as a 'flexible peaking' function as there is a degree of renewable balancing and conventional peaking functionality as reflected by the 10-30% energy+reserves capacity factor ranges.[18)]

In summary, we believe that a more accurate description for Gas Power would be as a provider of 'System Contingency Reserves' and 'Flexible Peaking' capacity.

Based on this new dispatch definition for Gas Power, we can then appreciate that the amount of Gas Power required would be significant and according to our analysis, new gas capacity roughly matches the amount of effective coal capacity going offline every year which is ~1 GW per year. And preferably, this capacity should be serviced by ultra-flexible engine technology in order to provide the best optimisation capability for the maximum contribution from renewable energy (i.e. reduced curtailment and maximum renewable penetration).

The engine technology is a least regret option to select as it clearly dominated the new build preferences under all scenarios and gas price sensitivities.

[18)] The ideal state requires approximately 10% of energy capacity from gas and an additional 30-50% of operational reserves capacity. If we estimate a 50% dispatch level on the operational reserves, the net effective Gas Power capacity factor is in the order of 10-30%.

Gas Supply

When it comes to the supply of gas to a ‘Flexible Peaking + System Contingency Reserve’ Gas Power plant, it is worthwhile to reflect on some of the implications of requiring such flexibility into the entire gas supply chain.

When looking at the total annual gas requirements for each of our scenarios, we see anything from 15 PJpa to 167 PJpa being required over the coming years. In context of the LNG supply world, these numbers may be percieved to be relatively low as a typical FSRU could supply as much as 200 PJpa. And in context of how much South Africa currently consumes, it represents 12-76% of what is currently supplied through the ROMPCO line from Mozambique (Old Mutual, 2022). These numbers do present some challenges should there be an intention to ‘anchor’ LNG imports through Gas Power demand but in our view, these are not insurmountable. As the LNG market continues to grow, the ability and appetite to enter into smaller, more flexible, contracting arrangements is becoming apparent. A perfect case study of how LNG imports have been anchored on a ‘small’ offtake is the Acajutla Power project in El Salvador. This project consists of a 378 MW ICE power plant with a direct connection to a dedicated FSRU (137,000m3). This project will be used to provide flexible and reliable energy to the grid in El Salvador.

Figure 17: Aerial view of the 378 MW Acajutla Gas Engine Power plant fed directly from the 137,000m3 FSRU BW Tatiana as seen in the distance.

The aggregation of gas demand through non-power users is also a key factor in reducing LNG costs and forming a part of that 'anchor' demand required for investment. It is also believed that adding more non-power users would support the enablement of a highly flexible Gas Power demand profile by acting as an offtake buffer to absorb the spikes in consumption.[19)] It should however be kept in mind that whilst we have shown Gas Power to be inelastic to gas price fluctuations, the same may not be true for non-power users who are likely to be more susceptible to gas price volatility and who in South Africa currently pays significantly lower gas prices than any new LNG supply option.[20)] This fact highlights the importance of adopting an effective LNG/gas contracting approach for the country which preferably consists of a mix of indices; tenures; and 'Take of Pay' obligations to find the best 'fit' between gas supply and demand profiles. To support this approach, we recommend that a central gas procurement office be established in South Africa to best optimize the mix of gas supplies to service South Africa's requirements.

We can't, however, ignore the immediate power crisis and whilst LNG solutions and regional supply options will be developed in due course,[21)] there is a need to add electrons onto the grid immediately (as reflected by the 850 MW of new ICE capacity built in 2023 in the Perfect World). One bridging solution that could be considered is to build multi-fuel ICE ('ICE DF') power stations that can operate on liquid fuels today but will seamlessly switch to gas and can later be converted to run on carbon neutral fuels when it becomes available. ICE DF power stations can switch between liquid and gas fuel sources even whilst in operations (Wartsila, n.d.) and there is no cost of conversions for when gas does become available. This ability to switch between fuel options introduces a myriad of additional benefits for the power projects and the power system, namely:

- Higher dispatch factors required during the System Contingency Reserve dispatch periods could be serviced by diesel whilst continuing with gas as the primary fuel option for the Flexible Peaking functionality;
- Diesel can be used in the event of a break in the gas supply chain (for example; if an FSRU is unable to delivery gas due to adverse sea conditions) thus ensuring high plant availabilities and;
- Diesel could be used in the off chance that LNG price exceeds that of diesel.

One drawback of the option to operate on diesel before gas arrives is that based on the South African Air Emissions Legislation today, liquid fuel plants of larger than 300 MWth would require some form of exhaust gas cleaning infrastructure in order to ensure compliance with the NOX emissions. This addition would deter the economics unless multiple projects of <120 MW can be built to avoid this requirement.

Lastly on the topic of gas supply, despite the uncertainty regarding the timing of potential H2 fuel options, there should be at least some degree of convertibility to H2 for future gas plants to mitigate or minimize the 'stranded asset' risk should natural gas not be allowed in the long term.[22)]

19) Any gas supply network, whether it be virtual pipelines or actual pipelines, has the ability to inherently store gas within its supply infrastructure. The bigger the supply network, the more ability to store gas and therefore manage the spikes in gas demand from Gas Power.

20) According to NBI, current gas users in South Africa pay ZAR30-90/GJ which is approximately 1/3 of the gas price assumed in this study (National Business Initiative, 2022).

21) There are a number of regional import initiatives which could service the Gas Power requirements in future. These include TNPA's LNG terminal project in Richards Bay (Creamer, 2022); the Beluluane Gas Company project in Mozambique (Beluluane Gas Company, n.d.); and the Total/Mulilo Coega project in Gqeberha (DMRE - IPP Office, 2022). The anticipated timing of these (and other) initiatives however varies with some of them potentially only being able to provide gas after 2026.

22) Reasons may include exorbitant costs; lack of global supply; or even policy decisions to further reduce emissions.

Reduced Concentration of Reserve Capacity

In today's power system, most operating reserves are provided by the coal fleet with an increasing reliance on the diesel OCGT's to balance the system as renewable penetration increases. Typically, a small fraction of a coal unit (~10%) capacity is allocated to providing such reserves. This approach however will not be sustainable as the coal fleet is decommissioned and there is an increasing reliance on gas and battery technologies to provide these reserves. New reserve providers must enter the system which our modelling shows to be a combination of BESS and Gas Power.

In the case where a Gas Power plant will be used to provide reserves, as the majority of the plant capacity would be dedicated to providing such reserves, and it is likely that any "large scale" Gas Power would provide the majority of required operating reserves, having such a large amount of system operating reserves concentrated into one plant represents a security of supply risk to the system. Should there be any issue with that 'Big Gas' power plant, then the whole power system may experience unexpected outages due to the lack of reserves available.

It is therefore recommended, from a total system integrity of supply perspective, that Gas Power be geographically spread across the grid through smaller, gas/fuel source diversified, plants in order to reduce the concentration risk.

Least Cost and Emissions

One often encounters a perception in the market that in order to reduce emissions, one must pay a premium as we saw during the introductory years of renewables which relied heavily on government subsidies. This, however, is no longer the case and renewables are undeniably the cheapest form of energy available today. And in order to achieve the least cost energy tariff, the generation mix should consist of technologies which enable the greatest amount of "cheap" renewable energy to be introduced into the system. Counterintuitively, as shown in our results (see section related to renewable curtailment), the addition of a carbon-based generation in the form of flexible natural gas ICE technology (together with BESS), reduces the system's reliance on more carbon intense and inflexible carbon emitters, such as diesel OCGT's and coal fired power generation, to balance the renewables. These emissions reductions, which without the addition of new Gas Power would be ~20% higher, are only possible thanks to the fast response times and high efficiencies across the entire output range of a typical ICE power plant (Wärtsila, 2022).

GAS POWER SOLUTION RECOMMENDATIONS

Our analysis and discussion has raised numerous findings and considerations which influences how South Africa could/should be approaching their future Gas Power endeavors. From this, we now provide guidance and definition around what a possible solution could look like.

From a technology perspective, highly flexible grid balancing engine technology, together with energy storage in the form of batteries, is the preferred route to provide flexibility to a future renewable power system. Many examples of utility scale engine power plants have been built with plants even reaching up to 573 MW per project (Wartsila, 2022) (Power Technology, 2015). And whilst South Africa needs several GW's to be erected in the coming years, it is prudent from both a gas supply and system reserves provider risk perspective to diversify both the geographic locations and fuel source options by building multiple, medium scale gas, multi-fuel power projects. This approach of having distributed Gas Power will also enable faster construction times (Clark, van Niekerk, Petrie, & McGregor, August 2022); rapid development of more regional gas resources;[23)] and greater job creation potential than would be seen through one or two 'Big Gas' projects. And as demonstrated in the Acajutla LNG-to-Power project, having a distributed approach may catalyze and unlock a multitude of potential new gas sources (both domestic and import) being developed thus creating further opportunity for cost savings and emission reductions in the downstream non-power sector.

A cursory view of the potential new gas sources indicates that there could be up to ten gas projects leveraging off at least seven different possible gas sources. And what's more is that the majority of these opportunities are located in areas which has sufficient grid capacity available as indicated in Figure 18.

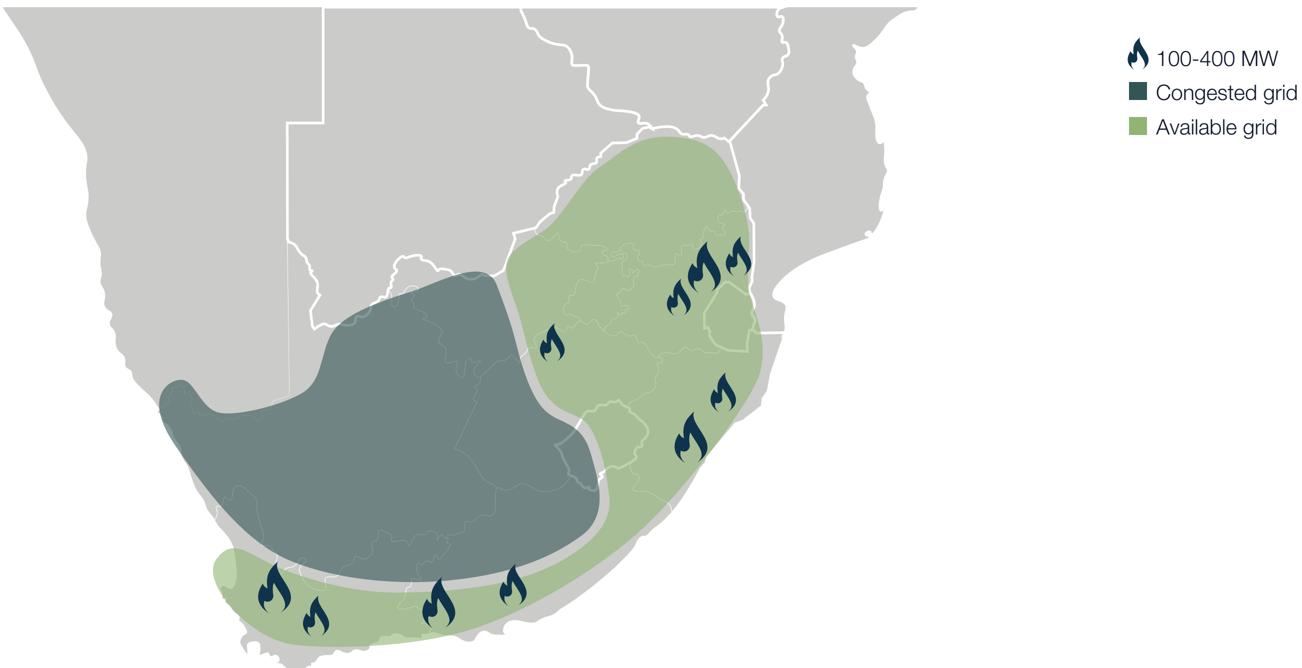

Figure 19:
Map of possible new Gas Power plants located at potential gas supply sources.

23) There are many smaller regional gas sources which could be fully developed through a Gas Power project. Examples include Renergen; Kinetiko; Kudu; etc…. (South African Oil and Gas Association, 2022)

This approach will also support the enablement of further emissions reductions beyond 2030 as we see a transition to greener future sustainable fuels such as Hydrogen which already today can be blended up to 25%.

In order to enact these recommendations, we believe that there should be a prioritization within the following areas of policy and procurement:

- Ensure that future IRP's adequately capture the value of flexibility and provide sufficient detail regarding the specific requirements of such flexibility (such as preferred technologies; capacity factors; roles in reserves; and minimum functional technology specifications); and
- Ensure that any upcoming gas IPP procurement programme sufficiently defines and values the need for flexibility as procured through multiple distributed; gas supply diversified; power projects.

AREAS OF FUTURE INVESTIGATION

We have identified the following areas of future investigation which we believe will add value concerning this topic of the role of gas in an energy crisis:

- An investigation into the practical limit of how much renewable can be built in South Africa is an important parameter to understand as it has a significant impact on how much of other technologies are built to meet the demand;
- Investigating the degree of flexibility and integrating any supply constraints which mimic real-life limitations one may encounter when considering the LNG supply chain and/or other gas supply options and;
- Investigating the possible changes in demand patterns caused by increased accessibility to embedded storage (eg: EV) and generation technologies.

CONCLUSIONS

This study set out to assess the adequacy of South Africa's proposed energy crisis mitigation measures (from a new-build capacity perspective) and to also understand whether there is a role for gas to power within this context and the future energy transition for South Africa. By virtue of the fact that the Planned World scenario yields virtually no load shedding over the next few years indicates that in theory, should South Africa manage to successfully execute all of the identified measures considered in this paper, then they can take comfort knowing that the current load shedding levels will soon be a thing of the past. However, based on experience, it is more likely that a fair portion of these measures will not be fully realized thus leaving the country with continued load shedding for the coming years at potentially levels significantly far worse than South Africa is currently experiencing. An effect which not only directly limits the economic growth of the country but also which indirectly accelerates the failure of the existing aged grid leading to further increases in extended load shedding.

The solution, as demonstrated in our "Perfect World" simulation, is to add as much renewable energy into the power system as possible through any means necessary but in parallel, flexibility in the form of BESS and Gas Power (based on ICE technology) needs to be added at scale. And whilst BESS is good for short term flexibility requirements, it is shown that Gas Power plays a far broader role in supporting the power system by providing a significant amount of both energy and operational reserves to the grid. Gas Power capacity factors can fluctuate between 1-30% in 'ideal' circumstances but grow to 60% when 'reality' creeps in. Similarly, up to 80% reserve capacity factors are called upon from Gas Power revealing that Gas Power plays a significant role as a operational reserves provider to the system. With this high degree of flexibility built into the system, South Africa can save $13B (13%) from the Planned World to the Perfect World and $26B (26%) from the Reality Check on the cumulative system costs up to 2032. Whichever way South Africa implements future Gas Power plants, there must be ample recognition of this wide range of dispatch profiles and the fact that gas acts as the system 'safety net' under any system contingency that may, and will likely, occur.

Counterintuitively, Gas Power has a significant role to play in reducing the net power system emissions by decreasing the reliance on coal and diesel to balance the system. Without building sufficient amounts of flexible Gas Power, South Africa's power emissions reduction trajectory would keep us diverted off the path to net-zero by 2050. And as an added benefit, again, contrary to common belief, by adding "expensive" gas to reduce emissions, one is also able to achieve the least cost for the system. A power system with 9 GW of flexible Gas Power by 2032 means that more renewables can be built thereby decreasing the total system cost. And in a world where no new fossil fuel plants are built, unrealistic amounts of battery capacity is required (shown to be approximately 3 GW / 24 GWh per year) and even nuclear is proposed in 2032 which incurs a 55% system cost premium with negligible (<1%) system emission reductions being achieved due to the continued usage of diesel and coal for our balancing needs.

Such flexible Gas Power additions could be integrated into the South African power system through multiple 100-400 MW; multi-fuel; geographically spread; gas source diversified; engine plants in order to reduce fuel supply price and availability risks and reducing the risk of concentrating the system's operational reserves providers. A cursory view of the gas market developments indicates a possibility to implement at least 10 such projects supplied from 7 domestic gas sources. Furthermore, there should also be some degree of convertibility to green fuel alternatives (estimated to be required beyond 2029) to ensure the continued realization of South Africa's energy transition to 100% renewables. In conclusion, whilst South Africa must continue to strive for the ideal world energy mix, which is dominated by renewable energy, it would be strongly advisable to continue undertaking flexible gas projects not only to support the rapid growth in renewables but to also ensure a stable supply should reality set in. To achieve this, we recommend that the next revision of the IRP provides further key details on the characterization of such flexibility (such as preferred technology; reserve requirements; and capacity factors) and that upcoming Gas Power IPP procurements should adequately value flexibility as part of their evaluation criteria. We believe that if South Africa can adapt their future Gas Power related policy and Gas Power procurement to align to the recommendations outlined in this report, they would be able to demonstrate to the world their leadership in the transition from a coal-based economy to a renewable based economy.

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Date: 5th September 2022

Dearest Esteemed Colleague,

As of late, much has been discussed concerning how South Africa can eliminate load shedding and what steps should be taken for us to enjoy a stable; reliable; and cost-effective supply of electricity. Within such discussions, the role of gas-based power generation has often found itself under the spotlight and being subject to varying, and sometimes divisive, viewpoints. Questions concerning size; dispatch; technology; fuel supply; and even whether gas is needed at all have often been tabled with little consensus or agreement.

We, as Wärtsilä[i], using our in-house modelling capabilities, wish to demystify this topic by undertaking a **completely transparent power system modelling process**[ii]. You, as a key player in the energy sector, can now make your contribution into a data driven and evidence-based modelling exercise intended to create consensus and alignment on if and how gas power should/could be advanced in South Africa over the coming years. With your inputs, we wish to unpack how gas plays a role in three scenarios:

- ***"Perfect World"*** – A world with no restrictions on what new capacity can be built;

- ***"Planned World"*** – A world where all the initiatives and plans currently tabled[iii] are successfully executed; and

- ***"Reality Check"*** – A world where our new build plans *don't* go according to plan.

We therefore invite all interested and affected parties to be a part of this process by sharing their experience and expertise to assist in defining the input parameter dataset and scenarios to be modelled. Attached to this letter is a list of the key inputs[iv] currently considered for the modelling along with reference information where available.

Should you have a different view on the current input parameters, or you believe there is information missing, we will revise the input parameters provided the proposed changes are sufficiently justified (through the presentation of evidence-based facts that are publicly available) and will likely have a material impact[v] on the results.

In order to be a part of this initiative, there is a two-step process to follow:

1. Review the current input parameters and add a description of your proposed changes along with attaching any relevant supporting information.
2. Join us on a call (multiple engagement sessions will be arranged depending on the level of response) to discuss your proposed changes and address any clarification questions we may have.

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WÄRTSILÄ

All validated inputs will be acknowledged in a White Paper targeted for completion in November 2022 and the results and model, will be made publicly available.

All comments and clarifications must be addressed to **Ms Keaobaka Poti** at keaobaka.poti@wartsila.com by the **30th September 2022**.

For those who wish to understand more about the modelling process and to see some examples that Wärtsilä has undertaken, we hereby invite you to attend a *"Power System Modelling by Wärtsilä - Introduction"* session to be held on the **14th September 2022 at 09:00 South African Time**. If interested, please send your names and email addresses to Ms Keaobaka Poti.

We look forward to engaging with yourselves and collectively taking meaningful steps forward to enrich and advance the discussions around gas power in South Africa!

Yours Sincerely,
Wayne Glossop
Senior Business Development Manager

Attachment 1 – Key Inputs and Scenarios

DISCLAIMER
*The information and conclusions in this document are based upon calculations (including software built-in assumptions), observations, assumptions, publicly available information, and other information obtained by Wärtsilä or provided to Wärtsilä by its customers, prospective customers or other third parties (the "**information**") and is not intended to substitute independent evaluation. No representation or warranty of any kind is made in respect of any such information. Wärtsilä expressly disclaims any responsibility for, and does not guarantee, the correctness or the completeness of the information. And whilst every reasonable effort is made to ensure the completeness and accuracy of our modelling, the calculations and assumptions included in the information may not necessarily take into account all the factors that could be relevant. Nothing in this document shall be construed as a guarantee or warranty of the performance of any Wärtsilä equipment or installation or the savings or other benefits that could be achieved by using Wärtsilä technology, equipment or installations instead of any or other technology.*

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[i] Wärtsilä leads the transition towards a 100% renewable energy future. We help our customers in decarbonisation by developing market-leading technologies. These cover future-fuel enabled balancing power plants, hybrid solutions, energy storage and optimisation technology, including the GEMS energy management platform. Wärtsilä Energy's lifecycle services are designed to increase efficiency, promote reliability and guarantee operational performance. Our track record comprises 76 GW of power plant capacity and more than 110 energy storage systems delivered to 180 countries around the world. For more information, please visit us at https://www.wartsila.com/energy.

[ii] Wärtsilä uses PLEXOS®, the world's most powerful energy market simulation engine providing analytics and decision-support to modelers, generators, and market analysts— offering flexible and precise simulations across electric, water, gas and renewable energy markets (reference: https://www.energyexemplar.com/plexos).

[iii] Currently identified measures to alleviate the power crisis include accelerating IPPO procurement programmes (RMIPPP; REIPPP; Gas; BESS); improving the coal EAF; implementing DSM; executing all private IPP's currently being licenced with NERSA; purchase of excess capacity from existing generators; Eskom/World Bank BESS programme; high uptake of unlicenced embedded generation; and increase in power imports.

[iv] It is recognized that Plexos, as a highly sophisticated modelling software tool, has many more inputs that could be considered however, we have attempted to simplify these inputs to the ones that we know will have a significant impact on the results. However, as we refine and optimize the model, more detailed inputs would be gladly welcomed.

[v] In the modelling process, one always has to weigh the impact versus the cost (i.e. modelling resource usage and processing time impact) of adding in certain inputs. Our team of experienced modelers will be able to advise on how certain inputs will likely alter the outcome (if any) and whether or not it will change the conclusions in a material way.

Planned New Capacities	Scenario		I&AP Comments	Reference/Supporting Ma
	Planned World	*Reality Check*		
RMIPPPP	All RMIPPPP planned capacity is procured and operation by 2024	1/2 of the RMIPPPP planned capacity is procured and operation delayed by 1 year	Please provide as much information as possible on the reasoning behind your comments such as real life reference; independent studies; etc.	Please provide the name/type of document and/or website link where it can be accessed.
REIPPP PV	Planned additional capacity is procured and operational on time as per IRP with doubling of capacity as per Presidents speech in 2024	A 2 year delay on the procurement and operation of additional capacity (full capacities are maintained due to historical success of this programme in realising all the bidded MW's)		
REIPPP Wind	Planned additional capacity is procured and operational on time as per IRP with doubling of capacity as per Presidents speech in 2024	A 2 year delay on the procurement and operation of additional capacity (full capacities are maintained due to historical success of this programme in realising all the bidded MW's)		
IPP Gas Programme	Planned additional capacity is procured and operational on time which is 2026	A 2 year delay on the procurement and operation of additional capacity.		
Eskom 3GW Gas	Planned additional capacity is procured and operational in Richards Bay on time (which is before 2028 as per draft Ministerial Determination)	No procurement of additional capacity due to environmental concerns in Richards Bay.		
IPP BESS Programme	Planned additional capacity is procured and operational on time. Projects come online in 2024	A 2 year delay on the procurement and operation of additional capacity		
Future IPPO BESS Programme	1231MW to come online in 2029	1231MW to come online in 2031		
Eskom World Bank BESS - Phase 1 8	Planned additional capacity is procured and operational on time. Phase 1 is online in 2023 and Phase 2 is online 2025	A 2 year delay on the procurement and operation of additional capacity. Phase 1 is online in 2025 and Phase 2 is online 2027		
Private PV IPPs	Annual additional capacity of 1GW is procured	Annual additional capacity of 500MW is procured		
Embedded Renewables (rooftop PV	Growth of Embedded renewables at 500MW per anum	Growth of Embedded renewables at 250MW per anum		
Purchase of excess capacity from e	1000MW additional dispatchable capacity procured and operational for a three year period.	500MW additional dispatchable capacity procured and operational for a three year period.		
Demand Side Management	Demand Side Management implemented accordingly and on time	1/2 of Demand Side Management implemented with a 1 year delay		
Eskom Maintenance Programme -	Maintenance programmes implemented accordingly and on time	The maintenance programme yields half of the expected MW's and is delayed by 2 years.		
International Imports	International imports realised	No international imports realised		
Eskom Medupi & Kusile Coal Units	- Medupi Unit 4 online in 2024 - Kusile Units 5 and 6 online in 2023	Commercial operation of the coal units delayed by 2 years		
Energy Availability Factor : Eskom C	After the Eskom Maintenance programme is implemented; EAF is halved from 3% to 1.5% year-on-year.	After the delayed and reduced Eskom Maintenance programme is implemented; EAF resumes its current trajectory of 3% drop per year.		

Input Name	Input Number	Input Unit	Reference document	Reference	Wartsila Comment	Link	I&AP Comments	Reference/Supporting Material to be submitted
Installed capacity								
Eskom Coal Fleet	38773	MW	2021 Eskom Integrated Report	Page 136 - Baseload Stations, Coal-Fired	The model is based on total nominal capacity and not the total installed capacity. Nominal capacity according to the integrated report accounts for auxiliary requirements as well as ageing.	2021IntegratedReport.pdf (eskom.co.za)	Please provide as much information as possible on the reasoning behind your comments such as real life reference; independent studies; etc.	Please provide the name/type of document and/or website link where it can be accessed.
Kelvin B	420	MW	Kelvin Power Station - Information Summary	Page 2		- https://www.kelvinsale.com/pdf/Kelvin-Information-Summary.pdf		
Peakers - Dedisa OCGT IPP	355	MW	Independent Power Projects in Sub-Saharan Africa - Lessons from Five	Page 176 - The Peaker Project	Diesel is regarded as the primary fuel source	https://documents1.worldbank.org/curated/fr/795581467993175836/pdf/104779-PUB-		
Peakers - Avon OCGT IPP	670	MW	Independent Power Projects in Sub-Saharan Africa - Lessons from Five	Page 176 - The Peaker Project	Diesel is regarded as the primary fuel source	https://documents1.worldbank.org/curated/fr/795581467993175836/pdf/104779-PUB-		
Ankerlig OCGT	1327	MW	2021 Eskom Integrated Report	Page 136 - Peaking Stations	The model is based on total nominal capacity and not the total nstalled capacity. Nominal capacity according to the integrated report accounts for auxiliary requirements as well as aging.	2021IntegratedReport.pdf (eskom.co.za)		
Gourikwa OCGT	740	MW	2021 Eskom Integrated Report	Page 136 - Peaking Stations	The model is based on total nominal capacity and not the total nstalled capacity. Nominal capacity according to the integrated report accounts for auxiliary requirements as well as aging.	2021IntegratedReport.pdf (eskom.co.za)		
Nuclear	1860	MW	2021 Eskom Integrated Report	Page 136 - Baseload Stations	The model is based on total nominal capacity and not the total nstalled capacity. Nominal capacity according to the integrated report accounts for auxiliary requirements as well as aging.	2021IntegratedReport.pdf (eskom.co.za)		
IPPO CSP	600	MW	Eskom Data Portal - Renewable Statistics		Installed Capacity utilised in the model as per the data portal	https://www.eskom.co.za/dataportal/renewables-performance/renewable-statistics/		
IPPO PV	2212	MW	Independent Power Producers Procurement Programme (IPPPP) - An Overview (December 2021)	Page 11 - Technology contributions (Procured vs operational)		https://www.ipp-projects.co.za/Publications/GetPublicationFile?fileid=2d03d621-6dc4-ec11-956e-2c59e59ac9cd&fileName=20220318_IPP%20Office%20Q3%20Overview%202021-		
IPPO Wind	3442	MW	Eskom Data Portal - Renewable Statistics		Installed Capacity utilised in the model as per the data portal	https://www.eskom.co.za/dataportal/renewables-performance/renewable-statistics/		
Other IPPO Renewable	50,5	MW	IPP Projects Database		Other Renewables include Landfill Gas, Biomass, and Small Hydro Projects. Only projects in operational state were considered in the model. 70% Availability	https://www.ipp-projects.co.za/ProjectDatabase		
Hydro_Import	1500	MW	Integrated Resource Plan 2019	Appenix A, 6.1.1 - Municipal, Private and Eskom Generators (Page 53 - Table 8)	Hydro import from Cahora Bassa	http://www.energy.gov.za/IRP/2019/IRP-2019.pdf		
Hydro_RSA	600	MW	2021 Eskom Integrated Report		Based on Eskom Hydro Plants which includes Gariep and Vanderkloof. Model assumed 70% annual capacity factor with no flexibility	2021IntegratedReport.pdf (eskom.co.za)		
Embedded_base	2091	MW	- Integrated Resource Plan 2019 - Kelvin Power Station - Information Summary	Appenix A, 6.1.1 - Municipal, Private and Eskom Generators (Page 53 - Table 8)	- Capacity includes other non-Eskom municipal and private generators (Kelvin B, Sasol Infrachem Coal, Sasol Synfuel Coal, Sasol Infrachem Gas, Sasol Synfuel Gas, Colley Wobbles, Other non-Eskom Hydro, Steebras, Sappi, and Mondi power plants). - It should be noted that only 420MW of the 600MW Kelvin power station capacity was considered (essentially Kelvin B). - Kelvin A is on long-term outage as per the Kelvin power station website - Model assumes 50% availability of these power plants	http://www.energy.gov.za/IRP/2019/IRP-2019.pdf		
PS_Hydro	2732	MW	2021 Eskom Integrated Report	Page 136 - Peaking Stations, Pumped Storage Schemes	Includes Drakensberg; Ingula; and Palmiet	2021IntegratedReport.pdf (eskom.co.za)		
Embedded Renewables (PV Rooftop)	700	MW	Small Scale Embedded Generation - Guide for Small South African Municipal Distributors	Page 1 - Installed capacity of SSEG	Modelled as PV technology. This is also assumed to be included in the demand curve data obtained from the Eskom data portal.	https://www.sseg.org.za/wp-content/uploads/2021/03/SSEG-Distributors-Guide.pdf		
International Exports	0	MW	2021 Eskom Integrated Report	Page 88 - Export Growth Strategy	- Exports are therefore not included in the model as they are treated as interruptable supply	2021IntegratedReport.pdf (eskom.co.za)		
Fleet Assumptions								
Coal Retirement Schedule			Formal communication from Eskom	Table 1 - Station and unit decomissioning dates		https://cer.org.za/wp-content/uploads/2020/05/Formal-Response-PAIA-ref-0087-Man-Affirmation-that-records-does-not-exist.pdf		
Energy Availability Factor : Eskom Coal			Coal stations performance Jan 2021 to date		Current trend of year-on-year EAF reduction is approximately 3%.	Document: 0220715 Coal stations performance Jan 2021 to date_Chris Yelland.xlsx		
Energy Availability Factor : Nuclear	74	%	Power Reactor Information System		Indicated EAF of 73,4% for Koeberg 1 and 74,2% for Koeberg 2 Reactors for 2021. Average EAF of 74% used in the model	https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=836		
Plant Efficiencies - Existing Coal	30,61	%	2021 Eskom Integrated Report	Page 130 - Technical Statistics, Primary Energy	Overal thermal efficiency used for all coal thermal plants in the model.	2021IntegratedReport.pdf (eskom.co.za)		
Plant Efficiencies - Existing Eskom OCGTs	30	%	2021 Eskom Integrated Report	Page 130 - Technical Statistics, Primary Energy (Diesel and Kerosene usage for OCGTs)	Efficiency calculated from the diesel usage, calorific value and density of fuel.	2021IntegratedReport.pdf (eskom.co.za)		
Plant Efficiencies - Existing IPP OCGTs	30	%	2021 Eskom Integrated Report	Page 130 - Technical Statistics, Primary Energy (Diesel and Kerosene usage for OCGTs)	IPP OCGTs assumed to have the same efficiency as Eskom OCGTs	2021IntegratedReport.pdf (eskom.co.za)		
Plant Efficiencies - Existing Nuclear	33	%	Energy Education - Nuclear Power Plants			https://www.nuclear-power.com/nuclear-engineering/thermodynamics/laws-of-thermodynamics/thermal-efficiency/thermal-efficiency-of-nuclear-power-plants/		
Plant Efficiencies - New Build (NB) Coal	32,9	%	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	- Efficiency assumption in the model is based on the average between heat rates of the low and high cases - Model assumed 80% annual Load Factor	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Plant Efficiencies - New Build Nuclear	32,7	%	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	- Efficiency assumption in the model is based on the average between heat rates of the low and high cases - Model assumed 80% annual Load Factor	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Plant Efficiencies - New Build OCGT	38,3	%	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	- Efficiency assumption in the model is based on the average between heat rates of the low and high cases - Model assumed 80% annual Load Factor	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Plant Efficiencies - New Build ICE	47,4	%	Wartsila Internal		Based on internal experience and observations			
Plant Efficiencies - New Build CCGT	52,3	%	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	- Efficiency assumption in the model is based on the average between heat rates of the low and high cases - Model assumed 80% annual Load Factor	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Fuel Price								
Coal	2,03	USD/GJ	2021 Eskom Integrated Report		Fuel price calculated based on the indicated output production, as well as fuel cost. Model assumed 17 USD/ZAR exhange rate.	2021IntegratedReport.pdf (eskom.co.za)		
Uranium	0,57	USD/GJ	2021 Eskom Integrated Report	Page 128 - Technical Statistics (Electricity output)	Fuel price calculated based on the indicated output production, as well as fuel cost. Model assumed 17 USD/ZAR exhange rate.	2021IntegratedReport.pdf (eskom.co.za)		
Diesel - Eskom Peakers	13,71	USD/GJ	2021 Eskom Integrated Report	Page 87 - Use of open-cycle gas turbines	Fuel price calculated based on the indicated output production, as well as diesel usage. Model assumed 17 USD/ZAR exhange rate.	2021IntegratedReport.pdf (eskom.co.za)		
Diesel - IPP Peakers	20,19	USD/GJ	2021 Eskom Integrated Report	Page 87 - Use of open-cycle gas turbines	Fuel price calculated based on the indicated output production, as well as diesel usage. Model assumed 17 USD/ZAR exhange rate.	2021IntegratedReport.pdf (eskom.co.za)		
Gas	15	USD/GJ			- Assumed gas price is delivered gas price to the power station - Assumptions based on internal Wartsila experience and market observations			
Fixed Operational Costs								
Existing & New Build Coal	60,1	USD/kW/yr	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Fixed operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Existing & New Build Nuclear	130,5	USD/kW/yr	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Fixed operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Existing & New Build OCGT	14,1	USD/kW/yr	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Fixed operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
NB ICE	15	USD/kW/yr	Wartsila Internal		Based on internal experience and observations			
NB CCGT	16,5	USD/kW/yr	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Fixed operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Variable Operational Costs								
Existing & New Build Coal	3,8	USD/MWh	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Variable operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Existing & New Build Nuclear	4,3	USD/MWh	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Variable operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
Existing & New Build OCGT	4,6	USD/MWh	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Variable operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		
NB ICE	7,5	USD/MWh	Wartsila Internal		Based on internal experience and observations			
NB CCGT	3,9	USD/MWh	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 18 - Levelized Cost of Energy, Key Assumptions	Variable operatoinal cost assumption in the model is based on the average between the low and high cases	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf		

Planned New Capacities						
RMIPPPP	1995	MW	IPP Risk Mitigation		Projects under RMIPPP treated as one generating unit in the model with the following assumptions: - Dispatch times of 5:00 to 21:30 daily (according to xxx) - COD at Q4 2024 - Decommisioning at 2022 (based on the PPA tenor) - Tariff at ZAR/kWh 1,83 (based on average of ZAR/kWh 1,63 with a 2 year CPI escalation)	https://www.ipp-rm.co.za/
REIPPP Round 5 - PV	1000	MW	Independent Power Producers Procurement Programme (IPPPP) - An Overview (December 2021)	Page 45 - Background	Assumed COD at Q1 2025 and Once-off capacity addition	https://www.ipp-projects.co.za/Publications/GetPublicationFile?fileid=2d03d621-6dc4-ec11-956e-2c59e59ac9cd&fileName=20220318_IPP%20Office%20Q3%20Overview%202021-22%20WEB%20VERSION.PDF
REIPPP Round 5 - Wind	1600	MW	Independent Power Producers Procurement Programme (IPPPP) - An Overview (December 2021)	Page 45 - Background	Assumed COD at Q1 2025 and Once-off capacity addition	https://www.ipp-projects.co.za/Publications/GetPublicationFile?fileid=2d03d621-6dc4-ec11-956e-2c59e59ac9cd&fileName=20220318_IPP%20Office%20Q3%20Overview%202021-22%20WEB%20VERSION.PDF
REIPPP Round 6 - PV	2000	MW	President Cyril Ramaphosa: Address to the nation on energy crisis		Assumed COD at Q1 2026 and Once-off capacity addition	https://www.gov.za/speeches/president-cyril-ramaphosa-address-nation-energy-crisis-25-jul-2022-0000
REIPPP Round 6 - Wind	3200	MW	President Cyril Ramaphosa: Address to the nation on energy crisis		Assumed COD at Q1 2026 and Once-off capacity addition	https://www.gov.za/speeches/president-cyril-ramaphosa-address-nation-energy-crisis-25-jul-2022-0000
REIPPP Round 7-onwards (PV)	1000	MW	Consultation Paper: Concurrence with the Ministerial Determination on the Procurement of new Generation capacity of 14 771MW from renewables (solar PV and wind) and storage technologies.		- Assumption that capacity is additional on an annual basis inline with IRP timeframes	https://www.nersa.org.za/wp-content/uploads/2022/08/Updated-Consultation-Paper-s38-determination-14-771MW-Renewables-Storage.pdf
REIPPP Round 7-onwards (Wind)	1600	MW	Consultation Paper: Concurrence with the Ministerial Determination on the Procurement of new Generation capacity of 14 771MW from renewables (solar PV and wind) and storage technologies.		- Assumption that capacity is additional on an annual basis inline with IRP timeframes	https://www.nersa.org.za/wp-content/uploads/2022/08/Updated-Consultation-Paper-s38-determination-14-771MW-Renewables-Storage.pdf
IPP Gas Programme	3000	MW	Ministerial Determination		Based on RFP's from DBSA for advisory services related to this programme under the IPPO, it states that the targetted COD date is in 2026. Furthermore, Ministerial determinations requires the capacity to be online before 2027.	https://www.gov.za/sites/default/files/gcis_document/202009/43734gon1015s.pdf
Eskom 3GW Gas	3000	MW	Consultation Paper: Concurrence with the Ministerial Determination on the Procurement of New Generation Capacity of 3000 MW from Gas Technology	Page 10 - Procurement Process under the IPP Procurement Prorgamme	The recent released NERSA determination indicates Eskom as the buyer of new generation capacity. Based on this, we believe and have assumed that 3GW of gas generation capacity will be procured in addition to the proposed 3GW Gas capacity as per the IPP programme	https://www.nersa.org.za/wp-content/uploads/2022/08/Updated-Consultation-Paper-s38-determination-3-000-MW-Gas.pdf
IPPO BESS Programme	513 / 2052	MW / MWh	Ministerial Determination		The Ministerial Determination states that this capacity should be online by 2022 however, this programme is already delayed but due for imminent release. We therefore assume that this capacity will be online by 2024.	https://www.gov.za/sites/default/files/gcis_document/202009/43734gon1015s.pdf
FUTURE IPPO BESS Programme	1231 / 4924	MW / MWh	Consultation Paper: Concurrence with the Ministerial Determination on the Procurement of new Generation capacity of 14 771MW from renewables (solar PV and wind) and storage technologies.		Assumed that this is a 4hr LiIon battery	https://www.nersa.org.za/wp-content/uploads/2022/08/Updated-Consultation-Paper-s38-determination-14-771MW-Renewables-Storage.pdf
Eskom World Bank BESS - Phase 1	199 / 833	MW / MWh		AFDB Website	Assumed that liIon technology is considered	https://www.afdb.org/en/documents/south-africa-eskom-distributed-battery-energy-storage-project-project-appraisal-report
Eskom World Bank BESS - Phase 2	160 / 640	MW / MWh		AFDB Website	Assumed that liIon technology is considered	https://www.afdb.org/en/documents/south-africa-eskom-distributed-battery-energy-storage-project-project-appraisal-report
Private PV IPPs	6000	MW	President Cyril Ramaphosa: Address to the nation on energy crisis		Private PV IPPs under Nersa Licensing according to the speech. However, it is not realistic to believe that all 6GW would be built and built in one year. It is all assumed to be based on PV technology.	https://www.gov.za/speeches/president-cyril-ramaphosa-address-nation-energy-crisis-25-jul-2022-0000
Embedded Renewables (PV Rooftop)	ssumed to already be con		Eskom Medium-Term System Adequacy Outlook 2022-2026 report	Page 13 - 6.3: Self-generation: Estimated rooftop PV	- Model assumptions on generation capacity addition are In line with MTSAO report, thereafter assumptions of 500MW annual generation capacity additions is assumed based on observed trend.	https://www.eskom.co.za/wp-content/uploads/2021/11/MediumTermSystemAdequacyOutlook2022-2026.pdf
Purchase of excess capacity from existing generators - Other	1000	MW	Consultation Paper: Concurrence with the Ministerial Determination on the Procurement of New Generation Capacity of 3000 MW from other Distributed Generation	Page 7 - New generation capacity from other technology	As the public NERSA consultation document outlines the need for baseload capacity, the model assumes dispatchable generators for annual capacity addition.	https://www.nersa.org.za/wp-content/uploads/2022/08/Updated-Consultation-Paper-s38-determination-1-000MW-other-technologies.pdf
Demand Side Management	1500	MW	Eskom Top CEOs Engagement Session (29 July 2022)	Page 4 - Reducing Demand		Presentation: Eskom Top CEOs Engagement Session (29 July 2022) - TO BE FILED IN DATA ROOM
Eskom Maintenance Programme - 1	1800	MW	Eskom Top CEOs Engagement Session (29 July 2022)	Page 6 - Overview of annual capacity that can be connected	- COD at Q4 2024 - Maintenance programme on Coal fleet	Presentation: Eskom Top CEOs Engagement Session (29 July 2022) - TO BE FILED IN DATA ROOM
Eskom Maintenance Programme - 2	1800	MW	Eskom Top CEOs Engagement Session (29 July 2022)	Page 6 - Overview of annual capacity that can be connected	- COD at Q4 2025 - Maintenance programme on Coal fleet	Presentation: Eskom Top CEOs Engagement Session (29 July 2022) - TO BE FILED IN DATA ROOM
Eskom Medupi & Kusile Co	2394	MW	Eskom Presentation to the Joint Portfolio Committee on Public Enterprises & Mineral Resources and Energy: System Status and Outlook	Page 15 - Overview of estimated additional capacity over 36 months (MW	- Medupi Unit 4 online in 2024 - Kusile Units 5 and 6 online in 2023	Presentation: Eskom Presentation to the Joint Portfolio Committee on Public Enterprises & Mineral Resources and Energy: System Status and Outlook - TO BE FILED IN DATA ROOM
International Imports	200	MW	Article from news24		Capacity modeled as not available during peak according to the source	https://www.news24.com/news24/southafrica/news/breaking-botswana-offers-off-peak-electricity-to-supplement-eskom-supply-20220727
Load Curves						
Annual Demand Curve			Eskom data portal			https://www.eskom.co.za/dataportal/demand-side/
Peak demand			Eskom data portal			https://www.eskom.co.za/dataportal/demand-side/
Load Projections						
Peak demand by 2035	46000	MW	Eskom Top CEOs Engagement Session (29 July 2022)	Page 3 - Insights	Eskom CEO preso Approximate linear growth of the peak demad until 2035 is assumed	Presentation: Eskom Top CEOs Engagement Session (29 July 2022)
New build CAPEX Assumptions						
Coal	4587,5	USD/kW	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 11 - Capital Cost Comparison	CAPEX assumption in the model is based on the average between the low price case of USD 2950 and a high case scenario of USD 6225	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf
Nuclear	10300	USD/kW	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 11 - Capital Cost Comparison	CAPEX assumption in the model is based on the average between the low price case of USD 7800 and a high case scenario of USD 12800	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf
OCGT	812,5	USD/kW	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 11 - Capital Cost Comparison	CAPEX assumption in the model is based on the average between the low price case of USD 700 and a high case scenario of USD 925	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf
CCGT	1000	USD/kW	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 11 - Capital Cost Comparison	CAPEX assumption in the model is based on the average between the low price case of USD 700 and a high case scenario of USD 1300	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf
ICE	747,5	USD/kW			Based on internal references	
Wind	1187,5	USD/kW	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 11 - Capital Cost Comparison	CAPEX assumption in the model is based on the average between the low price case of USD 1025 and a high case scenario of USD 1350	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf
PV - Utility Scale	875	USD/kW	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 11 - Capital Cost Comparison	CAPEX assumption in the model is based on the average between the low price case of USD 800 and a high case scenario of USD 950	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf
CSP	7545	USD/kW	Lazard's Levelized Cost of Energy Analysis - Version 15.0	Page 11 - Capital Cost Comparison	- CAPEX assumption in the model is based on the average between the low price case of USD 6000 and a high case scenario of USD 9090 - Referred to as Solar Thermal Tower with Storage in the Lazard Report	https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf
BESS (Li-Ion)	360	USD/kWh	BNEF Report			Bloomberg Report (paid study)
BESS (Flow)	560	USD/kWh	Email from Bushveld Minerals			Email from Bushveld Minerals with indicative prices
Pump Storage	2600	USD/kW	Wikipedia site on the Ingula Pump Storage project	Capex reference for Ingula project	We based our new pump storage capex inputs on the recently completed Ingula pump storage project which cost $3.5B for 1332MW.	https://en.wikipedia.org/wiki/Ingula_Pumped_Storage_Scheme

ANNEXURE B – DESCRIPTION OF APPROACHES AND ASSUMPTIONS ON KEY MODELLING INPUTS

INPUT CATEGORY	DESCRIPTION
Coal (and Nuclear) Fleet availability	The starting coal fleet availability was determined from the operational statistics presented in the Eskom Annual report (Eskom, 2021). This equates to approximately 55%. There was also an allowance to shift 7% of the planned maintenance within the year as Eskom currently does by undertaking their maintenance in the summer months in order to increase availability during winter. For Nuclear, an availability of 70% based on a view taken of the average availability of Koeberg in recent years (Eskom, 2022).
Reserves	Reserve requirements were extrapolated from the System Operator's 'Ancillary Services Technical Requirements for 2022/23 – 2026/27' (Eskom, 2022). Spinning reserve amounts derived from the culmination of Instantaneous and Regulating Reserves with an annual increase of 30MW; 35; 40; 45MW; 50MW per annum up to 2032 respectively. The above normal increase is attributed to the rapid increase in renewable penetration that is anticipated in the system. Non-spinning reserve allocations were derived from the Ten-minute reserve allocations in the Eskom Ancillary Services report. Whilst there is a small decrease in this value between 2022 and 2026, we have assumed a flat line requirement for these reserves up until 2032 due to the increased renewable penetration. For batteries operations, the minimum state of charge is 12%. The principal approach when deciding how much of the battery capacity can provide spinning reserves is that it must be able to provide this for at least 30min. The rest of the battery capacity, which in the case of a 4hr battery is 88% of the remaining capacity, can be used for energy shifting applications*. Coal is allowed to provide spinning reserves. CCGT can only provide spinning reserves and OCGT and ICE can provide non-spinning 10-min reserves and spinning reserves for the balancing needs.
Demand curve and growth	Assumptions around demand curves have a significant impact on what capacity gets built. Typically, as with the IRP, there would be various high; medium; low growth scenario trajectories however, to simplify our analysis, we have only considered a single growth trajectory of 2.5% per annum. This is inline with the assumptions taken by Eskom (deRuyter E. -A., 2022). The demand curve was extrapolated from current demand curves as obtained from the Eskom data portal (Eskom, 2022).
Renewable new build limitations	It is important to acknowledge that there is a practical limit as to how much renewable energy can be built in a single year. Such limitations may be caused by multiple factors such as global supply chain constraints; supply constraints of local component/services; and readiness of the grid to rapidly absorb large amounts in a short time. Views on what this limit could be for South Africa vary so in the absence of widely documented literature being available, we have adopted a view based on our experience of power systems in other countries. Based on Wärtsilä's experience of modelling over 200 power systems, we believe that a 10% of peak demand is a reasonable new build renewable (wind and PV) limit to consider.
Technology Capex and Opex	The majority of capex and opex inputs were obtained from the Lazard's levelized cost of Energy Analysis – Version 15.0 (Lazard, 2022). Exceptions to this include capex and opex for the Lithium Ion Energy Storage; Vanadium Flow Energy Storage; and Internal Combustion Engine technology. We have considered Bloomberg New Energy BESS price predictions for LiIon batteries and data for Vanadium Flow Batteries was obtained from Bushveld Minerals. Data for Internal Combustion Engine's was obtained from Wärtsilä internal data resources. For pump storage capex, we considered the latest costs from the recently completed Ingula Project which was $3.5B for 1335MW (Wikipedia, 2022).
Fuel Costs	Coal (2$/GJ); diesel (Eskom: 13.71$/GJ; IPP: 20.19$/GJ); and Nuclear (0.57$/GJ) fuel costs were derived from the Eskom Integrated Report (Eskom, 2021). Regarding diesel, the view has been taken that future diesel power plants would consider a fuel cost relating to an IPP and not the Eskom price which benefits from reduced levies. The remaining fuel cost is that of gas which is treated as a variable in this analysis but assumed to be sourced predominantly through LNG imports. Power plant delivered gas price is 15$/GJ which is the midway price as determined by the range of gas prices Eskom believes will be available (deRuyter A. , 2022). A sensitivity at 10$/GJ has also been considered.
Demand Response	Whilst this could be a significant contributor to the system stability, the rules of the DR programme mean that the annual contribution is minimal with only 200 events of 10minute dispatches modelled (Eskom, 2022).
Renewable Dispatch	Baseline dispatch data for the renewables (wind and solar) was obtained from the Eskom data portal (Eskom, 2022) and linearly extrapolated according to the MW's installed. It is recognized that there may be

	some aggregation effects when more renewables are on the system however, this has not been considered for this study.
Technology learning curves	Costs associated with the Electrolyzes used in the ‘Power-to-H’ generation option have been obtained from Lappeenrata University. Renewable learning curves were taken from BNEF H1 2022 “Learning curves 2023” and for BESS, BNEF H2 2021 “Learning curves 2023”.

*Note: It can be noted that to date, the BESS procured under the Eskom/WB programme has been required to provide a range of ancillary services however, the primary function cited is to provide daily energy shifting capabilities hence in our view, the assumptions made here seem to be reasonable.

ANNEXURE C – DESCRIPTION OF SCENARIO ASSUMPTIONS

	Planned New Capacities	Scenario		Comments
		Planned World	Reality Check	
1	RMIPPPP	All RMIPPPP planned capacity, which includes the 1995MW awarded in this programme, is procured and operation by 2024	1/2 of the RMIPPPP planned capacity is procured and operation delayed by 1 year only coming online in 2025	Delay reason: The RMIPPP projects are already delayed by almost 1.5 years with there still being no firm Financial Close date in sight (except for the Scatec Kenhardt 1,2,3 projects which reached FC in June 2022). We therefore believe it is not impossible for another year delay through further FC extensions and potential project delays. Allocation reason: It is widely known that project prices have escalated well above normal rates in the past year which has possibly made some projects unfeasible. There is also uncertainty whether some projects, in particular, the powerships totalling 1.2GW, will receive all their authorizations to proceed. Therefore, a view that only half of the capacity will be closed. Also to add that in the Perfect World, we only have the three Scatec Kenhardt projects confirmed totalling 150MW.
2	REIPPP Round 5, 6, and beyond.	Planned additional capacity is procured and operational on time as per IRP with doubling of capacity as per Presidents speech in 2024	A 2 year delay on the procurement and operation of additional capacity	Delay reason: REIPPP 6 is still being tendered and is due for submissions in Oct 2022. Whilst REIPPPP has shown it can run programmes on time, there are strong external factors including the surge in demand for renewable energy across Europe (due to the stoppage of Russian gas supplies) which may either influence pricing or even production capacity allocations available for South Africa. Allocation reason: To date, the IPP Office have shown excellent success rates in terms of reaching >90% COD for the awarded projects and there is no reason to deviate from this trend now (DMRE - IPP Office, 2021).
3	IPP Gas Programme	Planned additional capacity is procured and operational on time which is 2026	A 2 year delay on the procurement and operation of additional capacity.	Current timelines for new gas is planned COD before 2026. However, with the global demand for gas concentrated in Europe and there being a general lack of gas and FSRU's in the market today (Elliott, 2022), it is very reasonable to assume that there could be a 2 year delay on obtaining any gas or FSRU's for South Africa.
4	Eskom 3GW Gas	Planned additional capacity is procured and operational in Richards Bay on time (which is before 2028 as per draft Ministerial Determination)	No procurement of additional capacity due to environmental concerns in Richards Bay.	Delay reason: Whilst it is not 100% confirmed (at the time of writing this) whether this 3GW capacity replace or augments the 3GW in the IRP already approved in the Ministerial Determination from September 2020, we assume that it is an additional capacity understood to be at the request of Eskom and inline with their 3GW project in Richards Bay. This project however has recently experienced a significant setback as the Minister of Environmental Affairs has placed the EIA authorisation on review following objections by environmental lobbyists (Natural Justice, 2022) (News24, 2022). This may potentially kill the project entirely for Eskom hence we assume that no project proceeds under Reality Check.
5	IPP BESS Programme	Planned additional capacity is procured and operational on time. Projects come online in 2024	A 2 year delay on the procurement and operation of additional capacity	Delay reason: The current anticipated release date for the IPP BESS programme is Sept/Oct 2022 and whilst there is no apparent reason to believe this will be delayed, as this is a first time the IPPO is procuring BESS, there may be some unexpected delays during the procurement process (as was seen in the first REIPPP). Furthermore, there is also significant risk that due to the global surge in demand for BESS, that capacity may not be as readily available in the market. There is also additional risk in the fact that the majority of LiIon

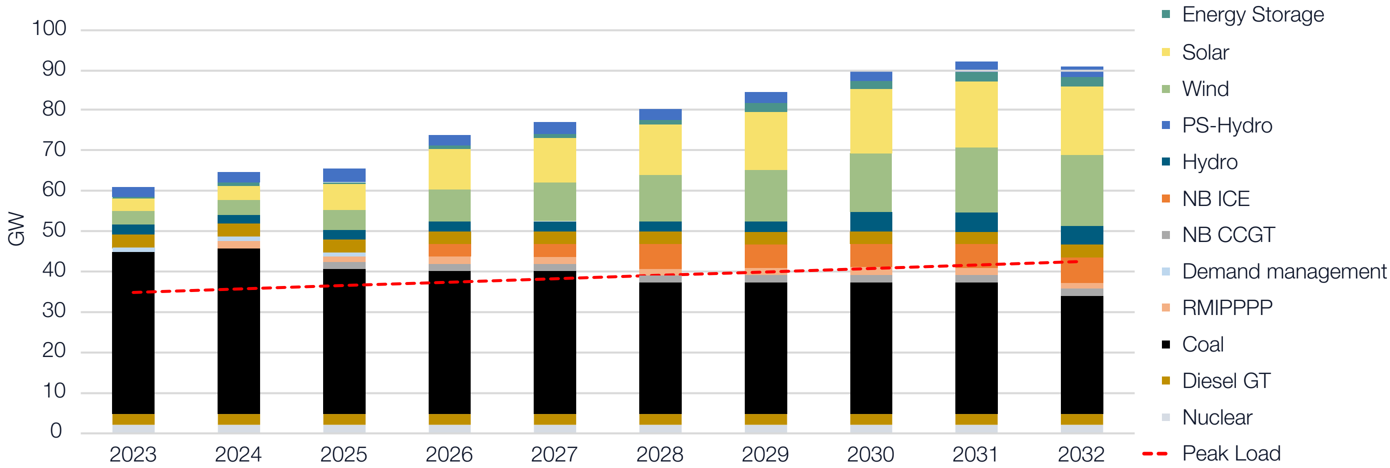
				batteries are supplied out of China and should there be any issues (such as Shanghai port lockdowns as recently experienced (McKinsey, 2022)), this could add further delays onto the projects.
6	Future IPPO BESS Programme	1231MW to come online in 2029	1231MW to come online in 2031	This is a recent addition inline with the draft Ministerial Determination as published by NERSA for comments. Timing for this capacity should be "as soon as reasonably possible in line with the timetable set out in Table 5 of the IRP 2019" (NERSA, 2022). The IRP indicates that this capacity should be online in 2029. In Reality check, we add a 2 year delay due to reasons not yet revealed to us.
7	Eskom World Bank BESS - Phase 1 & 2	Planned additional capacity is procured and operational on time. Phase 1 is online in 2023 and Phase 2 is online 2025	A 2 year delay on the procurement and operation of additional capacity. Phase 1 is online in 2025 and Phase 2 is online 2027	The Eskom/World Bank programme was originated due to the failure to undertake the planned CSP project as part of the loan agreement between Eskom and WB for the Medupi project (Moyo, 2018). This project, originated in 2010, then morphed into a 1440MWh BESS project in 2017 (African Development Bank, 2022). There were two phases, first phase of 800MWh was to be completed by December 2020 and the second of 640MWh to be completed by December 2021. There have already been significant delays on this programme with only the first phase having been awarded in June 2022 and the second phase not yet tendered (Engineering News, 2022). In our Planned World, we assume Phase 1 comes online in 2023 and Phase 2 only in 2025 (due to the fact that procurement could take almost a year as it has in Phase 1). In reality check, we only consider a delay of 2 years on each phase. Such extensive delays are not abnormal with projects undertaken by Eskom as has been seen with the recent coal new-builds.
8	Private PV IPPs	Annual additional capacity of 1GW is procured	Annual additional capacity of 500MW is procured	There is currently 6GW worth of projects undergoing the license application process (South African Government, 2022). However, given the recently relaxed requirements imposed by NERSA in order to obtain a license (such as not requiring a PPA), it is difficult to ascertain which project will proceed or not. Our view is that it is not realistic to assume that all 6GW will be executed immediately hence we assume that in the Planned World, 1GW is built every year and in Reality Check, 500MW is built every year. To add further uncertainty around this number, it is likely that the current draft ERA which removes the cap for license applications may increase these estimations.
9	Embedded Renewables (rooftop PV)	Growth of Embedded renewables at 500MW per year	Growth of Embedded renewables at 250MW per year	An annual embedded renewable (roof top PV) capacity of 500MW has been derived from Eskom's Medium-term System Adequacy Outlook 2022-2026 (Eskom, 2022). This report however does recognize that there is uncertainty but an indication that it may be approximately correct is that the equivalent value of PV panel imports was 500MW over the previous year (Reuters, 2022).
10	Purchase of excess capacity from existing generators - Other	1000MW additional dispatchable capacity procured and operational for a three year period.	500MW additional dispatchable capacity procured and operational for a three year period.	This is inline with the draft Ministerial Determination which is currently available for public comments (NERSA, 2022). The capacity sought for is 1000MW but the maximum PPA duration is only 3 years hence it is primarily targeted at accessing spare capacity within existing generators or rental type solutions. The Realistic scenario takes a view that only half of this could be realised as it is not unreasonable to assume that a significant portion of the available spare capacity may not be available due to maintenance/fuel constraints.
11	Demand Side Management	Demand Side Management implemented accordingly and on time	1/2 of Demand Side Management implemented with a 1 year delay	

12	Eskom Maintenance Programme - 1 & 2	Maintenance programmes implemented accordingly and on time which introduces 1.8GW in 2024 and an additional 1.8GW in 2025.	The maintenance programme yields half of the expected MW's and is delayed by 2 years. Therefore, only 900MW is added in 2025 and another 900MW in 2026.	Eskom have given priority to undertaking maintenance on their coal boilers and their requests to simplify the procurement of such services directly with OEM's has even been supported at the presidential level (South African Government, 2022) (Engineering News, 2022). Estimates are to add 3.6GW through this maintenance however, due to the age and extend of damage of the equipment, there is significant risk that there would be delays and reduced performance from such initiatives (deRuyter E. -A., 2022).
13	International Imports	International imports realised	No international imports realised	
14	Eskom Medupi & Kusile Coal Units	- Medupi Unit 4 online in 2024 - Kusile Units 5 and 6 online in 2023	Commercial operation of the coal units delayed by 2 years	Eskom are planning to have repairs on Medupi Unit 4 completed by 2024 and the final Kusile Units 5 and 6 online in 2023 (deRuyter E. -A., 2022). In our Reality check, based on the historical delays experienced by both of these projects, we take a view that all three of these units will experience a 2 year delay in reaching Commercial Operation.
15	Energy Availability Factor : Eskom Coal	After the Eskom Maintenance programme is implemented; EAF is halved from 3% to 1.5% year-on-year.	After the delayed and reduced Eskom Maintenance programme is implemented; EAF resumes its current trajectory of 3% drop per year.	Over the past years, the rate of coal fleet availability has been steadily declining (as is anticipated for equipment reaching the end of their life). In recent years, the trend is close to reach a reduction of 3% EAF drop per year. In the Planned World, we assume that Eskom will be able to continue their aggressive maintenance initiatives and thereby reduce the EAF drop to only 1.5% per year. In Reality Check, we take a view that the 3% drop per year will continue in a linear fashion.
16	Koeberg Availability due to maintenance	Koeberg, which is currently undergoing maintenance, is fully operational by 2023.	There is a 2 year delay in the maintenance of one Koeberg unit causing there to be only half the capacity available until 2025.	The maintenance of Koeberg has already experienced some delays and continues to experience them as seen with the recent incident whereby the boiler was dropped in China (News24, 2022).
17	Diesel Supply to OCGT's	It is assumed that there are no restrictions on the amount of diesel that can be supplied to these plants.	Diesel supply is restricted to the equivalent of 40% capacity factor.	During periods of high demand, it is not uncommon for Eskom to run out of diesel to supply their OCGT's (Smit, 2022).
18	Future IRP Hydro Import	The 2500MW as per IRP comes online in 2030.	No new future hydro import is realized.	There is a large amount of uncertainty around the timing and probability of hydro projects in the region hence the view has been taken that in Reality Check, it may not happen at all within the study time frame.

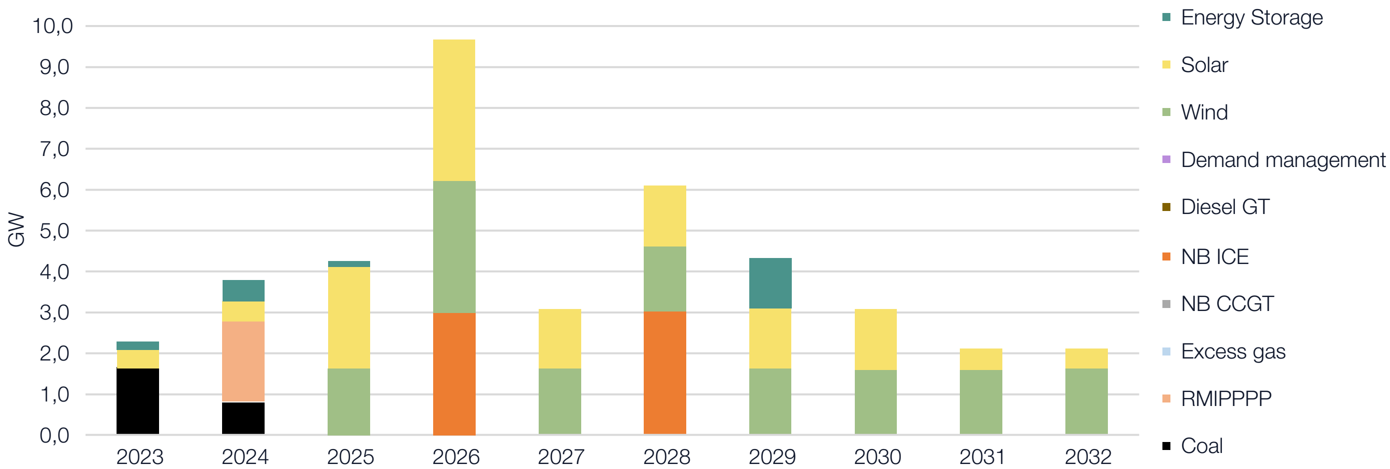
ANNEXURE D – NEW BUILD AND ENERGY SHARE GRAPHS

Planned World new capacity additions; installed capacity; and energy shared.

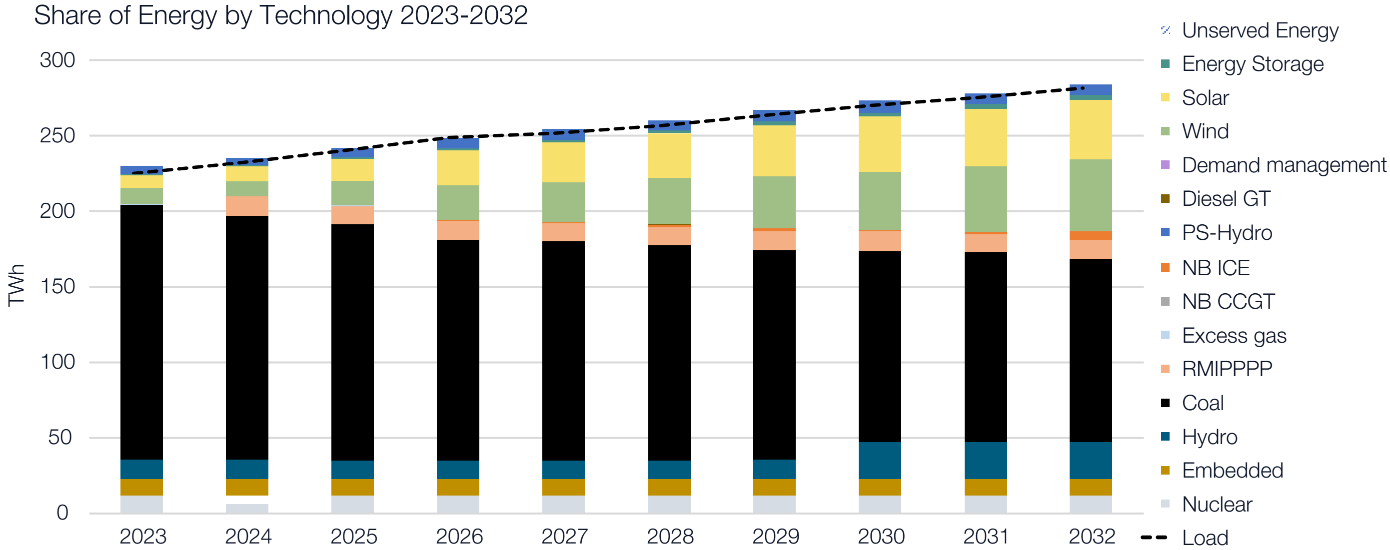
Installed Capacity 2023-2032



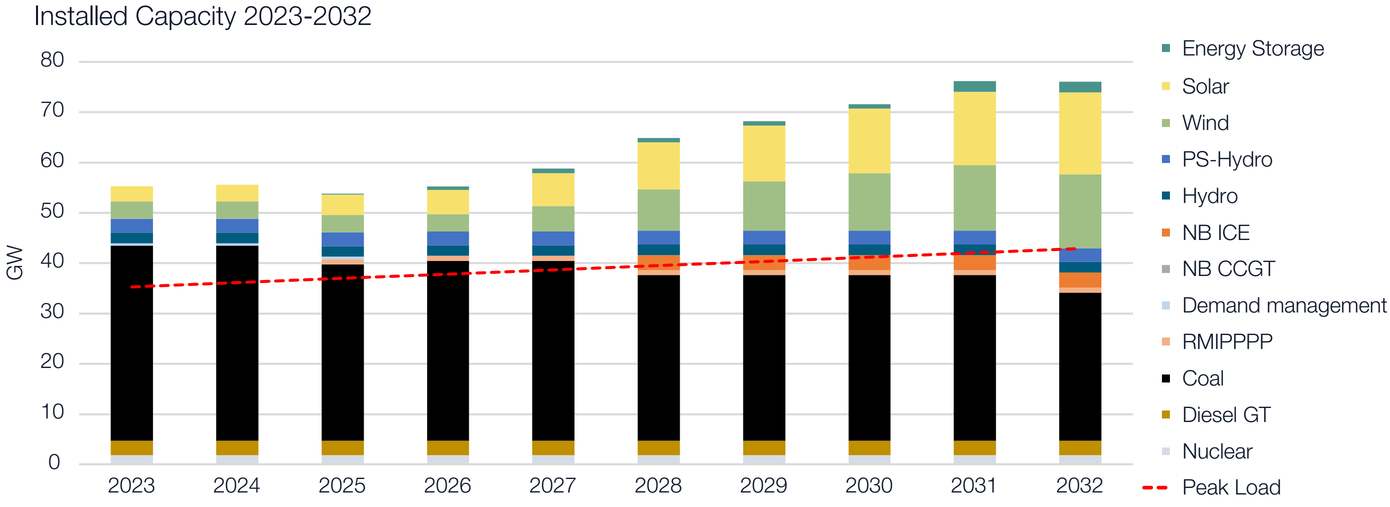
Annual Capacity Built 2023-2032

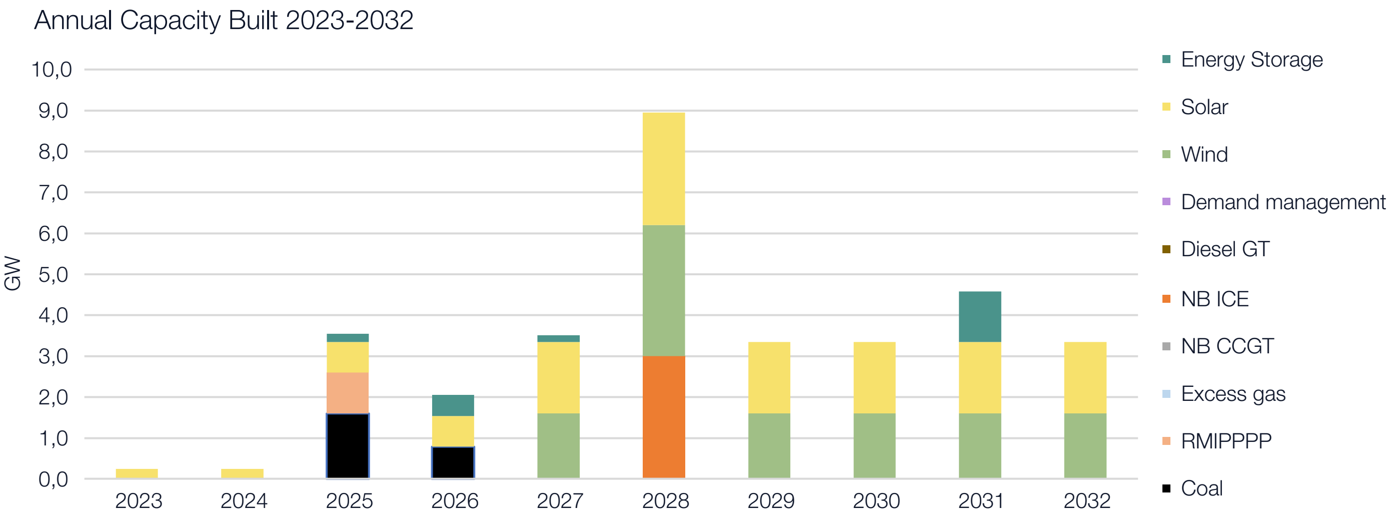


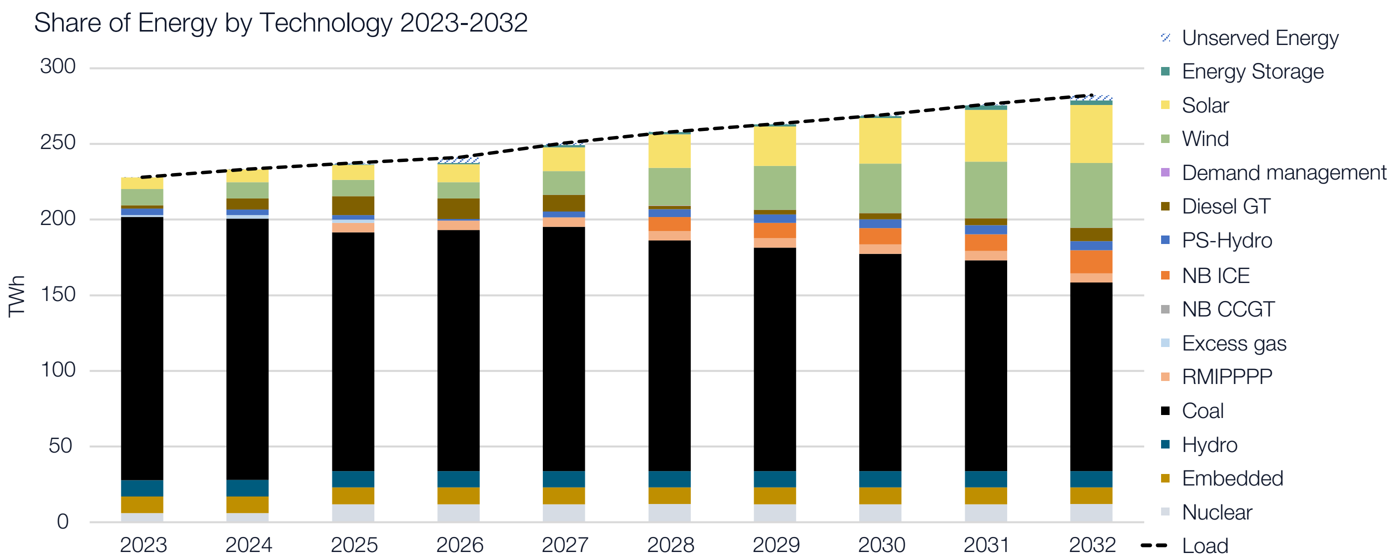
Share of Energy by Technology 2023-2032



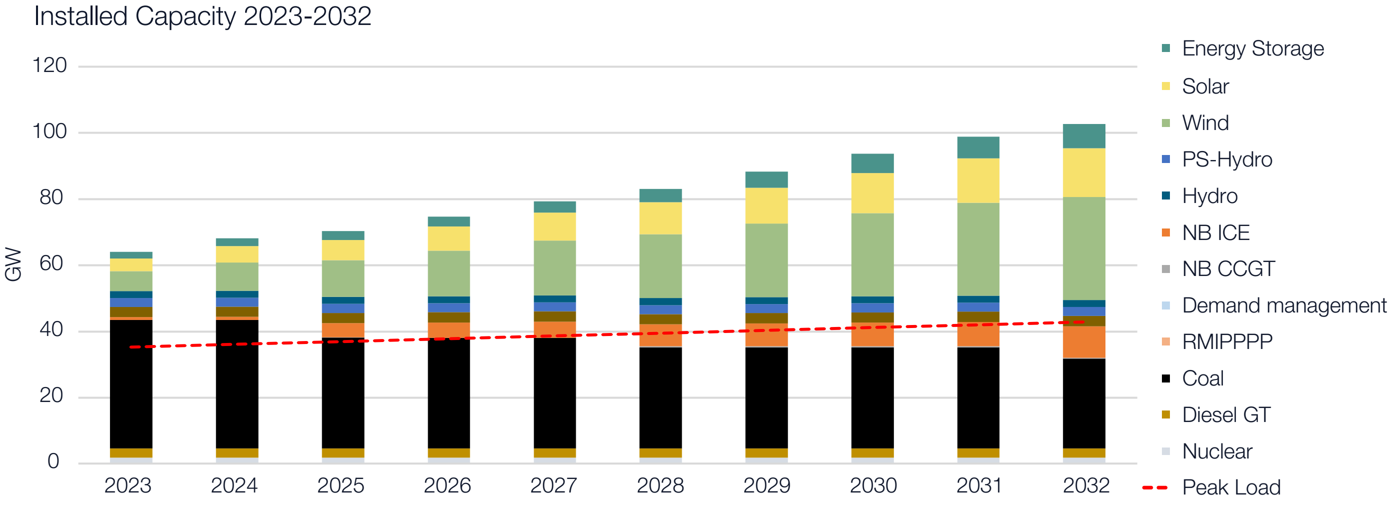
Reality Check new capacity additions; installed capacity; and energy shared.

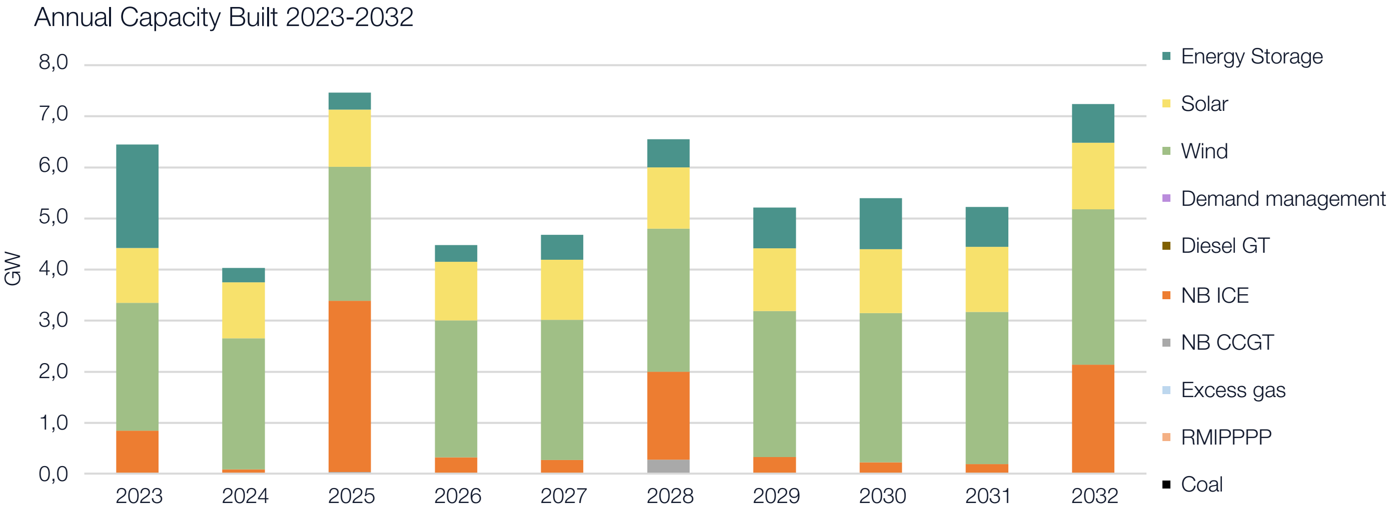


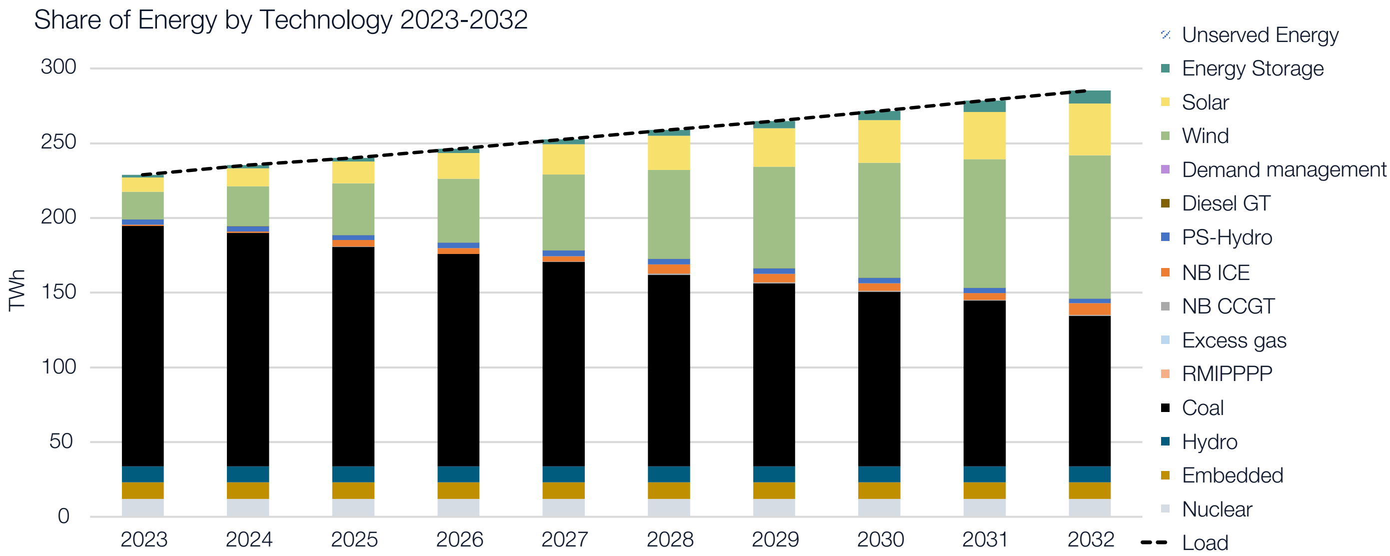


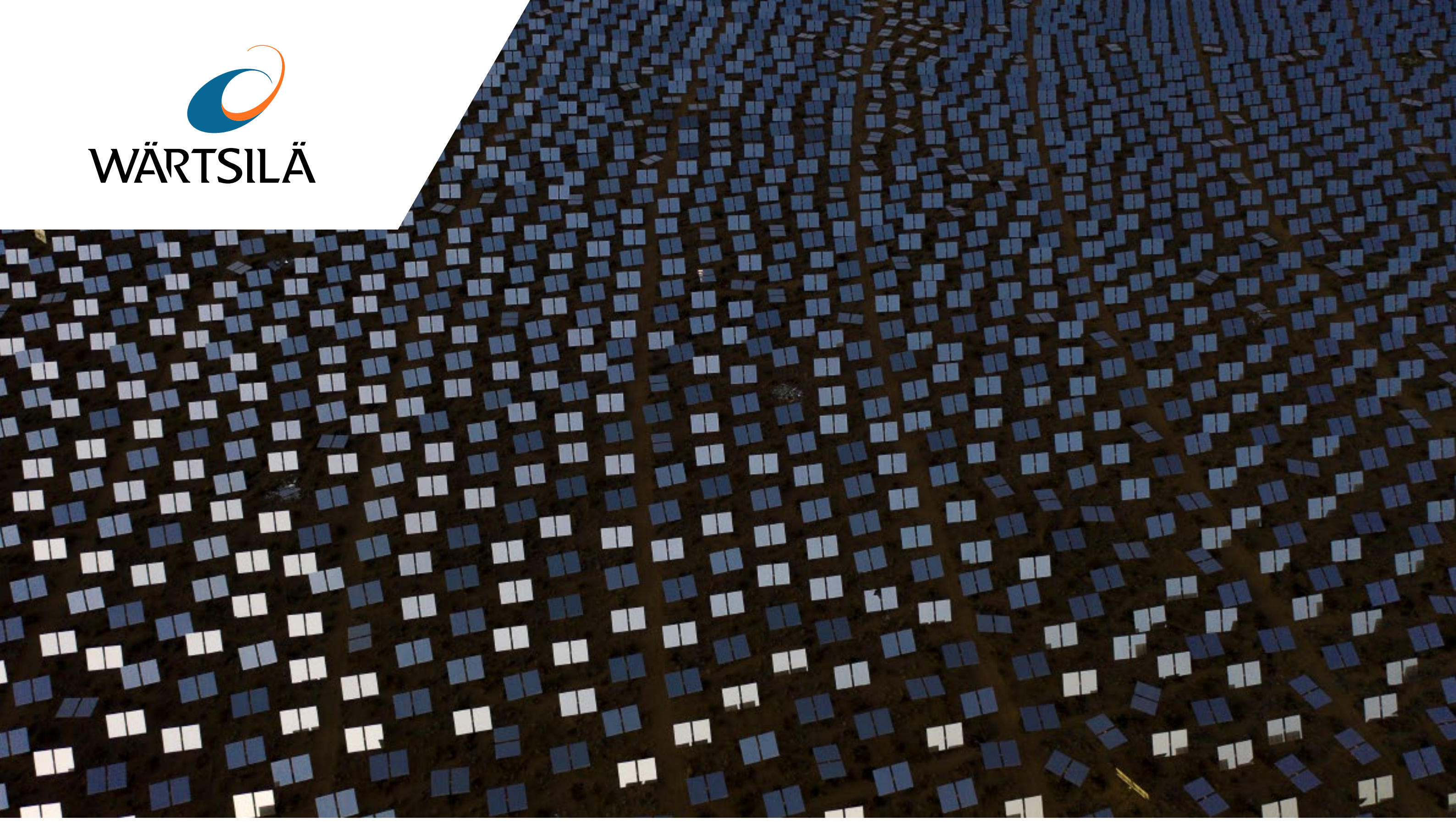


Perfect World new capacity additions; installed capacity; and energy shared.









ABOUT WÄRTSILÄ

Wärtsilä leads the transition towards a 100% renewable energy future. We help our customers to decarbonise by developing market-leading technologies. These cover future-fuel enabled balancing power plants, hybrid solutions, and energy storage and optimisation technology, including the GEMS energy management platform. Wärtsilä Energy's lifecycle services are designed to increase efficiency, promote reliability and guarantee operational performance. Our portfolio comprises 76 GW of power plant capacity and more than 110 energy storage systems delivered to 180 countries around the world.

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