Gas Pressure:

Exploring the case for gas-fired power in South Africa

IISD REPORT

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International Institute for Sustainable Development

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Executive Summary

The power sector in South Africa is facing multiple challenges. Eskom, the financially distressed public utility, is regularly unable to meet demand, resulting in load shedding. The existing fleet of ageing, heavily polluting coal-fired power stations will be retired in the coming decades. As a result, there is an urgent need for new, low-carbon, utility-scale electricity generators and infrastructure.

However, there are strong indications that South Africa is potentially on the verge of a gas investment flurry that could prove to be a very expensive mistake for the South African people. Many of these indications come from economically and politically powerful gas interests, including interests inside government.

There used to be a rational view that fossil gas would be necessary either during a transition to low-carbon energy or as part of the long-term energy mix for electricity production. But revolutions first in renewable energy costs and then in battery storage costs have upended this view. Analysis of the South African electricity system shows that gas supply is not technically necessary until at least 2035, if ever. In the last few years, either the risks associated with gas have increased, or the understanding of existing risks has increased. Consequently, South Africa may see significant negative outcomes from developing a large gas-to-power system now (See Figure ES1).

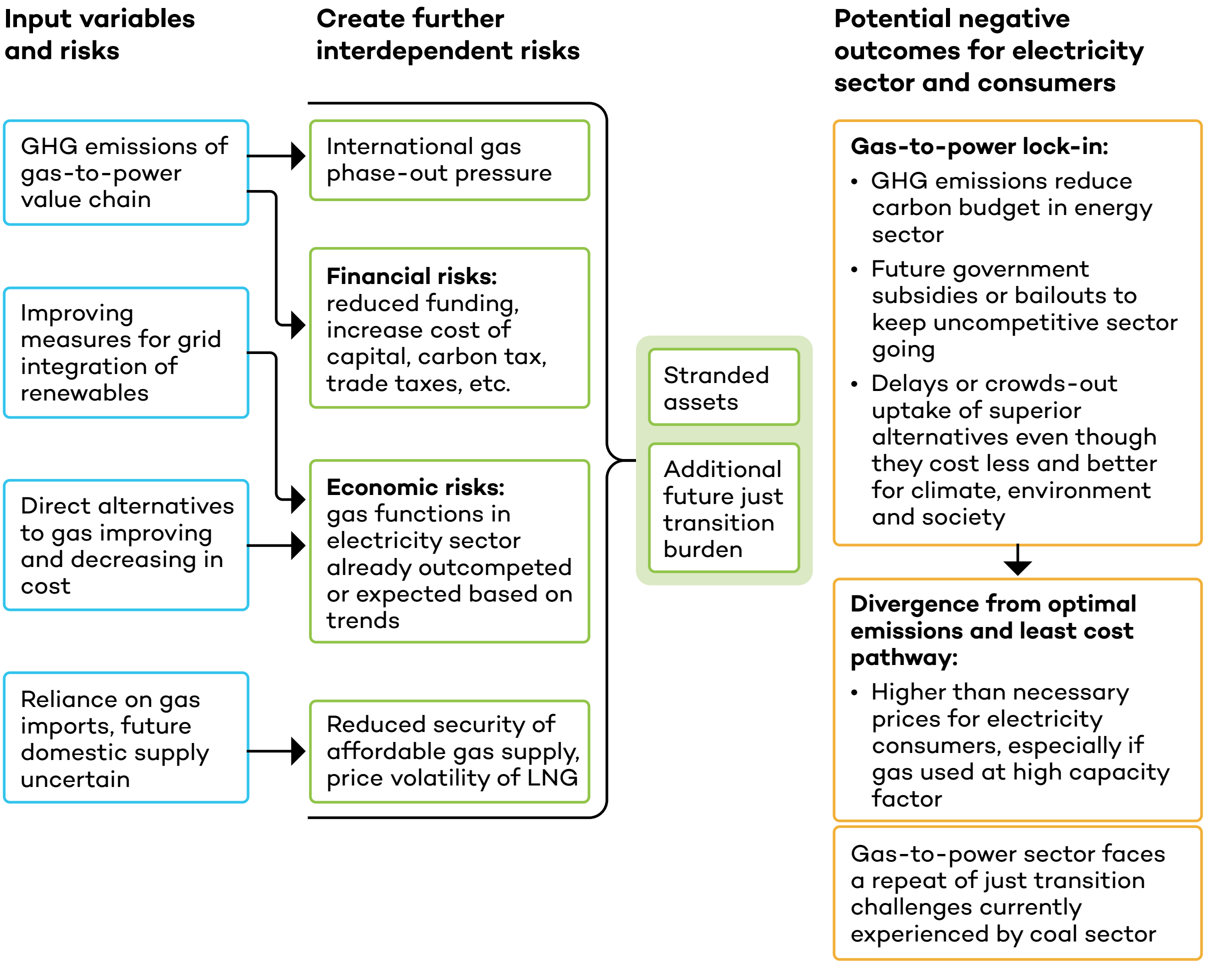
As indicated in Figure ES1, the trend toward decarbonization, coupled with cost reductions for renewable energy and storage, creates risks for gas investment. Investment in gas can reasonably be expected to lead to higher costs for consumers, just transition challenges for workers, and losses for investors. Because of these risks, it is time to rethink the development of the electricity supply sector.

The electricity system can be thought of as having three distinct types of supply. First, the majority of power (the bulk supply) should be as cheap as possible and always used when available. Second, the short-term daily peaks should be dealt with by peaking plants. Third, the balancing (or backup) should smooth over the crests and troughs of demand and supply (Figure ES2). Contracts should reflect these categories so that the more expensive peaking and balancing plants are generally only used when bulk power is unavailable.

It is now clear that renewable energy, in the form of wind and solar, provides the cheapest source of bulk supply. Similarly, battery storage is increasingly considered the lowest-cost power for new-build peaking capacity (See Figure ES2). South Africa's existing electricity system (dominated by dispatchable sources and minimal variable sources) is well suited to provide the balancing function in the short to medium terms. In addition, there are only very rare occasions in a future system based on optimally developed renewables and storage when flexible and dispatchable generators such as gas turbines are required. This development pathway also allows liquid fuels, within the existing use range, to provide this function until at least 2035, if required. Therefore, introducing gas into the power sector is not currently necessary.

The electricity market will also enter a new age around 2035, as most coal generators will be phased out. For this reason, the gas industry has identified an opportunity to expand gas usage and investment in gas generators, with a view to delivering peaking, balancing, and perhaps even bulk supply from gas. This would be a costly mistake.

Figure ES1. Risks of developing a gas-to-power sector in South Africa from 2022 onwards

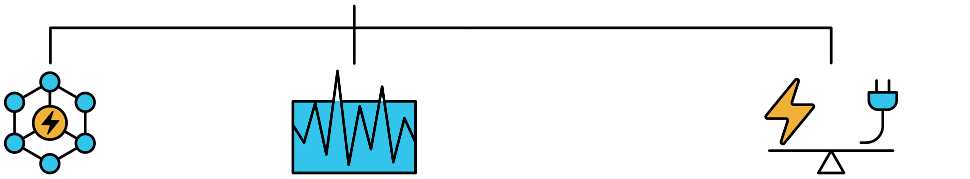


Even today, there is no economic case for bulk or peaking supply from new-build gas plants to supply bulk or peaking functions. We argue that, given the cost trends, it is likely that before significant new balancing capacity is needed, the costs of renewables and storage will have declined to the point that these technologies can provide more of the balancing function. Additional technologies, including green hydrogen, may well have also matured sufficiently to play a role in the post-2035 electricity sector. There remains some uncertainty about what the future will bring, which is why a decision on future balancing needs should be postponed.

South Africa should focus on low-risk, future-proof strategies to end load shedding and curb electricity price hikes. The short-term focus must therefore be centred on a rapid addition of least-cost renewable capacity coupled with storage, and increasing energy efficiency. The energy sector is in a disruptive phase due to rapid advances in technologies that compete with gas functions. Because gas is both high risk and not necessary in the power sector until at least 2035, a decision on a future requirement for gas should be revisited around 2030 based on available technologies and costs at that time. In the meantime, a moratorium should be placed on the development of the gas-to-power sector. Therefore, gas-to-power should certainly not be viewed as a way to secure sufficient domestic gas demand to grow broader gas supply in South Africa.

Figure ES2. Economic case and technical need for gas turbines and gas supply in the power system

Is there an economic case for new gas turbines?



BULK SUPPLY

No.

CCGTs already outcompeted by lower-carbon options of wind and solar PV.

PEAKING

No.

OCGTs outcompeted by renewables plus storage and utility-scale batteries.

Price reduction trend of alternatives set to continue.

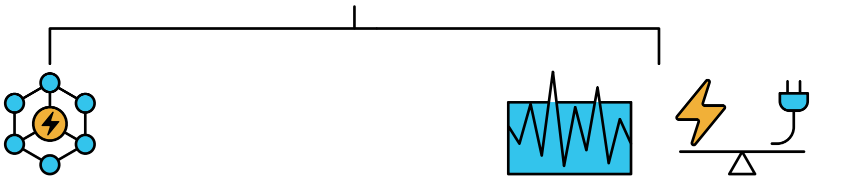
BALANCING & BACKUP

Becoming increasingly uneconomic.

Introducing other cheaper or cost-competitive methods for integrating renewables reduces the need for flexible and dispatchable generators (at a specific level of renewables penetration).

Costs are decreasing for alternative flexible and dispatchable generators (such as green hydrogen technology) and long-duration storage.

Is there a technical need for new gas turbines?



BULK SUPPLY

No.

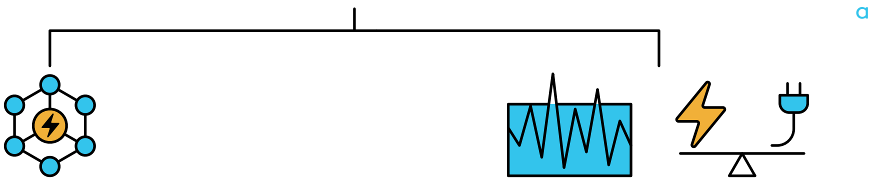
PEAKING/BALANCING & BACKUP

Increasingly outcompeted by alternatives.

In the short term, while renewables penetration is still low: Recent advances in energy storage capabilities decrease the need for new turbines before ~2030. Further research and revised modelling is required to better understand the scale of disruption caused by these advances.

In the longer term, when renewable penetration is high: Future improvements in energy storage, decentralized systems and renewables integration will further reduce the need for new turbines relative to current predictions, potentially to zero.

Is there a technical need for building new gas supply infrastructure? ← e.g., LNG terminals and pipelines



BULK SUPPLY

No.

PEAKING/BALANCING & BACKUP

Not prior to 2035, if ever.

Pre-2035, optimized models that do build OCGTs have also shown that the existing liquid fuel infrastructure is sufficient to supply fuel because these OCGTs are run so infrequently.

Post-2035, alternative fuels like green hydrogen may be cost competitive, or the need for any further flexible and dispatchable generators may have been negated by advances in long-term storage and grid technologies.

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Abbreviations and Acronyms

CCGT	combined-cycle gas turbines
CDC	Coega Development Corporation
CSIR	Council for Scientific and Industrial Research
DMRE	Department of Mineral Resources and Energy
DSI	Department of Science and Innovation
FSRU	floating storage and regasification unit
GHG	greenhouse gas
GMP	Gas Master Plan
GTL	gas-to-liquid
IEP	Integrated Energy Plan
IPP	independent power producer
IRP	Integrated Resource Plan
LCOE	levelized cost of energy
LNG	liquefied natural gas
NBI	National Business Initiative
NERSA	The National Energy Regulator of South Africa
OCGT	open-cycle gas turbines
PV	photovoltaic
RFI	request for information
RMI4P	Risk Mitigation Independent Power Producer Procurement Programme
VRE	variable renewable energy

1.0 Introduction

The power sector in South Africa is facing multiple challenges. Eskom, the public utility generating over 90% of the electricity in the country, is regularly unable to meet demand, resulting in load shedding (Eskom, 2021).[1] The existing fleet of aging Eskom coal-fired power stations, most of which will be retired in the coming decades,[2] are also the largest contributor to South Africa's greenhouse gas (GHG) emissions that contribute to climate change (Department of Forestry, Fisheries and the Environment, 2021). Eskom is in a financial crisis, with massive debt and no clear solution to this problem. This situation makes Eskom particularly vulnerable to any projects that could add unnecessary financial risk. As a result, there is an urgent need for new, low-carbon, low-cost, low-risk utility-scale electricity generators and supporting infrastructure, but the exact composition of optimal energy investments is subject to fierce debate, political manoeuvring, and industry lobbying.

Box 1. Energy system concepts and terminology

Utility-scale electricity facilities can be broadly divided into three functional categories

Other authors may use slightly different interpretations, but this is how concepts are used in this report. There is no strict boundary between peaking and balancing and backup.

1. **Bulk supply**—Where a facility provides a significant or majority proportion of total electricity generation. These plants will usually run continuously all year or when available.
2. **Peaking**—Where a facility is used to meet daily spikes of high electricity demand, often at peak times in the morning and evening. These plants have rapid response times and should only need to run for very short periods (minutes to hours) as required during the day.
3. **Balancing and backup**—Where a facility is used to respond to a change in supply or demand or to function as a backup for when other generation facilities are offline due to breakdown or maintenance. This function may be required for longer periods than peaking (hours to days), but it is still not for primary supply. Variable generators, such as wind and solar, generate in accordance with resource availability, so they present additional system balancing needs.

[1] "Load shedding" is a term used for scheduled, rotational power cuts among supplied regions to maintain overall grid stability. The steadily declining performance of Eskom power plants, measured by energy availability factor, means that load shedding will be a worsening long-term problem until the rate of new capacity addition increases significantly.

[2] Excludes the recently constructed Medupi and Kusile plants, which have a design life of 50 years.

Natural gas[3] is often assumed to be required either during a transition to low-carbon energy or as part of the long-term energy mix for electricity production. However, in the last few years either the risks associated with gas[4] have increased, or the understanding of existing risks has increased, while the alternatives that can play an analogous role in the electricity system have rapidly improved. Given these recent changes, an objective re-evaluation of the suitability of using natural gas for electricity generation (known as gas-to-power) in South Africa is now required.

This report summarizes the current and emerging factors related to developing a gas-to-power program in South Africa and how these could affect energy planning and investment decisions.

Energy generation and storage technologies can be described by the way they operate.

Table 1. Adjectives used for energy technologies

	Characteristics	Examples (non-exhaustive)
Flexible	Can be turned on and off quickly (within 5 to 10 minutes).	Batteries, pumped storage
Dispatchable	Power generation can be scheduled in advance, subject to constraints around starting up and ramping up output.	Coal, nuclear, combined-cycle gas turbines,
Flexible and dispatchable	Possible to schedule in advance and can also be turned on and off quickly (within 5 to 10 minutes).	Open-cycle gas turbines (gaseous or liquid fuel), hydropower
Variable	No fuel, relies on intermittent natural processes.	Wind, solar photovoltaic (PV)

[3] Natural gas is a fossil fuel occurring in sedimentary rocks as a mixture of hydrocarbons, primarily methane.

[4] In this report, "gas" is taken to mean natural gas unless otherwise stated.

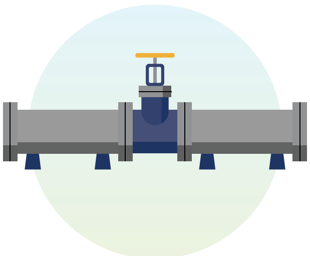
2.0 Status Quo of Gas-to-Power in South Africa

2.1 Gas Factors Within the Power System

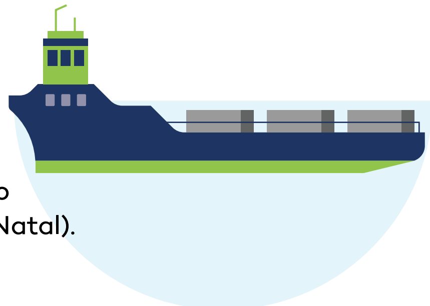
Five key facts set the scene for a discussion of gas demand, supply, infrastructure, and policy. These features inform the debate on developing a gas-to-power sector in the South African energy context (see Appendix 1 for further details and a map).

Figure 1. Five key status quo features to inform gas-to-power decisions in South Africa

1 **Gas is not yet used for utility-scale electricity production.** Gas use is almost entirely for industry, mainly the production of synthetic fuels.



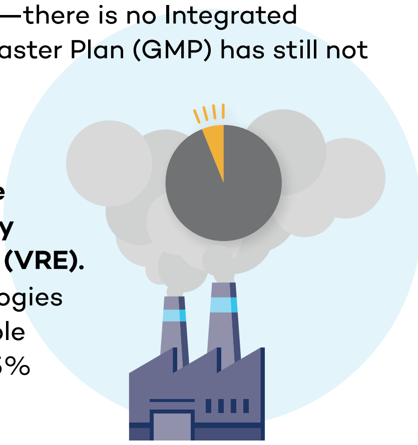
2 **Gas supply relies on overland piped imports from Mozambique, but future supply options (domestic offshore or land imported) remain on the drawing board.**



3 **There is no existing infrastructure for large-scale liquefied natural gas (LNG) importation via the sea.** Existing infrastructure for inland piped gas is limited to three provinces (Mpumalanga, Gauteng, and Kwazulu Natal).

4 **Several important gas-related plans and policies are still under development, require updating, or have not been implemented.** Overall, the policy framework is incomplete and insufficient to guide sectoral development—there is no Integrated Energy Plan (IEP) and a Gas Master Plan (GMP) has still not been completed.

5 **Gas is often promoted as a way to complement variable energy sources, but only a tiny fraction of the electricity supply currently comes from variable renewable energy (VRE).** Electricity supply is dominated by dispatchable technologies (coal, nuclear, and liquid fuels) at over 93%, while variable sources, mainly wind and solar, account for only about 5% (Statistics South Africa, 2021).



2.2 Substantial Appetite for Gas-to-Power Development

The Integrated Resource Plan (IRP) 2019 for electricity infrastructure development envisages 3,000 MW of gas by 2030 (Department of Mineral Resources and Energy [DMRE], 2019a); however, there are several indications that despite this official allocation, a much bigger gas-to-power sector is envisioned.

First, as of March 2022, there are proposed gas-to-power projects of at least 14,000 MW, equivalent to 36% of the nominal capacity of Eskom's coal fleet or 2.8 times the operational utility wind and solar capacity.[5] Of these projects, if the 9,500 MW of onshore gas plants were built near three ports along with LNG import terminals and pipelines, the construction costs could be over ZAR 184 billion (USD 12.1 billion, see Appendix 3). Given the state of gas-to-power policy, it is unclear how this quantity of potential projects aligns with current national power sector planning.

Second, the proposed Gas Amendment Bill (see Appendix 2), which is intended to "unlock investment into the gas sector and facilitate the development of gas infrastructure" (Mantashe, 2021b), also assigns powers to the Minister of Mineral Resources and Energy (including making capacity determinations) to direct development of gas-to-power infrastructure. The current Minister, Gwede Mantashe, has stated that a reason to update the IRP is to "increase the generation from gas" (Steyn, 2022). Combined with the President referring to gas as a "game changer" (Ramaphosa, 2019), it seems that a substantial gas-to-power sector, over and above the current IRP 2019, is envisioned.

2.3 The Risk Mitigation Independent Power Producer Procurement Programme: Expensive and delayed

The Risk Mitigation Independent Power Producer Procurement Programme (RMI4P) was initiated in December 2019 as an emergency measure to bring new generation capacity online as fast as possible to reduce the short-term supply gap and reduce occurrence of load-shedding (DMRE, 2019b). Gas projects totalling 1,418 MW accounted for 71% of the total preferred bidder capacity (1,995 MW) and will be the first gas-to-power projects in South Africa if they go ahead after three postponements. The latest deadline for financial close is the end of March 2022 (DMRE, n.d., 2022). The controversial Karpowership projects (1,220 MW), subject to multiple court cases, consist of gas plants on ships, moored at three harbours and supplied by imported LNG (amaBhungane, 2021).

[5] Projects were included as "proposed" if they had already been granted environmental authorization or applications were still in process during 2021: Richards Bay—6,520 MW (Phinda, Eskom, Nseleni, RBG2P2); Coega Development Corporation—3,000 MW; Saldahna—1,500 MW (ArcelorMittal); Atlantis— 1,500 MW (City of Cape Town Metropolitan Municipality); RMI4P—1,418 MW. All CCGTs. This list is not exhaustive.

Box 2. Level of gas plant utilization and capacity factor

The level of utilization of gas plants is critical in understanding power sector planning. For example, if a 1,000 MW gas plant is used for bulk supply, it will produce far more electricity and burn far more gas over a year than if the same plant is used for peaking. Where a plant is planned for backup or reserve capacity, it may sit idle for most of the year and only be used on rare occasions as required.

So, within the power system, the percentage of installed gas capacity can be much greater than the annual percentage of electricity produced from gas. For example, there could be 20% installed gas capacity on the grid, but if it is only used a few days of the year when required as a reserve, the annual electricity produced from gas may be less than 1%.

The term **capacity factor** is the ratio of actual electricity output relative to the maximum possible electricity output over a given time period (Energy Information Administration, n.d.). In power system modelling, planned gas plants are assumed to operate at designated capacity factors: these will be high in the case of bulk supply and much lower for peaking or balancing and backup. Consequently, the projected carbon emissions, gas demand, and electricity tariff are directly affected by the capacity factor.

Of most concern to energy analysts is the fact that the 20-year power purchase agreements for the RMI4P were constructed as a type of take-or-pay where **Eskom would need to pay for a minimum of 50% of the net available capacity each year** (DMRE, 2020). This take-or-pay structure is effectively forcing gas to be used to provide bulk supply, even though it has been shown in least-cost modelling scenarios that gas is never required at such a high-capacity factor (Wright & Calitz, 2020). Therefore, South Africa will be locked into paying more for gas power even when better and cheaper alternatives are available. A conservative estimate puts the additional costs of this arrangement over the contract period at ZAR 42 billion (USD 2.84 billion)[6] on Eskom and ultimately the consumer (Trollip, 2021). At higher LNG prices, these costs will be even more.

This background explains why South Africa is on the verge of a gas investment flurry that could prove to be a very expensive mistake for the South African people. Developing an extensive gas-to-power sector from scratch would involve significant investment in both gas supply infrastructure and power plants. Just to introduce the first 3,000 MW of gas capacity and gas supply by 2030 will cost at least ZAR 47 billion (USD 3.1 billion, see Appendix 3), money that could be wasted as gas is being functionally squeezed out by cheaper, low-carbon alternatives (discussed in Sections 4 and 5). So, are these gas-to-power investments still prudent?

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[6] Historical exchange rates are from Organisation for Economic Co-operation and Development, n.d.

2.4 Political Economy: The debate around scale, timing, and need for gas-to-power in South Africa is highly contested.

Members of the fossil fuel industry have been pushing hard for the development of a gas-to-power sector in South Africa, claiming it is an essential part of a just energy transition, including sponsored articles in mainstream media (see, e.g., Shell, 2021). The DMRE, the Minister of Energy, and Eskom are promoting gas-to-power (see, e.g., "Eskom CEO Sees End," 2021). Furthermore, the design of the RMI4P shows an intent by the government[7] to use gas-to-power at a high-capacity factor for bulk supply rather than for peaking or balancing where gas use is much lower. Conversely, many civil society organizations and institutions are against gas and gas-to-power based on economic, environmental, and climate change concerns (see, e.g., Project 90 by 2030, 2021). Several influential energy research groups and think tanks have nuanced views—currently perceiving some future role for gas as a balancing fuel (not for bulk supply) but based on interviews are reviewing their positions.

2.5 Vested Interests Are Pushing Gas-to-Power as a Way to Catalyze Growth in the Gas Industry as a Whole.

The broader gas industry in South Africa has faced a challenge for many years: Without secure and affordable supply, it is difficult to develop localized gas demand, and without guaranteed off-takers it is difficult to develop a supply industry. According to the 2021 stakeholder consultation document for developing a GMP, **"One way of breaking this impasse is to create significant "anchor" gas demand through the development of a gas-to-power programme"** (DMRE, 2021b). This is a problematic approach as it assumes that gas is both a necessary and optimal requirement in the power sector without interrogating or proving it.

Decisions need to be made in the right order. National energy planning must first demonstrate that gas-to-power investment is optimal in terms of its primary function (to generate electricity) before it is used as way to motivation for other investments (such as developing gas supply).

Policy-makers should judge what is best for the people of South Africa not what is best for the gas industry. In reality, gas-to-power faces many risks and is not where efforts should be focused now, as we shall show in the following sections.

Moreover, pushing for a gas-to-power industry to help kickstart domestic gas supply through extraction and production may have other negative outcomes. There is a large body of evidence that indicates that a sudden increase in resource extraction can lead to a "resource curse," which brings with it a range of negative socio-economic impacts (Gaventa, 2021; Hamilton, 2021; World Bank, 2003). This can include increased inequality, usually due to the concentration of wealth by industry and foreign investors (Beblawi & Luciani, 1987; World Bank, 2003), increased social conflict that is more likely to impact the poor (Collier

[7] In this report, "the government" is taken to mean the National Government of South Africa unless otherwise stated.

& Hoeffler, 2004; Ross, 2013), and lower economic growth (Auty, 2004; Sachs & Warner, 1995; van der Ploeg, 2011). These negative impacts are more likely in countries with fewer well-governed government institutions, weak rule of law, and a lack of regulations and complementary policies aimed at reducing inequality and poverty (World Bank, 2003).

3.0 Risks of Gas-to-Power Investment

No investment is without risk. Any energy investment could face risks related to construction costs, regulation, service demand, fuel prices, project finance, and many other factors. However, at the present time, investments in gas-to-power are subject to particularly significant risks. While in theory investments risks are usually borne by investors, in practice, powerful interest groups are often able to appeal to government to step in to secure their investments. Effectively, this means that some investment risks are borne by the people while the profits remain private.

This section outlines six of the most significant risks facing the sector. Additional upstream environmental impacts, such as those associated with offshore gas exploration and production are important, but not included in this report.

Risk 1: The gas-to-power value chain contributes significantly to climate change.

As a fossil fuel, gas emits carbon dioxide when burned, adding to the problem of climate change. While gas proponents claim that it is preferable to coal based on its lower emissions of carbon dioxide, it can be little or no better than coal when all greenhouse gases are taken into account. **Methane has a global warming potential about 85 times that of carbon dioxide over a 20-year period** (Myhre et al., 2013), and along the gas value chain (extraction, phase changes, transportation, and storage) it can escape into the atmosphere.

Methane leakage has been significantly underestimated, and the gas industry contributes far more to climate change than previously thought (Turner et al., 2016). Alvarez et al. (2018) estimated that around 2.3% of the natural gas extracted in the United States is leaked into the atmosphere, and Busch and Gimon (2014) found that poorly managed facilities can create leakages of up to 4%. Scholes et al. (2016) observed that there is no emissions benefit in shifting from coal to gas power at leakage rates from 1.9–3.2%. Therefore, switching from coal to gas may not result in any direct reduction in GHG emissions in the power sector.

The standard argument that gas-to-power is a smart climate change mitigation investment is flawed because it is often based on the misleading use of combustion-only GHG emissions (being 40–50% less than coal-fired power generation). A detailed supply chain assessment[8] in 2019 (Roman-White et al., 2019) concluded that **electricity produced from gas could have comparable or worse GHG emissions than that produced from coal when analyzed on a 20-year basis**. There is not a standard figure for gas-to-power emissions intensity, as methane leaks depend on regional details such as the source of gas, length and method of transport, amount of venting and flaring, and quality of facilities.

[8] This study showed that in Asia, for example, imported LNG has 2% to 53% less GHG emissions than coal, while imported piped gas has 38% less to 30% more GHG emissions than coal, to produce the same amount of electricity, measured in kg CO_2e/MWh at 20-year global warming potential.

Nonetheless, when making climate change investment decisions, gas-to-power should not be compared to coal: it should be compared with alternatives such as renewables plus storage, stand-alone storage, and green hydrogen turbines that can provide a similar function to gas during coal phase-out. These choices release far less life-cycle GHG emissions in providing electricity supply, and several are also more cost effective (United Nations Economic Commission for Europe, 2021). If investments in these technologies are delayed or displaced by gas investments, then these gas pathways may have higher cumulative GHG emissions compared to non-gas pathways (Busch & Gimon, 2014).

Choosing gas-to-power over lower-carbon alternatives will make it harder to meet international climate change commitments and reach net-zero by 2050.

Risk 2: There is increasing international pressure to move away from gas due to climate impacts.

Rising awareness about the significant climate change impact of the gas value chains (which may not be much better than coal) combined with a growing recognition of the extent of action required to avert a climate disaster, has resulted in increased pressure to limit or phase out gas usage in energy systems.

Important examples by category include:

- **Country level:** A growing number of countries have legal bans on gas exploration or extraction (including Costa Rica, Belize, Denmark, New Zealand, France, Spain, Portugal, Ireland and Greenland) ("Greenland Stops," 2021; Muttitt et al., 2021).
- **International institutions:** The International Energy Agency has stated that in terms of limiting global warming to 1.5°C, "there can be no new investments in oil, gas and coal" from 2021 (Harvey, 2021). Their *Net Zero by 2050* report further indicates: "Also not needed are many of the liquefied natural gas … liquefaction facilities currently under construction or at the planning stage" (International Energy Agency, 2021).
- **Coalitions:** The Beyond Oil and Gas Alliance is a growing coalition of countries working together to facilitate the managed phase-out of oil and gas production. The Alliance also aims to elevate this phase-out conversation in international dialogues, mobilize action, and secure commitments (Beyond Oil and Gas Alliance, n.d.).
- **International multilateral agreements:** At the 2021 United Nations Climate Change Conference (COP 26), over 100 countries signed the Global Methane Pledge to reduce their overall methane emissions by 30% by 2030 compared with 2020 levels (Vaughan, 2021).

This pressure is important for South Africa as it encourages debate and understanding on the risks of developing a gas-to-power sector, and it contributes to several of the economic risks described next.

Risk 3: The failing economics linked with gas-to-power.

Gas-to-power projects face a convergence of multiple financial risks. These threaten the competitiveness or viability of new gas projects.

Climate change is leading investors and governments to divest from gas assets, which is pushing up the cost of finance. Examples include:

- Over 20 countries have pledged to end new direct international public finance for unabated fossil fuel projects (including gas) by the end of 2022 (E3G, 2021).
- Banks and financing institutions have started to pull out of gas projects. For example, in South Africa, Nedbank stopped direct financing of gas exploration in April 2021 (Just Share, 2021).
- Goldman Sachs estimated that in 2020 the **cost of capital** for developing LNG projects globally had increased to around 10% compared to 3% to 5% for renewables (Quinson, 2021).
- South Africa passed the **Carbon Tax Act** in 2019, which imposes a tax on the carbon dioxide equivalent of greenhouse gas emissions (Carbon Tax Act, 2019). While the initial rate and tax-free allowances have resulted in a low effective tax rate, this will be reviewed in the second phase, delayed to 2026 (Godongwana, 2022).
- The **divestment** movement is growing in South Africa. Already, two cities (Cape Town and Durban) and the Tutu Foundation have committed to withdrawing their investments in fossil fuels. The movement is also expanding within universities and churches, and campaigns are targeting retirement funds and asset managers (D. Le Page, personal communication, November 25, 2021).
- The European Union has proposed a **Carbon Border Adjustment Mechanism** to be phased in from 2023. This is a duty on imports to the European Union based on the amount of carbon emissions resulting from their production, and as such encourages use of electricity sources with lower-carbon emissions than gas-to-power (Greenberg Traurig, 2021).

Risk 4: Risk of reduced security of affordable gas supply.

Domestic supply of gas for electricity generation is uncertain in South Africa.

While there have been recent offshore discoveries, the future of the reserves has not yet been determined, and their utilization would require significant capital expenditure. For example, ZAR 90–100 billion (USD 5.92–6.58 billion) estimates in the case of Brulpadda, plus significant extraction challenges to overcome due to the location of this reserve (National Business Initiative [NBI], 2022).

There have also been discoveries of shale gas in the Karoo, but a combination of major reductions in reserve estimates, strong civil society, community and landowner opposition, along with serious concerns about the environmental and water impacts in this highly arid region means that exploitation of this potential source of gas is also unconfirmed (Industrial Gas Users Association–Southern Africa [IGUA-SA], 2021; Scholes et al., 2016).

Long-term reliable options for importing piped gas are also not guaranteed.

In the absence of domestic gas supply, South Africa will continue to rely on imports. However, the Pande and Temane gas fields in Mozambique are running out, and the reserve receiving the most attention as a potential replacement is the Rovuma Basin in northern Mozambique. But even if Rovuma is further developed and the minimum length of pipeline (1,460 km) constructed, there is still risk of supply cut-off due to insurgency (NBI, 2022). This possibility was demonstrated in April 2021 when Total was forced to close gas operations, withdraw staff, and declare force majeure at their Afungi site within the Rovuma Basin area ("France's Total Shuts," 2021: Smith, 2021). Reliance on a single pipeline that is vulnerable to damage or sabotage for national supply would also threaten supply.

Gas comes with price volatility risk.

LNG imports via the sea to the ports of Richards Bay, Coega, or Saldanha have lower investment requirements and shorter lead times compared with developing domestic offshore gas or regional piped gas imports. However, LNG imports to South Africa are affected by exchange rate fluctuations (unpredictable) and global LNG prices, so there is no certainty regarding the affordability of the gas. To illustrate the possible extent of price volatility risk, in October 2021, spot prices for LNG in Asia reached over USD 56 per million British thermal units, an increase of almost 900% in 8 months since February 2021 (Russell, 2021). The impact of these gas prices could have been to push the Karpowership projects tariff to about ZAR 6 (USD 0.41) per kWh, more than 10 times that of renewables—but transparency on the tariff structures would be required to fully understand sensitivity to gas price (Steyn, 2021). Energy price increases fuelled by the conflict between Russia and Ukraine have further demonstrated how strategies relying on imported gas are exposed to volatility caused by world events.

Risk 5: Stranded gas assets.

A stranded asset is an asset that has suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities (Caldecott et al., 2014). As a result of asset stranding, investors or governments will be unable to recover their investments. Stranding can be caused by a number of factors related to the asset, including regulation of its impact on the environment (including climate change), changing availability or price of resources (including fuel), falling costs of alternatives, social pressure, consumer behaviour, new government regulations, and litigation.

The combination of risks already mentioned in this chapter means there is a high likelihood of new gas-to-power investments becoming stranded assets in South Africa.

Internationally, the stranding of gas-to-power infrastructure is already happening (Muttitt et al., 2021). For example, 60% (or 14.3 GW) of total gas-fired capacity in India was declared to be stranded in 2015 by the Ministry of Power, and in 2019, the State Bank of India indicated that they would need to write these investments off. Furthermore, 5.3 GW of capacity was built but deemed stranded before it had even begun operations and nine gas plants totalling 5.7 GW were stranded within 5 years of being commissioned (Ministry of Power, 2015, 2019).

In the United States, Climate Tracker estimates that 31% of existing gas-fired capacity is already unprofitable, and that all of the planned 28.1 GW of new gas capacity in unregulated grid areas will be unable to recover the original investment (Sims et al., 2021). The Climate Tracker project finance modelling results in a clear recommendation for both Europe and the US: "**building new gas plants is ill-advised and will produce projects that are unlikely to yield returns on investment in most regions**" (Sims et al., 2021).

With the peaking and balancing functions of gas being squeezed out by other technologies (Section 4), the length of time that unsubsidized gas could compete to provide these roles is decreasing, meaning assets could easily be stranded before reaching a break-even point. Therefore, if investments are still made in South Africa, then the losses could be higher compared to countries that have already developed gas-to-power as stranding may occur earlier in project lifetimes (Bos & Gupta, 2019).

An analysis of proposed gas generators and associated infrastructure in South Africa (see Appendix 3) is estimated to cost a minimum of ZAR 184 billion (USD 12.1 billion).[9] These assets could be stranded well before the end of their operational lives if international trends are repeated in South Africa.

Risk 6: Creation of additional just transition burden.

The just energy transition narrative in South Africa has largely focussed on coal, and how to manage coal phase-out so that all social partners agree it constitutes a just transition. This process is highly complex, and, after many years of debate, there has been very limited action despite a great deal of research, discussion, and stakeholder engagement. So, while a just transition from coal is absolutely necessary, it clearly requires concerted policy action and commitment of resources.

Reviewing the risks outlined above, there are many similarities between gas and coal in the power sector: pressure to phase out, becoming economically uncompetitive, improvements in alternatives, and asset stranding. In fact, gas has an additional risk in that affordable supply is not secured. Therefore, investing in gas-to-power could produce a short-lived industry and cause the next generation of gas workers and communities to face a repeat of the transition hardships faced by the coal sector now.

[9] USD:ZAR exchange rate of 15.2:1 used for March 2022 inflation adjusted figures in Appendix 3.

4.0 Alternatives to Gas-to-Power Are Improving

The chronic power shortages in South Africa combined with the need to decommission Eskom's coal-fired power stations mean that a primary energy investment decision for the government is around what new-build technologies to choose and associated grid enhancements.

When evaluating new-build generation options, the full life cycle of the projects must be considered, and a standard measure for comparing the prices of energy produced is the levelized cost of energy (LCOE).[10] Over the lifetime of the project, total costs (including fixed costs such as construction, operations and maintenance, and variable costs such as fuel) are divided by the total expected electricity output. This gives a present value figure for what it will cost to produce a unit of electricity per project.

Box 3. Gas power plants are based on two main turbine types

1. **Open-cycle gas turbines (OCGTs):** A simple combustion process where the heated gas drives the turbine to generate power, and residual heat is exhausted to the atmosphere.
2. **Combined-cycle gas turbines (CCGTs):** A more complex combustion process where residual heat is recovered and used to produce steam that drives a secondary turbine to produce extra electricity.

CCGTs are typically used for bulk supply as they are more efficient (producing more electricity from the same amount of gas), resulting in lower electricity prices, but are best run continuously or for long periods and take about 30 minutes to start up. OCGTs are usually used for peaking, and although less efficient with higher electricity prices, can respond quickly with rapid start-up times of less than 5 minutes. OCGTs are typically used for balancing and backup, but CCGTs could be used if the minimum timeframes (start-up, uptime, and downtime) allow for it (International Renewable Energy Agency, 2019).

A potential source of confusion is that **gas turbines can be built to run on liquid fuels, but the name stays the same**. South Africa has six utility-scale OCGTs to complement the coal fleet when required, but these all currently run on diesel and would require a conversion process to use gas.

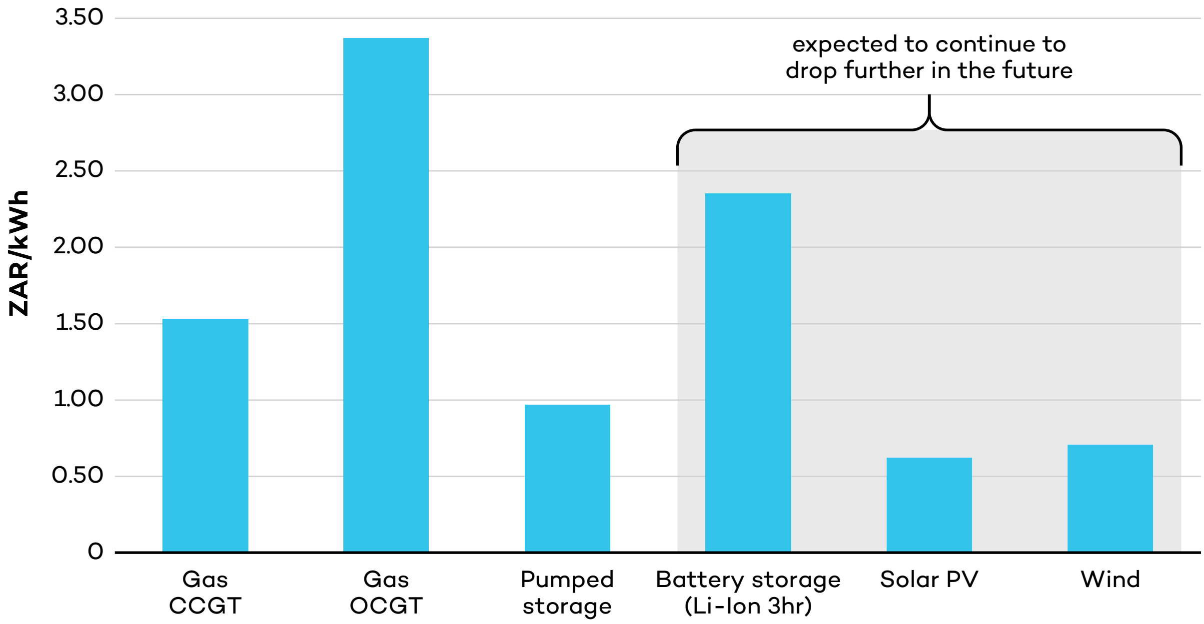
Gas-to-power is being functionally outcompeted by other technologies for new-build projects.

[10] While investors themselves use different metrics to assess profitability of their projects, LCOE is well suited to high-level comparison of the cost of technologies in general terms. LCOE calculations include assumptions for variables that may be project specific, such as cost of finance or land, or could be linked to systemic factors such as the merit order of generators and the frequency and duration of peaks. As such, LCOE is no replacement for either project-specific financial analysis or system-wide modelling. Bearing these factors in mind, LCOE is still a useful measure to compare the cost of technologies that can fulfil the same function or provide the same value proposition within the system.

4.1 Bulk Supply: Renewables can provide cheaper electricity than gas

Renewables are the least-cost option to address the supply shortage, meet new demand, and replace the coal fleet as it is retired. By 2016, new renewables (wind and solar) in South Africa were already estimated as 56% and 78% cheaper than electricity from new CCGTs and OCGTs respectively, based on LCOE analysis (Wright et al., 2017). In the subsequent 5 years, renewables prices have continued to drop widening their advantage over gas, which is a mature technology and cost reductions have not occurred.

Figure 2. LCOE estimates for South Africa 2020



Source: Roff et al., 2020; Wright & Calitz, 2020. The gas price assumption in 2019 was ZAR 147 (USD 10.17) per GJ, so at higher gas prices the LCOE for gas turbines will increase.

In October 2021, the fifth bid window of the Renewable Energy Independent Power Producer Procurement Programme yielded weighted average fully indexed prices of ZAR 0.5 (USD 0.034) per kWh and ZAR 0.43 (USD 0.029) per kWh for wind and solar PV, respectively (DMRE, 2021a), even lower than the 2020 estimates in Figure 2. Conversely, research by RethinkX suggests that gas LCOE estimates should increase (Dorr & Seba, 2021). As gas is outcompeted into the future, less electricity will be bought from gas projects over their lifetime (unless purchase quantity is contractually locked in) which increases the lifetime unit cost of what is produced (Dorr & Seba, 2021).

In addition to lower electricity costs and emissions, alternatives like renewables provide more employment than gas. Solar PV and off- and onshore wind together create almost 10 times more jobs per year per MW during construction, installation, and manufacturing and 11 times more jobs per MW in operation and maintenance, than gas-to-power (Teske et al., 2019).

4.2 Peaking: Energy storage prices have already dropped sufficiently to replace gas

Improvements in battery technology and dramatic decline in prices internationally have already reached the point where batteries have an economic advantage over gas for peaking functions. In just 2 years, from 2018 to 2020, the LCOE benchmark for utility-scale battery storage (4-hour duration) halved to USD 150 per MWh ("Scale-up of Solar and Wind," 2020), which equals the lowest international LCOE range for gas peakers (Figure 3). Research in Australia has calculated large-scale battery storage LCOE at 30% cheaper than gas peakers (Clean Energy Council, 2021), and in 2018 California started replacing gas peakers with battery storage (Bade, 2018).

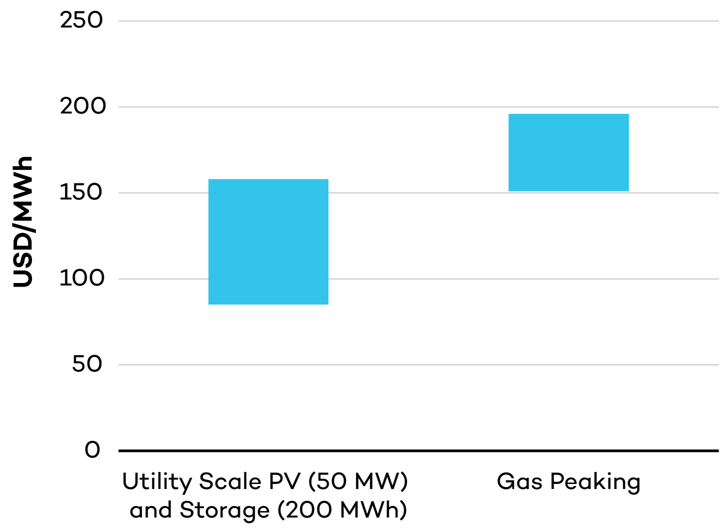
As seen in Figure 2, South Africa echoes this trend with **3-hour battery storage LCOE estimates already 30% cheaper than gas OCGTs for peaking**. In 2019, the Council for Scientific and Industrial Research (CSIR) found that the modelling requirement for gas turbines in the energy mix could be displaced by batteries in South Africa assuming continued cost reduction in the future (Klein et al., 2019). By 2020, the outputs of modelling scenarios from the University of Cape Town to meet Paris Agreement climate goals were to only build battery storage to complement renewables to 2050 based on these significant cost reductions (McCall et al., 2021). From a technical perspective, there are specific rare occasions when some form of flexible and dispatchable generation or longer-term storage capacity may be required in a future energy system (Section 6), but for the vast majority of the year, this is no longer required for peaking.

By LCOE, pumped storage is even cheaper than batteries, but it has long build times and geographical constraints that must be considered as this option is pursued in South Africa. Furthermore, the international price range for combined solar PV with storage projects, which can also provide peaking power, is also less than the lowest in the range for gas peakers (Figure 3).

While batteries have shown the fastest storage cost reduction, other options, such as gravitational storage with weights, are also improving rapidly and could be cost competitive with battery storage depending on the design and size relative to the application (Morstyn & Botha, 2021).

Internationally, energy storage is seeing massive investment in research and development, with global deployment increasing by 62% in 2020 alone (Xu, 2021). As a result, there are also significant advances in addressing some of the environmental concerns with lithium-ion batteries, such as the recyclability of components, along with improvements in other battery technologies such vanadium redox flow systems. Based on this development and growth, it is expected that batteries and other emerging storage options will continue to improve and undercut gas for peaking power.

Figure 3. International, unsubsidized LCOE ranges for utility-scale PV plus storage systems vs. gas peakers



Source: Lazard 2021a, 2021b. In the graph, "Utility-Scale PV and Storage" refers to an energy storage system designed to be paired with large solar PV facilities to better align timing of PV generation with system demand, reduce solar curtailment, and provide grid support.

4.3 Balancing and Backup: Alternatives to gas are improving and decreasing in price

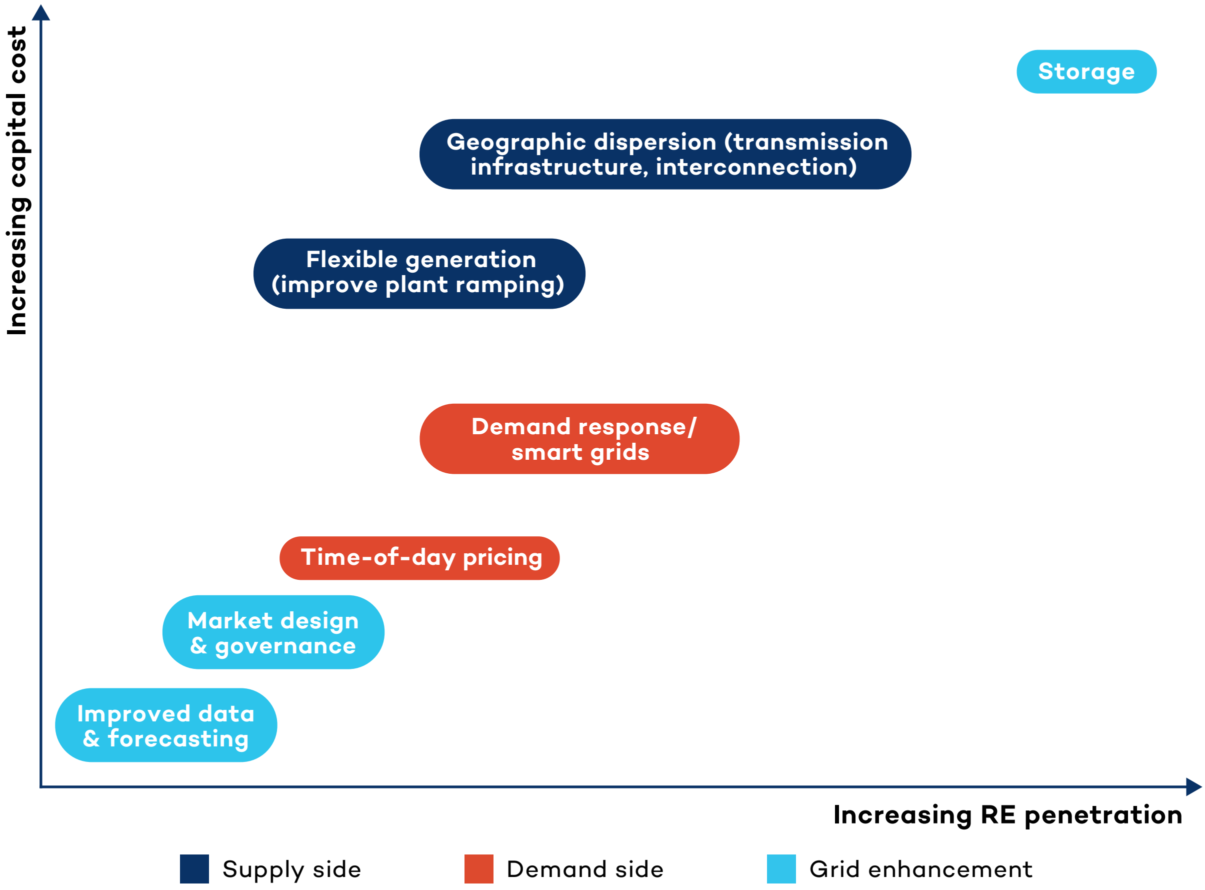
Integrating renewables into the energy mix can be done with a range of measures. Building new flexible and dispatchable generators to counter the variable nature of renewables is only one of the options. **Balancing the system can be achieved by managing supply, managing demand, energy efficiency, storing energy, and grid improvements.** As seen in Figure 4, many of these options are cheaper and more appropriate to invest in when there is a low level of renewable energy in the system, as is the case in South Africa. Furthermore, international work to accelerate the transition to low-carbon energy systems has resulted in continual improvements in the understanding, design, availability, and cost of these balancing measures, a trend that is expected to continue as research and development increase.

Given the rapid advances in energy storage and grid integration technologies, there is debate about whether flexible and dispatchable generators will even be required in future energy systems. In South Africa, where independent power system modelling still includes gas to provide flexible and dispatchable power, it is mainly as a reserve for rare situations (such as prolonged and unusual weather patterns) when the combination of other measures may be unable to meet demand (more in Section 6).

Where independent power system modelling still includes gas to provide flexible and dispatchable power, it is mainly as a reserve for rare situations (such as prolonged and unusual weather patterns) when the combination of other measures may be unable to meet demand.

However, there are other technologies that could directly fulfill this role, if it is required, in the future. Green hydrogen is one example that is receiving enormous attention, including in South Africa (Department of Science and Innovation [DSI], 2021a, 2021b).

Figure 4. Measures to integrate renewables into the grid



Source: Adapted from Muttitt et al., 2021.

Green hydrogen is the term used for the hydrogen produced from the electrolysis of water into oxygen and hydrogen using renewable (green) electricity. The world-class renewable resources in South Africa result in the country being well positioned for production of green hydrogen, which can also be used to run gas turbines (DSI, 2021b). Mitsubishi Power and General Electric are already converting existing natural gas power plants to run off hydrogen (Modern Power Systems, 2021). Other companies are working on reducing the costs and inefficiencies of hydrogen turbines so that integrated systems of renewables, storage and green hydrogen can meet energy demand without producing any net GHG emissions (see, e.g., Siemens Energy, n.d.).

Green hydrogen may become a cost-competitive power sector fuel during the 2030s (NBI, 2021). In recognition of this the Hydrogen Society Roadmap calls to "[r]evise the IRP to include hydrogen gas for generation" between 2025–2030. (DSI, 2021a). The arrival of cost-competitive hydrogen turbines could bring forward the date when gas is displaced by a green fuel and ceases to have any legitimate role in the power sector.

5.0 The South African Power System Can Meet Demand to 2035 Without Gas Supply

In recent years, Government has been increasingly vocal in its support for gas. The Minister of Mineral Resources and Energy, Gwede Mantashe, has stated that the "[a]cceleration of gas development projects will be crucial in the country's just energy transition" (Mantashe, 2021a). However, such assertions have not been accompanied by robust evidence, and, based on the risks presented in this report, the opposite may be true.

Gas-to-power has often been promoted as being lower carbon than coal, able to provide peaking power, and, being flexible and dispatchable, it can balance renewables in the energy systems. However, given recent technological and economic trends, these characteristics are no longer the sole preserve of gas, nor is gas the cheapest option. Moreover, decision-makers seem not to be adequately considering how the evolving risks associated with gas-to-power and the improvements in alternatives will alter the optimal investment choices for a least-cost, decarbonized energy sector considerably.

5.1 Bulk Supply: Gas is not required as a bridging fuel to a renewable energy-dominated system

The gas industry has long proposed that their product can act as a "bridge fuel" that facilitates the transition from high- to low-carbon energy systems (Muttitt et al., 2021). This notion is now obsolete as unsubsidized renewable energy in the form of wind and solar has already been successful developed in South Africa, and is significantly cheaper than any gas-to-power options, in addition to the benefits of higher job creation per unit of energy, reduced environmental impact, reduced GHG emissions and not being subject to fuel price volatility (Institute for Advanced Sustainability Studies Potsdam et al., 2020). There is no need for gas as a bridging fuel for bulk electricity supply.

5.2 Peaking, Balancing, and Backup: Gas supply is not necessary until 2035, if ever

Firstly, as LCOE estimates in South Africa show, for short-duration situations batteries are cheaper than gas OCGTs (Figure 2). This indicates a lower-cost and lower-emissions route to providing some peaking power requirements. Furthermore, as the international LCOE benchmark of renewables plus storage is cheaper than gas peakers (Figure 3) this could become an option in South Africa. Even where the RMI4P rules were seemingly tailored to favour gas projects (amaBhungane, 2021), the lowest bid price still came from a solar and battery storage project (DMRE, n.d.).

Secondly, Eskom already has 2,724 MW of pumped storage (Eskom, 2021). Due to the poor performance of the Eskom coal fleet, this pumped storage is not always fully utilized, as there has not always been adequate surplus capacity to fill the dams (Creamer, 2022). A sufficiently rapid build rate of renewables could replace decommissioned coal capacity to meet electricity demand and also produce enough surplus to allow for pumped storage to be optimally available for peaking requirements (Mallinson, 2020).

5.2.1 Liquid Fuels Can Do the Job as a Last Resort

An optimized build rate of renewables and storage will allow the future system to meet the peaking requirements for the vast majority of the time. The only exception in this future system could be during a long lull in renewables output, which may only occur 1 week in a year. For these very infrequent cases, there is already 3,414 MW of nominal OCGT capacity (see Appendix 1). Modelling analysis by Meridian Economics in 2020 concluded that these facilities and some additional OCGT capacity, run within the historical OCGT liquid fuel use range, can provide all peaking and balancing requirements in all realistic mitigation scenarios for the next 15 years (Roff et al., 2020). Therefore, there is no need to make an investment decision now about new gas supply from a power supply perspective.

In the context of growing risks linked to gas and improving alternatives, the option to delay making a decision on gas supply for the power sector for at least 10 years is of great value. It avoids locking the power sector into another fossil fuel now.

Running OCGTs on diesel may be more expensive than gas, but the objective is to develop the system so that OCGTs (regardless of fuel) are used as a last resort and for a small fraction of total generation. A full cost analysis[11] of continued use of OCGTs on diesel versus gas would need to factor in all the capital costs of establishing gas-to-power and gas supply infrastructure (whereas the liquid fuel infrastructure is a sunk cost). Given the number of hours run for these generators the case for large-scale fuel supply infrastructure investment is likely to be weak.

In addition, adding a new fossil fuel and investing in infrastructure at this stage of the energy transition creates a lock-in risk. The cost of this lock-in is hard to estimate, but, as infrastructure is built, there is pressure to use and expand it even when lower-cost options are available. This pressure leads to additional costs for the energy system and the consumers who pay the bills. Furthermore, the logical maximum timeframe for OCGTs to operate on either diesel or gas is limited by the availability of commercial alternative turbine fuels (like green hydrogen) or the emergence of other flexible and dispatchable generators. There is considerable uncertainty around when this may occur, but it is probably long before the end of the technical lifetime of new gas infrastructure.

[11] A GHG emissions analysis would need to include methane leaks on the value chain. As with the comparison between coal and gas, it could lead to minimal difference.

5.2.2 Excellent, Complementary Wind and Solar Resources Decrease the Need for Balancing in the Short Term.

The nature of wind and solar resources in South Africa means that if the system is suitably developed (rapid rollout of renewables and storage) there should be limited need for any additional flexible and dispatchable generators at VRE penetration[12] levels of 15%–30%.

In South Africa, the penetration of VRE for electricity supply is only about 5% (Section 1). In general, increasing renewables penetration up to rates of about 15% can be fairly easily managed by changes to operational practices (International Energy Agency, 2017) and the types of grid enhancement and demand interventions shown in Figure 4. In addition, South Africa has some of the best renewable resources in the world, with an extensive study[13] revealing two key factors. First, solar has nearly no seasonal variability, and the daily aggregated peaks of wind and solar generation complement each other, making grid integration and meeting demand easier. Second, **by optimally distributing VRE across the entire country, a 20%–30% share of VRE can still provide a reasonably smooth output without significant short-term fluctuations** (Knorr et al., 2016).

This smoother output makes it easier to integrate with the existing coal fleet (which has slow ramping times) and also allows for VRE to recharge interconnected energy storage facilities in a more predictable way. The net result being that there could be a minimal requirement for new flexible and dispatchable generators up to 30% levels of VRE penetration.

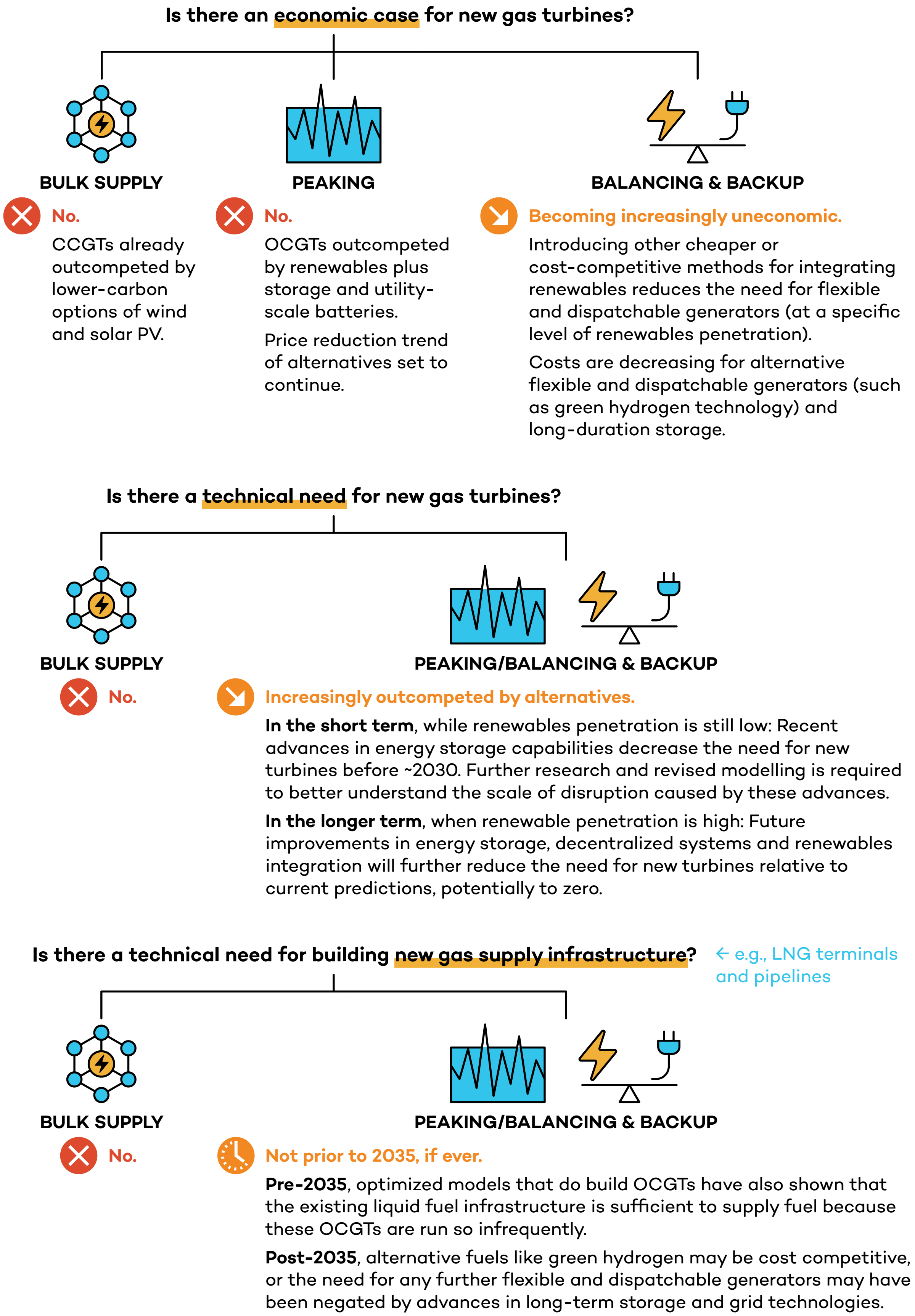
If the IRP 2019 is implemented on time, South Africa will only pass 30% penetration levels of renewables after 2030 (DMRE, 2019a), but it is widely understood that the pace of renewables capacity rollout must increase significantly.

The arguments raised in Section 4 and 5 are summarized in the figure below.

12 In this context, penetration refers to percentage of electricity generated, not percentage installed capacity.

13 5×5 km spatial resolution of entire country, 15-minute time resolution, 5 years of data.

Figure 5. Economic case and technical need for gas turbines and gas supply in the power system



6.0 Focus on Short-Term Priorities and Knowledge Gaps

6.1 Long-Term Vision to 2050

The critical point for this section is that **we do not need to solve the details of the 2050 energy mix now**, though we do need to avoid costly blind alleys. Technology is evolving so rapidly that it is impossible to predict the optimal pathway that far into the future. Models to 2050 are just a guideline based on current assumptions, which will change over time. However, before looking at what to do in the short term, it is useful to understand some of the parameters that influence planning and decision making in this context.

A large and growing number of international studies support the technical feasibility and cost effectiveness of 100% renewable-electricity systems (Brown et al., 2018). In South Africa, decarbonization pathways modelling to 2050 by Oyewo et al. (2019) concluded that **"a 100% renewable energy system is the least-cost, least-water intensive, least-GHG-emitting and most job-rich option for the South African energy system."**

Broadly speaking, 100% renewables scenarios are based on one of two situations: 1) renewables, storage, and flexible and dispatchable generators that run on fuels like green hydrogen or 2) entirely on renewables and storage where the capacities are overbuilt to handle variability.

In South Africa, there is not yet consensus among independent power system modellers on whether it is possible to develop the electricity system to 2050 in a way that is completely free of new flexible and dispatchable generators

On the one hand, where new OCGTs are still included in optimized[14], realistic models up to 2050 it is only to provide backup for long lull periods in VRE beyond the storage and recharging capabilities in those models. The key point is that this only happens on very rare occasions, which leads to several important outcomes (Roff et al., 2020).

Where new OCGTs are still included in optimized, realistic models up to 2050 it is only to provide backup for long lull periods in VRE beyond the storage and recharging capabilities in those models.

- Annual electricity output from OCGTs is at most a tiny fraction of all electricity generated in ambitious renewables pathways (typically <1% total system output), and, consequently, annual fuel use is very low.
- This low level of utilization of OCGTs is why the system can be developed without gas supply until 2035 because it still falls within existing liquid fuel supply infrastructure capabilities.

[14] For the model to be optimized, renewables and storage must be built at the required rate.

- The installed capacity requirement for OCGTs increases with increasing penetration in renewables (which is currently very low).
- Building a large fleet of CCGTs to run at high capacity is not an optimized modelling outcome.

On the other hand, **there are models based only on renewables and storage** (Dorr & Seba, 2020). For example, in Australia, the state of South Australia has been setting length records for supplying all electricity demand with wind and solar coupled with lithium ion battery systems, and the state plans to be completely fossil fuel-free by 2025 (Bowyer & Kuiper, 2021).

Facilitated by the massive storage-related changes in the last few years, an alternative IRP has recently been produced that only builds wind, solar, and storage to 2040. In addition to meeting yearly electricity demand (~230 TWh) at a price below Eskom's current wholesale rate, the recommended overbuild of renewables capacity will provide surplus electricity (~460 TWh) at near-zero-marginal-cost.[15] This very cheap "**superpower**," in excess of conventional demand, has many potential socio-economic advantages. It could provide electricity to low-income households, promote electrification of vehicles, produce green hydrogen, and increase economic competitiveness of existing activities (Creamer, 2021). While this proposal presents a deviation from "conventional" power system thinking and requires verification, the enormous potential costs and social benefits mean it must be further researched.

6.2 Planning to 2030

A key consideration for infrastructure planning decisions is that the uncertainty of predictions increases over the modelling time period. Therefore, action should be taken on the most logical choices in the short to medium terms (say to 2030), and then to continually monitor and regularly readjust the longer-term plans over time.[16]

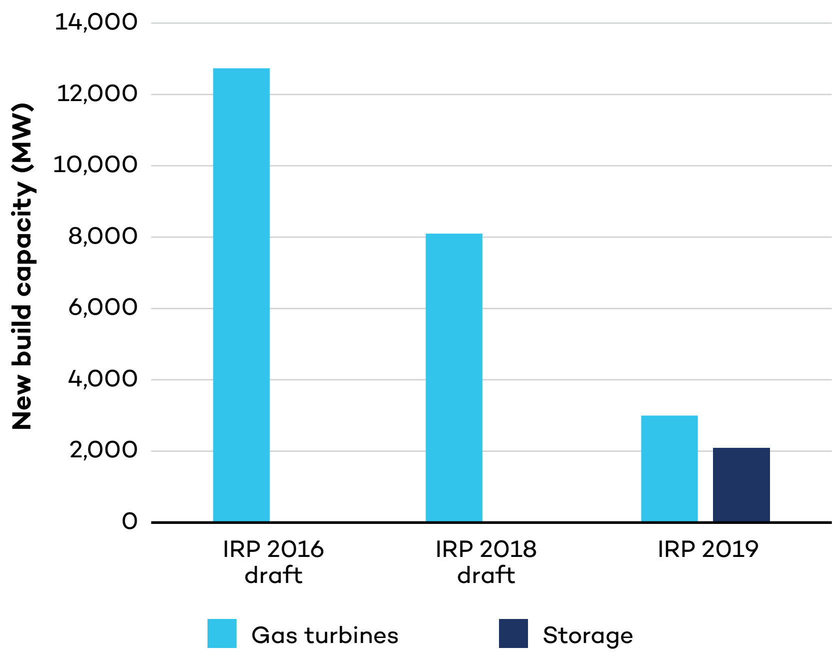
The disruptive changes in the energy sector since around 2016 have started to push gas turbines out of power sector modelling requirements. Even during the evolution of the government IRP from 2016 to 2019, the recommended gas turbine build (OCGT or CCGT) from 2020 to 2030 dropped by 76% (See Figure 6).

In addition to new build, there are also plans to repower or convert existing coal plants or liquid fueled OCGTs to gas. While the risks of gas-to-power investment (Section 3) still apply to these re-purposing plans, the capital costs and plant efficiencies differ from new builds. In the context of disruptive change, these re-purposing plans should not be assumed as prudent, and must be rigorously reassessed in comparison to improvements in alternatives.

15 The cost of producing surplus units of electricity in these circumstances has almost no impact on the total production costs that were used to determine the price for electricity to meet demand.

16 This is the way the IEP was meant to be approached but has not happened.

Figure 6. Capacity additions 2020 to 2030 in the development of the IRP 2019



Source: Department of Energy, 2016b; 2018, DMRE, 2019a.

An important question now emerges: **Is there still a need to build new OCGTs (liquid fuel or gas) as a capacity reserve in the short to medium term, for renewables penetration rates of 15-30%?** The same question applies to re-purposing existing coal plants to gas. The very recent changes in utility-scale storage capabilities and dramatic price reductions since 2019 mean that modelling outputs now will be different from work done in 2020. Coupled to this are significant shifts in the potential for residential, commercial, and municipal level energy services to alter requirements from utility-scale facilities.

Confidential interviews with several modelling teams in South Africa revealed a few knowledge gaps:

- Can an overbuild of utility-scale renewables and energy storage capacity in combination with existing OCGTs and pumped storage now meet system demand requirements at least cost and until when?
- What would the cost premium be, if any, of not building any OCGTs until 2030?
- Is there still a level of renewables penetration prior to 2030/35 where some form of new flexible and dispatchable generation is required?

Similar to delaying a decision on gas supply, being able to hold off on building new OCGTs (or converting existing coal/liquid fuel plants to gas) is also of value as it allows South Africa to observe how the suite of other technologies complements renewables advances. Storage is required in any event, and front-loading the rollout has the benefit of growing the industry quicker. However, for all these questions, robust analysis is required. Given the low level of renewables penetration in 2022, there is certainly no need for new OCGTs for a year or two, which gives time to answer these questions.

From the analysis presented in the report emerge a few key short-term priorities and knowledge gaps (Figure 7) as a low-risk way to develop the power sector amidst a disruptive period in energy technology shifts.

Figure 7. A low-risk approach to address power shortages and the rush for gas

Short-term priorities

Significantly increase rate of renewable capacity additions.

Implement:

1. Renewables grid integration techniques
2. Transmission network upgrades

Increase rate of storage capacity additions.

Develop bettering understanding of:

1. Role and timeframes for green hydrogen in power sector.
2. Potential for overbuild of renewables and storage to generate "superpower"

Gas recommendations

Do not use power sector as an anchor tenant for gas demand now.

A decision on whether any gas supply infrastructure is required for the power sector post-2035 can be made in ~2030 based on available technologies and costs.

Pause plans for the development of new gas turbines.

Fully investigate the short-term need for new OCGTs (or conversions to gas) given the significant recent changes in storage and renewables integration.

CCGTs run at high-capacity factor are not rational.

Source: Author diagram.

7.0 Conclusions and Recommendations

Evidence provided in this report indicates a shrinking role for gas in the power sector linked to increasing risks and improving alternatives, coupled with the ability to delay a gas decision and the possible advantages of significantly scaling up renewables and storage rollout.

Despite this, the South African government seems to be increasingly supportive of kick-starting a large-scale gas-to-power program. The DMRE rhetoric around gas, the extent of potential gas-to-power projects (mainly CCGTs) and the nature of the Karpowership deal suggest that gas plans could be pushed for bulk supply at high-capacity factor.

This divergence does not seem rational, and the onus of proof rests with the government to prove that any suggested gas-to-power investments are still sound. Given the current data, this appears unlikely.

7.1 There Are Significant Negative Outcomes of Developing a Large Gas-to-Power System Now

The growing risks of developing a large gas-to-power sector at this stage could lead to several negative outcomes for South Africa, where the severity is correlated to the extent of investment.

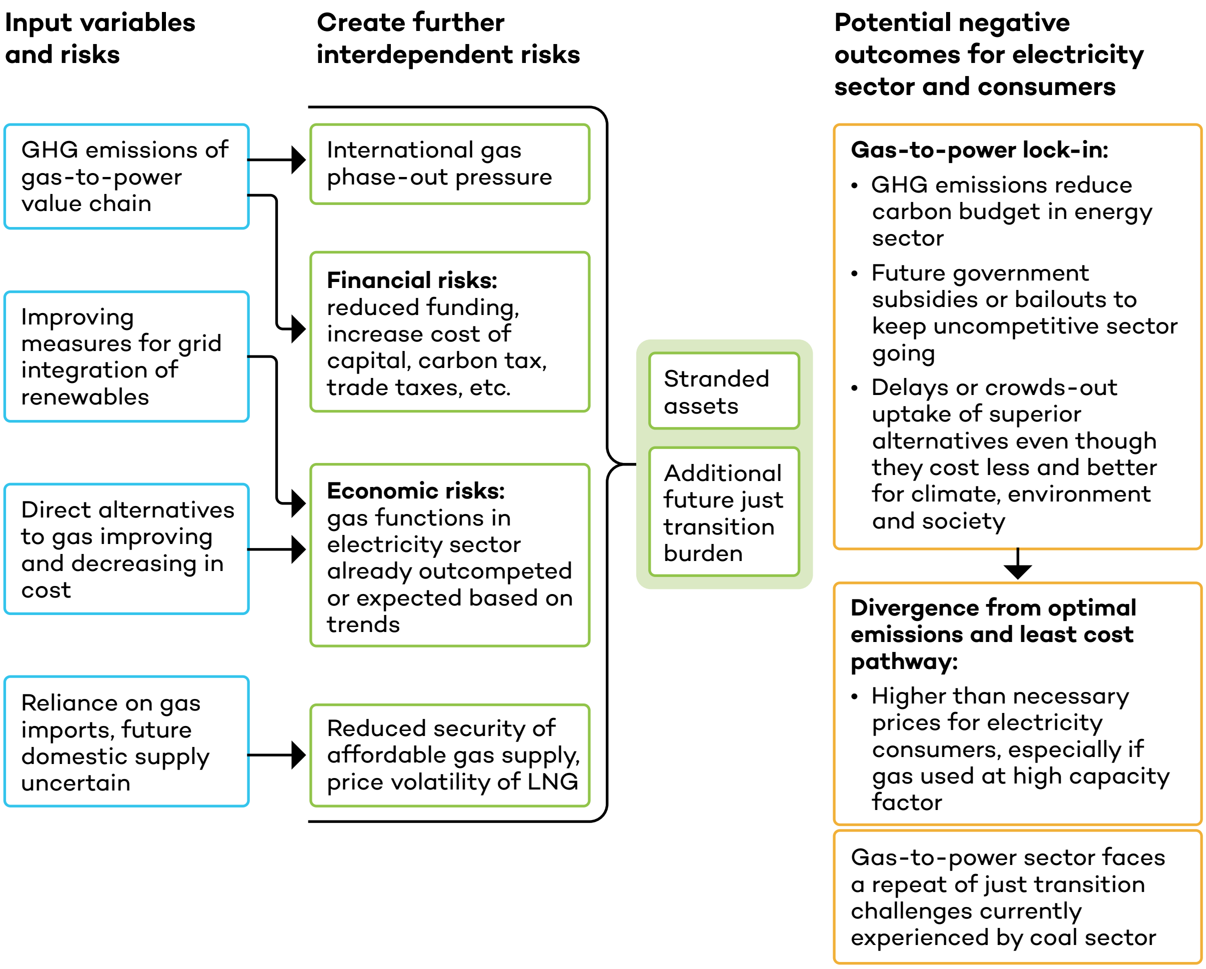
Adding more fossil fuels to the electricity sector uses up the carbon budget, making it harder for South Africa to meet international climate change commitments.

If gas assets are built and then become stranded, they may continue to operate even when cheaper, superior alternatives are available because the capital is already sunk. This type of lock-in can result in pressure from workers, investors, and companies on the government to introduce subsidies to protect the incumbent industry. These subsidies divert funds away from other projects with better socio-economic metrics and cause an industry to persist even when it is economically unviable. This is already happening with Eskom, which is locked-in to an uneconomic and unsustainable coal fleet and still receives bailouts (Bridle et al., 2022).

Where gas assets become central to economic activity in a region, there could be stranded economies. For example, Mossel Bay (see Appendix 1) is already heavily reliant on the gas-to-liquid (GTL) facility, but without a viable and affordable feedstock replacement for the depleted offshore gas reserves, the future of the entire municipality is uncertain.

Assuming the current trends continue and gas is further undercut in the power sector by renewables, storage, and grid enhancements, then without subsidies, the consumer will end up paying through higher-than-necessary electricity prices. The extent of tariff increases relative to an optimal system will depend on how frequently gas is used (capacity factor) and how many alternative low-carbon projects are displaced.

Figure 8. Risks of developing a gas-to-power sector in South Africa from 2022 onwards



7.2 Bring Renewable Energy Capacity Online as Fast as Possible and Complement With Storage as Required

As the least-cost, lowest carbon supply option with shortest lead times, renewables must form the basis of all new generation infrastructure to address current power shortages, enable optimal pumped storage usage and allow for ambitious coal phase-out. Furthermore, the rate of capacity addition must be scaled up significantly from the current IRP 2019. This is the most future-proof way to address load-shedding.

> Renewables must form the basis of all new generation infrastructure to address current power shortages, enable optimal pumped storage usage and allow for ambitious coal phase-out.

The negative impacts of the delays in the renewables program to date can be countered by ensuring a smooth and continuous rollout from now on. In parallel, sufficient resources must be allocated to investigating how other forms of ownership of renewable energy can successfully be integrated in South Africa.

Other urgent areas of action include prioritizing energy efficiency, actively working on reducing bottlenecks, such as the need for transmission grid expansion and implementing other measures to integrate renewables. The repurposing of Eskom coal power stations should also be directed toward renewables and storage only instead of gas.

Start building pumped storage options immediately, as they have the longest lead time, while increasing other storage capacity at a rate that ensures sufficient peaking and balancing to minimize or negate the need for OCGT use.

7.3 Electricity Planning Needs to Be Updated to Reflect Current Trends and Risks: A new IRP is needed.

A revised IRP should be a collaborative effort between DMRE and other stakeholders (including leading research institutes and think tanks). All modelling data and assumptions should be made publicly available. A method for factoring risks into modelling and policy adjustment needs to be developed and published. Resources must be devoted to developing a holistic, integrated energy plan for South Africa where the role of gas outside of the power sector can be evaluated.

7.4 Pause the Development of a Gas-to-Power Sector

Since gas supply is not necessary until 2035 in the power sector (if the system is optimally developed from now) it is logical to avoid unnecessary lock-in to another high-carbon fuel. Therefore, wait until 2030 to assess if any post-2035 role for gas exists.

Given the increasing risks of gas, improving alternatives, and the narrow window before gas would need to be phased out to reach net-zero by 2050 (or is outcompeted by green fuels), it is not rational to rush into building an extensive fleet of CCGTs that the government seem to be planning.

In terms of the debate about the need to build more OCGTs (liquid fuel or gas), provided there is a rapid rollout of renewables and an appropriate ratio of storage, there are a few years' leeway to properly investigate how the rise of storage affects the short-term need for more flexible and dispatchable generators.

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Appendix 1. Status Quo of Gas-to-Power in South Africa

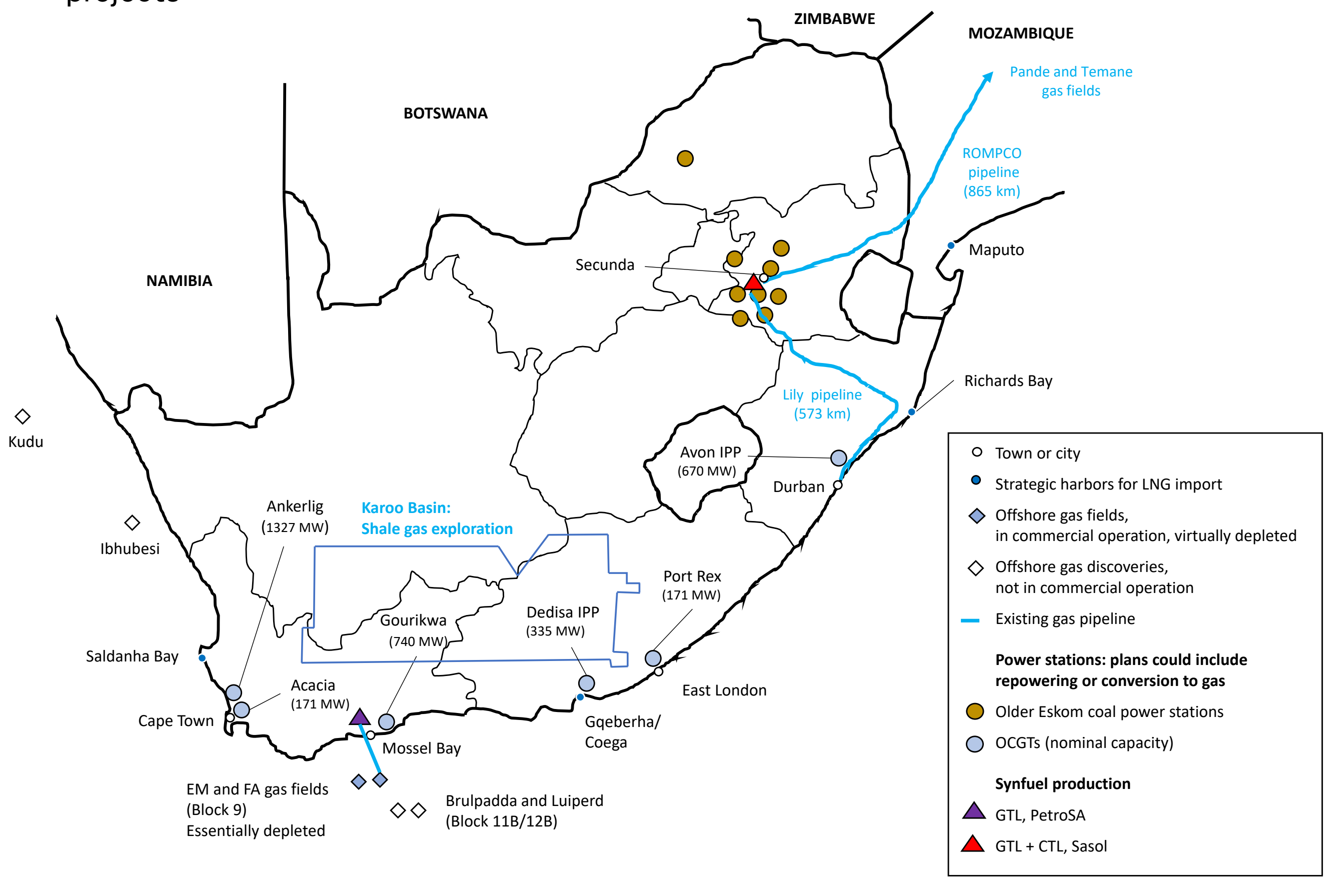

Figure A1. Infrastructure and reserves linked to existing gas or possible future gas projects

Notes: GTL is gas-to-liquid. CTL is coal-to-liquid.

Source: Author, with information from "Development studies progressing," 2021; DMRE, 2021b; Eskom, 2021; IGUA-SA, 2021; Petroleum Agency of SA Map, 2022.

1. Gas is not yet used for utility-scale electricity production. Gas use is almost entirely for industry, mainly the production of synthetic fuels

The majority of gas use in South Africa (~61% in 2020) is to produce synthetic liquid fuels via GTL processes and to produce other compounds via gas-to-chemical applications. Other industrial applications and gas retail account for the remaining demand, with household gas requirements at less than 0.6% of overall consumption (NBI, 2022).

By contrast, in sub-Saharan Africa, power generation accounted for 52% of natural gas use in 2020 (Muttitt et al., 2021). A draft regional gas master plan for the Southern African Development Community estimates power generation at ~60% of gas demand in 2050 (Africa International Advisors, 2021).

2. Gas supply relies on overland piped imports from Mozambique, but future supply options (domestic offshore or land imported) remain on the drawing board.

Domestic supply

Offshore gas wells have supplied the GTL refinery operated by PetroSA in Mossel Bay for over 20 years, but these sites are virtually depleted. The future of PetroSA relies on finding affordable feedstock as supply from Block 9 stopped in 2020 (IGUA-SA, 2021). The more recent discoveries of Ibhubesi, Brulpadda, and Luiperd are potential sources of domestic offshore gas, but the earliest production start date (if extraction commences) is suggested as 2028-2030 (DMRE, 2021b; NBI, 2022). Initial over-estimates of shale gas reserves in the Karoo Basin of 485 trillion cubic feet (tcf) have been revised down to 13 tcf (de Kock et al., 2017). While Parliament has authorized the use of hydraulic fracturing (fracking) to exploit these potential reserves (Regulations for petroleum exploration and production, 2015), the technical fracking regulations have not been drafted and draft water use regulations for fracking are still being finalized (as of March 2022).

Imports

The Pande and Temane gas fields in Mozambique are the only major sources of gas supply in South Africa, but these reserves are also expected to decline from 2025 (IGUA-SA, 2021). Of the potential reserves in the Southern African Development Community region, the Rovuma Basin in far northern Mozambique has received the most attention as a possible future source for South Africa imports (NBI, 2022). If South Africa were to import LNG, then Saldanha, Coega, and Richards Bay have been identified as strategic harbours.

The company Sasol Gas supplies 90% of South African demand using the Mozambique imports (DMRE, 2021b).

3. There is no existing infrastructure for large-scale LNG importation via sea. Existing infrastructure for inland piped gas is limited to three provinces (Mpumalanga, Gauteng, and Kwazulu Natal).

The Republic of Mozambique Pipeline Company (ROMPCO) pipeline brings gas from Mozambique to the Sasol site in Secunda. This hub is linked to Richards Bay and Durban via the Lily pipeline and to parts of Gauteng and Mpumalanga via the Sasol Gas pipeline network. Gas storage facilities are very limited in capacity (DMRE, 2021b). In November 2021, a request for information (RFI) was released by the Central Energy Fund to assess the potential for building an LNG import terminal at Coega, which would be the first in South Africa (Mills, 2021).

4. Several important gas-related plans and policies are still under development, require updating or have not been implemented. Overall, the policy framework is incomplete and insufficient to guide sectoral development.

Appendix 2 lists some of the national government legislation as well as planning and implementation documents relevant for developing a gas-to-power sector.

Several components have been in progress for many years and are still not finalized (as of March 2022). For example, work on the Gas Amendment Bill started in 2012 and on the GMP before 2014. Despite a legal requirement in the National Energy Act of 2008 for an IEP, the 2016 draft has still not been completed. The absence of an overarching, holistic plan for energy in South Africa is partly responsible for the lack of alignment between subsector plans and the resulting policy uncertainty.

Other plans that have been completed are widely viewed by energy analysts as suboptimal, outdated, or no longer fit for purpose. For example, the IRP 2019, which covers electricity infrastructure planning, has been demonstrated to cost more and produce higher emissions than alternative least-cost or optimized plans (Wright & Calitz, 2020). Many stakeholders are calling for a revised IRP with updated assumptions, full access to assumption data, and a modelling process that does not limit or force in certain technologies at the input stage.

Appendix 2. Policy Framework

Table A1. Some of the main components of regulation, planning, and implementation of activities linked to developing a gas-to-power sector

Document (year)	Key points related to developing a gas-to-power sector (including gas supply)
Legislation	
National Environmental Management Act (1998)	Requires gas exploration and production to get environmental authorization

Gas Act (2001) and subsequent proposed amendments in the **Gas Amendment Bill (2021)**	• Aims to:
	  • Provide a national regulatory framework for the orderly and environmentally sustainable development of the gas industry.
	  • Facilitate gas infrastructure development and investment, including in the gas-to-power sector.
	• Covers unconventional gases such as coalbed methane, landfill gas, and shale gas.
	• Defines the functions of The National Energy Regulator of South Africa (NERSA) in relation to gas, including tariffs and maximum charges.[17]
	• Gas licensing and registration.
	• Assigns powers to the Minister (including determinations) to direct development of new gas infrastructure and mandates the Minister to develop a GMP.

Upstream Petroleum Resources Development Bill (2021)	Aims to: • Contribute to the development of petroleum resources. • "Provide equitable access to and sustainable development" of South Africa's petroleum resources. • Contribute to active state and Black persons' participation in developing the country's petroleum resources. • Provide for security of tenure for the exploration and production of gas. • Give effect to Section 24 of the constitution by ensuring that gas development is conducted in an ecologically sustainable manner. • Accelerate the exploration and production of gas development. • Promote employment, skills development, and technology transfer through the development of this industry.

17 Gas charges (in ZAR/GJ) include a gas price (for gas molecules) and gas tariffs (for network services like transmission).

Document (year)	Key points related to developing a gas-to-power sector (including gas supply)
Carbon Tax Act (2019)	• Places a tax on carbon dioxide-equivalent GHG emissions above a threshold level. • Initial rate of ZAR 120 (USD 8.31) per tonne increased by inflation plus 2% until end of Phase 1 (revised to December 31, 2025). • Tax-free emissions allowances ranging from 60%–95%, with natural gas receiving a 95% allowance. • Phase 2 from January 1, 2026, will review rates and allowances (Godongwana, 2022).
Plans, programs, and implementation (including those at draft or proposed stage)	
National Development Plan (2012)	• Calls for greater share of natural gas in energy mix. • Investments priorities include: constructing infrastructure to import LNG, exploration for domestic gas reserves (including shale and coal bed methane) (NPC, 2012).
Draft Integrated Energy Plan (IEP) (2016), still not finalized by March 2022 The National Energy Act (2008) legally mandates the Minister of Energy to annually develop, review, and publish an IEP. This has not happened once since the Act came into effect.	• Core modelling scenarios assumed shale gas in Karoo would be abundant, economically recoverable and competitive (cheaper than imports), resulting in increasing proportions of gas for electricity generation up to 2050. • Sees potential for both CCGTs and OCGTs in the electricity sector. Assumption of 70% state-owned enterprise build, 30% independent power producers (IPPs). • Recommends research and funding for underground coal gasification projects. • Encourages the development of enabling legal and regulatory framework for offshore gas exploration. • Switching from electricity to gas for industry and households (DOE, 2016a).
IRP (2019)	• Electricity infrastructure development plan • Calls for 1,000 MW of new gas capacity by 2024 and 2,000 MW by 2028 (equating to 9% total installed capacity by 2030). • Supports the development of gas infrastructure and also converting existing OCGTs (peakers) to run on gas (DMRE, 2019a).
Risk Mitigation Independent Power Producer Procurement Programme (2020)	• Intention to bring additional capacity onto the grid as fast as possible. • Performance requirements of IPPs include: dispatchable and flexible generation, minimum load factor of 50% per year, reach capacity within 15 minutes of cold start. • Power purchase agreements of 20 years where Eskom must compensate the IPPs for a minimum of 50% of the net available capacity each year (DMRE, 2020).

Document (year)	Key points related to developing a gas-to-power sector (including gas supply)
Ministerial determination for 3,000 MW of gas-to-power capacity (2020)	• In September 2020 NERSA concurred with the Ministerial determination from February 2020 that included 3,000 MW of gas (Bungane, 2020; Determination Under Section 34(1) of the Electricity Regulation Act, 2006 (Act No.4 of 2006)). • Capacity from IPPs, electricity to be bought by Eskom. • DMRE indicated that the gas Request for Proposals should be out by March 2022 (DMRE, 2021a).
Proposed Gas Master Plan (GMP) In progress since at least 2014, a draft was released in 2016, and a "Base Case" consultation document was released for public comment in 2021	• Once developed, the GMP aims to provide a roadmap for taking strategic, political, and institutional decisions that will guide industry investment planning and coordinated implementation. • The 2021 consultation document provides selected background information on gas in Southern Africa but no planning details (DMRE, 2021b).

Appendix 3. Potential Stranded Asset Risk

In the absence of an IEP or a GMP, the only direction for gas-to-power infrastructure development is the IRP 2019. While this only allocates 3,000 MW until 2030, there are at least 14,000 MW total of gas-to-power plants that are at advanced stages of planning or have been granted environmental authorization (Section 2). It is unclear how these will get the go-ahead, but, as seen with the RMI4P, determinations and other measures could be introduced by the Minister of Mineral Resources and Energy.

It is recognized that the declining imports from Mozambique and undeveloped domestic offshore gas mean that LNG imports are the most likely supply option in the short to medium terms (NBI, 2022). Table A2 estimates overnight capital costs of gas plants, LNG terminals, and pipelines to indicate potential stranded asset risk.

The sequence is a hypothetical scenario based on the following evidence, which is limited, and several components could be done in parallel.

1. The RFI for Coega was already released in November 2021.
2. Media reports suggest the tender for Richards Bay LNG terminal has been expected since 2020 (Roelf, 2015), and the Eskom 3,000 MW plant has been planned since before 2017 (Savannah Environmental, 2019).
3. The third strategically identified port is Saldanha, but it seems to be the least progressed for LNG terminal construction.
4. The pipeline network aligns with a subset of the proposed CSIR gas corridors project (Department of Forestry, Fisheries and the Environment, 2019).
5. Further projects for Richards Bay seem to be at a more advanced stage than Saldanha.

Despite the RFI for Coega LNG terminal specifying a FSRU, in January 2022 the Minister of Transport announced that an onshore regasification would be built at Coega (Devdiscourse, 2022), with a total project value of USD 1.5 billion (ZAR 22.5 billion). It is unclear why there would be a need for both facilities at this stage, but if the additional onshore facility is built, that would add to the stranded asset potential.

Table A2. Estimated capital costs for basic gas-to-power infrastructure in South Africa

Project	Component	Overnight Capital Cost Estimate (ZAR billion)
1. Initial Coega Development Corporation (CDC) project	1,000 MW gas plant	12.5
	Floating storage and regasification unit (FSRU) LNG terminal[18]	9.5
2. IRP 2019 capacity of 2,000 MW (assume located at CDC)	2,000 MW gas plant	25
Sub-total for IRP 2019		**47**
3. Richards Bay	3,000 MW CCGT Eskom	37.5
	FSRU LNG terminal	9.5
4. Saldanha Bay and Atlantis[19]	FSRU LNG terminal	8.5
	Pipeline to Atlantis	1.75
	1,500 MW Atlantis plant	18.75
5. Pipeline network	Connect LNG terminals and inland to Gauteng from Richards Bay, approximately 2,350 km.	32–117.5
6. Increase gas-to-power capacity at Richards Bay	2,000 MW gas plant	25
7. Increase LNG imports at Richards Bay	Second FSRU	4.7
Total		**184.7–270.2**

18 Responses to the RFI from December 2021 are not in public domain.

19 Excluded the 1,500 MW ArcelorMittal plant as that seems to be purely for industrial offtake and not to supply the grid, so asset stranding would have less of an impact on the national power sector.

Basic Assumptions and Sources

The three cost components have been inflation adjusted to March 2022 ZAR from the sources indicated.

1. CCGT overnight capital costs: ZAR 12.5 million per MW (NBI, 2022; Roff et al., 2020).
2. FSRU LNG terminal ZAR 8.5-9.5 billion, depending on gas volumes and what port infrastructure is needed (Transnet, 2016). These estimates align with reported figures for the Matola terminal in Mozambique (Wendell, 2022).
3. Pipeline cost estimates vary substantially, as there are many variables (e.g., pipe diameter, type of material) that depend on the gas volumes to be transported. Other costs like acquiring land and property servitudes are location specific. Transnet data equates to 16-inch pipelines costing ZAR 13.7 million per km, while recent NBI estimates come out to ZAR 50 million per km (diameter not provided, but indicate that new pipelines should be compatible with hydrogen transportation) (NBI, 2022).

Limitations

1. Excluding associated transmission infrastructure will lead to an underestimation of stranded assets, but these could be repurposed for other power generation facilities.
2. Including LNG terminals might lead to an overestimation of stranded assets, if there is still sufficient gas demand outside of the power sector for them to remain viable.

Cost Overruns on Megaprojects

A recent report by the National Planning Commission documents significant cost overruns and delays across many public infrastructure projects, including the 715 km Transnet New Multi-Product Pipeline, which increased from ZAR R12.7 billion to ZAR 30.4 billion and took nine years to complete (Watermeyer & Phillips, 2020). **Therefore, the real stranded asset risk of a project can be significantly more than even the most up-to-date cost estimates before a project commences.**

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