



**SOUTH AFRICA'S ENERGY SECTOR
INVESTMENT REQUIREMENTS
TO ACHIEVE ENERGY SECURITY
AND NET ZERO GOALS BY 2050**

Literature Review
2025

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Suggested Citation

Development Bank of Southern Africa, National Treasury, National Planning Commission & Presidential Climate Commission. 2025. South Africa's Energy Sector Investment Requirements to Achieve Energy Security and Net Zero Goals by 2050: Literature Review. Midrand: DBSA.

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Abbreviations

Term	Definition
°C	Degrees Celsius
ABS	Accounting for Basic Services
AFOLU	Agriculture, Forestry, and Other Land Use
BESS	Battery Energy Storage System
BFT	Blended Finance Taskforce
CCGT	Combined-Cycle Gas Turbine
CCUS	Carbon Capture, Utilization, and Storage
CO ₂	Carbon Dioxide
COP	Conference of the Parties
CPI	Climate Policy Initiative
CSIR	Council for Scientific and Industrial Research
CSP	Concentrated Solar Power
CST	Centre for Sustainable Transitions
DBSA	Development Bank of Southern Africa
DFFE	Department of Forestry, Fisheries and the Environment
DFI	Development Finance Institution
DMRE	Department of Mineral Resources and Energy
DPWI	Department of Public Works and Infrastructure
EAF	Energy Availability Factor
EAP	Energy Action Plan
ERA	Electricity Regulation Act
ESAGE	Energy-South African General Equilibrium
ESRG	Energy Systems Research Group
FBE	Free Basic Electricity
FSCA	Financial Sector Conduct Authority
GDP	Gross Domestic Product

GH ₂	Green Hydrogen
GHG	Greenhouse Gas
Gt	Giga tons
GW	Gigawatt
HAP	Hazardous Air Pollutant
IDC	International Development Corporation
IEP	Integrated Energy Plan
IoT	Internet of Things
IPG	International Partners Group
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
JET	Just Energy Transition
JET IP	Just Energy Transition Investment Plan
JETP	Just Energy Transition Partnership
JTF	Just Transition Framework
km	Kilometre
LEDS	Low Emission Development Strategy
LMIC	Low- and Middle-Income Countries
LNG	Liquefied Natural Gas
MDB	Multilateral Development Bank
Mt p.a.	Million tonnes per annum
MtCO _{2e}	Metric tons of carbon dioxide equivalent
MW	Megawatt
MWh	Megawatt hour
NBI	National Business Initiative
NCCRWP	National Climate Change Response White Paper
NDB	New Development Bank
NDC	Nationally Determined Contribution

NDP	National Development Plan
NEA	National Energy Act
NERSA	National Energy Regulator of South Africa
NEV	New Energy Vehicle
NIP	National Infrastructure Plan
NTCSA	National Transmission Company of South Africa
OCGT	Open-Cycle Gas Turbine
OECD	Organisation for Economic Co-operation and Development
PARI	Public Affairs Research Institute
PCC	Presidential Climate Commission
PGM	Platinum Group Metal
PIR	Policy, Institutional, and Regulatory
PM	Particulate Matter
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photovoltaic
QPIB	Qualified Public Infrastructure Bond
R	South African Rand
R&D	Research and Development
RE	Renewable Energy
RED	Regional Electricity Distributor
REIPPPP	Renewable Independent Power Producer Procurement Programme
RMIPPPP	Risk Mitigation Independent Power Producer Procurement Programme
RSA	Republic of South Africa
SALGA	South African Local Government Association
SARB	South African Reserve Bank
SA-TIED	Southern Africa – Towards Inclusive Economic Development
SATIM	South African TIMES Model

SATIM-GE	South African TIMES Model with General Equilibrium
SDG	Sustainable Development Goal
SED	Sustainability, Equity, and Diversity
SERI	Socio-Economic Rights Institute of South Africa
SSEG	Small-Scale Embedded Generation
TDP	Transmission Development Plan
TSO	Transmission System Operator
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VOC	Volatile Organic Compound
VRE	Variable Renewable Energy

Overview of Key Documentation

Plan/Policy/Act	Brief overview of key documentation
Energy Action Plan (EAP)	In 2022, President Cyril Ramaphosa released the EAP. The short-term objective of the EAP is to reduce the severity and frequency of load shedding through immediate measures to improve the performance of Eskom’s existing power stations and stabilize the energy system. The long-term objective is to end load shedding altogether and achieve energy security by adding as much new generation capacity to the grid as possible, as quickly as possible.
Electricity Regulation Amendment Act 38 of 2024, Government Gazette No. 51778	The Electricity Regulation Amendment Act of 2024 establishes a national regulatory framework for the generation, transmission, and supply of electricity in South Africa.
Integrated Energy Plan (IEP)	The purpose of the 2016 IEP is to guide future energy infrastructure investments and policy development in South Africa by providing a roadmap of the future energy landscape in the country. It does this by analysing current energy demand and supply trends within the different sectors of the economy, using the information to project the country’s future energy requirements under a variety of different scenarios.
Integrated Resource Plan (IRP)	The 2019 IRP provides a roadmap for meeting South Africa's forecast electricity demand and is expected to be continuously revised and updated. Over the years, these plans have made provision for the sources from which energy will be generated (i.e., adding renewables to the electricity supply mix), and the replacement and decommissioning of power stations. The Draft IRP 2023 serves as a blueprint for meeting the country’s energy demand until 2050. At the time of writing, the IRP 2023 is being updated to reflect stakeholder perspectives and the rapid evolution of changes in the South African energy landscape as they occurred during 2024.
Just Energy Transition Investment Plan (JET IP) 2023–2027	The JET IP for the five-year period 2023–2027, first announced in 2021, speaks to the investments required to support the decarbonization of the energy sector in line with South Africa’s decarbonization commitments in the Nationally Determined Contribution (NDC). The JET IP is aligned with the National Development Plan (NDP) 2030 and is geared towards addressing the triple challenges of inequality, poverty, and unemployment. Interventions aimed at addressing these challenges include creating quality jobs, increasing energy security, addressing the risks of climate change, and promoting economic growth. The JET IP proposes investment apportionments towards catalysing a new configuration of South Africa's energy landscape. Through consideration of socio-economic factors and development goals towards net-zero emissions by 2050, the JET IP estimates that R648 billion (USD 43.2 billion) worth of investment is required, which amounts to R143 billion (USD 9.53 billion) annually from 2023 to 2027.
Low Emission Development Strategy (LEDS) 2050	South Africa’s LEDS 2050, submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2020, shows how various sectors of the economy could implement policies and measures to reduce emissions up to 2050, while ensuring broader socio-economic development. The goal of the strategy is for South Africa to follow a low-carbon growth trajectory, ensuring a just transition and a climate-resilient

	society, while making a fair contribution to global climate change efforts. The strategy aims for South Africa to reach net-zero emissions by 2050.
National Climate Change Response White Paper (NCCRWP)	The NCCRWP, approved in 2011, sets out the Government's official policy on the production, distribution, and consumption of energy. It represented, for the first time, a comprehensive perspective of South Africa's official overall energy needs and options, and laid the foundation for energy laws such as the National Energy Act (NEA) and the ERA. The goal of this White Paper is to address both mitigation and adaptation in the short, medium, and long term (up to 2050) through effective climate change response and to transition into a lower-carbon economy.
South Africa's Nationally Determined Contribution (NDC) under the Paris Agreement	The NDC, first submitted in 2015/2016, outlines the rate at which South Africa plans to reduce greenhouse gas emissions. It also represents the country's contribution to the goals outlined in the Paris Agreement. The updated NDC 2021 commits to a 31% reduction and a fixed target for greenhouse gas emissions levels of 398–510 MtCO _{2e} by 2025, and 350–420 MtCO _{2e} by 2030.
National Development Plan (NDP) 2030	The NDP 2030, adopted in 2012, aims to eliminate poverty and reduce inequality by 2030. The document serves as a blueprint for addressing South Africa's challenges, providing a long-term vision and plan for the country.
National Energy Act (NEA) 34 of 2008, Government Gazette No. 31638	The NEA of 2008 is South Africa's overarching piece of legislation for the energy sector. It directs the Department of Mineral Resources and Energy (DMRE) to ensure that a diverse range of energy resources are available, in sustainable quantities and at affordable prices. The NEA is supplemented by various pieces of legislation focusing on specific energy sources, such as petroleum, natural gas, and nuclear energy. The NEA aims to address South Africa's energy crisis and ensure a continuous energy supply.
National Infrastructure Plan (NIP) 2050	The main goal of the NIP 2050, first published in 2022, is to create a foundation for achieving the vision of inclusive growth by linking top NDP objectives to actionable steps and intermediate outcomes. The NIP 2050, therefore, promotes dynamism in infrastructure delivery and addresses weaknesses and institutional blockages that hinder long-term success.
Renewable Independent Power Producer Procurement Programme (REIPPPP)	The REIPPPP, launched in 2011, aims to facilitate private sector investment into grid-connected renewable energy (RE) generation in South Africa. In addition, this programme is structured to contribute to broader national development objectives focused on job creation, social upliftment, and broadening economic ownership, which is advancing equity. For tenderers to become a preferred bidder in the REIPPPP, certain criteria must be met, including job creation, local content, ownership, management control, preferential procurement, enterprise development, and socio-economic development. Additionally, the REIPPPP obliges the private sector renewable energy projects to engage with local communities through Sustainability, Equity, and Diversity (SED) by awarding tenders based on their promised contribution towards economic development.
Sustainable Development Goals (SDGs)	Seventeen SDGs were adopted by the United Nations (UN) in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people will enjoy peace and prosperity. These SDGs are integrated, recognising that development must balance social, economic, and environmental sustainability. Countries, including South Africa, have

	<p>committed to prioritizing progress on these SDGs. This report specifically examines SDG 7, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all. The SDG 7 targets include:</p> <ul style="list-style-type: none"> • 7.1 which aims to ensure universal access to affordable, reliable, and modern energy services. Achieving this goal is important for addressing poverty, improving living standards, and supporting economic development. • 7.2 which requires that the share of renewable energy in the global energy mix increase by 2030. • 7.3 which aims to double the global rate of improvement in energy efficiency.
<p>Transmission Development Plan (TDP) 2024</p>	<p>The TDP shows Eskom’s ten-year execution plan for delivering much-needed new transmission infrastructure. Therein, Eskom comments that as coal plants are decommissioned, additional generation capacity of 57 Gigawatt (GW) will be necessary to address the prevailing energy security challenges. The TDP also emphasises the need to build and connect 4–5 GW of new renewable generation each year to ensure a resilient power system by the early 2030s, translating to 16–20 GW over the next four years.</p>

Purpose and Scope

The Development Bank of Southern Africa (DBSA), Presidential Climate Commission (PCC), the National Planning Commission (NPC), and National Treasury (via its 'Southern Africa – Towards Inclusive Economic Development' (SA-TIED) programme), share similar commitments towards socio-economic development, energy¹ security and access, the Just Energy Transition (JET), and achieving the climate commitments of South Africa.

To that end, this strategic partnership appointed a project team led by PwC and supported by Osmotic Engineering Group (OEG) to assess the energy infrastructure investments required between 2024 and 2030 (and extended to 2040 and 2050) to achieve the energy and carbon targets specified in South Africa's Nationally Determined Contribution (NDC), National Development Plan (NDP), and National Infrastructure Plan (NIP) 2050, as well as the United Nations Sustainable Development Goals (SDGs) – specifically SDG 7 (affordable and clean energy). The objectives of this study pertain to the need to achieve energy security, at least cost, while meeting South Africa's NDC targets. Furthermore, the team needed to assess the funding gap to achieve the required outcomes.

The purpose of this document is to provide a review of literature relevant to South Africa's current energy infrastructure investment needs (i.e., generation, transmission, and distribution), as well as associated climate mitigation costing and relevant economic impact research. The literature review intends to report the funding that has been secured to date towards South Africa's energy infrastructure investment ambitions, as well as provide insight into the remaining funding gap.

Furthermore, this literature review explores how South Africa could address these financing challenges through targeted actions, innovations in technology, policy coherence, and international collaboration to ensure the country's energy goals align with broader development and environmental objectives, specifically as they relate to SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all), South Africa's NDP (aims to eliminate poverty and reduce inequality by 2030) and South Africa's NDC (contribution to the Paris Agreement) towards achieving net zero.

The literature review is structured around eleven questions relevant to the overarching goals of this project. To answer these questions, key information was extracted from selected sources, including study methodologies, relevant statistics, and key findings. The information gathered from the existing literature, policies, and legislation serves as a reference point that will assist the project team in producing the

¹ For the purposes of this report, "energy" is defined as electricity, encompassing renewable sources, coal, gas, uranium, and diesel. From an infrastructure perspective, the report deals with electricity generation, storage, transmission, and distribution infrastructure. Upstream infrastructure for the supply of coal, gas, and diesel fuels is incorporated in the unitised cost of these energy sources as they are consumed by the associated electricity generation plants, i.e., the study does not estimate the capital costs required for upstream infrastructure, such as gas pipelines, liquefied natural gas (LNG) terminals, petrochemicals manufacturing, and coal mines.

technical modelling, funding gap calculations, and regulatory reviews. Content from this document was also included in the main report titled South Africa's Energy Sector Investment Requirements to Achieve Energy Security and Net Zero Goals by 2050. This literature review was conducted during the described modelling processes and finished concurrently while the project team completed the integrated report from June 2023 to June 2025.

Introduction

Coal dominates South Africa's energy mix, with 80% of electricity being generated via coal-fired power stations. These stations are owned and operated by Eskom, the country's national power utility. Eskom generates approximately 95% of the electricity used in South Africa, which is equivalent to 45% of the electricity used on the African continent. It directly provides electricity to 45% of all end-users in South Africa, while the other 55% is resold by redistributors (including municipalities) (BMI Fitch Solutions, 2024).

South Africa is fortunate to have abundant potential for renewable energy capacity development. It has begun exploring several types of renewable energy technologies over the last decade to pivot towards low emission industrialization in line with emerging global climate demands.

South Africa's energy sector is undergoing a paradigm shift, driven by the dual objectives of meeting rising energy demands and fulfilling international commitments to reduce greenhouse gas (GHG) emissions. A well-resourced, just transition strategy is required to catalyze a shift towards low-carbon technologies for generation, maximize benefits from new energy systems, and minimize the adverse impacts on coal-dependent communities, workers, and the economy. Programmes to achieve this will require climate finance and other forms of support provided to developing countries as specified in Articles 9, 10, and 11 of the Paris Agreement (RSA: NDC, 2021).

In recent years, investments have been directed towards alternative energy generation sources, ranging from fossil fuels, such as liquefied natural gas (LNG), to renewable energy technologies, such as solar and wind. However, the intersection of clean energy infrastructure investments and climate mitigation efforts has transformed from a feature associated with environmental stewardship into a catalyst for national economic transformation. As a result, low-carbon societies represent the envisaged economic mode of many nations, including South Africa, particularly as countries attempt to adjust to geopolitical upturns. Capitalizing on low emission aligned economic development requires that materials and systems be developed with minimized embedded carbon in their value chain. This requirement could be challenging for hard-to-abate sectors, such as those related to mining, agriculture, and transport. Nevertheless, the bolstering of energy security through renewable deployment correlates with South Africa's growth trajectory towards a low emission economy, and is an imperative of the Department of Forestry, Fisheries and the Environment's (DFFE) Low Emission Development Strategy (LEDS) (DFFE: SA-LEDS, 2020).

Energy security also enables further socio-economic development and resilience, as more capacity becomes available at the household level for personal advancement, education, and the diversification of income streams. Additionally, energy access reduces the health impacts associated with household air pollution, specifically from the combustion of wood, paraffin, and waste fuel, thereby directly improving community health. At the community and regional level, access to energy allows the creation of jobs, the provision of healthcare, and the supply of educational services. A focus on reducing inequality through energy access could emphasise job creation and skills development as mechanisms to enable financial inclusion and independence, thereby fostering a broader sense of community participation.

This literature review aims to provide an understanding of the current state of South Africa's energy infrastructure, the investment requirements towards 2050, and the investment targets to address the funding gap. The review will cover the various climate finance options presented by various sources that are positioned to meet the finance targets. The literature review will also examine the balance between economic growth and environmental responsibility, elucidating any growth opportunities and challenges that arise. To achieve the required pace and scale, public and private economic stakeholders must align on the capital projects required within the South African economy.

1 Barriers to Achieving Universal Access to Energy Services

What are the barriers to achieving Sustainable Development Goal (SDG) 7.1 (ensure universal access to affordable, reliable, and modern energy services by 2030) and associated National Development Plan (NDP) goals, and what needs to be done?

This research identified several barriers that could hinder progress towards achieving SDG 7.1 and NDP goals in South Africa:

- **Infrastructure deficiencies:** While the distribution grid covers almost the entire country, many rural and underserved areas in South Africa still lack the necessary infrastructure for a reliable electricity supply. In most cases, expanding the grid is cheaper than any alternative options; however, the extension to some outlying areas can be cost-prohibitive and logistically challenging (Todd et al., 2021). Additionally, the existing infrastructure is often outdated and unable to support modern energy demands as it falls below the reliability standard (Lahnaoui et al., 2024). Eskom and municipalities must provide the National Energy Regulator of South Africa (NERSA) with official forms indicating the correct operations and maintenance of the grid. However, this process is not being adequately adhered to or monitored.
- **Financial constraints:** The high costs associated with expanding and maintaining electricity infrastructure are a significant barrier. Limited public funds and the need for substantial private investment complicate efforts (Folly, 2021). The difficulty in accessing financing remains a critical challenge, especially for renewable energy projects (World Bank, 2021). Municipalities are not bankable and cannot obtain external funding to invest in their energy infrastructure. Many municipalities do not fully understand their supply costs, leaving them unable to substantiate the required tariff level from NERSA for full recovery. Municipal finances are also further strained in scenarios where they lose income due to private electricity producers in their distribution area. This strain could have negative knock-on effects on the available subsidies for indigent users (Mawere and Andtshamano, 2024).
- **Technical challenges:** Integrating renewable energy sources into the existing grid can be a technically challenging process. To achieve SDG 7, issues such as grid stability and the intermittent nature of renewable energy sources need to be addressed (McCollum et al., 2017). Additionally, there is a lack of technical expertise and capacity to manage and maintain advanced energy systems (Africa Energy Portal, 2021).
- **Social and economic inequalities:** Disparities in income and access to resources can limit the ability of poorer households to afford modern energy services, which is exacerbated by the high upfront costs of renewable energy technologies (Ledger, 2021). The energy sector's historical reliance on coal has created economic dependencies that are difficult to transition away from without significant social and economic disruption (Ledger, 2021). Women, particularly in low-income households, are disproportionately affected by high energy costs, the unaffordable

renewable energy capital costs, coal community-related adversity, and limited access to modern energy services. This lack of energy access exacerbates existing social and economic inequalities, as women are often the most affected by energy poverty, for example, spending more time on unpaid domestic work or facing health risks from traditional cooking methods (Tandrayen-Ragoobur, 2024). The transition towards universal access to affordable, reliable, sustainable, and modern energy services is reliant on the learning rates of new generation technologies being sufficiently high to reduce overall electricity tariffs. High energy costs, especially for low-income households, therefore, remain a significant barrier (World Bank, 2021).

What needs to be done:

- **Investment in infrastructure:** Both public and private funding for the development and maintenance of energy infrastructure must be increased, especially in rural areas. Innovative financing mechanisms, such as green bonds and public-private partnerships (PPPs), can help mobilize the necessary funds (Africa Energy Portal, 2021).
- **Policy and regulatory reforms:** The policies and regulations to support the expansion of modern energy services must be streamlined. This includes creating a stable and predictable policy environment to attract investments. Policies should also focus on removing barriers to entry for renewable energy projects and providing incentives for energy efficiency. Long-term planning, policy, and fiscal incentives are crucial for creating a conducive environment for energy investments (Glazewski, 2010).
- **Financial support:** Subsidies or financial assistance must be provided to low-income households to make energy services more affordable. Innovative financing mechanisms, such as pay-as-you-go models, can be of use. Improving affordability through targeted subsidies and financial support mechanisms is essential (Inglesi-Lotz, 2023).
- **Technical innovations:** Investment in technologies that facilitate the integration of renewable energy into the grid is necessary. This includes energy storage solutions and smart grid technologies. Increased spending on research and development (R&D) can drive technological advancements and improve energy efficiency (Müller et al., 2020).
- **Community engagement:** Involve local communities in planning and decision-making processes to ensure that solutions are tailored to their needs. Community-based energy projects can also enhance local ownership and sustainability. Ensuring equitable access for all communities is crucial, especially those that have been historically disadvantaged (Cassim et al., 2021).
- **Political commitment:** Strong political commitment is necessary to drive the energy transition and achieve SDG 7.1. This includes fulfilling responsibilities around free basic electricity (FBE) to support low-income households (Ledger, 2021).

1.1 Obstacles to South Africa Fulfilling Sustainable Development Goal 7 (SDG 7)

South Africa has set out its ambition to achieve a prosperous society based on inclusive growth and sustainable development, as per the SDGs (end poverty and inequality, protect the planet, and ensure health, justice, and prosperity) and NDP 2030 (aims to eliminate poverty and reduce inequality by 2030), which has become the country's guide for achieving economic growth and development (World Bank, 2021).

Achieving SDG 7.1 is important for addressing poverty, improving living standards, and promoting economic development. Achieving SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all) is therefore fundamental to the development of South Africa's economy because income and energy consumption are closely linked (McCollum et al., 2017). For example, higher energy prices would disproportionately affect the low-income earners, thus preventing universal access.

South Africa has shown progress on some of the SDGs (including climate progress), and there has been improved electricity access, with 95% of the population having access to electricity (World Bank, 2021). Nonetheless, challenges remain around electricity access in informal settlements, while the electricity grid remains heavily dependent on coal, despite a rise in the use of renewable energy (World Bank, 2021).

In addition, despite the sophistication and depth of South African financial markets, the Just Energy Transition Investment Plan (JET IP) (which speaks to the investments needed to support the decarbonization of the energy sector) highlights several barriers that restrict the flow of funding towards climate change projects and modernizing the electricity supply (The Presidency, 2022). These are not unique to South Africa and include, amongst others:

- High degree of risk aversion among local financial institutions,
- Difficulty in accessing longer-term financing,
- Credibility of off-takers,
- High transaction costs for smaller projects,
- Long pay-back periods,
- Lack of attractive large low-carbon investment options,
- Difficulty in raising financing for technologies that have not been proven locally,
- Lack of concessionary wholesale finance,
- Uncertainty about future electricity prices,
- Complexity and regulatory burden of environmental regulations,
- Lack of public sector capacity in key areas, and
- Investment environment is not conducive to investment due to policy uncertainty.

Additional barriers to achieving universal access to affordable and reliable energy services include the following (Todd et al., 2021; UN, 2023):

- High energy costs, especially for low-income households that cannot afford to pay for such services,
- Lack of infrastructure, especially in rural and underserved areas,
- Inadequate grid reliability (i.e., load shedding),
- Heavy reliance on coal for energy production,
- Lack of awareness and education on the availability of alternative energy services, and
- Uneven distribution of energy services, especially for historically disadvantaged communities.

To achieve SDG 7.1 and the associated NDP electricity access goals, various stakeholders, including the government, the private sector, and civil society, must collaborate to address these challenges. This includes political commitment, increased spending on R&D, improving affordability, long-term planning, policy and fiscal incentives, transitioning to cleaner energy sources, and ensuring equitable access for all communities, especially those that have been historically disadvantaged.

Note that Regulation 28 of the Pension Fund Act, which sets out the investment limits of pension fund assets, aims to ensure that pension fund investments are diversified, thereby reducing risk and safeguarding the long-term interests of pension fund members (Müller, 2024). On 1 July 2022, the National Treasury published final amendments to Regulation 28 of the Pension Fund Act to enable longer-term infrastructure investment by increasing the maximum investment limits by retirement funds (National Treasury, 2022). Therefore, Regulation 28 of the Pension Fund Act can play a pivotal role in contributing towards financing energy infrastructure, which can positively affect the country's energy sector.

Furthermore, in 2018, President Cyril Ramaphosa announced the launch of the Infrastructure Fund to address the need for blended finance to enable the efficient execution of socio-economic infrastructure programmes and projects in South Africa. The purpose of the Infrastructure Fund is to transform public infrastructure through tailored blended financing solutions by sourcing and combining capital from the private sector, institutional investors, development finance institutions (DFIs), and multilateral development banks (MDBs) (Development Bank of Southern Africa (DBSA), 2023). This blended financing vehicle can significantly enable private funding of energy infrastructure in the future.

1.2 Unintended Consequences of Delivering Electricity Access to Low-Income Households

The Public Affairs Research Institute (PARI) is an African research institute affiliated with the University of Johannesburg and the University of the Witwatersrand. The PARI specializes in providing novel and original social science research, advocacy, and guidance support for South Africa, with translatable lessons applicable to the broader socio-economic dynamics of the Global South. Through PARI, Ledger (2021) published 'Broken Promises: Electricity access for low-income households: good policy intentions, bad trade-offs and unintended consequences', which establishes that South Africa's legacy of structural deprivation predates energy poverty.

While SDG 7 states that access to electricity facilitates economic participation, Ledger (2021) expresses that affordable, clean (i.e., non-polluting) and safe energy is related to both improved standards of living in households, as well as the country's ability to achieve its decarbonization targets. The authors express the following as key factors for how clean, modern energy sources can drive the development of South Africa and Southern Africa:

- Affordable energy facilitates food preparation, safety, and storage, which extends the value of perishable products and, by extension, the purchasing power of those with electricity access. Electricity access extends people's and communities' ability to work, read, and study after dark.
- Affordable energy stratifies and diversifies livelihood opportunities, facilitating novel actions ranging from domestic manufacturing to connecting homes to digital platforms, including the internet and job opportunities. Affordable, reliable energy reduces the share of household energy expenditure, which is constrained in Southern Africa. Ledger (2021) expresses that given 80% of South African households cannot afford to purchase a basic basket of nutritious food, whatever extra money can be apportioned for food purchases could significantly affect nutrition status and subsequent factors related to nutrition, morbidity, and household resilience.
- In developing regions, energy inaccessibility drives reliance on unsafe heating and cooking practices, such as makeshift gasoline stoves, which carry an increased risk of house fires and the associated loss of life and property. Walls et al. (2019) express that the frequency of indoor fire-related disasters leads to roughly 10 shack fires a day across South Africa.
- Clean, safely acquired energy reduces the risk of exposure to hazardous air pollutants (HAPs), indoor fires, and risks related to the burning of biomass, gasoline, and paraffin for heat.
- Access to clean, affordable energy conveys a disproportionately more advantageous benefit to women, as their primary responsibilities are often centred around labour-intensive domestic activities such as cleaning, cooking, and childcare (Ledger, 2021).

Ledger (2021) establishes that household access to clean and safe energy is mediated by the structure and operating model of the country's energy distribution system. While generation models largely influence national levels of carbon emissions and the baseline cost, distribution models have the most significant impact on whether a household can access and utilize energy based on household income and geographic constraints. Therefore, energy justice in South Africa would fundamentally relate to all households having access to sufficient, affordable, clean, and safe energy (Ledger, 2021). Ledger (2021) also speculates that due to the invisibility of energy distribution as a problem to be addressed in any meaningful just transition, the concept of energy justice will go unattended in relation to larger macro-economic policy and may worsen poverty as new energy models are adopted.

Ledger (2021) identified the following features of the South African policy environment as being responsible for the inaccessibility of energy services:

- The failure of policy and plans to give effect to the comprehensive affordable access goals of the White Paper on the Energy Policy of 1998.

- The conflicts of interest (between the financial viability of municipalities and the ability of low-income households to access affordable, clean, and safe energy) that were inadvertently created through an opaque and non-optimal local government fiscal framework, and
- The prevailing gaps across energy governance, which have prevented a broader, realistic overview of the realities related to providing affordable access to clean and safe energy, coupled with the fact that there is no singular organization responsible for realizing the goal.

Ledger (2021) states that the failed policy implementation exposes the unintended consequences of incorporating multiple, complex development goals into a maturing South African policy environment. These consequences manifest as trade-offs, which have been deeply prejudicial to poor households. The evolution of public administration from a bureaucratic approach to a new public management approach following the 1990s coincided with the democratic transition in South Africa. The energy sector was plagued with devices that exemplified the “user-pays principal” and failed to consider that many South African households depended on subsidized electricity, which was a function of racialized dynamics at the time.

Ledger (2021) therefore recognises an inherited oversight from the country’s seminal energy documentation and establishes that the drafters of the White Paper on the Energy Policy of 1998 clearly differentiated between physical access and affordable access. Therefore, additional measures were required to ensure that affordability was advanced. More recent policy has shifted the responsibility for delivering on the affordability objective onto the Integrated Energy Plan (IEP), as seen in Section 6(2) of the IEP. The IEP guides future energy infrastructure investments and policy development in South Africa. However, Ledger (2021) states that the IEP does not present a meaningful strategy for delivering affordability as a function of energy access. Furthermore, features such as FBE have become contentious trade-offs at the local government level, which reflects the unclear interdependencies that undermine access to affordable energy for millions of households.

Ledger (2021) concludes with several policy recommendations relating to the development of the South African energy landscape, but with a focus on policy, reporting, and implementation. Some of the policy recommendations include:

- Taking decisive action to ensure that municipalities significantly increase the number of registered indigent households eligible for and who receive services, including FBE,
- Defining what constitutes ‘affordable access to sufficient quantities of clean and safe energy’ and incorporating the definition into existing policy,
- Improving the oversight system around FBE service delivery significantly,
- Expanding South Africa’s JET definition so that distribution is enabled in addition to generation and transmission, with a clear focus that sees energy access as a transformative, pro-poor mechanism for socio-economic development, and
- Jointly developing a policy that integrates distribution while tackling the electricity supply crisis and energy system decarbonization.

2 Financing Targets for Achieving SDGs and National Development Plan (NDP) Goals

Given the probable impacts of climate change on the global commitment to decarbonization over the coming decades, what should the financing targets be for optimizing achievement of the energy and carbon SDGs and NDP goals by 2030, and extended to 2040 and 2050?

Low emission development and economic decarbonization are both required to meet the development goals in Chapter 5 of the NDP (regarding South Africa transition to an environmentally sustainable, climate-resilient, and low-carbon economy and society) and the NIP 2050 (which links the NDP objectives to actionable steps and intermediate outcomes), the socio-economic imperatives of the SDGs (end poverty and inequality, protect the planet, and ensure health, justice, and prosperity), as well as the decarbonization objectives of South Africa's NDC (South Africa's commitments to the Paris Agreement) (United Nations Framework Convention on Climate Change (UNFCCC), 2022).

To estimate the financing targets to address the overall and sectoral funding gaps, a contextual understanding of the total investment required to achieve these different goals is necessary. While this study aimed to determine the funding gap as a key outcome, most literature focuses primarily on investment needs. Accelerated impacts of climate change are likely to drive rapid financing into decarbonization, which involves mitigation-related development pathways. The Integrated Resource Plan (IRP) is the primary driver of generating capacity in South Africa and provides a roadmap for meeting South Africa's forecasted electricity demand. However, the development of the energy system is expected to align pathways that fundamentally enable GHG emission reduction and are cognisant of other overarching frameworks, due to global and national imperatives such as the SDGs, NDP goals, and the NDC (Department of Mineral Resources and Energy (DMRE), 2019). To achieve the required pace and scale of low emission development, public and private economic stakeholders must align on the capital projects required within the South African economy.

2.1 Factors Regarding Developing the Energy Landscape

Countries that have established renewable energy as a key feature of their energy landscape may express highly variable costs compared to distribution. Several key factors related to energy costs include geography, the type of renewable energy sources used, South Africa's overall energy mix ambitions, government policies, and prevailing economic conditions (Thiam, 2011). Some of the determinants of energy distribution from countries that have adopted renewables into their energy mix include the following:

- **Upfront costs:** The variability around high initial investments, which highlights the need to frontload the development of a renewable energy market, potentially plays the largest role in determining the affiliated energy pricing. The upfront costs for renewable energy infrastructure, such as solar panels, wind turbines, and hydropower plants, can be high. However, these costs have been decreasing as technology advances and economies of scale are realized, hence the

concept of scaling up (green infrastructure) to phase down (fossil fuel infrastructure) (World Bank 2023).

- **Government incentives:** Government incentives represent a major factor in determining capital expenditure and energy costs. Several countries offer incentives, subsidies, or tax breaks to encourage the adoption of renewable energy, including at the household level. These incentives can help offset the initial investment costs for both individuals and businesses. (Qadir et al., 2021). Recently, South Africa's policy landscape initiated several incentive opportunities to promote the uptake of renewable energy, including a solar panel subsidy for home installations (Viviers, 2023).
- **Running costs:** Aside from capital expenditure-related costs, operating and maintenance costs may define a sizeable portion of the subsequent energy pricing. The energy-utility death spiral is a phenomenon that relates how aging and inadequate infrastructure relay costs back to energy consumers, as is the case with conventional coal-fired power stations (Athawale and Felder, 2022). Compared to fossil fuel power plants, renewable energy facilities have lower operating and maintenance costs; however, technical ability may still drive operational expenditure costs in skill-scarce regions. Fundamentally, solar and wind farms require minimal ongoing expenses once they are operational compared to fossil energy plants (Cantarero, 2020).
- **Fuel cost variability:** Renewable energy sources such as sunlight and wind do not require fuel for generation. This can contribute to stable and predictable energy costs over the long term, as there is no exposure to fuel price volatility (Kumar and Jaipal, 2022). However, in South Africa, transmission and grid integration are expected to present a major source of pricing variability due to the limited capacity in many regions. The integration of renewable energy into existing power grids may require additional infrastructure investments, such as smart grids and energy storage systems, to handle intermittent energy from sources like wind and solar, which are generated outside the system controllers' landscape (Eskom, 2022a). Furthermore, variability is expected in legacy and future systems due to climate change. This may directly affect power generation, which relies on the availability of wind and sunlight (Yalew et al., 2020).
- **An enabling policy environment:** Supportive policies, such as feed-in tariffs or renewable portfolio standards, can impact the distribution of costs by providing financial incentives or requiring a certain percentage of energy to come from renewables (Kumar and Jaipal, 2022; Qadir et al., 2021). South Africa's energy and climate policy has been evolving over the past decades, and key instruments are discussed in subsequent questions in this report.

2.2 Estimating the Average Annual Investment Required

The accelerated impacts of climate change are likely to drive rapid financing into decarbonization, particularly across mitigation-related development sectors, of which energy is South Africa's most prominent. The IRP is the primary driver for guiding the development of new energy generating capacity in South Africa and has included funding for new coal-related generating capacity in several iterations (Merven et al., 2021a). However, due to global and national climate-related imperatives, such as the

SDGs, NDP goals, and the NDCs, the development of the energy system is expected to realign with pathways are cognisant of decarbonization and enable GHG emission reduction (DMRE, 2019, 2024a).

Estimates for the energy infrastructure funding requirements from various leading institutions are represented in Table 1. While the values were obtained across several studies, which investigated the energy infrastructure needs of South Africa, they represent different timeframes and development objectives. The average investment requirements of the studies considered here range from R86 billion to R157 billion annually (considering different timeframes).

Table 1: Funding Required to Transform South Africa’s Energy Infrastructure Landscape

Source	Total investment required (R’bn)	Period (Range)	Average annual investment (R’bn)
Meridian Economics – IRP 2023 Costs	3 800	2025–2050	152
Meridian Economics – Base Case RE Build	3 721	2025–2050	149
Meridian Economics – Likely RE Learning	3 642	2025–2050	146
Meridian Economics – Coal off by 2040	3 922	2025–2050	157
JET IP	648	2023–2027	130
NBI	2 850	2020–2050	95
BFT	3 225	2022–2050	115
Eskom	1 119	2022–2035	86
WEF Working Group	635	2024–2030	106

Sources: Meridian Economics, 2024; The Presidency, 2022; National Business Initiative (NBI), 2022; Blended Finance Taskforce (BFT), 2022; Eskom, 2022; World Economic Forum (WEF), 2024a.

Given the various criteria and assumptions that were considered in each report, the rationale behind these criteria includes:

- **Meridian Economics:** The ‘Review of the IRP 2023’ includes modelling several scenarios, namely ‘Base Case RE Build’, ‘Likely RE Learning’, and ‘Coal off by 2040’, where RE refers to renewable energy. An additional scenario, ‘IRP 2023 Cost Assumptions’, is also included, which is a least-cost optimization based on the cost assumptions from the Draft IRP 2023. The total cost metrics provided in Table 1 were estimated based on the limited cost metrics available in the report. Finally, while the Meridian Economics report considers grid constraints, it did not include grid costs. Therefore, the total costs presented for these scenarios are the total generation costs (Meridian Economics, 2024).

- **JET IP:** The JET IP establishes an investment target of R647.7 billion (USD 43.2 billion) specifically for the national electricity sector's infrastructure investment needs for five years from 2023–2027 (The Presidency, 2022). This includes coal plant decommissioning, transmission, distribution infrastructure, new solar photovoltaic (PV), new wind, and new batteries. The average annual investment to address the national electricity infrastructure requirement is estimated to be R130 billion (USD 8.6 billion).
- **National Business Initiative (NBI):** The components of the transition that the NBI forecasts include power generation, green hydrogen (GH₂), adjustments to the petrochemical, mining, heavy manufacturing, transport, building and construction, as well as agriculture, forestry, and other land use (AFOLU) sectors. When isolating the power sector investment focus for the NBI study, which includes generation and grid expansion costs, this value amounts to R2 850 billion and averages to R95 billion (USD 6.3 billion) annually from 2020 to 2050.
- **Blended Finance Taskforce (BFT):** The BFT expresses the following breakdown of their energy sector finance investment estimate: renewable energy build-out (R1 875 billion / USD 125 billion), flexibility in relation to electricity storage and gas (R750 billion / USD 50 billion), transmission and distribution (R600 billion / USD 40 billion), green industrialization (amount not stated), early retirement of coal plants (R360 billion / USD 24 billion), climate justice outcomes (R150 billion / USD 10 billion). Isolating purely infrastructure-related estimates, incorporating renewable energy (R1 875 billion / USD 125 billion), grid flexibility (R750 billion / USD 50 billion), and new transmission and distribution (R600 billion / USD 40 billion) equates to R3 225 billion (USD 215 billion) between 2022 and 2050. This results in an estimated annual investment of R115 billion (USD 7.7 billion) between 2022 and 2050.
- **Eskom:** In the JET Fact Sheet #005, Eskom indicates that the total funding required by 2035 amounts to R1 200 billion (USD 80 billion) (Eskom, 2022). Isolating energy infrastructure costs, Eskom estimates that R947 billion (USD 63.1 billion) would be necessary by 2035 for additional generation and storage, R120 billion (USD 8 billion) for additional transmission infrastructure, and R52 billion (USD 3.5 billion) to strengthen the distribution network. This translates to R86 billion per annum over the period 2022–2035.
- **World Economic Forum (WEF) Working Group:** A WEF-Accenture-DBSA working group forecast that doubling renewable energy capacity, to align with Horizon 1 from Draft IRP 2023, would require an estimated investment of around R245 billion (USD 16.3 billion) by 2030; however, generation capacity would be highly constrained by insufficient transmission on-take availability. The partnership reported that the additional infrastructure investment required for transmission capacity is estimated at R390 billion (USD 26 billion). Collectively, the physical infrastructure electricity investment put forward by the working group to transform the South African energy sector by 2030 would amount to R635 billion (USD 42.33 billion) (WEF, 2024a). This sum translates to R106 billion (USD 7.05 billion) annually up to 2030.

2.3 Scale of Need and the Investments Required to Achieve the JET IP Decarbonization Commitments

The JET IP addresses the investments required to support the decarbonization of the energy sector, in line with South Africa's updated NDP 2030 (The Presidency, 2022; UNFCCC, 2022). The implementation plan covers the investment requirements for the transformation of South Africa's energy sector from 2023 to 2027. The JET IP is geared towards addressing the triple challenges of inequality, poverty, and unemployment. Due to the embedded nature of the coal value chain and the pace of emerging technologies, the energy transition in South Africa must remain cognisant of disruptive social and economic consequences, as well as novel economic opportunities. To this end, several components of the JET IP framework highlight broader considerations, such as reskilling, skills development, municipal support, and social support, specifically for individuals and communities that may experience socio-economic fallout due to the transitioning energy sector (The Presidency, 2022).

Table 2: JET IP Financing Portfolios for NDC Alignment (2023–2027) and Approaching Net Zero (2023–2035)²

Allocation	Cost 2023 – 2027	Cost 2023 – 2035	Notes on investor expectation
Coal plant decommissioning	4.1	19.3	Eskom – These Eskom estimates are based on the cost of decommissioning of plants set to retire over three time frames and are in addition to the investment costs of repowering and repurposing projects contained in Eskom's project pipeline.
Transmission	131.8	373.2	Eskom-owned and operated.
Distribution	13.8	127.5	This investment requirement covers both Eskom and Municipal distribution systems, but excludes the current maintenance backlog in Municipal distributors.
New Solar photovoltaic (PV)	233.2	418.5	This includes utility-scale PV and distributed PV. Most investment is expected to come from the private sector, with some investment from Eskom in its repowering and repurposing programme.
New wind	241.7	874.3	Apart from an extension of Eskom's Sere wind farm and additions through its JET repowering and repurposing programme, this will be built and operated by the private sector.
New Batteries	23.1	44.2	Eskom has just awarded a contract to deliver phase 1 of a battery storage project. Other battery capacity may be built by Eskom or the private sector.
Total	647.7	1 857	

Source: The Presidency, 2022.

² Costs are reflected as R in billions, at time of financing forecasts: R15 (ZAR): USD 1 (USD)

Overall, the JET IP stipulates that the investment necessary for the entire portfolio, which includes energy, new energy vehicles (NEVs), GH₂, skills development, and municipal capacity sectors, amounts to R1 480 billion (USD 98.6 billion). The investment needed for the transformation of the physical energy infrastructure alone amounts to approximately R130 billion (USD 8.7 billion) annually from 2023–2027 and R143 billion (USD 9.5 billion) annually, based on the values from 2023–2035.

Regarding the net-zero goal and investment as forecasted by the JET IP, the report indicates that the five-year investment plan is designed to achieve the most ambitious outcome possible by 2030. This establishes the groundwork for long-term decarbonization in line with the accepted definition of a just transition in the JET IP. Therefore, the total JET IP funding requirement per sector, in relation to enabling the just transition and net-zero goals, spans multiple sectors and amounts to the previously stated R1 480 billion (USD 98.6 billion) over five years from 2023–2027 (The Presidency, 2022). The average annual investment necessary is estimated to be R296 billion (USD 19.7 billion).

2.4 Presidential Climate Commission (PCC) Assessment of the South African Climate Finance Landscape

The Presidential Climate Commission (PCC) represents an independent, multi-stakeholder body established by President Cyril Ramaphosa to address the pressing climate-related development challenges within South Africa. The overall mission of the PCC is to oversee and facilitate a just and equitable transition towards a low emissions and climate-resilient economy (PCC, 2023b). The PCC recognises that South Africa is committed to low-carbon sustainable development aligned to the UN 2030 Agenda, with similar ambitions established at the local level in South Africa's own NDP 2030. The PCC remains aware of guidance from the scientific community, and South Africa's updated NDC reiterates the commitment towards limiting global temperature rise to 1.5 °C above the pre-industrial level (PCC, 2023b).

Considering the breadth of climate financing required to address these framework guides, the PCC conducted a comparison of major climate funding flows, particularly related to the sectors of clean energy, low-carbon transport, smart water (supply and demand), circular economy, and sustainable agriculture. The PCC indicates that their snapshot study was based on both publicly available and proprietary data to map South Africa's current climate finance landscape and used climate finance accounting methodology from the Climate Policy Initiative (CPI) (2023) to adapt values to the South African context.

The PCC's assessment of the climate finance landscape found that current levels of climate financing were insufficient, and that annual climate finance in South Africa needed to increase by at least three to fivefold from the current average of R131 billion (USD 8.7 billion) per year.

The PCC's methodology estimates that South Africa requires R334 billion (USD 22.3 billion) per year to meet its net-zero goal by 2050, and R535 billion (USD 35.7 billion) per year to align with the NDC carbon budget window by 2030. The PCC forecast that NDC-related financing goals total R4 280 billion (USD 285.3 billion) per annum by 2030, while the total net-zero sum amounts to R8 684 billion (USD 578.9

billion) by 2050. With respect to sources of funding secured at the time of writing (which is only a fraction of the total required), the PCC, through values expressed in the second iteration of the South African Climate Finance Landscape, found that domestic sources of funding accounted for 91% of tracked climate finance. In comparison, international sources only accounted for the remaining 9% (PCC, 2023b).

2.5 National Business Initiative (NBI) on Decarbonizing the Power System and Associated Financing Strategies.

In a study relating to decarbonizing the South African power system (NBI, 2021), the NBI estimates that transitioning South Africa's power system to be less reliant on fossil fuels would require the deployment of at least 190 Gigawatt (GW) of wind and solar capacity by 2050. The assumed GW contribution assumes that the power sector will incorporate GH₂ as a last-mile decarbonization technology to provide seasonal balancing.

The anticipated power requirement is almost four times the total capacity of South Africa's coal power plants today. Meeting this requirement would require substantial investment annually until 2050, which is the anticipated net-zero milestone. In keeping with the updated NDC carbon budget, the NBI has expressed that R1 000 billion (USD 66.7 billion) is required by 2030, while R5 900 billion (USD 393.3 billion) would be needed by 2050 to fund the net-zero transition. When breaking these values down further, the NBI has attributed R460 billion (USD 30.7 billion) for 2020–2030, R1 020 billion (USD 68 billion) for 2031–2040, and R1 370 billion (USD 91.3 billion) for 2041–2050 for the power sector alone. Cumulatively, this means that R2 840 billion (USD 189.3 billion) would be required by the energy sector by 2050. The NBI based its calculations around a carbon budget of 9–10 Giga tons (Gt) by 2050.

The NBI has recognised that platinum and platinum group metals (PGMs) will play a crucial role in developing dispatchable GH₂ once the sector matures. However, dispatchable hydrogen will require a significant amount of renewable energy to be traded as a green fuel. Taking these factors into account, the NBI has established that investments in South Africa's energy infrastructure that will change the economic system catalytically are: 1) the funding of 190 GW of new renewable energy capacity by 2050; 2) the retiring of 70% of the current coal-generating capacity by 2040; 3) satisfying an emerging demand of 9 Mt p.a. of GH₂ through developing the hydrogen sector in proximity to South Africa's platinum group metals mining regions in the Bushveld Complex (primarily located in Limpopo, North West, and Mpumalanga provinces) (which will require an additional ~190 GW of renewables); and 4) the electrification of transport and other sectors (NBI, 2022).

According to the NBI study, assuming a historical real GDP growth rate of 2.4%, new investments should amount to at least 1.5% of GDP in the 2020s and 3% of GDP by 2050. Comparing the mitigation cost profile to similar developing nations indicates that while South Africa's mitigation costs compare favourably against India (60% of their total cost), South Africa is outperformed by Brazil (150% of their total cost). Brazil currently relies on significant hydroelectric capacity and a substantial ethanol-based liquid fuels sector; hence, a more diverse energy generation base requires lower mitigation investment. While South Africa's hydropower and ethanol fuel sectors are immature, South Africa does receive

comparatively higher rates of solar radiation than most other countries, which bodes well for private sector investment and solar market development (NBI, 2022).

The NBI expects that these investments will follow the demand and adjustments of the nascent renewable energy market, thereby reducing existing expenditure on fossil fuel procurement. Currently, the NBI has identified the electricity generation sector as the top priority for immediate investment, as it alone contributes 50% of South Africa's total annual emissions. The NBI states that while approximately R70 billion (USD 4.7 billion) per annum has already been mobilized for energy sector transformation, an average gap of R140 billion (USD 9.3 billion) per annum must be closed to fund the technical mitigation investment in the transition to 2050 (NBI, 2022).

The NBI indicates that 40% of the investments needed by 2030 would not be commercially bankable for the necessary projects without the catalytic role of blended finance. Concessional funding enables crowd-in commercial funding by facilitating blended finance opportunities on a project-by-project basis which makes it an important motivator of other funding instruments. A concessional loan from the International Partners Group (IPG) was recently made available to South Africa to support the Just Energy Transition (JET) initiative. While the USD 8.5 billion (R135 billion) mobilized by the JET Partnership (JETP) is considered a step forward for climate finance in South Africa, the total funding impact will depend on the proportion of funds originating from concessional sources and the blended finance ratios achieved (NBI, 2022).

Commenting on the role of business, the NBI states that the commercial finance sector is currently still a minor investor, contributing around 10% of total funding for adaptation and social components of a Just Transition. The NBI indicates that the commercial finance sector must adopt a mindset shift from a focus on core business operations towards strengthening their resilience, their supply chains, and communities through galvanizing peripheral and indirect resources.

The NBI argues that a lack of policy and strategy alignment, high perceived investment risk, a limited pipeline of shovel-ready projects, insufficient blended finance, and inconsistent green standards may hinder business-driven funding across the commercial finance sector. While these barriers are being addressed to enable greater private-public integration, the NBI also recognised new infrastructure opportunities, including GH₂, green power, gas, grid expansion, electric vehicles (EVs), and social and adaptation activities (NBI, 2022).

Regarding the NBI's net-zero goal, the NBI study establishes 2050 as a target year with major investments aligned to meet this goal, including energy, GH₂, petrochemicals and chemicals, mining, heavy manufacturing, transport, building and construction, as well as AFOLU sectors. The NBI states that R5 900 billion (USD 393 billion) is required in investment by 2050 to fund the net-zero transition. Many of these investments are commercially viable and will reduce existing expenditure on fossil fuel procurement (NBI, 2022). The average net zero-related investment necessary, as per the NBI, amounts to R196.7 billion (USD 13.1 billion) annually from 2020 to 2050.

2.6 Centre for Sustainability Transitions (CST) Stance Towards Just Energy Financing

Following the 2021 Conference of the Parties (COP) meeting, several Western nations agreed to pledge a substantial quantum of funds towards South Africa's JET IP, to expediate and catalyse transformation of South Africa's coal heavy energy sector. An amount of USD 8.5 billion (R128 billion) was committed by the IPG, the first of several country-led climate deals, specifically to accelerate the phasing out of coal, scale up renewables, and support workers and communities impacted by the transition towards a low-carbon economy. The BFT, in conjunction with the Centre for Sustainability Transitions (CST) at Stellenbosch University, produced the consultation paper 'Making Climate Capital Work' in 2022. The document speaks directly to the fact that IPG's concessional loan only represents 3% of the funding required for South Africa's ambitious energy transition. However, if used strategically, the loan could catalyze the transformation of the national energy landscape and potentially mitigate more than 1 Gt of carbon emissions (BFT, 2022).

The BFT identified several transition imperatives and opportunities that frame their assessment of the funding needed for an accelerated transition, which could prevent an additional 1.4 Gt of carbon emissions compared to the least-cost reference case. This would be highly dependent on coal as the primary source of energy and the coal value chain being deconstructed faster than the current 2040 deadline that is stipulated in Eskom's decommissioning schedule (Eskom, 2022c). According to the BFT, the investments necessary to maintain the country's generation capacity following an accelerated decommissioning would cost USD 250 billion (R3 750 billion) between 2022–2050.

The BFT also expresses that the capacitation could be covered by new renewable energy capacity coming online at 5 GW a year (effectively doubling the current installation rates). This uptake of new capacity would future-proof South Africa against some degree of energy insecurity challenges and is forecast to meet the projected energy demand growth of 1.5 times the current demand by 2050. To meet this goal, the BFT believes that approximately 50% of the country's electricity generation needs to be derived from renewables by 2030 which leaves less than six years to invest in the required infrastructure.

To identify the specific quantum of investment necessary to achieve net zero, the BFT does not specify a sum for the South African energy landscape. However, the report does compare the investment required to that of Indonesia, a similarly coal-heavy developing nation. Estimates of investment requirements range from R150 to R2 250 billion per annum (USD 10 to 150 billion per annum). The report also states that a portion of these investments will need to be concessional to decommission coal and mediate some of the social costs (BFT, 2022).

2.7 Eskom Regarding Building New Generation and Decommissioning Old Plants as Parallel Processes

The 2022 Transmission Development Plan (TDP) is Eskom's ten-year execution plan for delivering new transmission infrastructure. Through this 2022 TDP and related announcements, Eskom established that

South Africa is enduring an ongoing electricity shortage crisis for multiple reasons (Eskom, 2023a). These include the running of older coal-fired plants beyond their design life leading to increased rates of equipment failure. This stressed coal supply value chain results in quality, volume, and supply logistics challenges, as well as material power generation losses due to unavoidable decommissioning (c. 10 GW).

With respect to decommissioning existing plants and supplementing the grid with additional new generation capacity, Eskom plans to close seven coal plants out of their existing fleet of fifteen by 2030, as well as two more by 2035. Coal plant decommissioning costs reflect what Eskom has currently provided for in its planning. These costs exclude the costs of repurposing or repowering retired plants or other infrastructure investments. Eskom comments that as coal plants are decommissioned, an additional generation capacity of 57 GW and a storage capacity of 10 GW will be necessary to address the prevailing energy security challenges. Eskom underscores the need to build and connect 4–5 GW of new renewable generation each year to ensure a resilient power system by the early 2030s, translating to 16–20 GW in the next four years (Eskom, 2022a).

In addition to Eskom’s estimate, other institutions have also forecast the annual GW of renewable energy required to address the contemporary energy issues related to coal plant decommissioning. See Table 3.

Table 3: Annual Renewable Energy On-Take to Balance Coal-Plant Decommissioning

Institution	RE to be procured annually (GW)	Timeline
Eskom	4–5	2023–2030
Department of Public Works and Infrastructure (DPWI)	5	2023–2050
Meridian Economics	6	2023–2030
PCC	6–8	5 years

Sources: Eskom, 2022a; DPWI: NIP, 2022; Roff et al., 2023; PCC, 2023a.

Eskom is the architect of the grid potential and estimates grid development will cost at least R947 billion (USD 63.1 billion) and therefore comprise the majority of new infrastructure investment up to 2035. While this is expected to be driven by the private sector and blended finance vehicles, the financing of new transmission lines to support the uptake in this renewable energy will require state asset investments (Eskom, 2023b).

Eskom stated that the to-be-procured 57 GW of new additional power would be required to address the deficit in generation supply, which has steadily deteriorated since 2022, with losses averaging 14.2 GW in winter 2024. However, grid on-take capacity remains a critical challenge with respect to the rollout of new energy infrastructure. To accommodate this additional capacity, and assuming that obstacles to the implementation of the rollout plan are removed, the transmission infrastructure would need to be augmented by approximately 14 200 kilometres (km) of extra-high voltage lines, substations, and

transformers by 2035. The estimated cost of transmission infrastructure, as per Eskom's JET Fact Sheet #005, is R120 billion (USD 8 billion) (Eskom, 2022b).

Regarding the distribution network, Eskom is focused on implementing major energy infrastructure projects over the next five years. However, that requires the complementary strengthening of the distribution network. Eskom estimated that upgrading and bolstering the distribution network would cost R52 billion (USD 3.5 billion) by 2035.

Regarding decarbonization and net-zero goals, Eskom states in the JET Fact Sheet #001 that net zero implies some residual emissions, which will be reduced by carbon-absorbing technologies (Eskom, 2021a). Eskom adopts the view that these technologies will advance in the future; however, Eskom also recognises that the JET is part of the long-term strategy to transition towards financial sustainability and therefore hopes to achieve net zero carbon emissions by 2050. Eskom has not released quantitative estimates of the funding required for the net-zero goal, but has expressed that the JET will focus on elements in four main areas over the next five years to drive net-zero and social impact goals. These areas relate to justice for the people and the planet, providing energy, driving transformational change in business models, and creating a supportive ecosystem (Eskom, 2021a).

The National Treasury released the 2023 Budget Review, which focused on Eskom debt relief. The review states that a debt-relief arrangement is being established to cover R254 billion (USD 16.9 billion) in debt. The debt relief covers approximately R168 billion (USD 11.2 billion) in capital and R86 billion (USD 5.7 billion) in interest, over the next three years, with strict conditions. Of note is that a condition for the bailout is that Eskom's capital expenditure is restricted to transmission and distribution development. Therefore, the Government will be limited in providing funding for developing new generation infrastructure through Eskom, a state-owned entity (National Treasury, 2023).

2.8 World Economic Forum (WEF) Considers South Africa as Primed for Renewable Energy Investment

A WEF-Accenture-DBSA working group report forecasts that doubling the renewable energy capacity to align with Horizon 1 from the Draft IRP 2023 would require an estimated investment of R245 billion (USD 16.3 billion) by 2030; however, the generation capacity would be severely constrained by insufficient transmission on-take availability. The additional infrastructure investment required for transmission capacity is estimated at R390 billion (USD 26.0 billion). The working group determined that, in total, the infrastructure investment required to transform the South African energy sector by 2030 would amount to R635 billion (USD 42.3 billion) (WEF, 2024a).

3 Investment in Energy Infrastructure and the Funding Gap

What is the funding gap between current levels of investment in energy infrastructure and what will be required to achieve the relevant energy and carbon SDGs, NDP, and NDC goals, covering new capital, operations, and maintenance spending?

The energy and carbon related SDGs (end poverty and inequality, protect the planet, and ensure health, justice, and prosperity), NDP (aims to eliminate poverty and reduce inequality by 2030) and NDC (South Africa's commitments to the Paris Agreement) goals represent the overlapping lenses of social, socio-economic and climate-focused imperatives that are predicated on the transformation of the South African energy system and associated carbon-heavy industrialization (hard-to-abate sectors). Various current and planned energy generation technologies require connection and support through tailored funding mechanisms to meet the goals outlined in the frameworks.

3.1 JET IP Indicates a Persistent Funding Gap of R315 Billion for Transforming the Electricity Sector by 2027

Currently, numerous JET guidance- and implementation-related initiatives are underway in South Africa, driven by government institutions, research organizations, the private sector, and civil society. These initiatives, which range from infrastructure to skills development, are financed by a range of government programmes, partner governments, DFIs, MDBs, philanthropies, corporate social investments, impact investors, and commercial investors (The Presidency, 2022).

While new development is paramount for bolstering South Africa's energy supply to meet the increasing demand from a growing population, addressing the current and expected energy shortfalls has made it clear that further funding must be mobilized at scale to support the JET IP. With respect to translating funding for the JET into alleviating energy insecurity, South Africa's energy landscape remains impacted by complex challenges. Fundamentally, project preparation is yet at the stage of being bankable. Additionally, only a few of the concessional loan pledges made to the JET IP have become financing agreements, showing that new climate finance funds are not yet flowing at scale into targeted projects. The Presidency expressed that there is much to be done to create the institutional capability for efficient and cost-effective execution (2022).

The JET IP establishes that the total quantum of funding needed for meeting the goals of the JET, which includes remaining within the updated NDC carbon budget, is R1 480 billion (USD 98.7 billion) from 2023 to 2027. Specifically related to electricity and excluding NEVs and GH₂, the value amounts to R1 030 billion (USD 68.6 billion). The JET IP assessment determined that the total financing target of R1 400 billion (USD 98.7 billion) should stem from public funding (DFIs and MDBs) of R150 billion (USD 10 billion), private sector funding of R500 billion (USD 33.3 billion), and the IPG offer of R128 billion (USD 8.5 billion), leaving a total funding gap of R700 billion (USD 46.7 billion), or 44%.

The JET IP estimates that R1 030 billion (USD 68.7 billion) would be required for the electricity commitment. Of that, R100 billion (USD 6.7 billion) would be obtained from public funding (DFIs and MDBs), R500 billion (USD 33.3 billion) would be from the private sector, and R115 billion (USD 7.6 billion) would be from the IPG loan, subsequently resulting in a funding gap of R315 billion (USD 21 billion), or 25%.

The Presidency (2022) recognises that the needs of the necessary grant funding outstrip the supply of concessional financing for this period of the JET IP. However, the loans and grant funding provisioned between South Africa and the IPG represent a significant first phase of investments towards managing South Africa's JET. Understanding the basis of the JET IP forecast quanta per committed investor clarifies how the JET IP expects funding to be mobilized. The JET IP assessment of the South African financial sector landscape presumes that South Africa presents a favourable sector for attracting foreign and local investment, particularly due to the following key factors:

- 1) Established and liquid capital markets with a sizable asset base, an active foreign exchange platform, and a mature bond market,
- 2) Maturing financial governance framework, with several established functional entities such as the Prudential Authority, the South African Reserve Bank (SARB), and the Financial Sector Conduct Authority (FSCA),
- 3) Independence and functionality of the central bank that protects the value of the currency in the interest of balanced and sustainable economic growth, and
- 4) Emerging specificity of sustainable finance regulations, and
- 5) Initiatives that generate interest and buy-in from the private sector to participate in the JET.

The JET IP reports that there appears to be significant funding already from the private sector, which can provide commercial debt funding, particularly in relation to the development of renewable energy generation. For example, the Renewable Independent Power Producer Procurement Programme (REIPPPP) facilitates private sector investment into grid-connected renewable energy generation in South Africa and municipal-level projects. The values utilized in the JET IP are based on the already tracked funding estimates found in the South African Climate Finance Landscape for 2020 (Cassim et al., 2021).

The Presidency (2022) report serves as a useful benchmark for understanding the quanta of current private and public funding deployed towards climate and JET-related outcomes. The report estimates that an average R70 billion (USD 4.7 billion) has been annually mobilized for climate and energy purposes, which is double the average invested in the sector over the last six years. However, the updated carbon window, which reflects South Africa's updated NDC submission, estimates that an average USD 8 billion (R120 billion) is required annually until 2030. The preeminent funding sources, as alluded to by the JET IP, include public institutions, such as DFIs and MDBs, the private sector, and grant or concessional loan instruments such as the IPG. The contributions of each are briefly outlined in the following sections.

3.1.1 South Africa's Development Finance Institutions (DFIs)

At various stages, South African DFIs have been central to attracting and enabling access to international climate and energy transition finance facilities. The JET IP estimates that existing investments from this sector may already be focused on new renewable energy projects (e.g., REIPPPs), with the International Development Corporation (IDC) already having assisted with financing approximately R24.5 billion (USD 1.63 billion) of climate and energy related development, effectively facilitating a project pipeline valued at R12.3 billion (USD 0.82 billion).

MDBs such as the New Development Bank (NDB) have also made considerable contributions towards JET-related financing. The Presidency (2022) reported that in addition to JET-related financing of R81 billion (USD 5.4 billion), the NDB committed a further R45 billion (USD 3 billion) over five years in co-financed investments. The aim of the finance relates to the explicit intent of the NDB to advance the decommissioning of coal-fired power stations, upgrade the transmission lines, and develop the nascent GH₂ sector through several strategic plays.

3.1.2 Investments from the Private Sector

The Presidency (2022) recognises that South Africa has a highly heterogeneous economy, characterized by extremes in both wealth and poverty. Similarly, South Africa has entrepreneurial and educated individuals who are aware of the risk of climate change and willing to advance mitigation and adaptation measures, which will indirectly boost South Africa's global standing. To this end, the local private sector has shown an appetite for investing in climate finance assets, particularly new renewable energy supply. This aligns with South Africa presenting a prime location for renewables due to the geographic insolation factor, the need for new energy to combat energy insecurity challenges, as well as the need to address the enduring challenges of inequality, poverty, and unemployment.

The JET IP indicates that several local financial institutions have made public commitments to finance climate and energy related assets, totalling R500 billion (USD 33.3 billion) over the next three to five years. The 'just' element of the proposed funding commitments is expected to mirror the REIPPPP and be incorporated in both project planning and as a contribution to the project's total value (The Presidency, 2022).

3.1.2.1 Registration of New Generation Through the Private Sector Grew in 2024

NERSA established that from January to March 2024, 105 generation facilities had been registered into the energy system, raising the total number of private facilities to 1 415 since the system's inception in 2018. The energy regulator expressed that the newly registered facilities generated a combined capacity of 788 Megawatt (MW) and presented a total investment of R18.4 billion (USD 1.2 billion), increasing the overall contribution from the sector to 7 158 MW valued at R131 billion (USD 8.7 billion) to date (Engineering News, 2024).

The market has been responsive to the liberalization of the regulatory restrictions that had previously governed private generation. NERSA stated that as of May 2024, 77 generation facilities, with a combined capacity of 664 MW, had been connected to the Eskom network, while 28 generation facilities, with a capacity of 124 MW, were connected to the municipal distribution network (Engineering News, 2024).

3.1.3 Other Financing Instruments

The JET IP indicates that blended finance will be obtained from various instruments, such as concessional and grant funding, government guarantees, DFIs (in addition to the IPG pledges), climate finance institutions, and philanthropies, deployed in a way that mobilizes, or crowds in, additional local and international private sector capital (The Presidency, 2022).

3.2 PCC Base a Funding Gap on Estimates Extrapolated from the South African Climate Finance Landscape (2020)

With respect to the mix of climate finance and the associated transformation of the energy sector, the PCC determined that mitigation financing represents 81% (R105 billion / USD 7 billion p.a.) of total finance tracked, adaptation finance 12% (R16 billion / USD 1.06 billion p.a.), and dual benefits financing 7% (R10 billion / USD 0.67 billion p.a.) (PCC, 2023b). The enduring energy insecurity in South Africa, combined with falling technology costs (e.g., for solar PV panels) and increasing grid-bound electricity prices, has resulted in the energy sector remaining the greatest priority for transformation, receiving more than 63% of the total tracked climate investment.

Caveats of the PCC assessment of the climate financing landscape include that estimates of South Africa's annual climate finance needs will vary depending on the period, sectoral focus, and methodology of the study. Nevertheless, the breakdown reiterates that energy, transport, and energy efficiency account for the majority of the mitigation finance needs across the studied reports (PCC, 2023b). The PCC assessment of the energy sector needs found that the investment requirement ranges from a minimum of R42 billion (USD 2.8 billion) p.a. to a maximum of R198 billion (USD 13.2 billion) p.a., with an average investment need of R111 billion (USD 7.4 billion) p.a.

The PCC quantified the received funding according to the report and associated methodology published by the CPI (2023) on the South African Climate Finance Landscape. It reports a total of R131 billion from public and private sources for uses of mitigation, adaptation, and dual benefits. Segmented for clean energy and energy efficiency investment only, the R131 billion reduces to R103.11 billion. In addition to this amount, the IPG loan of approximately R5 billion per annum is acknowledged separately, as the commitment was only made after the funding received for clean energy and energy efficiency was quantified. These values show that South Africa's climate finance needs must increase by three to five times to achieve the country's climate objectives, which are related to the NDC targets and the net-zero ambition by 2050 (PCC, 2023b).

Utilizing the annual average climate finance available for the earlier 2019–2021 period, which was R131 billion (USD 8.7 billion), the PCC estimated a funding gap of R404 billion (USD 26.9 billion) per annum. This value may present a more realistic estimation of the funding outstanding that is required to meet South Africa’s NDC goals. However, this value needs qualification as it extends beyond new generation, transmission, and distribution infrastructure requirements (PCC, 2023b). The PCC (2023b) found that within the energy sector, investment requirement estimates range from a minimum of R42 billion p.a. to a maximum of R198 billion p.a., with an average investment need of R111 billion p.a. The study stopped short of attributing an estimated funding gap directly to the energy sector.

3.3 Energy Landscape Forecast by the NBI

The NBI expects that the required investments should follow the demand and adjustments of the emerging renewable energy market and will therefore reduce existing expenditure on fossil fuel procurement. Currently, the NBI has identified the electricity generation sector as the top priority for immediate intervention, as it contributes approximately 50% of South Africa’s total annual emissions. The NBI reports that while approximately R70 billion (USD 4.7 billion) per annum has already been mobilized for energy sector transformation, an average gap of R140 billion (USD 9.3 billion) per annum must be closed to fund the technical mitigation investment in the transition to 2050 (NBI, 2022).

4 Policy and Regulatory Frameworks for Investment in Energy Infrastructure

What policy and regulatory frameworks are in place to govern the flow of public and private investments in energy infrastructure and service delivery with respect to technologies, service levels, and resilience in the face of climate change?

There are two elements of regulatory oversight to consider when assessing the extent to which South Africa's regulatory framework supports the flow of investment into energy infrastructure. Firstly, the regulatory framework governing the actual generation and flow of electricity must be considered. This includes energy and climate change-related laws and policies, which require investment in green electricity. However, energy and climate-related policies only provide greater regulatory certainty for prospective investors in energy infrastructure.

Secondly, financing mechanisms must be in place to facilitate the actual flow of investment, linked to the regulatory certainty provided by energy and climate-related laws. The existing energy regulatory framework and investment flow instruments are discussed below.

4.1 Energy and Climate Change Regulatory Framework

The primary regulatory framework for the deployment of energy infrastructure consists of the relevant energy and climate-related laws and policies adopted in the country. Based on a review of applicable laws and policies, a regulatory hierarchy becomes apparent, whereby international law and best practice examples from foreign jurisdictions influence domestic laws and policies. Figure 1 is a high-level overview of the applicable laws and policies that will be assessed as part of this study.



Figure 1: Laws and Policies Assessed

From a global perspective, South Africa’s international commitments must be considered as part of the country’s energy planning processes. While South Africa is not legally bound to reduce its GHG emissions (being a non-Annex I developing country member of the UNFCCC and the Kyoto Protocol), South African courts have ruled that climate change assessments are required as part of the environmental authorization process, before approving new coal-fired power plants. The continued reliance on conventional fossil sources could be construed as contrary to South Africa’s obligations under international laws governing GHG emissions. Additionally, South Africa has committed to its self-imposed NDC to mitigate emissions under the Paris Agreement on Climate Change. These international imperatives must therefore serve as push factors for a transition towards a greater share of renewables in the energy mix.

At the apex of the domestic legislative hierarchy, the Constitution³ sets out how all the elements of Government are organized and legislates what power is wielded in terms of electricity provision, who wields it, and over whom it is wielded. All laws and policies related to energy and electricity reticulation must therefore conform to the provisions expressed in the Constitution. Section 153 of the Constitution

³ *Constitution of the Republic of South Africa, 1996.*

places the responsibility on municipalities to ensure the provision of services to communities in a sustainable manner and to promote economic and social development. These services include electricity reticulation. Providing electricity is therefore an important funding source for local governments, particularly for larger urban municipalities.

National climate change governance in South Africa is the product of over two decades of policy evolution and has been shaped by a complex landscape of executive policies, strategies, regulations, and institutions. The 2004 National Climate Change Response Strategy, followed by the National Climate Change Response White Paper (NCCRWP) approved in 2011, forms the foundation of national climate policy. In 2012, climate change became a key element of the NDP, and in July 2024, the Climate Change Act was signed into law. The Climate Change Act enables the alignment of policies that influence South Africa's climate change response, to ensure that policy contradictions do not constrain South Africa's transition to a low-carbon and climate-resilient economy and society. The current provisions of the Act will require the private and public sectors to reduce emissions and explore alternative energy options and investment in energy infrastructure as part of their response to climate change.

South Africa has a plethora of laws that aim to regulate the energy and electricity sectors. South Africa's energy laws primarily regulate who may generate, transmit, and distribute electricity. However, the generation, transmission, and distribution aspects of the laws are somewhat limited to fossil fuel-based energy sources such as coal. Nonetheless, South Africa's emerging climate change legislation will necessitate the increased uptake of low-carbon energy infrastructure. The White Paper on Energy Policy of 1998 is South Africa's overarching document that sets out the Government's official policy on the production, distribution, and consumption of energy. It provided the first comprehensive perspective of South Africa's official overall energy needs and options and laid the foundation for energy laws such as the National Energy Act (NEA)⁴ and the Electricity Regulation Act (ERA). The initial commitment to renewable energy technologies in the White Paper on Energy Policy was supplemented by the White Paper on Renewable Energy of 2003. However, the provisions of the White Paper on Energy policy are now two decades old and must be reviewed to account for the technological advancements and changes that are currently occurring in the energy sector.

South Africa's primary pieces of legislation regulating the electricity sector, which have led to the energy investments seen thus far, namely the NEA and the ERA, contain provisions that can be argued to support renewable energy implicitly.

The NEA is South Africa's overarching piece of legislation for the energy sector and directs the DMRE to ensure that a diverse range of energy resources are available, in sustainable quantities and at affordable prices. The NEA is supplemented by various pieces of legislation that focus on specific energy sources, such as petroleum, natural gas, and nuclear energy.

⁴ *National Energy Act 34 of 2008, Government Gazette No. 31638, 24 November 2008.*

The ERA establishes a national regulatory framework for the generation, transmission, and supply of electricity in South Africa. Although the promotion of renewable energy is not explicitly mentioned in the objectives of the ERA, there are implicit references used to support the argument for increased renewables in the country's energy mix. This is evident when considering the references to sustainability and the acknowledgement that the interests of future electricity customers must be considered.

Although South Africa's energy legislation supports the uptake of renewables and the concept of sustainable development, these laws have no specific provisions that would directly result in the increased uptake of renewable energy, and their provisions remain fossil fuel oriented. However, on 10 February 2022, the Minister of Mineral Resources and Energy published the Electricity Regulation Amendment Bill (promulgated in January 2025) to support the transition from the current vertically integrated, Eskom-dependent electricity market to a multilateral and competitive one, managed by a transmission system operator (TSO). There will be three ways in which electricity can be bought and sold, which will foster competition, increase investment in the necessary electricity infrastructure to support the deployment of low-carbon electricity generation, and drive down electricity prices in the medium term. These are:

- Trading, through a non-discriminatory trading platform on which market participants may trade with each other on an hourly and daily basis,
- Private power purchase agreements (PPAs) between licensed or registered generators and direct customers and traders, and
- Regulated PPAs between generators and the single buyer office of the TSO, or the buyers determined by the Minister of the Department of Electricity.

Supporting the development of the electricity market envisioned under the Electricity Regulation Amendment Act⁵ will require several supporting regulations, market codes, and guidelines. This study will explore these supporting regulatory measures.

4.1.1 Financing Mechanisms

The South African Government is undertaking a massive infrastructure drive to revive growth and increase employment. This undertaking comes at a time when the country is facing a deep economic crisis that has progressively worsened over the past few years, exacerbated by the COVID-19 pandemic. Private sector infrastructure investment will be crucial for driving the country's economic recovery process. However, this requires that Government introduce measures to de-risk infrastructure investment. The three most prominent de-risking policy-based mechanisms introduced by the South African Government are:

⁵ *Electricity Regulation Amendment Act 38 of 2024, Government Gazette No. 51778, 18 December 2024.*

- a) **Blended finance:** This refers to the use of public and development finance to attract private sector participation by providing incentives, such as subsidies, revenue guarantees, and capital grants.
- b) **Converting infrastructure into an asset class:** A process whereby funds invested in infrastructure projects, like loans, are repackaged into financial instruments to be traded in the financial market. For example, the amendments to Regulation 28 of the Pension Fund Act,⁶ which allow private retirement funds to invest in alternatives such as infrastructure asset classes, represent a major regulatory change aimed at encouraging investment in clean energy infrastructure.
- c) **Public-private partnerships (PPPs):** These are a highly controversial form of infrastructure financing, which involves long-term contracts with private partners. The activity of PPPs is expected to increase over the next few years. Processes are also underway to deregulate the PPP framework to make it easier to set up PPPs and attract private investors.

The trend towards private provision of infrastructure has also been reinforced by the emergence of significant capital availability in South Africa for infrastructure investment, resulting from financial deregulation and South Africa's superannuation. However, most climate finance flows are facilitated through market-rate debt instruments, with an average cost of capital ranging from 10% to 12% (PCC, 2023b).

Given the long-term nature of infrastructure, investing in these assets can be appealing to retirement funds, particularly in times of rising interest rates and inflation. As of 1 January 2023, amendments to Regulation 28, issued in terms of Section 36(1) (bB) of the Pension Fund Act, became applicable to encourage investment in infrastructure. Regulation 28 protects retirement fund member savings by limiting the extent to which funds may invest in a particular asset or particular asset classes, and prevents excessive concentration risk.

The regulations widen the scope of potential investments for retirement funds but continue to leave the final decision on any investment to the trustees of each fund, who determine the investment policy for any fund. The review of Regulation 28 is in response to several calls for increased investment in infrastructure, given the current low economic growth climate. The amendments seek to make it easier for retirement funds to invest in infrastructure.

To that end, the amendments introduce a definition of infrastructure and set a limit of 45% for exposure in infrastructure investment. To facilitate further investment in infrastructure and economic development, the limit between hedge funds and private equity has been split. There will now be a separate and higher allocation of 15% to private equity assets, which is an increase from 10%. A limit of 25% has been imposed across all asset classes to limit the exposure of retirement funds to any one entity (company),

⁶ *Pension Funds Act 24 of 1956, Government Gazette No. 5679, 11 May 1956.*

not just infrastructure. However, exceptions to the per-entity limit include debt instruments issued by, and loans to, as well as any debt or loan guaranteed by the Government of South Africa.

5 Policy, Institutional, and Regulatory (PIR) Changes to Enable Increased Investment

What policy, institutional, and regulatory (PIR) changes will be required to enable an increased level of investment in climate-resilient energy infrastructure and services to achieve the NDP and SDG targets?

Regulatory support must be provided from an energy and climate change perspective, as well as a financing perspective. The high-level recommendations associated with developing both these elements are discussed below.

5.1 Energy and Climate Related Laws and Policies

The various energy laws and policies revealed that South Africa's energy laws are based on the procurement of fossil fuel-based energy. Legal reforms aimed at promoting renewable energy and green infrastructure development appear to have been superseded by developments in both technology and the social, economic, and political climate in South Africa. Piecemeal policy interventions such as the now-outdated IRP (the IRP provides a roadmap for meeting South Africa's forecast electricity demand), the Electricity Regulations on New Generation, and the amendments to Schedule II of the ERA (the ERA sets up a national regulatory framework for electricity in South Africa) have all demonstrated the precariousness of truly promoting renewable energy generation. To address the electricity supply gap and support the economic development in the country, more robust mechanisms are needed to create the certainty for private sector investors to realize returns on investments in energy infrastructure. Integrating renewable energy into South Africa's energy law fully requires a drastic overhaul of a fair number of energy laws or the drafting of new legislation to integrate and regulate renewable energy in South Africa properly.

To a certain extent, the National Energy Act⁷ (which aims to address the energy crisis and ensure a continuous energy supply) can be used to transform the energy industry by promoting low-carbon renewable sources. The National Energy Act requires the Minister, in consultation with the Minister of Trade, Industry and Competition, the Minister of Employment and Labour, and the Minister of Forestry, Fisheries and the Environment, to "adopt measures not contemplated in any other legislation, to minimise the negative safety, health and environmental impacts of energy carriers."⁸ Renewable energy is an option to minimize environmental and climate change impacts whilst providing an affordable source of energy as required by the SDGs (end poverty and inequality, protect the planet, and ensure health, justice, and prosperity).

Furthermore, Section 5 of the NEA imposes a duty on the Minister of Mineral Resources and Energy to promote access to affordable, sustainable, and environmentally suitable energy and energy services to

⁷ *National Energy Act 34 of 2008, Government Gazette No. 31638, 24 November 2008.*

⁸ *See section 4 of the National Energy Act 34 of 2008.*

all people. This provision supports the environmental right as contemplated in Section 24 of the Constitution and confirms the Minister's duty to supply environmentally conscious electricity as a basic human resource as set out in Section 26 of the Constitution. Section 5 of the National Energy Act also mandates the Minister to maintain and build new infrastructure for the provision of energy, this mandate is elaborated upon in Section 18 of the Act.

The National Energy Act appears to promote renewable energy to a certain extent in Section 19(1) that provides that: "The Minister may, after consultation with those Cabinet Ministers whose areas of responsibility will be affected by the proposed regulations, without derogating from his or her general regulatory powers, by notice in the Gazette make regulations regarding: (d) minimum contributions to national energy supply from renewable energy sources; (e) the nature of the sources that may be used for renewable energy contributions to the national energy supply; and (f) measures and incentives designed to promote the production, consumption, investment, research and development of renewable energy". To date, South Africa has yet to see such regulations, which are specifically aimed at promoting the adoption of renewable energy in the country.

Based on international experience, deploying renewable sources has been easier where the market has been liberalized, as the sector is more active. This contrasts sharply with the situation in South Africa, where the energy system remains largely managed by the state-owned utility that not only monopolizes the industry but also influences policy directions. However, the promulgation of the Energy Regulation Act⁹ in January 2025 will formally set up a wholesale electricity market in South Africa, supported by a day-ahead electricity trading platform. However, the setup of the trading platform to allow for increased investment in privately funded energy infrastructure will require additional inception elements to be finalized. This includes the design of the market itself, its associated trading infrastructure, market codes, and participation guidance. These aspects are likely to take three to five years to complete and should be expedited once the Bill is passed into law.

The role that laws play in promoting renewable energy infrastructure is evident in jurisdictions such as Germany, Spain, Denmark, and China, which have made renewable energy a major component of their energy mixes. Countries such as Germany and the United Kingdom (UK) have concurrently implemented climate change and renewable energy laws and policies to increase the generation capacity of renewable energy, thereby contributing to climate change mitigation targets. However, the fact that strategies have worked with varying degrees of success elsewhere is no guarantee that they will work in the South African social, economic, governance, and political environment.

South Africa's Climate Change Act¹⁰ does not refer to renewable energy or the phasing out of fossil fuels. In fact, the Act does not even mention the importance of decarbonizing the energy sector, which is currently the country's largest contributor to GHGs and climate change. The final version of the Climate

⁹ *Electricity Regulation Amendment Act 38 of 2024, Government Gazette No. 51778, 18 December 2024.*

¹⁰ *Climate Change Act 22 of 2024, Government Gazette No. 50966, 23 July 2024.*

Change Act does not acknowledge the role that renewable energy can play as a catalyst to drive climate change mitigation and does not highlight the interdependency between renewable energy and climate change. This could be considered a flaw when compared to the integration of energy and climate change law that has occurred in other jurisdictions. Interconnecting energy and climate change laws will also enable stakeholders and government officials to understand their roles and apply the laws to achieve the legal objectives and SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all).

South Africa could also consider supporting investment by adjusting the existing tax incentives under the Income Tax Act¹¹ and the Customs and Excise Act¹² (such as accelerated depreciation, tax allowances, and duty-free) to make them more favourable for investments in energy and climate-related sectors. Such incentives have proved effective in other emerging and industrialized countries. The development of eco-industrial parks under the Special Economic Zones (SEZs) Act¹³ should be accelerated to help realize economies of scale for investors (World Bank Group, 2022).

5.2 Infrastructure Financing Mechanisms

The local market has been slow to adopt new instruments that can ramp up funding for infrastructure. This may be a function of the market still playing catch-up with regulatory changes, i.e., the increase in the ceiling for self-generation under Schedule 2 of the Electricity Regulation Act, as well as the change in the infrastructure investment ceiling for pension funds. Furthermore, there is little evidence to suggest that practitioners are proactively thinking about designing new and innovative instruments and mechanisms that could accelerate the mobilization of private sector funding for infrastructure investment.

Complex issues, including pricing, access, public policy and regulation, risk-sharing, tendering processes, taxation, and governance, are key challenges that will influence whether the private provision of infrastructure can provide a viable new model in South Africa. Sustainability has introduced an additional dimension into the calculus of infrastructure provision. A framework that considers environmental and social aspects, as well as economic aspects, is now widely accepted as necessary (PCC, 2023a).

The only way that South Africa will ever attract funding at scale is if the country can offer liquid investments to capital allocators that yield competitive, risk-adjusted returns over the medium to long term. There is a need for packaging transition financing instruments in a way that is accessible to institutional investors. This is applicable for both domestic and offshore investors. For example, portfolios of renewable energy IPPs that are in the operations phase could be more attractive than investing in a single renewable energy project, as this diversifies investor exposure (AIIM Africa, 2022).

¹¹ *Income Tax Act 58 of 1962, Government Gazette, 25 May 1962.*

¹² *Customs and Excise Act 91 of 1964, Government Gazette No. 866, 31 July 1964.*

¹³ *Special Economic Zones Act 16 of 2014, Government Gazette No. 37664, 19 May 2014.*

Stronger adoption of sustainable finance instruments listed on exchanges is required to develop the market and increase liquidity. To achieve this, local capital markets need more robust engagement with transactors to determine what is hindering the adoption and widespread utilization of these instruments. At the same time, banks need to think about how these instruments can be pooled into funds to improve the risk profile for institutional investors, including liquidity and credit risks. Banks will become crucial participants as they possess the networks and relationships necessary to build the required momentum for asset management, contributing to partnerships with DFIs and others. While this is already being demonstrated, the scale required is not yet being achieved.

Additionally, multilateral organizations can create fund structures to overcome the issues related to deal size and due diligence costs. Developing a renewable energy fund, for example, will de-risk investments from a portfolio diversification perspective. To enhance the appeal for commercial capital, development funders can provide first-loss capital, guarantees, or foreign exchange hedges.

Global institutional investors can contribute by using innovative financing solutions such as green and sustainable bonds. In 2014, South Africa was the first country in Sub-Saharan Africa to issue a green bond. Still, only 18 corporate issuances totalling USD 1.3 billion (R19.5 billion) had taken place up to the end of 2021. The green bond market could be expanded by providing tax exemptions and by building additional ability for green bond verifiers, so that issuance costs could be decreased. The Government can provide benchmarks for private issuers by proceeding with public offers in line with the debt sustainability framework, the Green Bond Principles and the applicable taxonomy, which will identify eligible investments (World Bank Group, 2022).

Key themes related to financing mechanisms appear that would need to be considered when designing investment vehicles. Particularly if these vehicles are to realize the NDP goals (aims to eliminate poverty and reduce inequality by 2030) and SDG targets. (Cergibozan, 2022):

- **Diversification and flexibility:** Flexibility is a key aspect of innovative financing models. For example, Qualified Public Infrastructure Bonds (QPIBs) introduce flexibility in attracting taxable investors to PPPs. Green bonds provide a flexible avenue for investors interested in environmentally conscious projects.
- **Risk considerations and credit enhancement:** Credit enhancement mechanisms and the potential role of monoline insurance will become increasingly important to attract investors and ensure the success of infrastructure financing.
- **Government backing and stability:** Government, municipal, and sub-sovereign bonds are considered traditional and stable sources of infrastructure funding. The explicit or implicit backing from sovereign entities provides investors with a sense of security.
- **Appeal to environmental consciousness:** The emergence of green bonds marks a growing trend in the financial markets, appealing to investors seeking to finance projects with positive environmental impacts. The role of green bonds in funding clean energy and climate change initiatives is growing, and offers tremendous opportunities for infrastructure investment.

- **Long-term financing and maturities:** Long-term financing is crucial in infrastructure projects, and various instruments, including corporate bonds and project bonds, offer longer maturities. This aligns with the need for sustained funding throughout the construction and operational phases.

To create a more conducive investment financing environment, South Africa and its development partners should collaborate to mobilize additional external concessional funds. This could include leveraging the financial mechanisms of the UNFCCC, such as the Green Climate Fund and the Global Environment Facility. As mentioned, blended finance (mixing domestic and international resources) could help spread the risks and crowd in private capital alongside proper domestic policies. Such solutions should involve technical assistance grants and credit enhancement mechanisms (for example, first-loss) that partially de-risk pools of financial investments. As part of this support, development partners should consider the use of concessional resources to lower the cost of financing. The international community should help provide these long-term financing instruments, such as concessional debt with a long grace period (World Bank Group, 2022).

Further research is required to map out the various funders in the financing ecosystem and identify who is best suited to fund specific energy related infrastructure projects, as well as the specific mix of local vs foreign commercial capital, public sector financing, development funding, and philanthropic funding that needs to be mobilized along the 30-year time horizon (AIIM Africa, 2022).

6 Improving the Reliability of the Power Supply

How can the reliability of power supply, which disproportionately affects poorer households, be improved to meet SDG targets, whilst being aligned to the Just Transition Framework (JTF)?

A range of mechanisms exists to improve the reliability of power supply, especially to poorer households, including:

- **Diversification of energy sources:** This includes reducing reliance on coal by increasing the share of renewable energy sources like solar and wind. This can mitigate the impact of power outages and improve overall energy security (Cergibozan, 2022). The Draft IRP 2023 suggests a significant build-out consisting of solar PV, wind, and gas at mid-merit or higher utilization. This build-out is essential to ensure long-term reliability of supply, with significant requirements by 2035 to prepare for subsequent periods up to 2050 (DMRE, 2024a). This study also established that significant solar PV, onshore wind, and battery energy storage system (BESS) capacities are being built and spread throughout the nine provinces to improve the security of supply in the medium to long term.
- **Grid modernization:** Improve overall reliability by upgrading the existing grid infrastructure to manage intermittent renewable energy sources. This includes investing in smart grid technologies that can enhance grid management and reduce outages (Energy Journal Africa, 2023). The deployment of smart grid technologies can decrease outage durations and improve system reliability (Saini et al., 2022).
- **Energy storage solutions:** This includes investing in energy storage technologies, such as batteries, to ensure a stable electricity supply. Energy storage can help balance supply and demand, providing back-up power during outages (Thango and Bokoro, 2022). This can be especially useful in ensuring rural areas of the country have access to electricity, despite not being directly connected to the national grid.
- **Decentralized energy systems:** While this might be more related to access rather than reliability, decentralized systems can provide reliable power to communities that are not connected to the main grid (Bloem et al., 2021). Renewable energy-based microgrid systems are particularly viable for rural communities, improving quality of life and creating job opportunities (Adefarati and Bansal, 2019).

6.1 Contextualizing the JET Framework Goals in Relation to Realizing SDG 7

Regarding material environmental adversity, South Africa is significantly impacted by climate variability, characterized by frequent droughts, floods, and other extreme weather events. There is evidence that the frequency and intensity of these events are increasing due to climate change. Such events have inflicted extensive harm on infrastructure, ecosystems, lives, and livelihoods, especially in poorer communities (PCC, 2022a).

These catastrophic disruptions compound the stress related to the triple challenges of poverty, unemployment, and inequality. This vulnerability highlights the high rate of unemployment and inequality between the affluent and impoverished in South Africa, which, when exacerbated by climatic phenomena, erodes social cohesion and the national development agenda (PCC, 2022b).

SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all) is undermined by several linked factors including energy insecurity, reliance on 'dirty' and dangerous forms of energy (such as paraffin and coal), adverse climate, and rising costs associated with the energy utility death spiral (Li et al., 2023; Hutchinson et al., 2016). A transition towards improving the security of supply, accessibility, and affordability of clean energy underpins South Africa's energy ambitions as laid out in the 1998 White Paper on Energy (RSA, 1998).

The Just Transition Framework (JTF) aims to reduce the negative impacts on workers and communities associated with transitioning the energy landscape to align with a zero-carbon economy. Improving the reliability of power supply to meet development targets aligned with the JTF is essential to ensure that households, especially low-income households, have access to consistent and affordable clean electricity.

To realise this, energy infrastructure at scale is required and will necessitate sizeable investments. Energy projects will inevitably rely on more developed nations for energy and climate financing (Li et al., 2023). Researchers have noted through econometric analysis that while energy related financial aid does drive long-term economic growth, there is no direct impact of energy related aid on electricity access (Li et al., 2023). Nevertheless, Li et al. (2023) found that an increase in per capita GDP, facilitated by energy security, is positively associated with electricity access in both rural and urban areas. Li et al. (2023) also found that carbon emissions are effectively mitigated through energy related investment, which contributes to the GDP over time.

Regarding localized energy insecurity, load shedding has affected South African households for over a decade. Low-income households are most heavily affected by unreliable electricity supply as they often lack the financial resources to cope with the associated disruptions, such as back-up power or the capacity to travel. Some of the consequences of an unreliable power supply on low-income households include disruptions in daily activities, food spoilage, limited access to information, loss of income, and reduced productivity, thereby affecting their quality of life (Inglesi-Lotz, 2023). The following high-level strategies are suggested to improve the reliability of the power supply (Inglesi-Lotz, 2023):

- Transitioning to more reliable and sustainable energy sources such as renewables,
- Implementing decentralized energy solutions to allow access to reliable power to communities that are excluded from the main grid,
- Promote energy efficiency practices and provide incentives to reduce energy costs,
- Prioritize regular maintenance and upgrades of existing energy infrastructure,
- Implement targeted energy subsidies or social safety nets,
- Invest in job creation and skills development,

- Foster collaboration among the public and private sectors, and
- Establish a regulatory framework that captures socio-economic development into energy transition policies and strategies.

6.2 Decommissioning Coal-Fired Power Stations Are Expected to Deliver Social, Economic, and Environmental Co-benefits to Local Communities

Munnik et al. (2010) established that coal-fired power, as the foundation of South Africa's energy supply, conceals several externalized issues that greatly impact the health and livelihood potential for affected communities. Air pollution, a persistent residual from fossil fuel mining, transport, and combustion, was responsible for 1.1 million deaths across Africa in 2019, with household air pollution accounting for 697 000 deaths and ambient air pollution for 394 000 (Fisher et al., 2021). Additionally, a gendered lens often frames the social inequalities related to the lack of access to clean energy. Women within coal mining communities are adversely affected through exposure to pollution such as GHG and volatile organic compounds (VOCs), acid mine drainage, hazardous particulate matter (PM10 and PM2.5), as well as gender-based violence and decreased livelihood opportunities, due to the nature of coal mining communities.

This needs to be understood within the context that South Africa introduced Minimum Emissions Standards (MES) for combustion installations in 2010, and this required coal-burning facilities to install sulphur dioxide (SO₂) emissions controls by 2020.

During 2019 and 2020, Eskom applied for postponements and alternative limits to the MES for 16 power stations, citing extensive public participation and several reasons. These included plans for emission reduction through technology retrofits, closing older stations, and transitioning to a cleaner energy mix, which would significantly cut emissions by 2035. However, full compliance costs were estimated at over R300 billion and would increase electricity tariffs by at least 10%. Additionally, compliance would require 20% more water, which could be detrimental in a water-stressed country, such as South Africa. Furthermore, adherence to the MES would result in the immediate shutdown of 16 000 MW of installed coal-fired capacity. Despite generally meeting ambient air quality standards, Eskom emphasised the need to consider broader sustainable development issues, such as balancing environmental goals with economic and social impacts (Eskom, 2021b).

Eskom received postponements until 2025, with compliance for plants scheduled to retire by 2030 suspended. In 2020, the SO₂ emission limit was doubled, allowing cheaper compliance. Despite these lenient standards, Eskom remains the largest SO₂ emitter globally, while other major emitters, like Chinese utilities, have successfully reduced their emissions (Myllyvirta and Kelly, 2023). Myllyvirta and Kelly (2023) estimate that under the current planned retirement schedule and emission control retrofits, emissions from Eskom's power plants would be responsible for a projected 79 500 air pollution-related deaths from 2025 until the end-of-life of the power plants.

The reduction of externalities is expected to reduce the social costs associated with living near coal-fired power stations. The JET IP establishes that the co-benefits that could be realized from the transition range from the freeing of water resources for domestic use, agriculture, and other industries. In addition to the reduction in air pollution, broader improvements, such as improved road conditions and the regeneration of mining-affected land could be actualized (The Presidency, 2022).

Making Climate Capital Work (BFT, 2023) similarly states that the Pretoria High Court has recognised that the poor air quality in Mpumalanga, a direct result of the coal-centred economy, was a breach of the residents' constitutional right to an environment not harmful to their health and wellbeing. However, the study also highlights that the shortfall in livelihoods related to the coal economy needs to be better managed, as power plants and coal mines prepare for decommissioning to reduce demand. New employees tend to be on short-term contracts with no benefits. Additionally, cheaper contract workers are occasionally brought in from other regions, straining employment opportunities in the area, which could spur retaliatory dynamics and delay realizing the co-benefits expected from decommissioning.

6.3 Energy System Selection Forecast from the Draft IRP 2023

Unlike previous studies, Draft IRP 2023 does not contain quantitative values for the required investment or funding; instead, it explains the approach through the selected models. The capacity expansion model utilized in the Draft IRP 2023 incorporates least-cost principles based on linear optimization. This balances supply and demand in the medium to long term by considering cost and performance characteristics of generation options while making provision for specified reliability metrics. The objective is to minimize total power system cost and enable a decision to either operate existing generation resources more intensively or invest in new resources. The Draft IRP 2023 explains that this investment decision will be driven by a choice of resources that are cheaper and are able to meet the required power system characteristics, while reducing unserved energy (DMRE, 2024a).

The decisions are subject to constraints, such as user-defined reliability criteria, environmental considerations, and water consumption. While there are no quantitative forecasts of the costs in rands for the development pathways found in the IRP, there are valuations in terms of relative cost to each other, with the Draft IRP 2023 establishing that the renewable energy only pathway has the highest cost compared to the other pathways. The reference case in the IRP modelling is based on a simulation output that used a least-cost energy mix (DMRE, 2024a).

The results of the reference case prove a significant build-out consisting of solar PV, wind, and gas at mid-merit or higher utilization. The results also show a significant build requirement by the year 2035 to prepare for subsequent periods up to 2050. The Draft IRP 2023 selects the reference case using a security of supply perspective, as this indicates which energy mix provided is adequate considering demand. The pathway comprises dispatchable technologies with high utilization factors to enable security of supply. In addition to the delayed shutdown scenario, the technologies and options include different combinations of nuclear, renewables, clean coal, and gas. Notably, these pathways support the carbon reduction commitments.

In terms of impacts on the selection of the reference case, the results show significant reductions in carbon emissions driven by the shutdown of coal-fired plants and their replacement with renewable energy and gas. However, emissions show an increasing trend from 2042 as gas utilization significantly increases due to high demand projected to begin around 2041. The reference pathway is established at the least cost as the model is allowed to choose technology combinations without any restrictions (DMRE, 2024a).

The Draft IRP 2023 also establishes that apart from the reference pathway, the transitioning pathways, which refer to renewables only, show high costs due to high unserved energy and new build costs. The nuclear pathway costs are also higher than those from the reference pathway. Pressing NDC, SDG 7.2 relatable aspects, and decarbonization features, such as GHG minimization and transitioning away from coal, are expected to be increasingly incorporated into the IRP, which is updated every few years. As of 2024, the Draft IRP 2023, which is a living document, was being updated to better reflect these changes, challenges and public perspectives that were not fully contained in the Draft IRP 2023 upon release.

6.4 Translating the Benefits of Energy Supply to All South African Households

The objective contained within SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all) in relation to South Africa is strongly related to advancing the standard of living at the domestic level as well as the pursuit of South Africa's national decarbonization targets (Ledger 2021). Affordability stays the operative term in relation to households being able to access energy, and given that almost 80% of households struggle to purchase a basic basket of nutritional food, extra spending can have significant implications for households and their nutrition-related morbidity status (Ledger, 2021).

The 1998 White Paper on Energy enshrines the underlying objective of SDG 7, i.e., providing universal access to sufficient and affordable energy for all households (RSA, 1998). Towards this aim, the White Paper on Energy articulated a restructuring of the electricity distribution sector, whereby local municipalities would no longer serve as the gatekeepers in relation to the distribution of electricity. Rather, the White Paper envisaged a consolidated distribution system through regional electricity distributors (REDs). Later policies and plans such as the NDP also refer to the provision of amenities and subsidies packaged as the social wage, of which some free services such as water, sanitation, and electricity are applicable. The aim of the social wage was intended to raise the standard of living for the unemployed and indigent (Ledger, 2021).

While the recurring theme of the White Paper on the Energy Policy of 1998 and the NDP speaks to the universal access of services and the provision of FBE, Ledger (2021) establishes that households in South Africa are deprived of three million Megawatt hour (MWh) of free electricity each year, valued at approximately R6 billion (USD 0.4 billion) for the year 2021 alone. The systematic deprivation of FBE to these households erodes progress relating to SDG 7, and is a culmination of several factors, as expressed by Ledger (2021).

These include related features such as:

- Domestic, on-grid, energy distribution being a function of Eskom, local municipalities, and the associated municipal tariff structure, a 50/50 split,
- The practice of some local municipalities that serve as gatekeepers in terms of FBE applying to all the households they serve, through strict and exclusive terms for indigent homes,
- The registration and acknowledgement of households as indigent to qualify them for FBE, and
- The invisible trade-off occurring at the municipal level between a municipality mobilizing national funding for FBE and the municipality reorganizing the provision to utilize as an equitable share of funds for operational expenditure.

Ledger (2021) established that fewer than 25% of households funded by the National Treasury are receiving the benefit of FBE, i.e., there are over 8 million households in South Africa that are funded for FBE and are not receiving it. This finding is supported by the earlier works of Socio-Economic Rights Institute of South Africa (SERI) (2013) and Accounting for Basic Services (ABS) (2018).

While more in-depth policy assessment and recommendation are stipulated by Ledger (2021), critical themes such as empowering indigent households to be registered at their municipality, defining 'affordable access to sufficient quantities of clean and safe energy' to be concurrent with current household needs, and improving oversight of systematic processes from generation to utilization, need to be considered in the larger adoption of the JTF. Ledger (2021) concludes by stating that for justice to apply to the distribution element of the transition, a significant re-orientation of the energy system is necessary, towards a system that encapsulates energy primarily as transformative and pro-poor.

6.5 Utilizing Energy Sector Development to Advance Reliability and Equitability of Power Supply

The REIPPPP aims to facilitate private sector investment into grid-connected renewable energy generation in South Africa (World Bank Group, 2022). In addition, this programme is structured to contribute to broader national development aims focused on job creation, social upliftment, and broadening economic ownership, thereby advancing equity. For tenderers to become preferred bidders in the REIPPPP, certain criteria must be met, including job creation, local content, ownership, management control, preferential procurement, enterprise development, and socio-economic development (Ettmayr and Lloyd, 2017).

The Government can potentially re-examine the local content criteria requirements by reducing imports and promoting local procurement to address economic disparity where possible. Local content inclusion creates a drawcard for manufacturers to consider setting up a physical base in a new economy. Some of the key drivers for enhancing local content include supplier support, skilled labour, R&D, location and infrastructure, incentives for manufacturers, and government support (Ettmayr and Lloyd, 2017).

Local procurement can help ensure transitioning to more reliable and sustainable energy sources, which are accessible and affordable to the low-income market. Furthermore, the private sector can play a crucial role in enhancing this from a financing perspective. For example, banks can develop inclusive financing models that are accessible to businesses in underprivileged and/or marginalized communities. They can provide funding through corporate investment initiatives or financing through preferential credits and loans for pro-ecological investments for small businesses (Daszyńska-Żygadło et al., 2021). Additionally, the REIPPPP obliges the private sector renewable energy projects to engage with local communities through Sustainability, Equity, and Diversity (SED) by awarding tenders based on their promised contribution towards economic development. SED funds can be redirected towards setting up community trusts to help enhance energy transition in local communities, especially underprivileged communities, where there is a lack of infrastructure. IPPs can invest in these trusts to promote community participation in the renewable energy transition, and community members can hold a stake in these trusts, and participate in key decisions (Morar, 2019). Some of the benefits of this include job creation and skills development, as well as access to sustainable, reliable, and affordable energy, as the energy mix is diversified and investments in renewable energy sources increase.

Similar community-owned energy mechanisms have been introduced in other jurisdictions. More than 4 000 community-owned projects provide power in Australia, Europe, and the United States (International Renewable Energy Agency (IRENA), 2020). These mechanisms allow energy related assets, such as energy generation systems, energy storage systems, energy efficiency systems, and district cooling and heating systems, to be collectively owned and managed by their users. A community-ownership project is characterized by local stakeholders owning most of the project and voting rights, with control resting with a community-based organization. Most of the project's socio-economic benefits are, therefore, distributed at the local community level (IRENA, 2020).

The implementation of community-ownership models for energy related assets can be structured differently, based on various legal frameworks, forms of ownership, benefit distribution, and levels of democratic governance. A community model includes a combination of at least two of the following elements:

- **Ownership structure:** Local stakeholders may own part or all of a renewable energy project. Usually, community-ownership models involve full ownership by the community. However, in such cases other stakeholders – such as conventional energy companies (utilities, retailers, etc.), non-profit organizations, and (local) authorities – can take part as individual members of the community. In other cases, the local community may own a majority stake, while other stakeholders can participate in the ownership arrangement as partners. In many cases, renewable energy projects are developer-led, and communities are given the choice to take partial ownership of the project.
- **Level of democratic governance:** Voting control of the business around the renewable asset rests with a community-based organization, meaning that local stakeholders have most of the voting rights concerning the decisions taken on the project.

- **Local distribution of profits:** Most social and economic benefits are distributed locally (e.g., jobs created locally, power supplied to the community, profits shared among individual participants in the community scheme).

The possible adoption of similar models in South Africa should support the achievement of the SDGs, such as ending poverty and inequality, protecting the planet, and promoting health, justice, and prosperity, as well as the achievement of the NDP, which aims to cut poverty and reduce inequality by 2030 (Inglesi-Lotz, 2023).

7 Trade-off Between SDG 7, Sectoral Targets, and the NDC Commitments

Is there a trade-off between SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all by 2030), sectoral targets, and the NDC commitments, and if so, what are they?

From this research and based on the outcomes of the technical modelling work performed, five main trade-offs were identified:

- **Economic versus environmental goals:** Balancing economic growth with the need to reduce GHG emissions can be challenging. South Africa's heavy reliance on coal for energy production significantly impacts both economic development and the environment. Transitioning away from coal to renewable energy sources, as required by SDG 7.2 and the NDC commitments, could result in job losses in the coal sector and affect energy access for underserved communities (The Presidency, 2022; RSA: NDC, 2021). This transition is essential for reducing emissions, but poses significant socio-economic challenges (Inglesi-Lotz, 2023). Furthermore, setting out the pathways made it clear that the level to which individual countries adhere to their NDCs under the Paris Agreement will affect other countries' decision-making regarding energy investments. This includes investing in a modern technology mix relative to the current use of fossil fuels, aiming to achieve economic growth and remain economically competitive.
- **Short-term vs long-term goals:** Continuing from the previous point, immediate economic and social needs might conflict with long-term sustainability targets. While SDG 7.2 (increase substantially the share of renewable energy in the global energy mix by 2030) and the NDP both aim for universal access to affordable, reliable, and modern energy services by 2030, achieving these goals requires balancing short-term energy needs with long-term sustainability (UN, 2023). For example, investment in or continued reliance on coal-fired power plants can provide short-term energy security, but conflicts with long-term climate goals (Inglesi-Lotz, 2023).
- **Resource allocation:** With South Africa's history of regular load shedding, meeting electricity demand remains a challenge. Considering Eskom's debt and operational challenges, its tariff revenue collections and budget allocations from NT will not result in a significant contribution to the overall contribution to new generation, transmission, and distribution infrastructure that is required from 2025 to 2050. Therefore, the use of limited existing financial and technical resources may need to be prioritized, potentially leading to trade-offs between different goals. For example, funding allocated to renewable energy projects might reduce the resources available for other critical infrastructure projects (Inglesi-Lotz, 2023). In South Africa's case, this could mean continued investment in the maintenance of coal-fired power plants to ensure the energy demand is met. Effective policies, international investment, and support are crucial to balancing these trade-offs, thereby ensuring that energy remains affordable and accessible while reducing emissions (RSA: NDC, 2021). The speed of technology learning rates will be a key determinant in reducing electricity costs and meeting SDG 7 under limited resource availability.

- **Social and economic impacts:** The transition to renewable energy sources can have a disproportionate effect on certain communities, particularly those dependent on coal mining and related industries. Ensuring a just transition that minimizes negative impacts on workers and communities is essential. The JTF aims to reduce these negative impacts and ensure that the benefits of the energy transition are shared equitably (The Presidency, 2022). The supplementary CGE model report will shed more light on this specific topic.
- **Sectoral targets vs national commitments:** Different sectors may have conflicting priorities and targets. For example, the industrial sector may prioritize energy-intensive processes for economic growth, while the NDC focuses on reducing overall emissions. Balancing these sectoral targets with national and international commitments requires careful planning and coordination (RSA: NDC, 2021).

South Africa faces challenges and trade-offs when it comes to aligning SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all), NDP goals (aims to eliminate poverty and reduce inequality by 2030), sectoral targets, and its NDC (South Africa's commitments to the Paris Agreement) in the context of energy access, environmental sustainability, and economic development. Continued reliance on coal could have negative implications for the environment, while transitioning away from coal could potentially affect energy access, especially for underserved communities, and economic development, due to job losses, particularly for those in the coal sector.

SDG 7 and the NDP aim to ensure access to affordable, reliable, sustainable, and modern energy for all (UN, 2023; RSA, 2021). This goal is central to achieving many other SDGs (such as to end poverty and inequality, protect the planet, and ensure health, justice, and prosperity) and NDP goals, particularly since energy is crucial for economic development, poverty reduction, and addressing environmental challenges (UN, 2023).

South Africa's sectoral targets for energy transition aim to 1) increase the share of renewable energy sources; 2) reduce reliance on coal-fired power generation; 3) improve energy efficiency; 4) modernize the electricity grid to support a diverse energy mix, and 5) expand electricity access, particularly to underserved communities (The Presidency, 2022).

South Africa's update to the first NDC acknowledges that a just transition in South Africa will require international cooperation and support to harness various technologies to reduce emissions (RSA: NDC, 2021). South Africa's LEDS for 2050 (which shows how sectors could implement policies and measures to reduce emissions up to 2050) supports this view and highlights the need to focus on a range of strategic elements that will together promote the change to low-carbon growth, while continuing to align with the goals of the Paris Agreement (UNFCCC, 2022; DFFE: LEDS, 2020).

Regarding the energy mix, SDG 7.2 requires that the share of renewable energy in the global energy mix increase by 2030 (UN, 2023), which is aligned with one of South Africa's sectoral targets. In 2012, the NDP set out that renewable energy contracting must account for half of an envisaged 40 GW electricity generation build by 2030 (RSA, 2021).

South Africa's economy and energy system is one of the most coal-dependent in the world and features a large stock of high-carbon infrastructure, particularly in the energy sector. The coal industry is a significant source of employment in the country and is a major source of the country's GHGs. As such, transitioning from coal to cleaner energy sources could potentially have adverse social and economic consequences, including job losses, energy affordability, and energy access.

Promoting the development of renewable energy sources aligns with SDG 7, NDP goals, NDC aims, and sectoral targets, which all aim to reduce emissions and expand access to cleaner energy. South Africa is fortunate to have abundant renewable energy resources and favourable economic developments for low-carbon technologies over the last decade. However, a well-resourced JET strategy will be needed to shift to low-carbon technologies, maximize benefits, and minimize adverse impacts on communities, workers, and the economy. Programmes to achieve this will require climate finance and other forms of support provided to developing countries as specified in Articles 9, 10, and 11 of the Paris Agreement (RSA: NDC, 2021).

From an access perspective, SDG 7.2 requires countries to ensure universal access to affordable, reliable, and modern energy services by 2030 (UN, 2023). This is also an aim of the NDP. Increasing energy access, particularly in underserved communities, is crucial as these communities rely on fossil fuels as an alternative form of energy, which conflicts with the emissions reduction targets set out in the NDC. Transitioning to cleaner energy sources can lead to higher energy costs, potentially affecting the affordability of energy for some segments of the population (Inglesi-Lotz, 2023). Effective energy policies can make renewable energy more affordable through incentives and subsidies, ensuring that energy access remains affordable while reducing emissions.

Economic growth is a priority for South Africa and the 1 °C increase in global temperatures over the last century has already reduced the size of the South African economy by between 10% and 20% (RSA: NDC, 2021).

The 'Southern Africa – Towards Inclusive Economic Development' (SA-TIED) research group, which is affiliated with the National Treasury, finds that shifting the country's energy mix to increase the contribution of renewable energy significantly will have a positive impact on real GDP and employment in South Africa (Merven et al., 2021b). The report highlights an observable trend in international research which shows that renewable energy and environmental considerations are no longer mutually exclusive. This is due to the competitive pricing of renewables compared to more environmentally adverse technologies (Merven et al., 2021b). In the South African context, real GDP and employment are expected to benefit from the increased use of renewable energy, due to increased energy security, industrial growth, and lower costs associated with this technology compared to, for example, coal power. The positive gains are expected to materialize across sectors. Overall, the results indicate the potential to create an additional 2.5 million jobs by 2050 because of the savings in energy costs that can be directed towards investment and other productivity-boosting spending.

8 Expected Contribution of the Existing IRP and SDG 7.2

What will be the expected contribution of the existing IRP 2019 (and Draft IRP 2023 and 2024) to SDG 7.2 (increase substantially the share of renewable energy in the global energy mix by 2030)?

8.1 Comparing the Proportional Renewable Energy Contributions

The following section highlights key findings from the IRP review, followed by sections providing more detail on each.

- Currently, renewable energy contributes close to 10% of South Africa's total energy mix (Centre for Renewable and Sustainable Energy, 2024) with a net maximum dispatchable capacity of 49 389 MW, including imports and emergency generation resources (Eskom, 2025).
- The IRP 2019 sets a measurable target of an increase in renewable energy from the current state of 10% to 40% by 2030, aiming to reduce the share of fossil fuels from 80% to 50% out of a projected installed capacity of 78 284 MW, excluding distributed capacity in the total (EnergyGroup, 2024). The remaining 10% consists of nuclear, distributed (rooftop and other), and concentrated solar power (CSP).
- This will be achieved through the new additional capacity of 14 400 MW of wind, 6 000 MW of solar PV, and 2 500 MW of hydropower, excluding already contracted or committed projects (DMRE, 2019). To facilitate the stable integration of renewable energy technologies, the IRP 2019 plans for the addition of 3 000 MW of gas and 2 088 MW of energy storage. The current progress indicates that the 2030 projected renewable energy capacity of the IRP 2019 will be exceeded, except for CSP. This combined 22 900 MW in new additional renewable capacity would surpass the 20 000 MW envisaged by the NDP for 2030 (DMRE, 2019).
- The Draft IRP 2023 splits generation build-out across two horizons, Horizon 1 (2023 to 2030) and Horizon 2 (2031 to 2050). Horizon 1 speaks to South Africa's immediate energy needs, stabilizing the supply of energy, and establishing the foundation for the transition to renewables (DMRE, 2024a), and aligns with the SDG target date. Draft IRP 2023 expects the development of additional new capacity to bring the total contribution of renewable energy to 16 639 MW by 2030, consisting of 5 902 of PV, 7 911 MW of wind, 600 MW of CSP, and 2 226 MW of hydro. This amounts to renewable energy contributing approximately 21% to the total national capacity of 77 200 MW by 2030, excluding distributed capacity in the total (DMRE, 2024a).
- After the Draft IRP 2023, the DMRE released a Draft IRP Stakeholder Workshop document in November 2024. The stakeholder workshop document outlines the incorporation of more renewables, particularly up to 2030. The Draft IRP 2024 Stakeholder Workshops document (referred to as the 'Draft IRP 2024' document in the comparison review and tables in this report) also states that variable renewable energy (VRE) will contribute an additional 27.4 GW to the national capacity by 2030. This would comprise 11.3 GW of rooftop solar PV, 7.8 GW of utility-scale solar PV, and 7.2 GW of wind energy by 2030. The aggressive development of renewable

energy, as per the Draft IRP 2024, includes the total build-out of VRE by 2050, potentially contributing 127 GW to the national total by 2050. This would be due to 24.3 GW of solar PV and 76.4 GW of wind energy being added to the grid between 2031 and 2050 (DMRE, 2024b).

The following table provides an overview of the key differences in total installed capacities operational by energy type between the IRP 2019 and Draft IRP 2023 for 2030. Several energy sources were grouped based on their relevance to the grid. Coal plant life extension, an intervention proposed by IRP 2023, is included in the coal capacity contribution in Table 4.

Table 4: Forecast Installed Generation for 2030 by Energy Type

Application	Energy Source	IRP 2019 (MW)	Draft IRP 2023 (MW)
Dispatchable	Nuclear	1 860	1 860
	Hydro	4 600	2 226
	Coal	33 364	39 440
Grid-stabilizing	Dispatchable	6 830	12 426
	Pumped Storage	5 000	2 732
	BESS		4 103
Variable	Distributed	4 499	11 300
	Wind	17 742	7 911
	PV	8 288	5 902
	CSP	600	600
	Hybrid IPP		
	Private projects		
	Total	82 783	88 500
Total capacity sans distributed		78 284	77 200
RE (excluding distributed in total)		31 230 (39.9%)	16 639 (21.6%)

Sources: IRP 2019 (DMRE, 2019); Draft IRP 2023 (DMRE, 2024a).

8.2 IRP 2019

The IRP 2019 was developed by projecting the country's long-term electricity demand and accounting for the role that energy-efficiency and demand-side interventions could play, while remaining cognisant of the need to increase renewable energy as a substantial proportion of the generation mix for the national energy system. The scenarios assessed in the IRP 2019 indicate that policy adjustments are required to ensure the flexibility of a practical low emission development plan.

The emerging IRP will need to accommodate new, innovative technologies that are not currently competitively priced and minimize the impact of decommissioning of coal power plants and the changing demand profile (The Presidency, 2022; UNFCCC, 2022).

The 2019 IRP provides an indicative generation build plan up to 2030, due to technological uncertainties beyond that period. Furthermore, a provision for small-scale embedded generation (SSEG) is included in the IRP. Embedded or distributed generation refers to electricity installations with capacities between 1 and 10 MW that are connected to the national grid (Eskom, 2023a).

The IRP is socially driven and proposes new research and analysis to support the low-carbon transition of the electricity supply sector, and investigate the proportionality of the renewable energy delivery. These include detailed studies on the level of penetration of renewable energy in the South African national grid, the cost and economic benefits associated with other clean energy options, as well as the socio-economic impacts on communities affected by the decommissioning of coal-fired power stations (The Presidency, 2022).

The IRP 2019 sets a measurable target for a renewable energy increase from the present 10% to 41% by 2030. The goal is to reduce the share of fossil fuels from 80% to 51% out of a projected installed capacity of 77 834 MW (Climate Policy Lab, 2020). This will be achieved through the installation of 17 742 MW of wind, 8 288 MW of solar PV, 4 600 MW of hydropower, and 600 MW of CSP (DMRE, 2019). To integrate renewable energy technologies, the IRP 2019 also recommends adding 3 000 and 2 088 MW of gas and energy storage, respectively. The current trajectory suggests that the 2030 capacities set out in the IRP 2019 will be exceeded, except for hydropower. The combined 29 376 MW in renewable energy capacity would surpass the 20 000 MW in renewable energy capacity envisaged by the NDP for 2030.

8.3 Draft IRP 2023

The Draft IRP 2023 divides the generation build-out into two horizons: Horizon 1 (2023 to 2030) and Horizon 2 (2031 to 2050). This summary focuses on Horizon 1 as it relates to SDG 7.2, which has a 2030 target date. Despite prominent solar installations during the period of release, IRP 2023 indicates a decrease in overall capacity available. The document states that 55 812 MW (actual value in IRP 2023) is online, compared to the 57 583 MW projected by IRP 2019 and expected by 2023. While roughly there was overall alignment with the IRP 2019 projections, the Draft IRP 2023 seeks to replace coal with gas and extend the lifespan of coal-fired power plants as part of necessary power system developments. This fails to achieve system adequacy in the short term.

By Horizon 1 (2030), the baseload capacity remains coal dominant as the IRP 2023 circumvents the shutdown of 11 000 MW of coal and discards the addition of 7 232 MW of new generation. Instead, 1 440 MW of new coal generation, which is under construction, is added to the baseload. The IRP 2023 also omits 1 575 MW of pumped storage that was planned for 2029, as mentioned in the IRP 2019.

However, the Draft IRP 2023 increases the capacity of the grid-stabilizing segments from 11 830 to 19 261 MW. This is largely due to a near doubling of BESS and dispatchable capacity to 12 400 MW, of which 89% is gas.

Lastly, there is a drop in the variable capacity installed by the end of Horizon 1. The IRP 2019 had forecast 31 129 MW being derived from VRE, while the Draft IRP 2023 only forecast 25 713 MW. This decrease is due to solar PV being reduced by 29% and wind being reduced by 55%, despite a 151% distributed increase that occurred between IRP iterations. Essentially, renewable energy makes up 30% of the total energy mix by Horizon 1, despite the total planned capacity increasing to 84 414 MW in the Draft IRP 2023.

In their review of the Draft IRP 2023, the PCC emphasises the need for a policy-adjusted approach to introduce approximately 50–60 GW of VRE by 2030, complemented by storage solutions and 3–5 GW of peaking support, such as low-utilization gas. The report suggests that achieving an affordable mitigation target below 370 MtCO_{2e} requires the early retirement of coal plants. This exceeds what the IRP 2019 proposed and poses political and social challenges. The PCC highlights that electricity sector mitigation could be optimized by allowing endogenous retirement of coal fleets, rather than adhering to fixed dates.

Moreover, their consultation process revealed alignment among major modelling exercises in South Africa regarding the NDC period, despite differing methodologies and assumptions. These models consistently indicate that a least-cost electricity system prioritizes VRE, storage, and peaking support, rather than new coal or nuclear power plants. The PCC recommends that the Draft IRP 2023 should focus on transparent spatial planning centred on grid access points to create a comprehensive and centralized resource plan. Thus, aiming to eliminate load shedding and ensure cohesive energy planning (PCC, 2023).

8.4 Achievements Affecting the National Energy Landscape to Date

Some notable achievements include:

- Schedule 2 of the ERA (the ERA sets up a national regulatory framework for electricity in South Africa) has been amended to remove the licensing requirement for generation projects of any size, which will enable private investment at a larger scale. Previously, this was a maximum of 100 MW.
- A new ministerial determination has been published for over 18 000 MW of new generation capacity from wind, solar PV, and battery storage.
- The pipeline of private-sector embedded generation projects has grown to over 100 projects as of June 2023, with a total capacity of more than 9 000 MW.
- 19 projects from Bid Window 5 have signed project agreements to supply 1 800 MW of solar PV and wind capacity, and a further six preferred bidders from Bid Window 6 will provide 1 000 MW of capacity.
- An additional 300 MW of power has been imported from neighbouring countries, with work underway to increase imports from the region as a product of South Africa's partnership with the Southern African Power Pool (SAPP).

- In line with the emerging Draft IRP 2023 and the ‘first come, first serve’ platform, Eskom has launched a Standard Offer Programme to purchase up to 1 000 MW of power from companies that have existing generation capacity for a period of three years, as well as an Emergency Generation Programme to purchase additional power when the grid is constrained.

8.5 Required IRP Adjustments to Incorporate SDG 7.2

8.5.1 Perspectives from IRP 2019

The IRP 2019, which included coal as a major component for delivering baseload energy, is expected to change in future iterations and will reflect an updated baseline moving away from a coal and nuclear focus and towards VRE and dispatchable energy, including BESS.

Several institutions in South Africa have expressed that future iterations should include a greater focus on promoting, subsidizing, and installing rooftop solar PV. As the popularization of renewable energy technologies penetrates new markets, there will be a wider call for energy generation independence, which will have to integrate with the primacy of Eskom and the IRP as the sole source of provision (Meridian Economics, 2024). For example, SSEG capacities are being advanced through the South African Local Government Association (SALGA) and the SSEG portal (Eskom, 2023a).

8.5.2 Perspectives on the Draft IRP 2023

The Draft IRP 2023 (released in 2024) employs a dual horizon approach, which attempts to disaggregate the power system needs over two horizons of development. Horizon 1 spans up to 2030 and focuses on addressing the prevailing generation constraints relating to contemporary issues such as load shedding (DMRE, 2024a). Horizon 2 covers the period of 2031 to 2050 and is more focused on securing South Africa’s long-term security of electricity supply through guidance on policy choices (DMRE, 2024a). In relation to SDG 7, the Draft IRP 2023 is conscious of the necessary role of renewable energy in the South African energy system, but still endorses coal and gas as key features of the country’s energy future.

While the Draft IRP 2023 does recognise the need for enabling the installation and prioritization of building out RE, there are aspects which are unclear and could be sources of contestation couched within the build pathways located therein. For example, the assumptions used and their consequences are not evident from the resultant build pathways. Coupled with the inherent uncertainty of generation are the forecasting of parameters such as technology costs, demand, fuel prices, and the subsequent consequences of carbon pressures and emissions related to the described builds (Meridian Economics, 2024).

Meridian Economics (2024) assessed the Draft IRP 2023 and provided an independent integrated resource planning analysis on the Draft IRP 2023. The analysis found that when the IRP modelling is reconstructed, the emissions curve may align with the upper limit of allowed carbon based on the NDC.

Meridian Economics (2024) determined that the emissions reductions by 2030 (Horizon 1) will have to be more intensive than previously stated in the Draft IRP 2023 to achieve a lower carbon limit alignment and improve South Africa's resilience to risk related to carbon-pricing.

Meridian Economics (2024) list several criticisms of Draft IRP 2023, addressing features of the approach, method, assumptions, and the plan. The submission is comprehensive and calls for an independent interrogation. However, for this literature review, features pertinent to SDG 7.2 (the inclusion of renewable energy) are discussed below. Regarding the approach, the reason a net-zero trajectory is not achieved in any scenario must be explained, as this issue relates to the core environmental objectives (Meridian Economics, 2024). Compared to SDG 7.2, the approach adopted by the Draft IRP 2023 does not account for: uncertainty in relation to fuel prices, domestic and international carbon pricing, and technological breakthroughs which may accelerate the realization of the SDGs (including to end poverty and inequality, protect the planet, and ensure health, justice, and prosperity).

Additionally, the authors express that due to a lack of transparency and the failure to disclose key methodological aspects, it is challenging to reconstruct and engage with the outcomes, which hampers understanding the contribution of renewable energy. There is also an unusual technology costs assumption, which Meridian Economics (2024) says remains unmotivated. In relation to the approach and the infrastructure build-out, there is no systematic evaluation of scenario performance against the planning goals of security of supply, cost, and environment to which the incorporation of renewable energy remains foundational.

Meridian Economics (2024) notes that the method utilized is confusing and does not give substance to the emerging plan. The four features the authors find most disconcerting in the Draft IRP 2023 method relate to: 1) the lack of optimization; 2) the use of predetermined technologies; 3) inexplicably stringent new-build limits, which cap solar and wind deployment inconsistently across the IRP pathways, and 4) those that relate to the coal decommissioning schedule. Regarding the assumptions of Draft IRP 2023, Meridian Economics (2024) states that several of the cost assumptions used as inputs for the Draft IRP 2023 are problematic. These include the technology costs for wind, solar PV, CSP, and battery storage, which are established as significantly higher than the actual realized market pricing as understood through the REIPPPP, which facilitates private sector investment into grid-connected renewable energy generation in South Africa, and other reference data. The authors notes that the Draft IRP 2023 fails to account for future technology learning, which can result in the cost of new technologies appearing inflated compared to the costs of mature technology such as coal, nuclear, and gas.

The presentation of the scenarios in the IRP (firm initiative, reference, all initiatives, gas, and recovery) does not provide costing for the flue gas desulphurization retrofits, which would be necessary to meet minimum emission standards, nor the costs for carbon capture, utilization, and storage (CCUS). These costs are not provided or incorporated in the IRP assessment of the energy landscape build-out necessary (Meridian Economics, 2024).

The Meridian Economics (2024) analysis of the Draft IRP 2023 indicated that the plan is unrealistically constrained with representation of over-priced renewables to facilitate a gas-heavy energy future, in discord with SDG 7.2. Notably, the Draft IRP 2023 attempts to replace the retiring coal capacity with gas, which results in fossil fuel reliant generation being maintained and even increasing in capacity by 2050; 10 GW of coal remains online in 2050; no new nuclear is present without the soon-to-be released RFP for 2.5 GW of new nuclear power; the highly emphasised role of dispatchability and the connotation to gas which is considered able to alleviate load shedding and provide long-term energy security and the assumption of the fulfilment of capacity of all Risk Mitigation IPP Procurement Programme (RMIPPPP) and REIPPPP projects despite capacity in these projects reflective of uncertainty. While the Draft IRP 2023 is aware of the NDC and contemporary guidance frameworks, it does not attempt to align the power system development to any transformative aspects of SDG 7.2.

9 Eskom Transmission Development Plan (TDP) 2024 and SDG 7

What would be the expected contribution of investment in transmission, according to the Eskom TDP 2024, in terms of supporting SDG 7 (ensure access to affordable, reliable, sustainable, and modern energy for all by 2030)?

SDG 7 is a multidimensional issue in the Global South. Due to infrastructure underdevelopment, energy may be generated, but electrification at a national scale remains highly dependent on the availability of transmission and distribution capacity to all households. Furthermore, generation shortfalls undercut SDG 7, as these shortfalls necessitate that new transmissions and distribution networks are aligned with attachment points for new, modern generating capacity.

According to the TDP 2024, its contribution to SDG 7 will be multifaceted:

- **Enhanced grid capacity and renewable energy integration:** The TDP 2024 proposes the installation of 14 494 km of transmission lines and 210 transformers, thereby adding 133 GVA of capacity, which will significantly boost the grid's ability to manage increased load and integrate these new generation sources. The previous TDP 2022 stated that 53 GW of new generation capacity would need to be integrated from all technologies by 2034. This figure increased to 56 GW by 2034 in the TDP 2024 (Eskom-NTCSA, 2024a).
- **Enhanced grid stability:** The installation of synchronous condensers at seven sites and additional transformers at existing substation sites will ensure system stability and reliability amidst the large-scale penetration of renewable energy and the planned decommissioning of Eskom's coal-fired power plants (Eskom-NTCSA, 2024a).
- **Energy sector investment:** With a total estimated capital of R112.5 billion for the first five years, including R85.6 billion for capacity expansion, the TDP 2024 aims to address current network constraints, support future demand growth, and generate new job opportunities. Initiatives to attract private sector investment through Independent Transmission Projects (ITPs) can enhance the efficiency and speed of implementation, while collaboration with the Government and stakeholders to develop funding models and regulatory frameworks ensures the financial sustainability of transmission projects (Eskom-NTCSA, 2024a; 2024b).
- **Reduced power outages:** Upgraded transmission lines can reduce the frequency and duration of power outages. This can improve the reliability of the power supply and support economic activities. The JET IP emphasizes upgrading transmission and distribution networks to accommodate the renewable energy generated by the private sector, ensuring energy security and decarbonization (The Presidency, 2023).

The following section examines some of these elements more closely.

9.1 Investment into New Transmission Infrastructure

As coal plants are decommissioned, capital investments in renewable energy totalling R475 billion (USD 31.7 billion) will be required over the next five years. While this is expected to be driven by the private sector, the financing of new transmission lines to support the new renewable energy is estimated at R132 (USD 8.8 billion) and will require state asset investments.

Over the medium to long term, added transmission infrastructure is required to connect 36 GW of new generating capacity (mostly renewable) by the early 2030s. To ensure sufficient connection capacity, the grid build rate needs to increase from 300 to 2 300 km per year. Based on Eskom's TDP 2023–2032, 14 000 km of transmission lines need to be constructed in the next ten years. This requires a build rate increase to 2 300 km per year from 2028 to 2032. Even more is required to meet power demand for the new generation from 2030 to 2050 as existing coal plants retire (Eskom-NTCSA, 2024a).

9.1.1 The Objective of the 2024 Transmission Development Plan (TDP)

The TDP is an annual document prepared by the facilities of the state-owned enterprises that details the state of energy transmission infrastructure. The objectives of the TDP include 1) advancing and attaining Grid Code compliance through resolving violations, 2) determining the new network infrastructure requirements for future demand, and 3) determining the new network infrastructure required for integrating new generation capacity and addressing system stability by considering the asset replacement requirements necessary for network optimization (Arnoldi, 2024; Slabbert, 2024).

Despite the drive to develop and connect projects to the grid, existing infrastructure is severely limited. The transmission network capacity in the Western Cape, Eastern Cape, Northern Cape, and parts of the North-West Province is severely constrained. It requires significant upgrades at the local and corridor level to increase network capacity and introduce new generation to the system. In addition to grid on-take challenges, the increasing proliferation of renewable technologies has also created novel challenges for System Operators (Eskom-NTCSA, 2024).

9.2 Commentary from the JET IP on New Transmission Infrastructure

The Presidency (2023) states that the JET IP (which addresses the investments required to support the decarbonization of the energy sector) prioritizes investments in state-owned infrastructure to upgrade the transmission grid and distribution networks. This will enable them to manage the renewable energy that will be generated largely by the private sector in the years to come. This critical network infrastructure investment will leverage large-scale private investment in renewable, thus supporting both energy security and decarbonization.

The JET IP delineated national infrastructure investment requirements for the South African electricity sector for two periods: 2023–2027 and 2023–2035. The following six areas have been highlighted as regions for catalytic financing across the two periods: coal plant decommissioning, transmission,

distribution, new solar PV, new wind, and new batteries. From 2023–2027, the estimated costs for the sectors total R647.7 billion (USD 43.2 billion), while from 2023–2035, the estimated costs for the sectors total R1 857 billion (USD 123.8 billion). The national electricity sector’s total infrastructure investment needs linked to new transmission are approximately R131.8 billion (USD 8.8 billion) from 2023 to 2027.

Most generation investment is expected to come from the private sector or other non-state entities, including some investments from community- and worker-owned trusts, via the REIPPPP (facilitates private sector investment into grid-connected renewable energy generation in South Africa) or its successor, via bilateral contracts, or via commercial, industrial, and residential embedded generation. Transmission and distribution infrastructure will also require investment from Eskom and local authorities. Renewable energy integration will require upgrades to the transmission and distribution networks and related infrastructure at a much more accelerated pace than currently outlined in the TDP to meet the country’s strategic objectives and NDC (The Presidency, 2022; Burton et al., 2020).

9.3 The Draft Transmission Development Plan (TDP) Update (2024)

9.3.1 Development of the National Transmission Company of South Africa (NTCSA) During 2024

Leading up to and during 2024, South Africa’s energy landscape has undergone significant changes, particularly from the planning and activation perspectives. A major development was the unbundling of the functions of Eskom into three standalone entities related to generation, transmission, and distribution. The National Transmission Company of South Africa (NTCSA) represents an independent entity from Eskom’s generation and distribution operations that is primarily concerned with transmission network infrastructure and its development in South Africa (Eskom-NTCSA, 2024). The NTCSA oversees procuring electricity to be transmitted by the grid network, the majority of which still emanates from Eskom power stations. Other sources of energy are procured through the Southern African Power Pool (SAPP) and the independent power producers, which are part of the REIPPPP (Eskom-NTCSA, 2024).

9.3.2 Effect of the Renewables Boom on Load Shedding

The TDP states that the renewable energy boom, particularly rooftop solar PV, has changed the demand profile. This evolution of the energy demand and supply profile represents an example of technological disruption to the South African energy landscape. The employment of rooftop solar PV has mitigated load shedding, and due to the improvements in the generating capacity of conventional power stations (quantified as the energy availability factor (EAF)), Eskom has had to rely less on emergency resources such as open-cycle gas turbines (OCGTs) and pumped storage.

Despite the capacity contributed through solar PV installations, Eskom indicates that there is still highly variable demand on a day-to-day basis based on sunlight availability. This poses a risk to energy intensive provinces such as Gauteng, which require thousands of MW of generation to be dispatched rapidly to compensate for reduced generation and increased demand (Eskom-TCSA, 2024).

This arrangement has initiated the need for ancillary services, including a system restoration plan that can bring the national power grid back online via a black start. The key ancillary services mentioned in the TDP 2024 update relate to the system reserves required for addressing generation and load contingencies, reactive power and voltage control, constrained generation, and the various procedures necessary to restart the grid from a complete collapse. (Eskom-NTCSA, 2024; Slabbert, 2024).

9.3.3 Relationship between the TDP 2024 and Draft IRP 2023

The TDP 2024 generation assumptions are based on the Draft IRP 2023. The Draft IRP 2023 expects 30 GW of new generation capacity by 2030, increasing to 56 GW by 2034. Therefore, strengthening the grid to support large-scale renewable energy integration and ensuring network sustainability requires significant investments. Building transmission infrastructure typically takes eight to ten years due to challenges related to servitude and limited resource capacity within the Engineering, Procurement, and Construction Management (EPCM) value chain. The TDP 2024, based on the Draft IRP 2023, anticipates minimal changes in the first five years, providing confidence in infrastructure and capital requirements for this period. Beyond five years, adjustments will be made as more information becomes available. The focus is on the first five years, with projections for the subsequent five years based on current assumptions (Arnoldi, 2024; Eskom-NTCSA, 2024; Slabbert, 2024).

The Draft IRP 2023 suggests that total generation capacity will increase to 106.5 GW by 2034. Demand forecasts, based on customer applications and network analysis, in a low-demand scenario, indicate a need for around 35 GW up to 2034. However, the TDP 2024 prefers a moderate-to-high demand scenario, aligning with the Draft IRP 2023 and macroeconomic forecasts of 1.6% GDP growth. The TDP 2024 expects generating capacity to increase from 66 GW in 2024 to 107 GW in 2034, with significant changes in the technology mix. This includes increases in solar PV (+9 GW), gas (+7 GW), and coal (+3 GW) by 2034, and a decrease in wind and battery storage. The revised shutdown plan for the Tutuka coal plant to run until 2040 also influences these projections (Eskom-NTCSA, 2024; Slabbert, 2024).

9.3.4 Challenges and Opportunities Outlined in the TDP 2024

The TDP outlines that grid congestion is a feature at this point due to a misalignment in generation on-take, grid availability, and forward quotation applications. Regarding the large-scale integration of renewable energy, the TDP identified security and stability issues in the power system. These issues include reduced system inertia and strength, as well as voltage and frequency deviations. Dynamic studies confirmed that synchronous condensers may be necessary to maintain system security and stability, preventing grid collapse. The studies recommended installing new synchronous condensers at various transmission substations. Essentially, there is a need for flexibility to balance the uptake of renewables, which creates an opportunity for grid-enhancing technologies. The conclusion of TDP 2024 identifies several solutions to accelerate medium- to long-term implementation of TDP projects. The report indicates that the NTCSA is supportive of innovative funding solutions, such as ITPs; however, enablers need to be in place to ensure successful implementation (Arnoldi, 2024; Eskom-NTCSA, 2024; Slabbert, 2024).

9.3.5 Summary of Key Findings from Final TDP 2024

Both 2023 and 2024 represent critical years with respect to the formalization and alignment of the NTCSA mandate to energy infrastructure development. The previous version of the TDP was released while the NTCSA was a bundled feature of Eskom and had initially forecast that 53 GW of new generation capacity would be required by 2032. Approximately 39 GW of the generation projected by the TDP 2022 was expected to be derived from renewable sources such as solar PV and wind. Supporting these generation aspirations would require 14 200 km of extra high voltage transmission lines, interspersed with transformers, which would subsequently deliver 105 000 MVA of capacity by 2032 (Eskom-NTCSA, 2024a).

Since the forecasts made in the TDP 2022, the NTCSA and Eskom have indicated that significant progress has been made to materialize earlier energy related ambitions. The NTCSA indicates that currently, 61 projects are in the execution phase and expected to unlock 30 GW of new generation connectable capacity by 2030 (Eskom-NTCSA, 2024a). Of the 61 energy projects, 31 are currently in development and will deliver 1 445 km of transmission lines as well as 16 945 MVA of transformer capacity to connect the 16 GW of generation that are expected to come online by 2028. The NTCSA also states that the remaining 30 projects are in the procurement phase and will deliver 14 GW of new generation by 2030. In addition to the 61 official projects outlined above that will contribute to the transmission uplift, 47 other projects have been ringfenced to accelerate delivery of the TDP objectives (Eskom-NTCSA, 2024a, 2024b).

Between the TDP 2022 and the TDP 2024, which included the unbundling of Eskom and the creation of the NTCSA, several data points were examined further to inform the forecasts laid out in the TDP 2024. The Draft IRP 2023 by the DMRE was used as a major input and was employed in-house for verification purposes. Furthermore, the Generation Assumptions Report 2024 and the Transmission Demand Forecast Report for the TDP 2024 provide details on the methodology and analysis of each of the generation and load assumptions and forecasts (Eskom-NTCSA, 2024a).

The TDP 2024 specifically states that 56 GW of new generation must be integrated into the transmission network between 2025 and 2034, not dissimilar to the 53 GW stated by the TDP 2022. The TDP 2024 also states that 14 500 km of new transmission lines (300 km more than expressed in the TDP 2022) and 210 transformers will be required to contribute to 133 000 MVA of energy capacity. The transmission line build-out represents a five-fold increase in terms of delivery over the next decade when compared to the preceding ten years (Eskom-NTCSA, 2024a).

In addition to the new capacity and transmission line extension, other infrastructure additions to the TDP 2024 compared to the TDP 2022 relate to the installation of synchronous condensers at several sites. This maintains system stability and supply security due to the widespread penetration of renewable energy as well as the scheduled decommissioning of coal-fired power stations. Additionally, new transformers have been incorporated into the TDP 2024 to advance the integration of renewable energy resources at existing substation sites rapidly (Eskom-NTCSA, 2024a).

The NTCSA, through the TDP 2024, states that the infrastructure rollout presents an opportunity for enhanced localization and industrialization, representing a critical window to develop local supply chains. Financing for the capital infrastructure, as mentioned in the TDP 2024, amounts to R112.5 billion (USD 1 687.5 billion) with 80% forecast for the capacity expansion portfolio, which relates to environmental authorizations (EAs) as well as land and servitude acquisition (Eskom-NTCSA, 2024a).

The NTCSA expresses in the TDP 2024 that while an adequate capital budget has been secured for the first five years of the plan, the bulk of the capital spend will take place in the latter five years of the ten-year plan. The NTCSA also states that its capital plan is limited by its balance sheet and allowable revenue streams. Due to these potentially limiting factors, the NTCSA has focused on its aims for the first five years, while engaging with stakeholders and the Government to address medium- and long-term investment needs (Eskom-NTCSA, 2024a).

10 The Expected Contribution of Disruptive Innovations on SDG 7.2 and SDG 7.3

What would be the expected contribution of disruptive innovations on SDG 7.2 (increase substantially the share of renewable energy in the global energy mix by 2030) and SDG 7.3 (double the global rate of improvement in energy efficiency by 2030)?

A disruptive technology is a specific technology that can fundamentally change not only established technologies but also the rules and business models of a given market, and often, business and society overall (Perez and Leach, 2022). The following list refers to numerous technologies and associated functions in the electricity industry value chain that can be categorized as disruptive or innovative:

- **Digitalization in the energy sector:** Digitalizing renewables by combining data, analytics, and connectivity serves as a facilitator in upcoming energy systems. New technologies should enable faster integration of renewable energy projects into the grid. Furthermore, this integration provides increased flexibility to customers, utilities, and other market participants (Johnstone et al., 2020). Technologies like the Internet of Things (IoT) and smart grids enhance the efficiency and reliability of energy systems, supporting the expansion of VRE technologies such as solar PV and wind. Specifically, these technologies have the potential to cause a wide range of improvements and benefits:
 - Real-time data: Smart meters provide real-time data on energy usage, allowing consumers to monitor their consumption patterns and make informed decisions to reduce their energy use and costs. This transparency promotes energy efficiency (IEA, 2023).
 - Grid stability: Grid-forming inverters can ensure frequency and voltage stability in grids with high renewable energy penetration, mimicking the inertial response of traditional generators. They also provide black start capability and fault ride-through support, ensuring grid reliability and stability (Lin et al, 2020).
 - Grid-scale energy storage: Large-scale energy storage systems, such as lithium-ion batteries and pumped hydro storage, are crucial for balancing supply and demand. They help stabilize the grid by storing excess energy during low-demand periods and releasing it during peak demand (StartUs-Insights, 2024).
 - High-Voltage Direct Current (HVDC) Transmission: HVDC technology allows for the efficient transmission of electricity over long distances with lower losses compared to traditional AC systems. This technology is particularly useful for integrating remote renewable energy sources into the grid (FutureBridge, 2023).
 - Dynamic Line Rating (DLR): DLR systems use real-time data to determine the actual capacity of transmission lines based on current weather conditions and line temperatures. This enables the optimization of existing infrastructure, thereby increasing the capacity and reliability of the grid (Arusi LLC Engineering, 2023).

- Demand response: By providing detailed consumption data, smart meters enable demand response programmes where consumers can adjust their energy usage during peak times in response to price signals or incentives from the utility. This helps balance the load on the grid and reduce the need for additional power generation during peak periods (IEA, 2023).
- Enhanced billing accuracy: With smart meters, billing is based on actual consumption rather than estimates, leading to more accurate and fair billing. This reduces disputes between consumers and suppliers, thereby improving customer satisfaction (European Commission, 2024).
- Fault detection and maintenance: Smart meters can quickly detect outages and other issues in the energy supply, enabling faster response and maintenance. This improves the reliability and resilience of the energy grid (IEA, 2023).
- Customer empowerment: Consumers have easy access to their energy consumption data and can permit third parties to use this data to provide tailored energy-saving solutions. This empowers consumers to take control of their energy usage and participate actively in the energy market (European Commission, 2023).
- Personalized services: Energy suppliers can use data analytics to offer personalized energy plans and recommendations based on individual consumption patterns. This can include suggestions for energy-saving measures or the best times to use energy-intensive appliances (IEA, 2023).
- Enhanced communication: Digital platforms facilitate better communication between suppliers and customers. For example, mobile apps and online portals allow customers to track their energy usage, pay bills, and receive notifications about outages or maintenance work (IEA, 2023).
- Load forecasting: Advanced data analytics and machine learning algorithms can predict energy demand patterns, allowing utilities to optimize their operations and reduce costs. Accurate load forecasting helps to ensure a stable and reliable energy supply (IEA, 2023).
- Integration of renewable energy: Smart grids, enabled by digital technologies, can better integrate variable renewable energy sources, such as solar and wind. By matching supply with demand in real-time, smart grids enhance the efficiency and reliability of renewable energy systems (IEA, 2023).
- Energy storage management: Digital tools can optimize the use of energy storage systems, ensuring that excess energy generated during low-demand periods is stored and used during peak demand times. This helps to balance the grid and reduce reliance on fossil fuels (IEA, 2023).

- Grid curtailment and weather forecasting:** This refers to the intentional reduction of renewable energy output to maintain grid stability when supply exceeds demand or due to transmission constraints. Accurate weather forecasting is essential for day-ahead predictions of renewable energy generation and effectively managing curtailment (World Climate Service, 2024). Advanced forecasting solutions, such as those using AI and high-resolution models, enable utilities to anticipate periods of high renewable generation and adjust grid operations accordingly. This helps minimize curtailment losses, optimize energy storage use, and ensure a stable and reliable energy supply (Climavision, 2025). Specifically in South Africa's case, grid curtailment can be used to increase the integration of wind generation capacity within constrained grid areas. This mechanism increases the utilization of the transmission grid (capacity factor), thereby enabling more energy to flow through the limited grid capacity to the load. The weather forecasting will improve planning, prediction, and associated dispatch of the flexible or dispatchable technologies, thus facilitating higher integration of VRE into South Africa's grid at any time.

While some technologies may be emerging in new regions, they can be defined as disruptive. Fundamentally, emerging technologies are innovations that are still in development or in the early adoption stages, such as advanced nuclear reactors and AI-driven energy management systems. They promise significant improvements but require refinement and scaling. In contrast, disruptive technologies fundamentally alter existing markets and practices. Examples of disruptive technologies include solar PV and battery storage, which have drastically reduced reliance on fossil fuels. These technologies often face initial resistance but eventually reshape industries (Capgemini, 2025).

Table 5 provides a summary of the maturity levels and applicability of innovative renewable energy generation technologies to the South African context by 2050.

Table 5: Innovative Renewable Energy Generation Technologies Towards 2050

Technology	Disruption Potential	Maturity	Expected Full Deployment	Applicability to South Africa
Small Modular Reactors (SMRs)	Moderate	Developing	2040–2050	High, with various spheres of government already announcing interest (Engineering News, 2025; World Nuclear News, 2024).
Offshore Wind	Very High	Developing	2030–2040	Moderate, with potential in coastal areas but higher costs and technical challenges (Hutt, 2022).
Long-Duration Energy Storage (LDES) e.g., flow batteries	Very High	Emerging	2030–2040	High potential to support grid stability and renewable integration (McKinsey & Company, 2024).

Technology	Disruption Potential	Maturity	Expected Full Deployment	Applicability to South Africa
Ocean Energy (Tidal and Wave)	Low	Preliminary stages	2040–2050	Low, due to limited coastal infrastructure and higher costs (IRENA, 2020).
Solar Photovoltaic (PV)	Very High	Fully developed	Ongoing	Very high due to abundant sunlight and decreasing costs (IEA, 2023; McKinsey & Company, 2024).
Floating Photovoltaics (FPV)	High	Emerging	Ongoing	High potential due to numerous water bodies, such as reservoirs or dams (Zero Point Energy, 2020)
Concentrated Solar Power (CSP)	Moderate	Developing	2030–2040	High potential in sunny regions, but higher costs compared to PV (IRENA, 2020).
Onshore Wind	Very High	Fully developed	Ongoing	High potential, especially in coastal and inland regions with strong wind resources (McKinsey & Company, 2024; IRENA, 2020).
Geothermal	Low	Developing	2030–2040	Limited by geographic availability in South Africa but potential in certain regions (IRENA, 2020).
Bioenergy	Moderate	Fully developed	Ongoing	Regionally variable, with potential in agricultural and forestry sectors (IRENA, 2020).
Hydropower	Moderate	Fully developed	Ongoing	Limited due to environmental concerns and site availability (IRENA, 2020).

Sources: Listed in table, PwC research.

However, disruptive innovations, through increasing renewables, could have potential negative consequences in South Africa, such as:

- Potential job losses:** The coal industry is a significant source of employment, and the transition away from coal to cleaner energy sources may lead to job losses and higher electricity costs, potentially affecting affordability for certain segments of the population (Inglesi-Lotz, 2023). Nonetheless, research shows that the increased use of renewables, due to more competitive pricing and economies of scale, will yield positive gains for real GDP and employment. This will see an added 2.5 million jobs created by 2050 due to the savings in energy costs (RSA: NDC, 2021).

- **Grid spikes caused by intermittent power supply:** Disruptive innovations, particularly those related to renewable energy sources like solar and offshore wind with their associated micro-grids and storage solutions, can introduce intermittency into the power supply.
- This periodic generation can worsen peaks and valleys in aligning the supply and demand of energy. Sudden increases in energy production (grid spikes) from these sources, combined with fluctuations in demand, can therefore challenge grid stability (Johnstone et. al., 2020).

The deployment of disruptive innovations has the potential to transform traditional energy systems, making them more sustainable, resilient, and accessible, thereby accelerating the development of renewable energy sources and increasing access to electricity. Collaboration between policymakers, businesses, and innovators is crucial to harness the full potential of these technologies for achieving the targets outlined in SDG 7.2 and SDG 7.3.

11 What Would Be a Cost-Effective Path to Achieve SDG 7.1?

What would be a cost-effective path to achieve SDG 7.1 (ensure access to affordable, reliable, sustainable, and modern energy for all by 2030) based on existing service standards?

The following key focus areas contribute to ensuring universal access to affordable, reliable, and modern electricity services by 2030.

1. **Focus on least-cost generation technologies, such as VRE:** This includes wind, solar PV, and stabilizing back-up storage (batteries and gas). The South African TIMES Model with General Equilibrium (SATIM-GE) identified that the most cost-effective new capacity primarily consists of VRE (The Presidency, 2023). The benefits of incorporating these technologies are supported by various mitigation modelling exercises in South Africa, including those by the NBI, Meridian Economics, the Council for Scientific and Industrial Research (CSIR), and the Energy Systems Research Group (ESRG), which recommend focusing on VRE supported by storage and peaking support as a least-cost solution (Tyler et al., 2023; Roff et al., 2023; Meridian Economics, 2024; CSIR, 2020; Renaud et al., 2020).
2. **Incorporate gas and battery storage:** Open-cycle gas turbines (OCGT) and combined-cycle gas turbines (CCGT) provide the necessary peaking support and flexibility to complement VRE (The Presidency, 2023). However, it is important to guard against using gas as a baseload power source due to its higher costs as well as the non-negligible carbon footprint of gas (IEA, 2023). Battery storage is crucial for balancing the intermittent nature of wind and solar power, ensuring a stable and reliable energy supply (The Presidency, 2023). Batteries are quick to bring online and effective for stabilization requirements measured in hours (i.e., up to 8 hours), while gas is more suitable for stabilization requirements measured in days (i.e., one to four days) (The Presidency, 2023; NREL, 2019).
3. **Limit new coal and nuclear plants:** Findings from additional studies (Tyler et al., 2023; Roff et al., 2023; Meridian Economics, 2024; CSIR, 2020; Renaud et al., 2020), as well as the Reference Case from the Draft IRP 2023 (DMRE, 2024a) and Draft IRP 2024 (DMRE, 2024b), indicate that new coal and nuclear capacity should not form part of the least-cost energy mix under a wide range of scenarios and sensitivities. This conclusion is based on the current mainstream projections of the costs of conventional nuclear and small modular reactors (SMRs). However, if learning rates turn out to be similar to what advocates of nuclear power propose, these cost projections relative to the costs of VRE may change. It is not just a question of reduced costs of nuclear, but also the real possibility that the costs of VRE start to rise in the 2030s due to natural resource constraints. If the whole world commits to an accelerated energy transition, the supply of materials for VRE construction will be affected (WEF, 2024b).

4. **Implement transparent and centralized planning:** By optimizing resource allocation and minimizing inefficiencies, policies can lead to lower costs and improved reliability of energy services (United States Department of Energy (US-DOE), 2017).
5. **Leverage existing infrastructure:** Optimizing the use of existing energy infrastructure can expand access. This includes upgrading and maintaining current facilities to improve efficiency and reliability (Africa Energy Portal, 2021).
6. **Public-private partnerships (PPPs):** While selecting the least-cost option remains a key priority, encouraging collaborations between the government and the private sector to fund and implement energy projects could benefit from leveraging the private sector's expertise and resources (Africa Energy Portal, 2021).
7. **Community-based solutions:** Exploring community-based energy solutions that are tailored to local needs and conditions. Community energy projects can enhance local ownership and sustainability (Africa Energy Portal, 2021). This topic has not been covered as part of this analysis and needs further research, given the financing implications and structures needed.
8. **Focus on energy efficiency:** Implement energy efficiency measures to reduce overall demand and lower costs. This includes promoting energy-efficient appliances and industrial processes (Constellation Energy, n.d.).
9. **Decentralized energy systems:** Decentralized systems can provide reliable power to communities that are not connected to the main grid (Roff et al., 2023). Renewable energy-based microgrid systems are particularly viable for rural communities, improving quality of life and creating job opportunities (Roff et al., 2023).
10. **Co-locate renewable energy generation infrastructure with demand:** Co-locating renewable energy generation infrastructure with demand centres, such as industrial parks, data centres, or urban areas, can significantly reduce transmission losses and improve energy efficiency. Co-location can facilitate the integration of renewable energy sources with local energy needs, enhancing grid stability and reliability (Constellation Energy, n.d.).

By focusing on least-cost generation technologies like wind, solar PV, gas, and battery storage, and limiting new coal and nuclear plants, South Africa can achieve a cost-effective path to SDG 7.1. This approach is supported by various modelling exercises and the IRP 2019, which recommends approximately 26.6 GW of VRE by 2030.

11.1 Commentary on the South African TIMES Model with General Equilibrium (SATIM-GE)

The JET IP addresses the investments required to support the decarbonization of the energy sector. According to The Presidency (2023), the modelling within the JET IP analysed the investment requirements for the electricity sector in the context of South Africa's 2030 NDC target (South Africa's commitments to the Paris Agreement) and was developed using SATIM-GE.

The framework consists of:

- The South African TIMES Model (SATIM): an economy-wide partial equilibrium linear optimization model built on the TIMES platform, which was developed and is maintained by the ESRG at the University of Cape Town.
- The Energy-South African General Equilibrium (ESAGE) model, a Computable General Equilibrium (CGE) model of the South African economy, which has the increased granularity necessary for the energy sector, as well as two spreadsheet-based models of the waste and AFOLU sectors to cover all GHG emissions sources.

The scenarios developed using SATIM-GE incorporate the committed capacity of Eskom, which refers to the final units of Medupi and Kusile, the remaining projects from the REIPPPP bid windows 1–6, and Eskom’s other project pipelines. Within the scenarios developed by the model, Scenario E0, which represented no constraints in the build approach, was configured to meet demand in the most cost-effective way, based on the existing stock of generation capacity and the available technology options. Scenario E0, as per the JET IP, results in new capacity consisting primarily of wind, PV, gas (OCGT and CCGT), and battery storage. The other scenarios developed in the model were designed based on the policy requirement of localizing the renewable energy value chain by specifying a minimum amount of added capacity required to be built per year to create certainty for investors. The model is dynamic enough to incorporate other capacities, including additional gas, battery storage, and other technologies, as required for system stability and to meet demand. Aside from these constraints, the model found that E0 was the least-cost solution.

11.2 Commentary on the NBI Towards Achieving a Least-Cost Electricity Supply

The NBI quantified the 2050 supply and demand gap as a starting point for the assessment of a least-cost electricity system supply option. This supply and demand gap was calculated using the IRP low-demand profile as a basis for how electricity demand will evolve from 2020 to 2050 and mapping this against available supply. Available supply was quantified by decommissioning existing infrastructure in line with the decommissioning dates outlined in the 2019 IRP. To account for the potential impact of demand-side management on supply requirements, a demand-side response of 2.5 GW is assumed (increasing linearly from 0.3 GW in 2026 to 2.5 GW between 2035–2050). In later phases, this demand assumption could also be updated to reflect key sector insights and findings (e.g., electrification in the transport sector), as well as the implications of sector coupling and more granular demand-side management (NBI, 2022).

11.3 Commentary from Meridian Economics on Approaching a Least-Cost Energy System

Meridian Economics identified that a net-zero date must be determined, with associated implementation and monitoring mechanisms at the national level, to provide the essential stepping stones towards the net-zero emissions goal from the power system. This is due to the nature of the country’s power system,

which is undergoing a transition while being responsible for achieving SDG 7.1 (Tyler et al., 2023; Roff et al., 2023; Renaud et al., 2020; Meridian Economics, 2024).

With a major focus on a national net-zero ambition, only three of seven scenarios modelled by Meridian Economics achieve net-zero emissions for the power system at any point in the modelling period, and only under conditions where a net-zero date is imposed. Without an implementable net-zero policy, carbon emissions from fossil energy remain in the national energy system post-2060.

Roff et al. (2023) emphasise the utilization of policy levers towards achieving energy related goals, particularly the transformation of the energy system. Findings associated with the use of the individual levers underscore that all sectors need to achieve net zero. The energy sector is a significant contributor to overall decarbonization and offers the least-cost mitigation opportunities. The authors at Meridian Economics expressed that it would be a priority to ensure that the power sector achieves net zero as soon as is feasible (Roff et al., 2023).

Meridian Economics links the net-zero goal to climate, and therefore energy system finance, whereby stipulating a date by which coal must be phased out achieves significant emission reductions over the full modelling period within their analysis to 2060.

Dasgupta et al. (2023) show that notable increases in inequality are expected permutations of climate risk at higher temperatures when compared to that of growth impacts. The authors mention that the effects are more noticeable for low-income groups in the population, whose productivity and wages decline as temperatures increase. At the same time, the impact on richer population segments is less pronounced due to higher adaptive ability. The study also found that agricultural households, which are prevalent among the many South Africans who rely on subsistence livelihoods, are more likely to experience an increase in inequality due to warming (Tyler et al., 2023; Roff et al., 2023; Renaud et al., 2020; Meridian Economics, 2024).

11.4 Commentary from the PCC on Achieving SDG 7.1

Due to the current shortfall in energy generation in South Africa, new generation capacity is needed, in addition to the transformation of fossil-based energy sources. The PCC expects a policy adjusted IRP, which provides a roadmap for meeting South Africa's forecast electricity demand, to promote approximately 50 to 60 GW of VRE by 2030, supported by co-located storage, and between 3 and 5 GW of peaking support (for example, gas, running at low utilizations). The IRP would be improved by focusing on transparency and spatial planning centred on grid access points (PCC, 2023a).

For South Africa to mitigate affordably below 370 MtCO_{2e}, which relates to the lower limit of the NDC carbon budget window, earlier coal plant retirement than that contained in the IRP schedule would be required, which is politically and socially challenging. Mitigation in the electricity sector is traded off against more expensive mitigation in harder-to-abate sectors.

The extent of electricity sector mitigation is highly related to whether the coal fleet is modelled as being able to endogenously retire, or whether retirement dates are fixed according to the IRP 2019 schedule (both options were modelled). During its consultation process, the PCC found that the main mitigation modelling exercises undertaken in the country – those of the NBI, Meridian Economics, the CSIR, and the ESRG – were all broadly aligned in their conclusions pertinent to the NDC period, albeit using different approaches, models, and assumptions (Tyler et al., 2023; Roff et al., 2023; Renaud et al., 2020; Meridian Economics, 2023)

All models examined by the PCC conclude that, even if no climate restrictions are put in place, a least-cost electricity system comprises VRE (wind and solar), storage (batteries and pumped hydro), and peaking support (typically, but not necessarily gas). None of the models, including the IRP 2019 least-cost scenario, includes new coal or nuclear, even though these are technology options within the models. The PCC recommends that the IRP adopt a spatial, grid-focused approach, creating a public and transparent detailed resource plan to end load shedding and establish a centralized planning process (PCC, 2023a).

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