Navigating South Africa's Energy Crisis: Advancing Toward a Solar-Powered Future

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Abstract

In South Africa, daily losses of US $51M – $237M, attributed to power shortages and inadequate national grid management, underscore the urgent need for a more comprehensive energy reform. The economic costs, coupled with severe social impacts, are further compounded by the country's significant environmental footprint. With 85% of electricity derived from coal, South Africa ranks as the 14th-largest global emitter of greenhouse gases, jeopardizing its climate commitments under the Paris Accord. Despite government pledges, achieving net-zero emissions and aligning with climate targets remains uncertain. This paper discusses some of the root causes of South Africa's energy crisis, investigating barriers to optimal energy resource usage. It emphasizes the imperative for strategic government initiatives to attract investments and enhance existing energy infrastructure. Additionally, a significant move toward practical solar possibilities, specifically, rooftop solar PV, may be required as the foundation for energy independence and a long-term resolution to South Africa's energy challenges.

Keywords: Energy crisis, South Africa, renewable energy, solar power, energy security

Introduction

Despite South Africa (SA) having the largest and most advanced economy in Africa, it has been plagued by a persistent energy crisis since 2008. The Central Bank of South Africa estimates that the economic impact of these frequent blackouts costs the nation almost US $51M daily, sometimes reaching between US$87M – $237M, depending on the stage of load shedding (Gbadamosi, 2024; Naidoo, 2023). Although the government recognizes the problem of energy supply deficits, attempts to address these have been inadequate.

The Electricity Supply Commission (Eskom), the state regulatory body that manages all three aspects of electricity supply, generation, transmission, and distribution, produces about 95% of the country’s power. The challenges faced by Eskom have led to a massive accumulation of debt coupled with the mismanagement of the country’s aging coal infrastructure. Besides these constraints, dependence on coal also heightens CO_2 emissions, affecting commitments from the Paris Agreement that involve scaling back and decommissioning of some coal-fired power plants in favor of renewable energy sources.[3]

Pragmatically, the scale of the current energy crisis has forced the government to further scale back on many of its climate-related commitments. However, this may not be the optimal solution to the pressures facing the economy, as global efforts toward a lower-carbon future intensify. This paper aims to dissect some of the root causes of SA's energy crisis, investigating barriers to optimal energy resource use. The study makes the case that given the severity of the crisis, solar energy presents the best potential for mass uptake and a guarantee for energy security in the short to medium term.

[3] The country has committed under the Paris Climate Agreement to cut emissions by decommissioning eight of its fourteen coal-fired power plants by 2030.

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1.1 South Africa's Energy Profile

South Africa is endowed with abundant energy resources including coal, uranium, some natural gas, and oil; and renewable energy, notably solar, wind, and hydro. Primarily, coal accounts for 77% of the energy supply, followed by crude oil at roughly 14%. Renewable technologies saw a recent increase from 5.5% in 2020 to 8% in 2022. In terms of the ratio of total energy production to supply, the country remains energy self-sufficient (Figure 1). While coal has provided a reliable source of electricity for decades, it has also exacted a toll on the environment, contributing to air pollution and greenhouse gas emissions (Ncube, 2021).

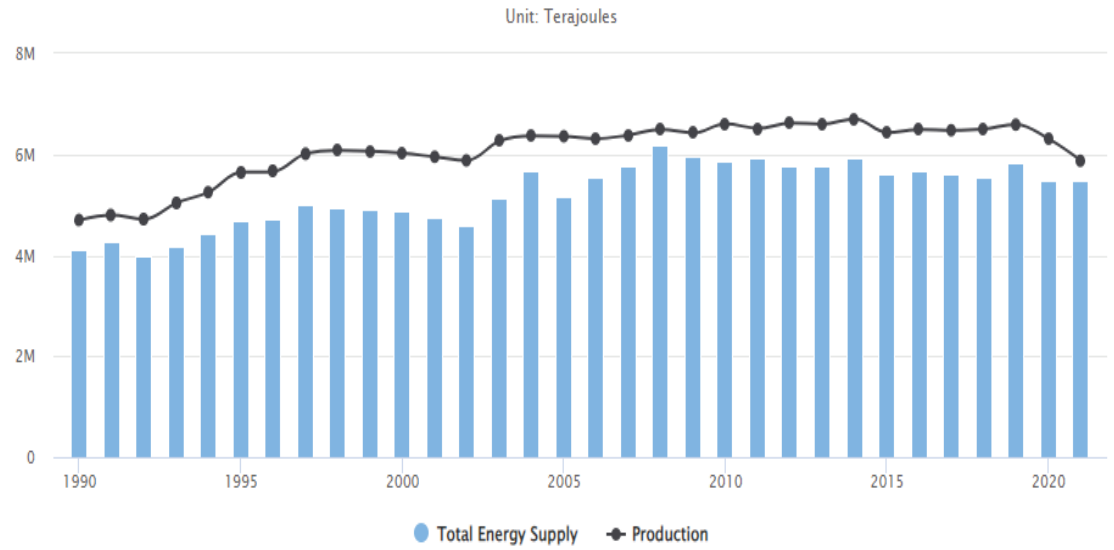

Figure. 1. Total Energy Production and Energy Supply 1990-2020 (UNSD, 2024)

In terms of the electricity sector, 14 large coal plants account for 85% of the utility's installed capacity, followed by hydroelectric capacity at 6%, 5% of electricity generated by open-cycle gas, and 4% generated by Koeberg nuclear power. Figure 2 puts into perspective the plant mix for electricity generation managed by Eskom.

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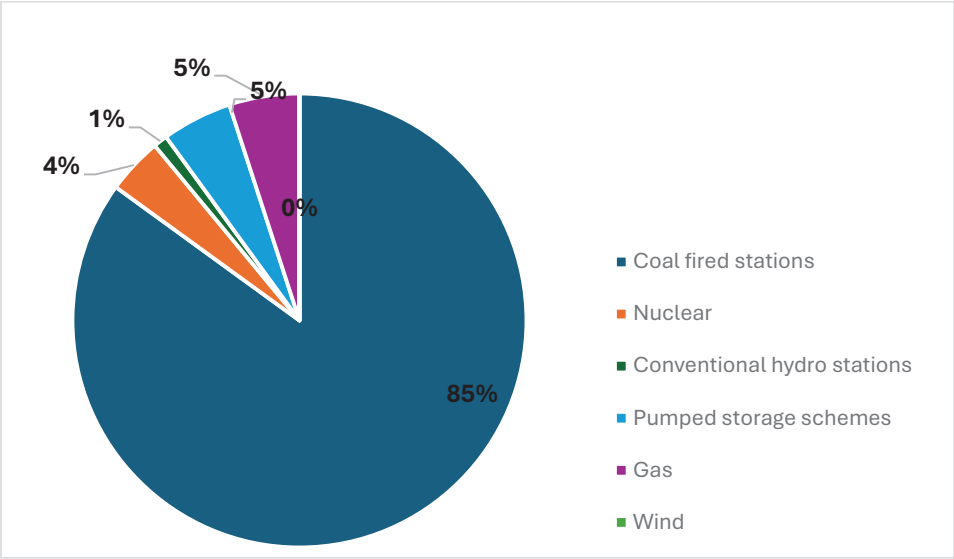

Fig. 2. Plant Mix for Electricity Generation by South Africa's Utility Provider Eskom (Eskom, 2022)

From Figure 2, it can be observed that coal remains the dominant energy source in electricity generation. The country's natural comparative advantage in coal has become a key fixture in its energy makeup. This overdependence on coal has led to national energy intensity per capita being high at (92.33 GJ/person) compared to most developing countries and in the African region.

South Africa exports coal power to neighboring countries through the Southern African Power Pool founded in 1995. Much of this sale is at the expense of domestic demand, since only 70% and 80% of produced and consumed coal respectively go towards domestic electricity production (African Energy Chamber, 2023). Even during times of severe load-shedding crisis (stages 4-6) between 2018- 2022,[4] the country has maintained net exports of coal power to Botswana and Namibia at the expense of local demand. Beyond coal, Eskom also manages seven hydropower plants with an energy capacity of 3,484 megawatts and gas-fired power plants that often serve as backup or supplemental energy. Currently, renewable energy plays a small role in the total energy supply in the country with installed capacity gradually increasing (see Figure. 3).

[4] Load-shedding is an electricity-supply tool used to reduce excessive demand for electricity on the grid. It consists of (1-8) stages, where at each stage 1000 MW of power is unavailable. The schedule was developed ensure that power rationing is conducted in an equitable manner.

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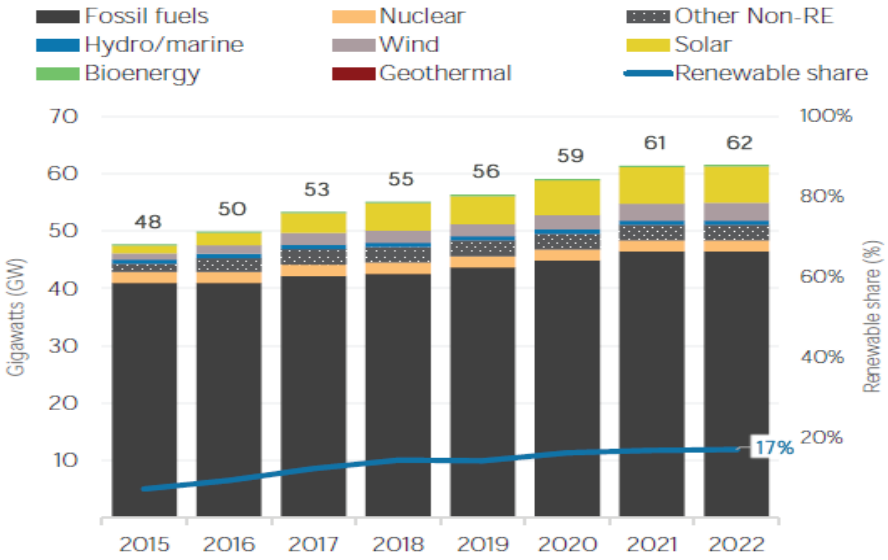

Fig. 3. Installed Capacity Trends 2015- 2022 (IRENA, 2023)

To help manage its debts, Eskom recently increased electricity tariffs to stay profitable as production of primary coal reduced in 2021. Overall, the utility's systemic challenges, mismanagement, and a rapidly evolving global energy landscape have resulted in supply unable to meet the power needs of the nation. The rate of expansion of renewable energy is not increasing quickly enough to meet rising demand.

1.2 The Energy Crisis in South Africa

The building of new coal power plants managed by Eskom increased when the country's need for electricity started to rise in the early 2000s. Because the utility has a monopoly over energy transmission and distribution, internal strife naturally affects the overall national energy situation. This aside, there are diverse factors that have led to the current energy crisis. A few are discussed below.

Firstly, a major element of the crisis has been Eskom's debt burden, which hampered the utility's efforts in managing its portfolio. Nkosi's (2020) assessment of Eskom's financials showed that a bailout from the government and increasing tariffs have kept the utility afloat from 1985-2017, rather than sales contributing to profitability. The utility's poor management led to the massive accumulation of debt, to the tune of 450 billion rands (about US $31 billion) (Nguyen, 2023). These financial constraints have hindered needed infrastructure upgrades and maintenance, perpetuating the cycle of energy shortages.

Also, political interference in Eskom's management has affected the stability and effective functioning of the agency. Wentink (2023) and Naidoo (2023) note that corruption and state capture have led to the government often using the utility as a vehicle for scoring

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political points.[5] Some of these fraudulent dealings are part of the reason for Eskom's mounting debt and mismanagement. Hence, although the crisis may be self-inflicted, as noted by Wentink (2023), the impact has been extensive, resulting in decreased industry productivity, job losses, and reduced investor confidence in the country.

Moreover, despite rich coal reserves, rapid expansion to address the current crises may be cost-prohibitive. The current financial climate makes obtaining financing for new coal plant development an impossibility. This may lead to a renewed focus on expanding nuclear energy options. However, detractors of this choice also argue that the environmental implications and costs of the potential expansion of the Koeberg nuclear plant may not be commensurate with the benefits. This is because nuclear energy's risks are negatively wide-reaching, such as those that occurred in the cases of Fukushima and Chernobyl (Steve, 2015).

Another notable element of the crisis has been the inconsistent policies and regulatory frameworks that have previously limited the diversification of the sector and investments in renewables. Commitments were made in 2018 to scale back coal. However, increasing energy insecurity led to the government reneging on some of its climate commitments (Mukherjee, 2023). Also, initial limitations that were set for renewable generation under the Electricity Regulation Act (ERA) of 2006 limited generation capacity for renewables. This caused delays in uptake due to bureaucratic challenges in the issuing of these licenses. This led to the World Energy Council recommending that SA adjust its policy proposals to foster public-private partnerships in favor of the energy transition (Todd & McCauley, 2021).

Overall, the current crisis cannot be pinpointed to one source, but rather is due to a hodgepodge of policy indecision, political agendas, mismanagement on the part of Eskom, and the inability to plan and adequately forecast energy demand to meet supply. Together with climate-centered improvements to its aging coal fleets, the country needs to smartly upgrade its national energy systems and expand renewable energy generation.[6]

1.3 Expanding Renewable Energy Supply in SA's Energy Mix

Regarding the production of energy from renewable sources, SA released a white paper in 2003 that set a goal of producing 10 TWh of power from biomass, wind, solar, and small-scale hydro. This was followed by the Integrated Resource Plan, which introduced the Renewable Energy Independent Power Producer's Programme (REIPPP) in 2011,

[5] 'State capture' is a phrase used to refer to corrupt government machinery that siphons state resources in favor of personal interest over the public interest.
[6] The expectation is for coal to decline in the long term. This has been problematic, as recently, almost 20,000 MW of coal power went offline resulting in Stage 6 load-shedding of more than 37% of the population without power.

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setting a target of an additional 17,800 MW of renewable energy generation by 2030. Thus far, it has increased renewable installed capacity by over 6280 MW from different technologies, mostly from wind and solar. Although, this has not been enough to diversify the energy mix sufficiently to accomplish its climate goals.

Moreover, because of renewables' non-dispatchability issues and the grid's limitation in absorbing large renewably sourced power, the REIPPP planned a phase-wise scaleup. The REIPPP has had six bidding procurement windows for independent power producers (IPP). The current 7th window seeks to procure 14,771 MW of new generation capacity – 3,940 MW of PV, 9, 600 MW of wind, and 1,231 MW of battery energy storage capacity (IPP Renewables, 2024). The IPPs are expected to develop 5,000 MW of new generation – 1,800 MW from solar PV and 3,200 MW of wind power.

Another challenge beyond the phase-wise additions to the grid was the generation-capacity license for IPPs. This required producers to apply for a license of 1 MW of solar generation. The threshold was later extended to 100 MW and was finally scrapped under amendments to section 3 of the ERA, Act 4 of 2006 in 2022. This currently allows the generation of renewable power without limitations in so far as IPPs have an agreement with municipalities to access their point of connection for the transmission and distribution of solar power. Currently, the IPPs generate and use third-party transmission of generated power to municipalities who then distribute power to customers. Locally, this is referred to as third wheeling. This policy directive is the single most influential directive that has transformed and liberalized the generation, transmission, and distribution of power in SA.

Physically, SA's atmospheric characteristics are ideal for solar and wind, with the annual solar radiation average at 220 W/m^2 of direct normal irradiance. Many areas average annual sunshine of more than 2,500 hours per day in the range of between 4.5 and 6.5 kWh/m^2 which are also ideal conditions for solar (Soly, 2023). Currently, renewable energy's levelized cost of electricity (LCOE), which measures the net present value of building, generating, and operating an energy system, divided by the total electricity generation over the entire lifetime of the system, shows that renewables are comparable and cheaper to build than coal, the dominant power system (see Figure. 4).

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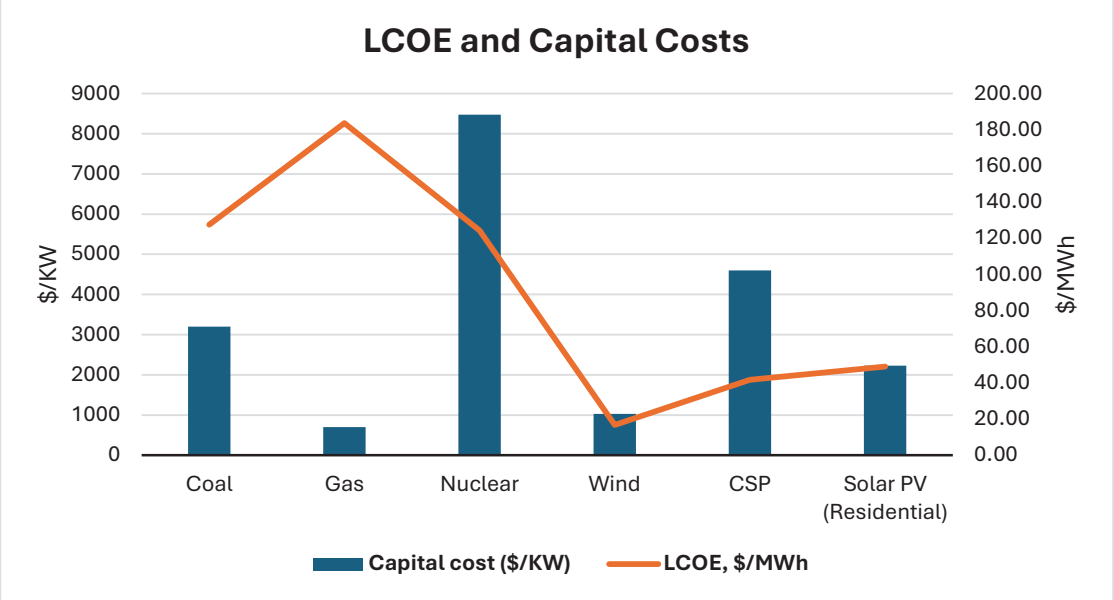

Fig. 4. Comparing Levelized Costs of Electricity and Capital Costs by Energy Technology (Data sources: Lazard, 2023; Mulongo & Kholopane, 2018)

Our updated calculations for LCOE from Mulongo and Kholopane's (2018) study show the LCOE for wind ($16.72/MWh) and solar PV (Residential) ($41.68/MWh) are cheapest compared to building a new coal and natural gas plant or a nuclear plant. Capital costs for natural gas ($700/KW), wind ($1,025/KW), and solar PV (residential) ($2,230/KW) are lower compared to coal, nuclear, and concentrated solar power. Although the LCOE assessment shows lower costs for wind compared to solar, expanding rooftop solar PV access may have a wider ameliorating effect of relieving the pressures on the grid and providing energy security for households. Current estimates of solar PV (rooftop) additions to the energy mix show more than a quadrupling of solar generation since 2022 (see Figure. 5).

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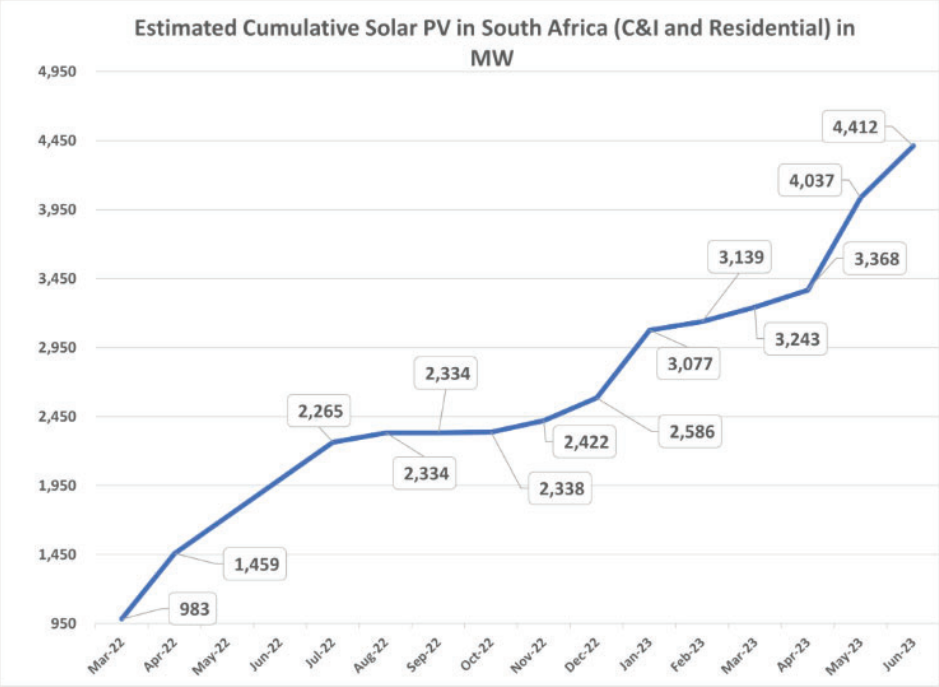

Figure. 5. Solar PV Capacity Additions (Kuhudzai, 2023)

From 2022 to 2023, there were over 3000 MW of solar rooftop systems added for commercial and industrial (C&I) users and the residential sector combined, reaching 4,412 MW as of June 2023 (Kuhudzai, 2023).

1.4 Conclusion: Toward a Solar-Powered Future and the Goal of Net-Zero by 2050

The current energy crisis has negatively impacted the economy and its dependence on coal has caused untold environmental damage to mining communities and the broader biosphere. According to the Climate Action Tracker (CAT) (2023), SA is unlikely to meet its climate commitments. CAT, the tracking agency that models scenarios of national climate commitments rated the country's current efforts as 'insufficient' in meeting its net-zero commitments by 2050. Although its targets are aimed at maintaining the range of 350-420 $MtCO_2e$, the severity of the crisis has led to a scaling back of goals.

To tackle the energy crisis, a comprehensive strategy consisting of diversifying the nation's energy sources toward renewable energy sources such as solar, wind, and hydroelectric power will be needed. Solar presents the biggest potential since the country's atmospheric conditions and current LCOE indicate a viable alternative to help reduce the burden on the grid and foster energy security.

A lack of infrastructure investments and smart upgrades to the national grid and liberalization of the power system were the optimal barriers to renewable solar energy

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expansion. With the amendments of Schedule 3 under the ERA 4, opportunities for liberalization have commenced. Also, enhancing public-private partnerships can further mobilize more capital and expertise to accelerate infrastructure development. Since the limitation on the license system for generation has been removed, 'wheeling' will be one of the best options to enhance utility-scale solar for municipalities in terms of relieving the grid's load burden.

Moreover, a policy focus on subsidies in the form of incentives to encourage rooftop solar PV uptake for the residential and C&I sectors would have to be amplified through credit schemes, tax breaks, and rebates. The rebate consideration should be higher than the current 25% of the cost of the panels and establishing a net metering system nationwide would be beneficial. The rapid adoption of distributed solar systems can reduce the demands on the grid. Lastly, to boost solar potential, supply-side promotion through government-driven awareness programs and retrofitting of government buildings with solar can increase interest. This must be done in concert with energy efficiency and conservation measures to reduce the grid's load. Finally, solar energy can be strategically positioned, with other renewables and natural gas, to address the intermittency issues, and help close the energy deficit gap. This will improve national energy efficiency targets in line with the Paris Accords.

Conflict of Interest

The authors declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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