
CENTRE FOR RENEWABLE & SUSTAINABLE ENERGY STUDIES

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# Visualisation of South African Electricity Data

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# South Africa’s Power System from a Geospatial Perspective

South Africa's power system is comparable in scale to that of Western Europe. It shares some characteristics with Australia's power system, such as extensive transmission lines with limited meshing and relatively weak interconnections with neighbouring countries.

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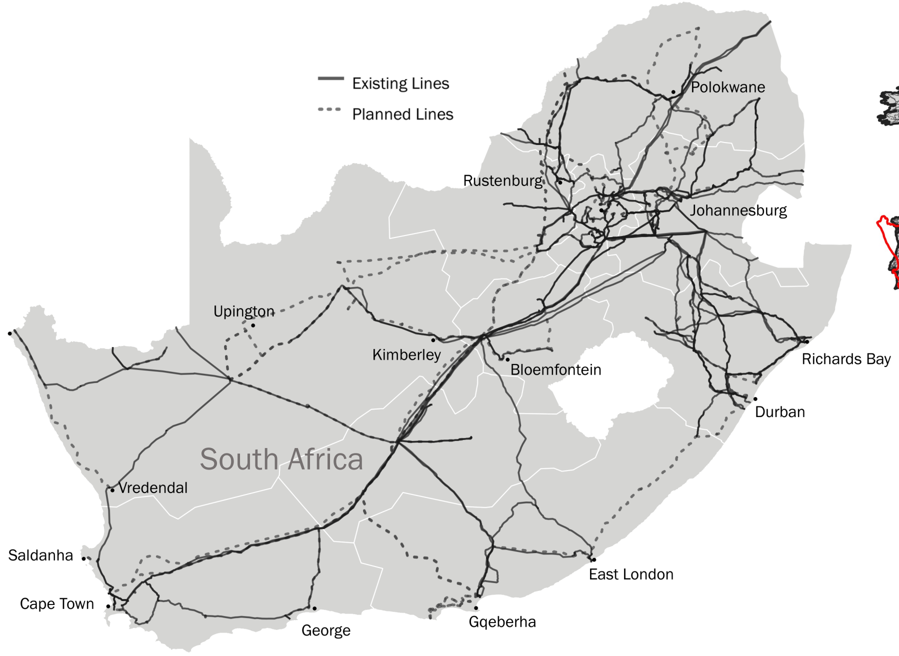
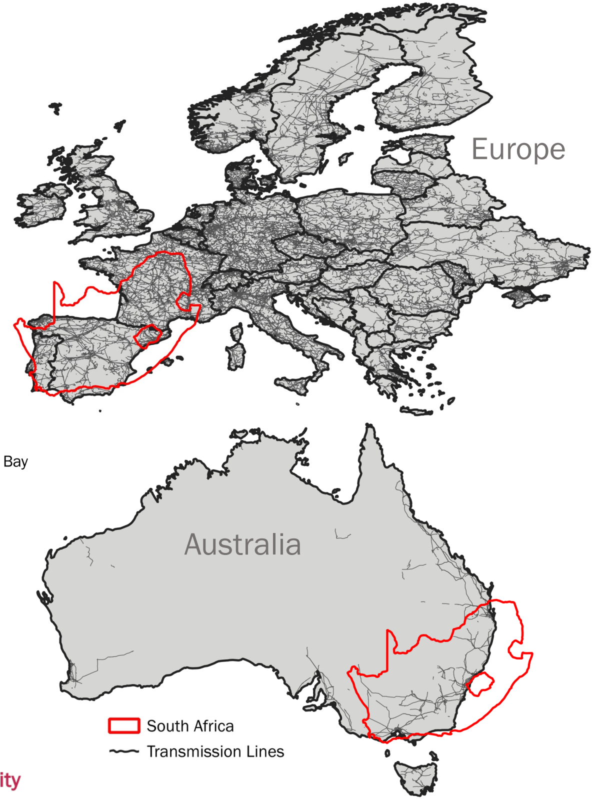
# South African Transmission Grid in Context

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**Source:** Eskom 2025; World Bank Group 2023.

In 2017 (the most recent year for which data is available), around 35% of SA's electricity consumption was geospatially centred in the metropolitan areas shown in yellow below, with the largest consumption occurring in the Gauteng province.

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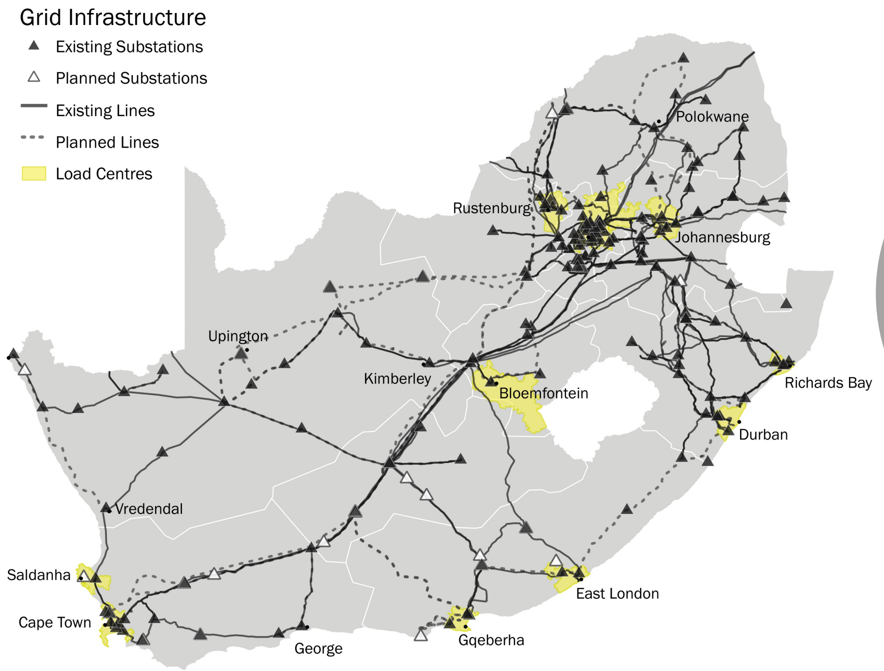
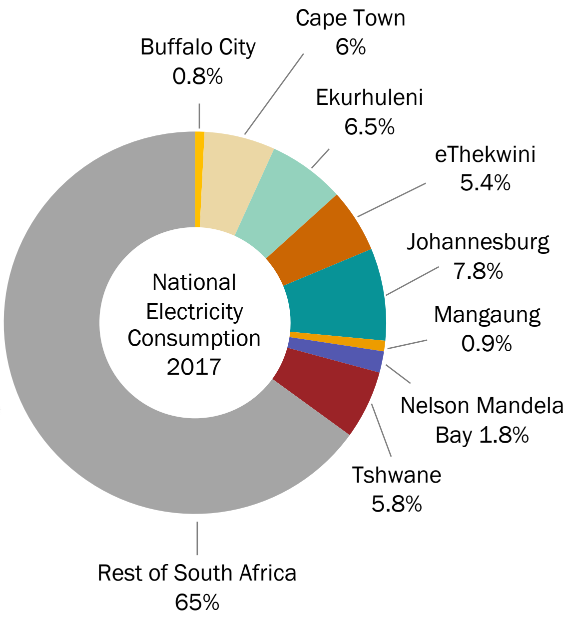
# South African Transmission Grid and Load Centres

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**Source:** Eskom 2025; Sustainable Energy Africa 2020.

Dispatchable electricity generation in South Africa predominantly relies on coal, concentrated in the Mpumalanga region, which hosts the country's coalfields. South Africa's single nuclear power station is situated in the Western Cape near Cape Town, while pumped storage facilities are located in the mountainous regions of the Drakensberg and Kogelberg. As a water-constrained country, South Africa has limited hydroelectric resources. Additionally, the gas distribution infrastructure is underdeveloped, resulting in gas generation facilities being located primarily along the coast.

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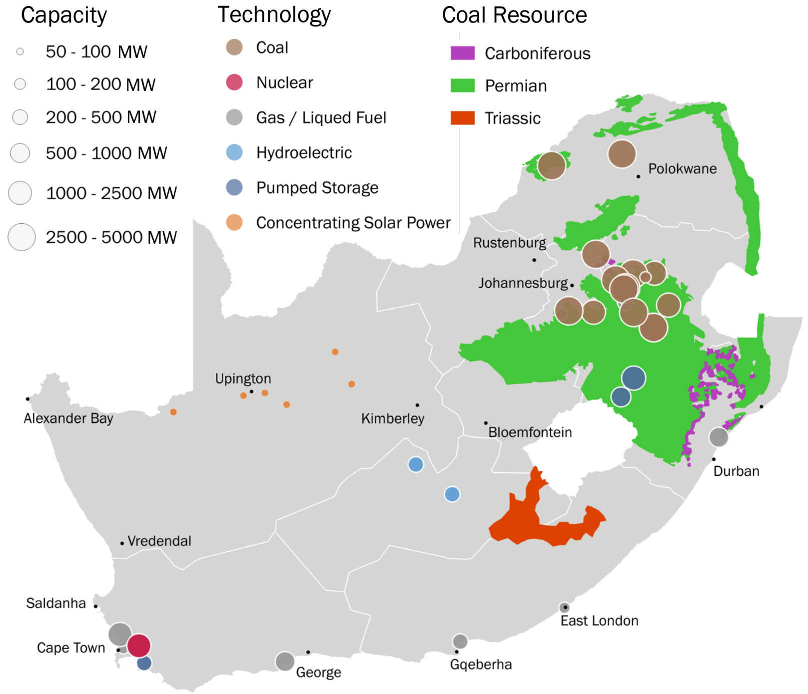
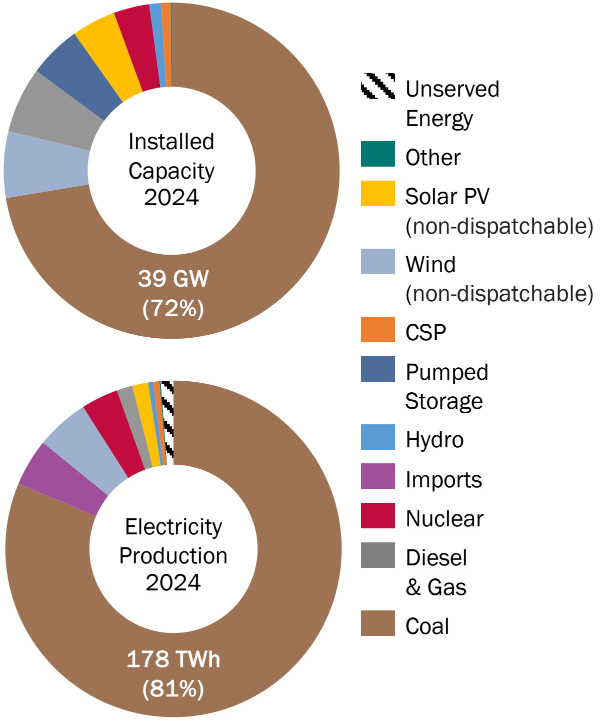
# South African Dispatchable Power Plants

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**Source:** Eskom 2025a; Merrill & Tewalt 2008.

Non-dispatchable electricity in South Africa is generated mainly by solar photovoltaic (PV) and wind technologies. Most wind and around a quarter of the solar PV plants in South Africa have been installed through the Renewable Energy Independent Power Producer Procurement Programme (REIPPP), with the rest typically connected to the existing distribution grid and behind the customer's utility meter. Driven by cost considerations, the siting of utility-scale wind and PV plants is generally near a connection to the transmission grid. As shown in the picture below, the distance between current REIPPP plants and main transmission stations rarely exceeds 60km.

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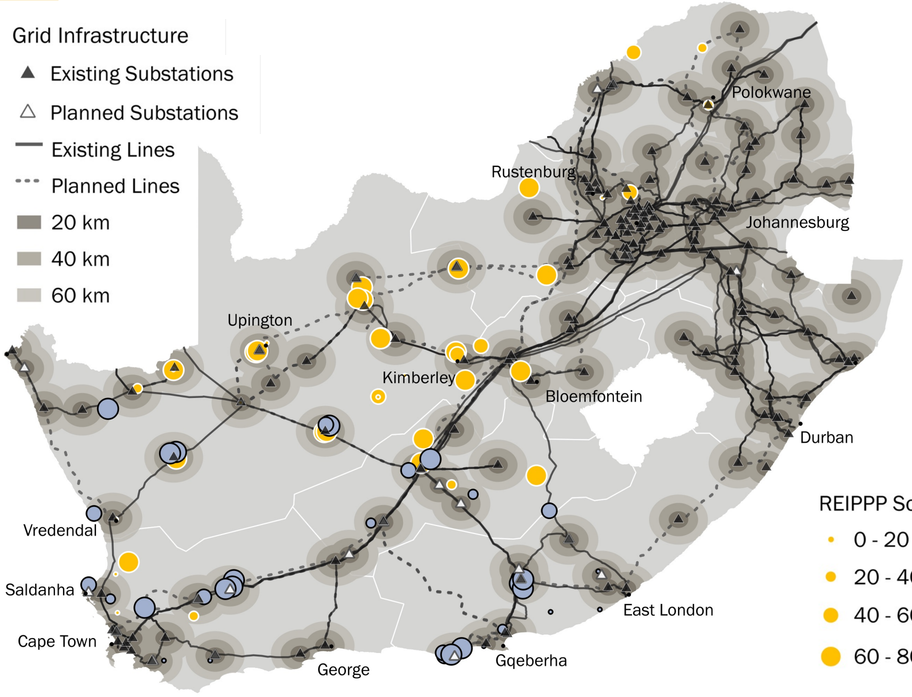
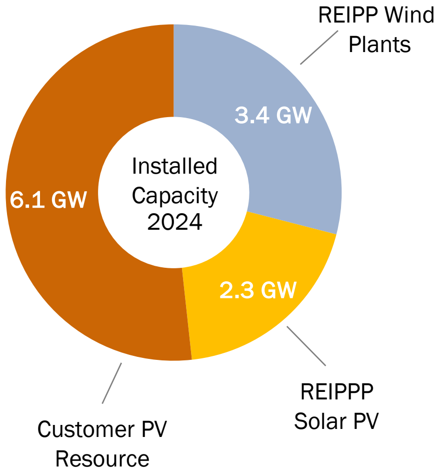
# South African Non-dispatchable Power Plants

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**Source:** Eskom 2025a. **Notes:** REIPPPP: Renewable Energy Independent Power Producer Procurement Programme.

# 2

# The Challenge of Constrained Generation in South Africa

The diagram below provides a perspective of how South Africa's electricity consumption changed over time. Various factors influenced these changes, including South Africa's very successful electrification program which commenced in 1990, rising electricity prices, increasing appliance efficiency, and recurring load shedding since 2008.

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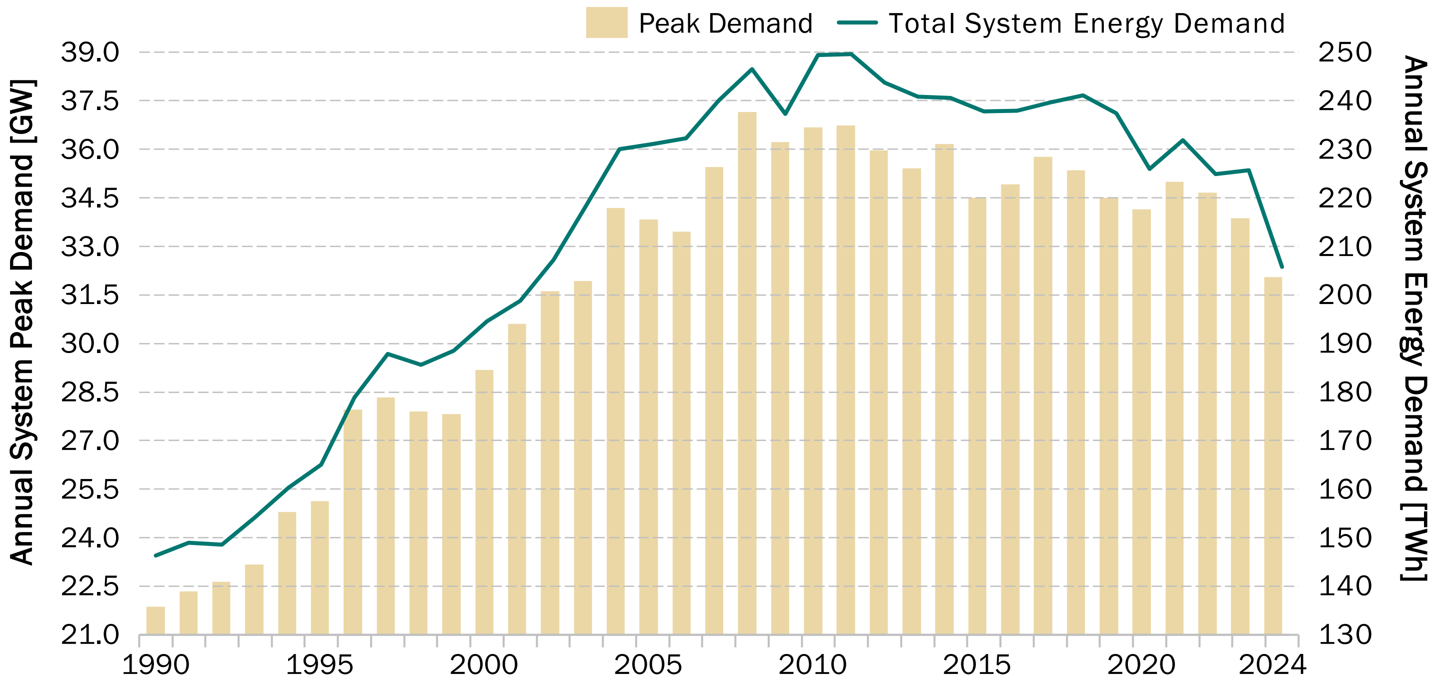
## Annual South African Electricity Consumption

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**Source:** Eskom 2025a; Eskom 2025c.

Electricity intensity measures the electrical energy used per gross domestic product (GDP). For South Africa, this declined sharply from 2002, mirroring an international trend towards more efficient electricity usage. South Africa saw a significant rise in electricity costs between 2008 and 2023 (720%), which far outpaced SA's inflation during the same period (215%), strongly incentivising more efficient electricity use and, from the mid-2010s, self-generation.

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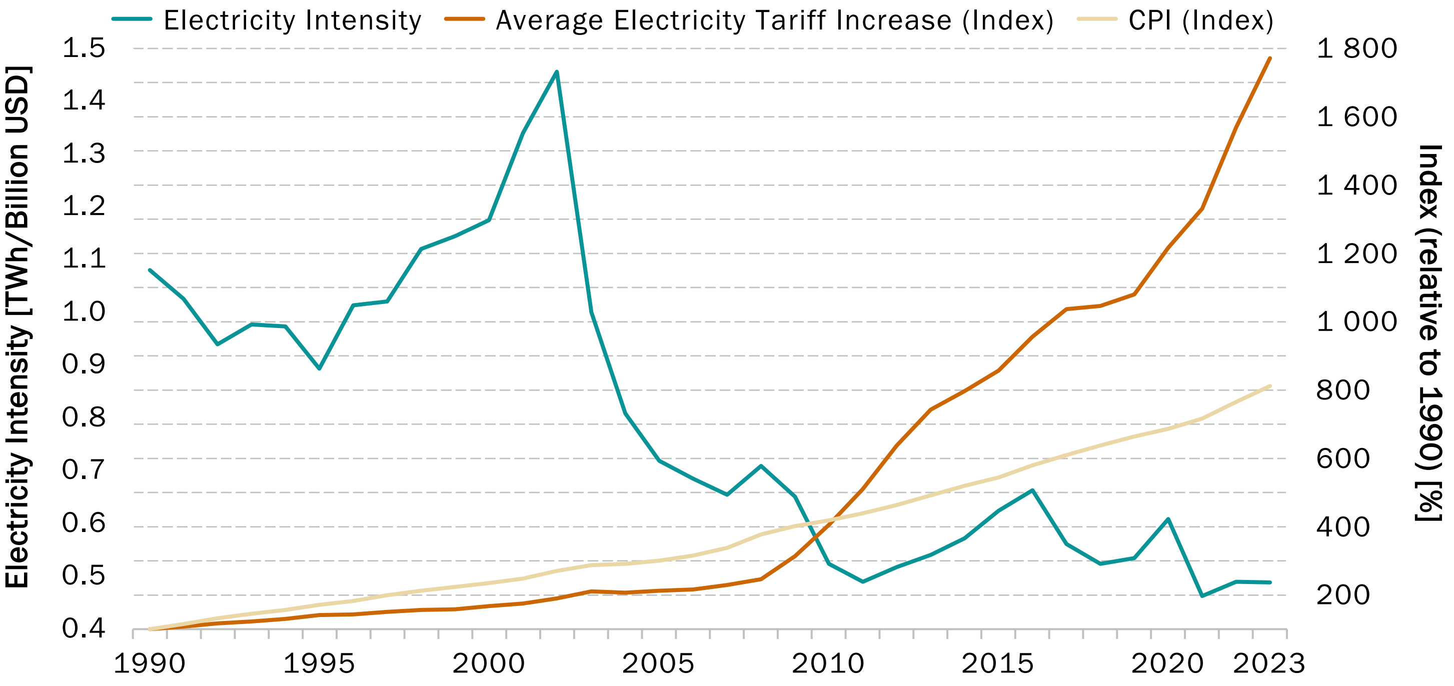
## South African Energy Intensity and Electricity Pricing

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**Source:** Eskom 2025a; Eskom 2025c; Data Commons 2025; Statistics South Africa 2025. **Notes**: CPI = Consumer Price Index.

Generation capacity has been sporadically added to the South African power system since 1990, with the reserve margin increasing from 1990 (~55%) to 2024 (~65%). The reserve margin measures the percentage of additional generation capacity available above the annual peak demand for use in case of planned and unplanned generation outages. At face value it gives a good indication of the power system's resilience to unforeseen events, but in South Africa's case it is less useful. Between 1990 and 2024 the amount of unplanned generation outages significantly increased, while non-dispatchable generator additions like solar PV and wind, included in the metric, are not always available when system peak load occurs.

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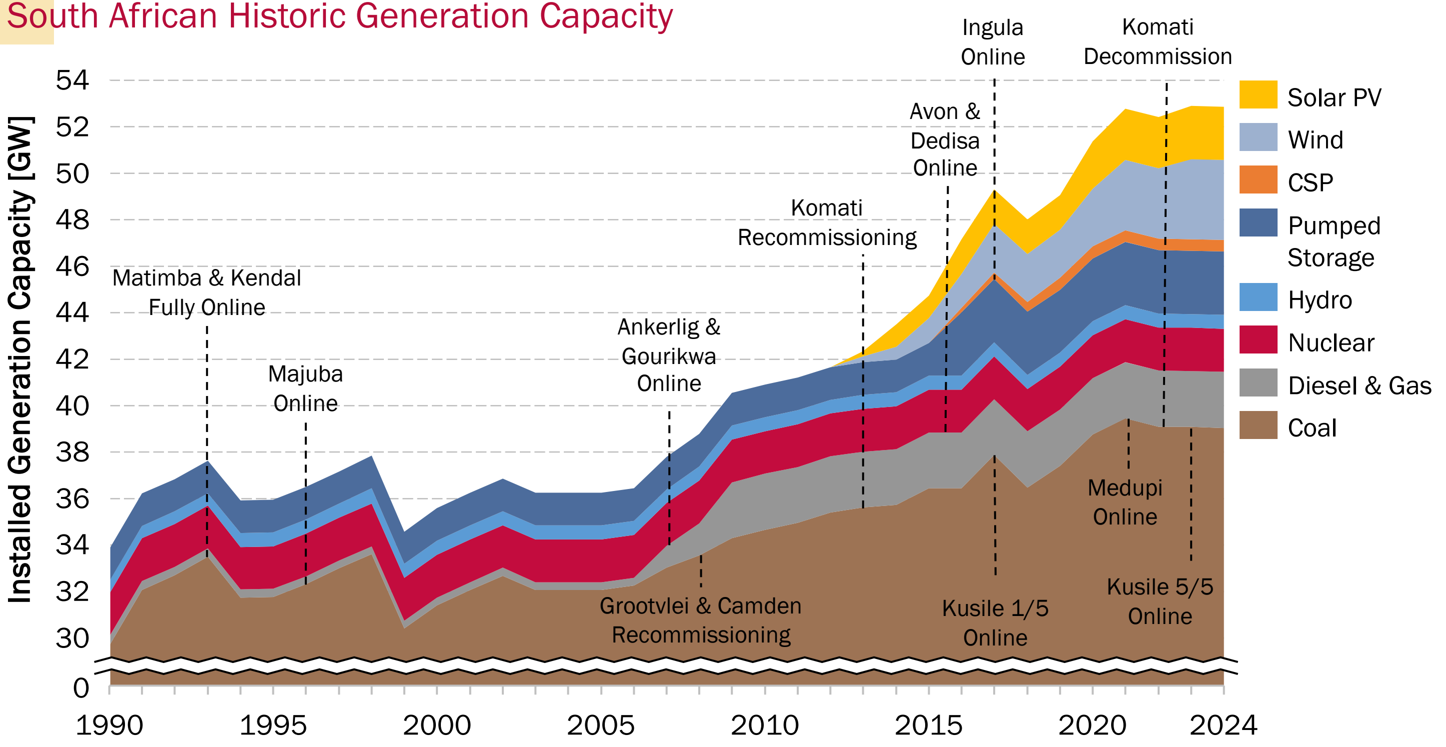
## South African Historic Generation Capacity






**Source:** Design as per Fraunhofer ISE 2021 and CSIR 2023; Eskom 2025c. **Notes:** The status of power stations over 300MW are labelled.

The reliability of South Africa's ageing coal fleet declined drastically in recent years. Given coal's dominance in the energy mix, this impacted the reliability of the total South African generation fleet, as illustrated by the Energy Availability Factor (EAF) graphs below. EAF represents the amount of energy a generator was able to produce compared to its capacity over a period. As seen, EAF follows a seasonal trend informed by planned maintenance typically scheduled during lower-demand summer periods and more efficient coal plant operation during colder and dryer winter months. Noteworthy is how the EAF improved by July 2024, countering the declining trend of the preceding years.

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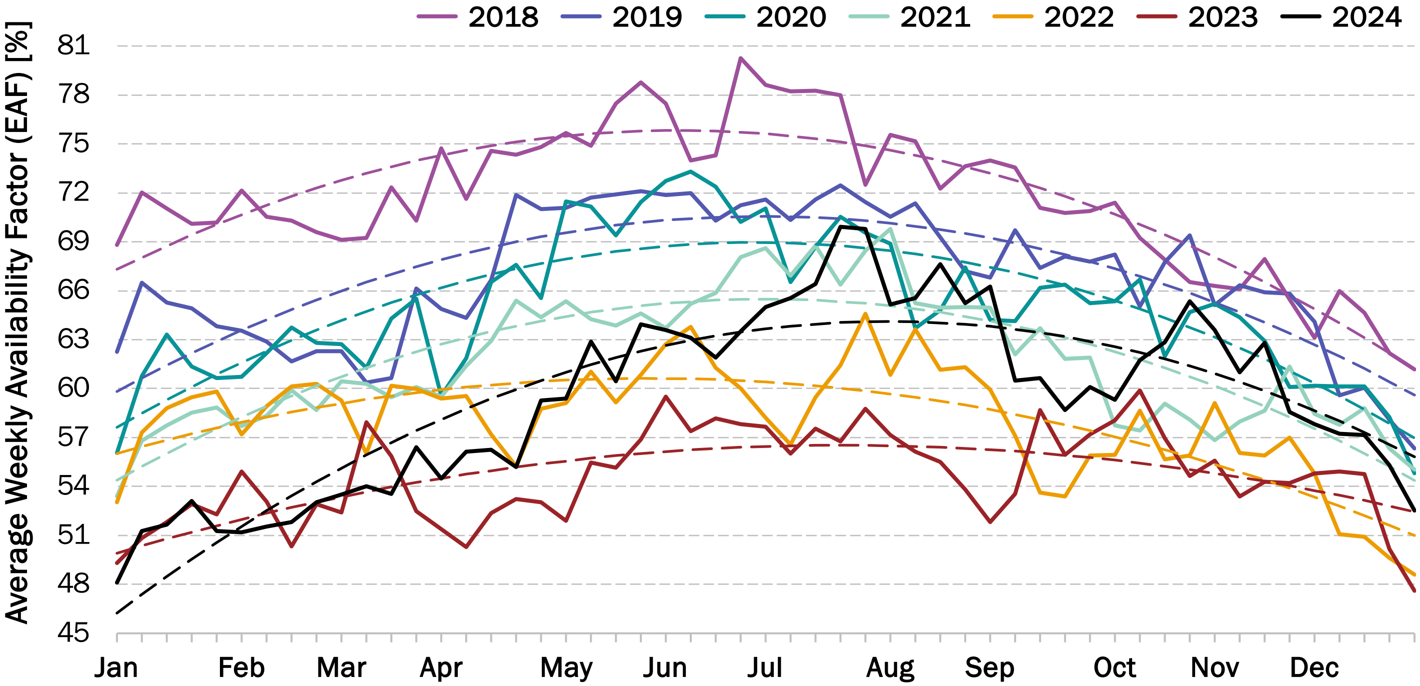
## South African Generation Fleet's Reliability






**Source:** Design as per Chris Yelland 2023; Eskom 2025a.

The combination of declining generation capacity and the increased unreliability of South Africa's coal fleet ultimately made it impossible to satisfy the country's electricity demand at all times. From 2008, this resulted in scheduled, stage-based national load reduction known as load shedding. Eight stages of load shedding were defined, with stage 1 resulting in the reduction of 1 GW of demand nationally, stage 2 in 2 GW, etc. Load shedding has increased exponentially in recent years.

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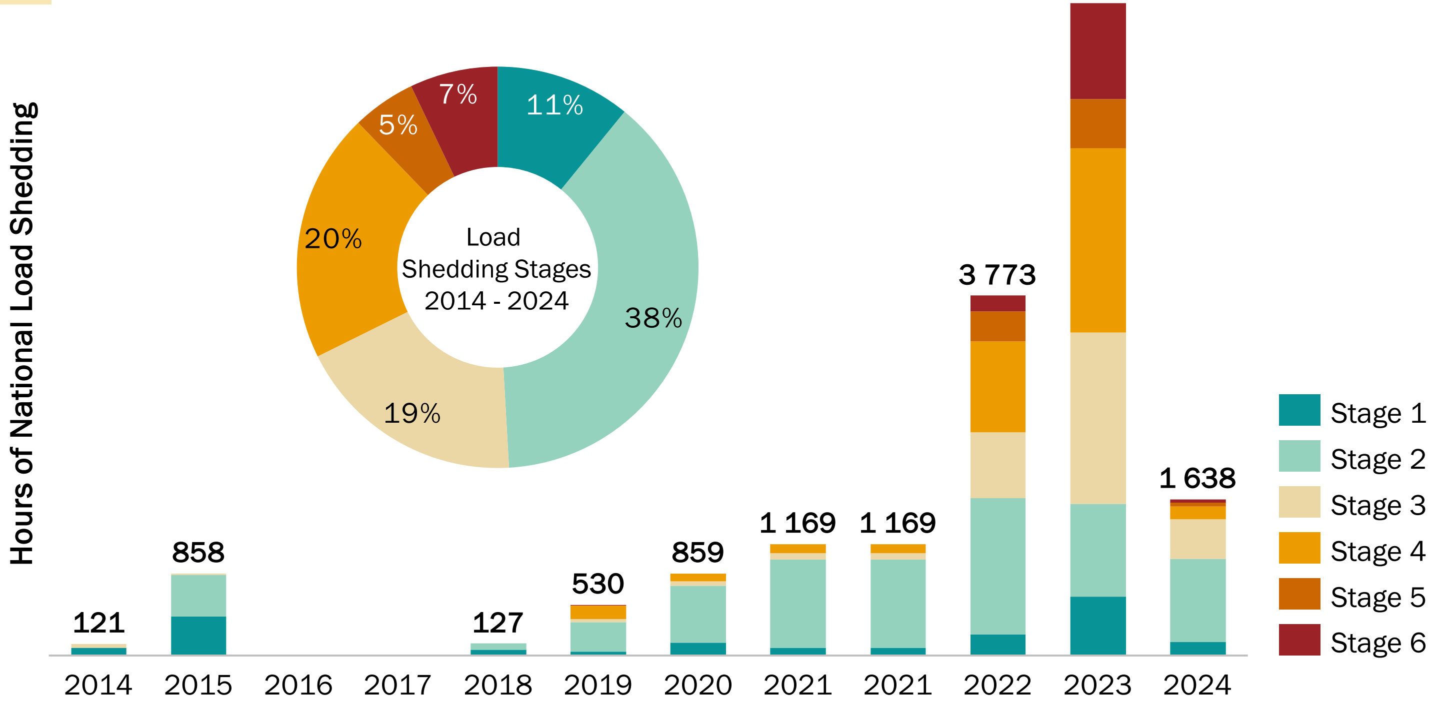
## South African Load Shedding

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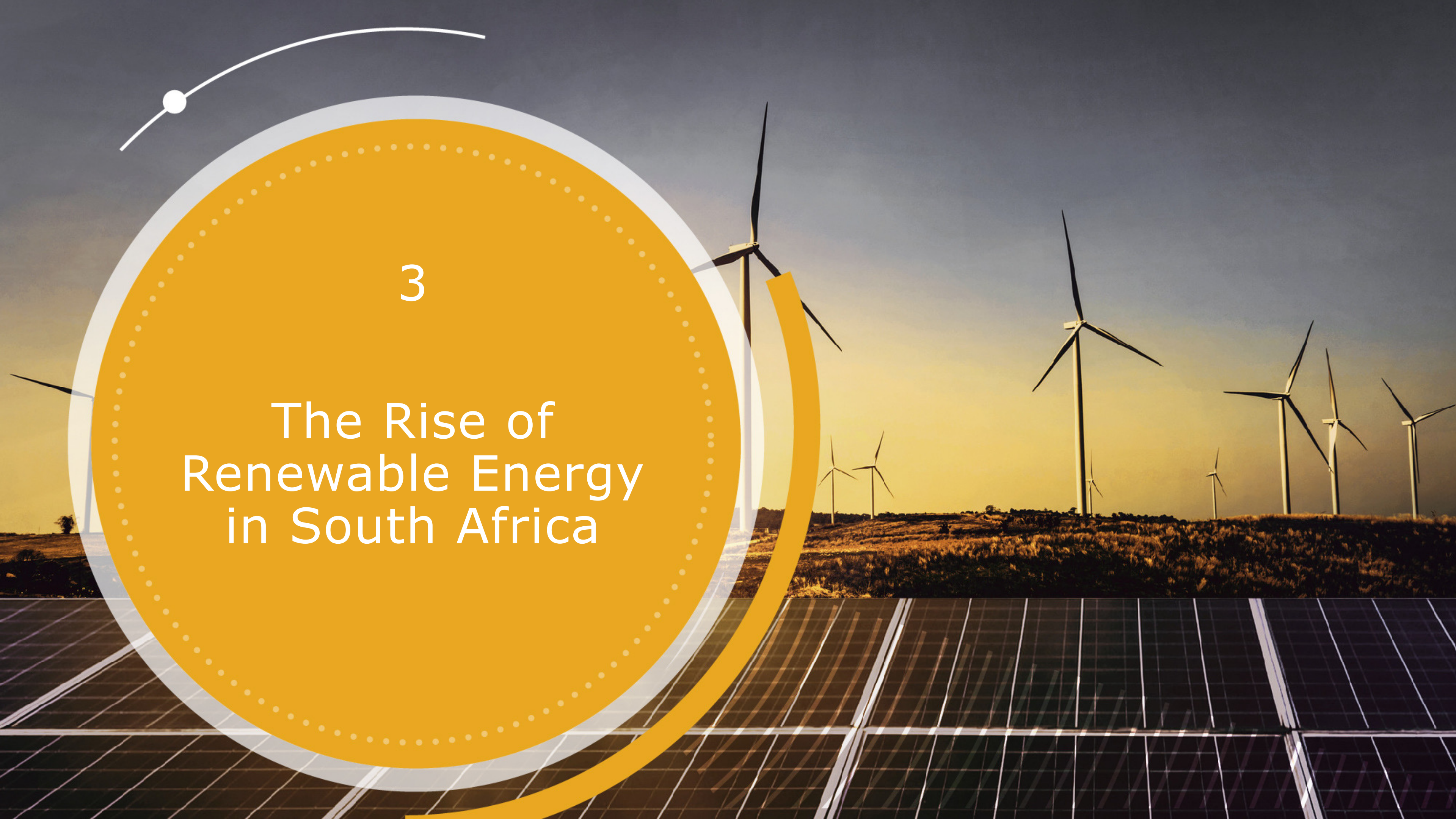
**Source:** Eskom 2025c; EskomSePush 2024.

# 3

# The Rise of Renewable Energy in South Africa



A strong correlation exists between rising global atmospheric CO2 and rising surface temperatures, as shown below. As fossil-fuel based electricity generation has been found to significantly contribute to this rise in atmospheric CO2, decision makers world-wide have mandated the large-scale adoption of variable renewable energy (VRE) generation into power systems.

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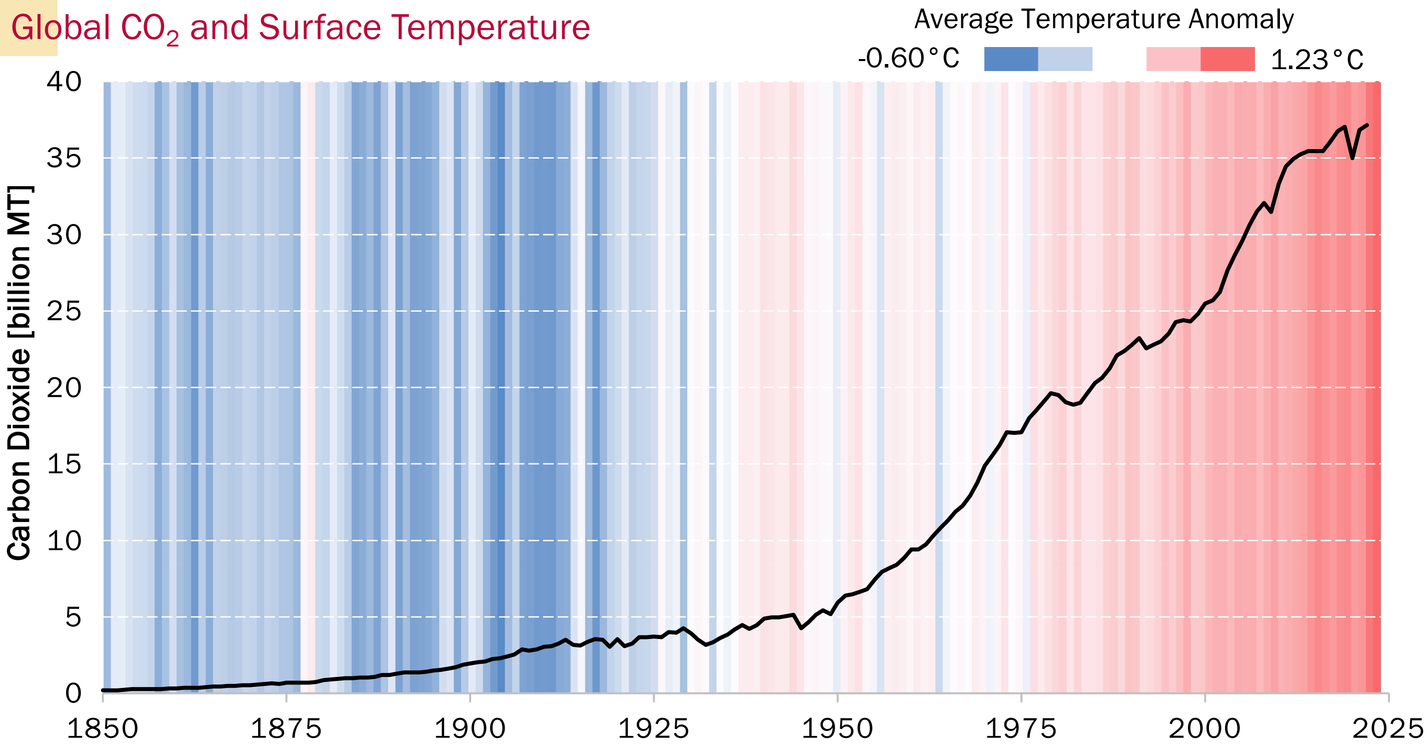
## Global $CO_2$ and Surface Temperature

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**Source:** Design as per Hawkins 2018; Our World in Data 2024. **Notes:** Temperature data is the global average temperature anomaly relative to 1961-1990.

The trend towards increased renewables can also be seen in South Africa, where the installed capacity and energy production from renewable energy have increased steadily in the last decade but still constitute a small portion of the total capacity and energy mix. CSP costs are high and have more variability than wind and solar PV costs, which are both on a stable downward trend. Note that CSP costs often include energy storage, which wind and solar PV do not, making direct comparisons between the technology costs more complex.

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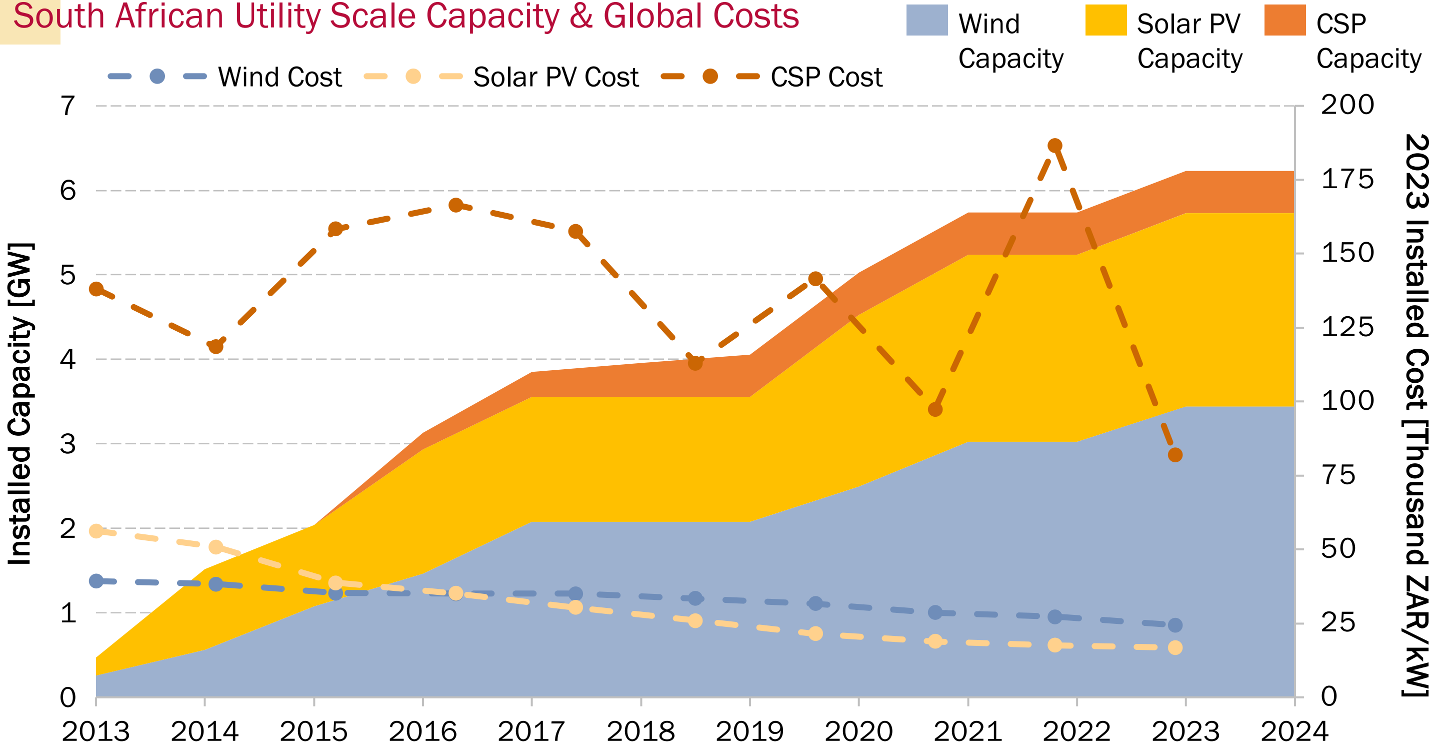
## South African Utility Scale Capacity & Global Costs






**Source:** Eskom 2025c; IRENA 2023. **Notes:** IRENA costs are in 2023 value. Solar PV capacity is at the point of common coupling.

Utility-scale wind and photovoltaic (PV) projects procured during bid windows one to six of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) were selected based on the lowest cost per unit of energy produced, without consideration of the time of day or season in which the energy was generated. Consequently, the geospatial distribution of the resulting wind and PV plants aligns with areas in South Africa that have the highest wind speeds and solar irradiation, as illustrated in the following images.

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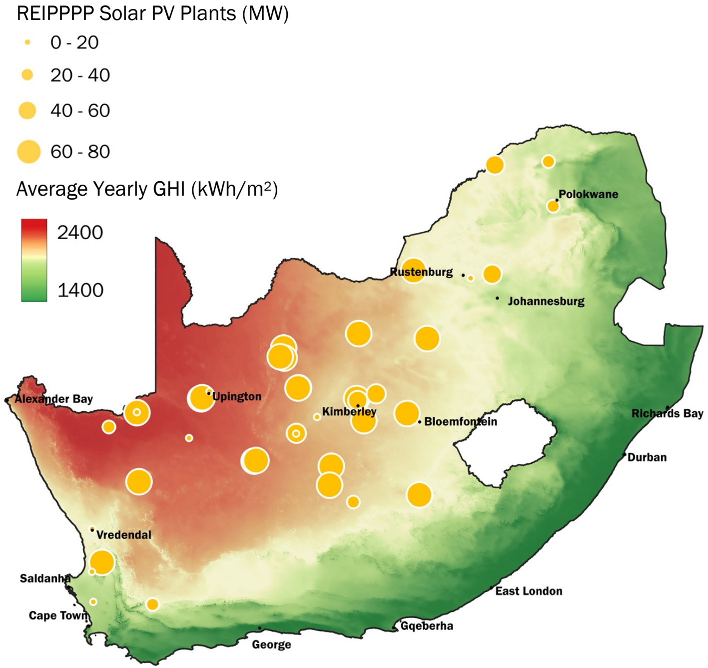
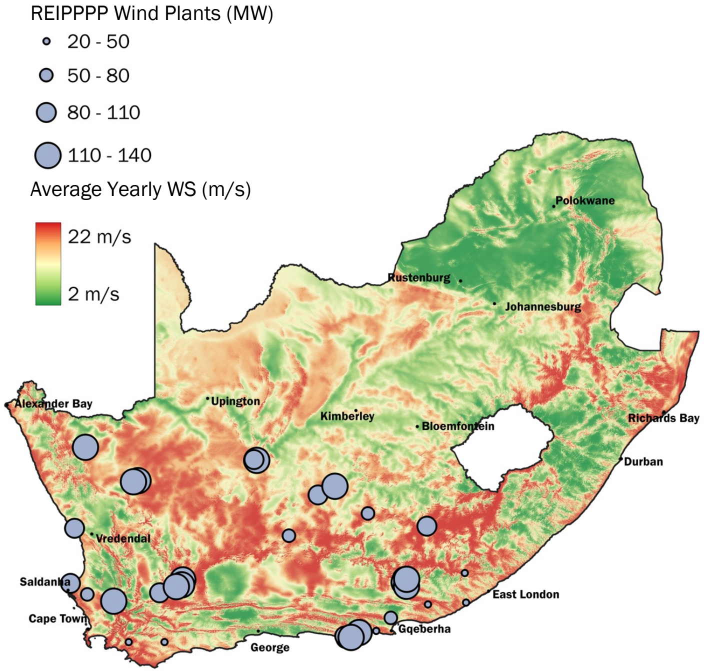
# South African REIPPPP Solar PV and Wind Plants

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**Source:** Eskom 2025a. **Notes:** REIPPPP: Renewable Energy Independent Power Producer Procurement Programme; GHI: Global Horizontal Irradiance.

In South Africa, the installation of privately owned solar photovoltaics (PV), also known as embedded generation, has increased dramatically in recent years, driven by increasing electricity prices, decreasing PV technology costs, and increased load shedding.

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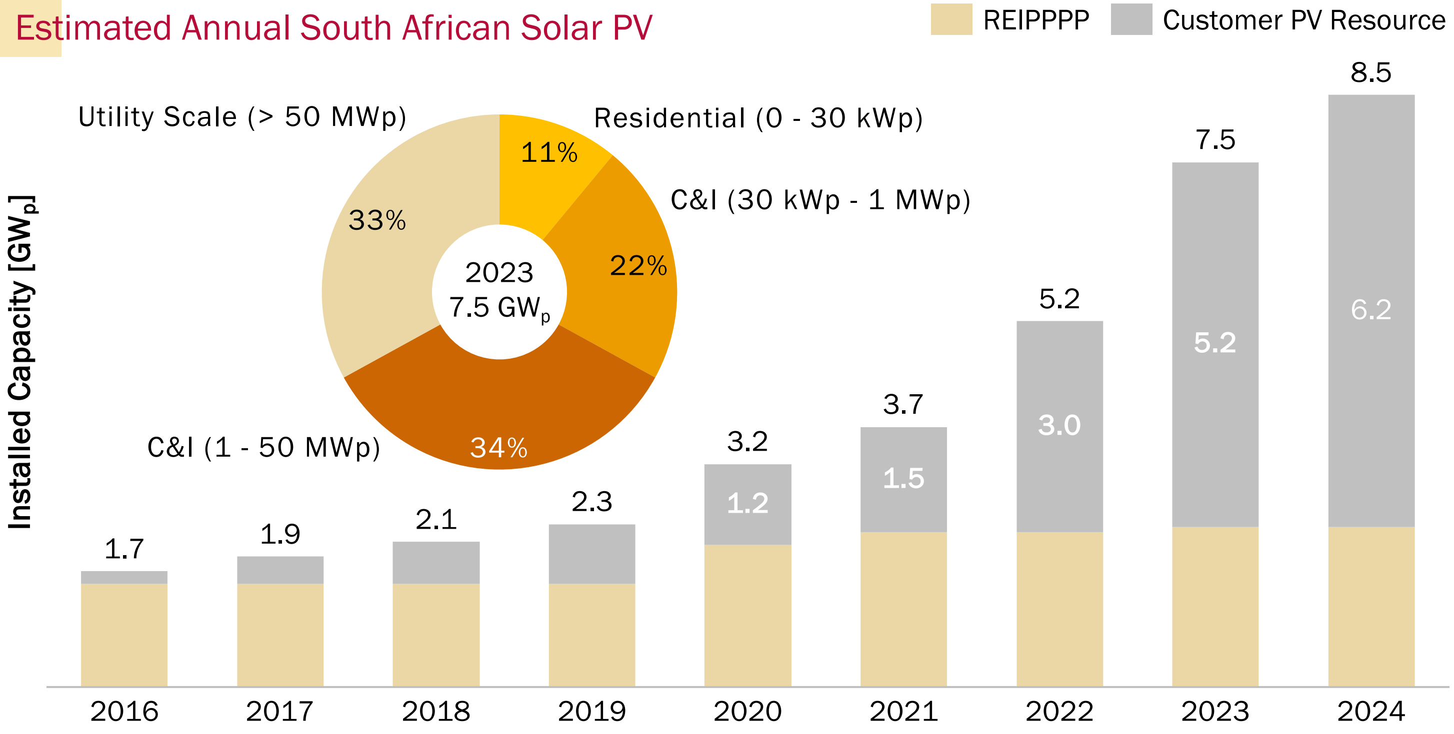
## Estimated Annual South African Solar PV

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**Source:** Eskom 2025b; SAPVIA 2023. **Notes:** C&I: Commercial and Industrial; REIPPPP: Renewable Energy Independent Power Producer Procurement Programme.

By May 2024, embedded PV capacity was almost double that of utility-scale PV. This contributes to South Africa's generation capacity, helping mitigate the generation adequacy problems resulting in load shedding.

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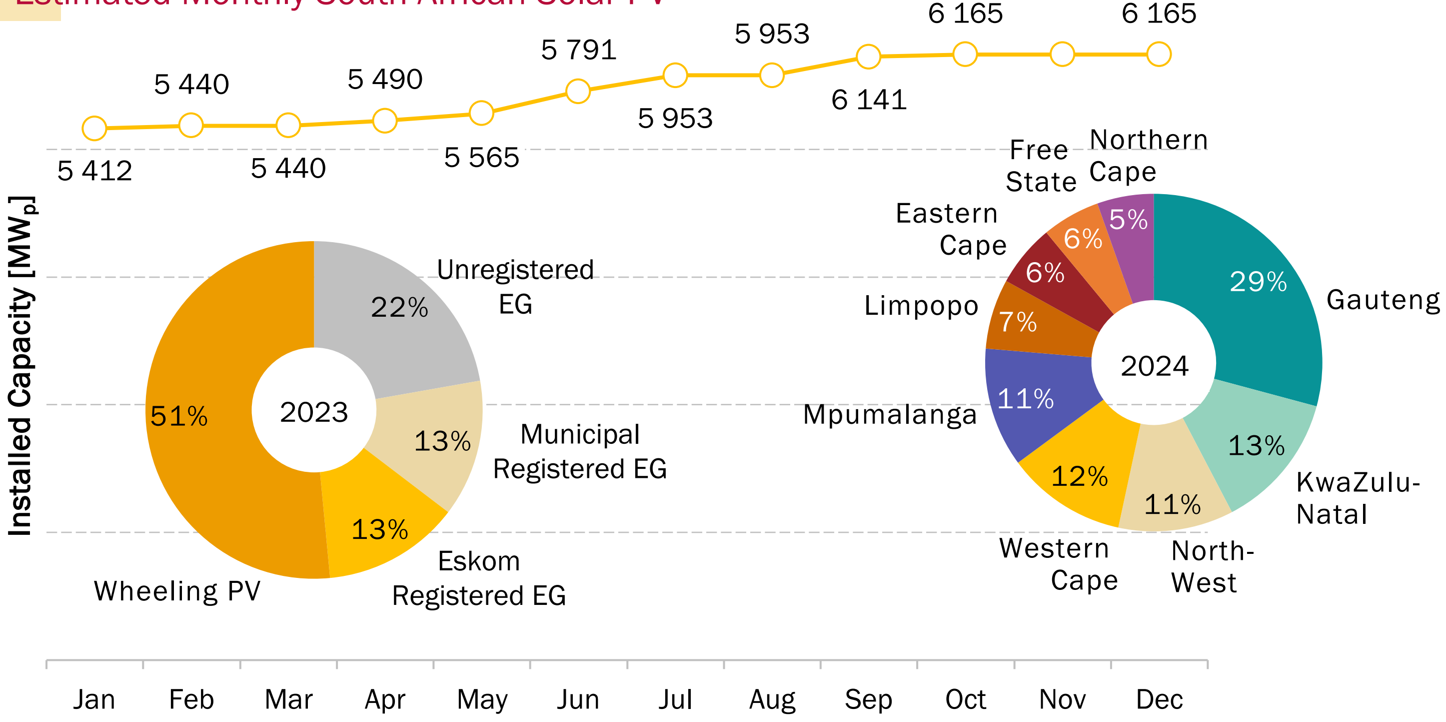
## Estimated Monthly South African Solar PV






**Source:** Eskom 2025b; SAPVIA 2023. **Notes:** EG: Embedded Generation; REIPPPP: Renewable Energy Independent Power Producer Procurement Programme.

# 4

# The Complexity of Integrating Variable Renewable Energy into the South African Power System

Integrating wind and PV into existing power systems impacts various technical aspects on a local, regional, and system-wide level. International experience highlights that constrained transmission is one of the first challenges a power system experiences as the level of renewable energy increases. The next challenge typically experienced is flexibility: a measure of how quickly the generation and load on a power system can respond to changing conditions. Once inverter-based renewable generation constitutes a majority share of the generation capacity, constrained inertia becomes the primary challenge, leading to stability risks.

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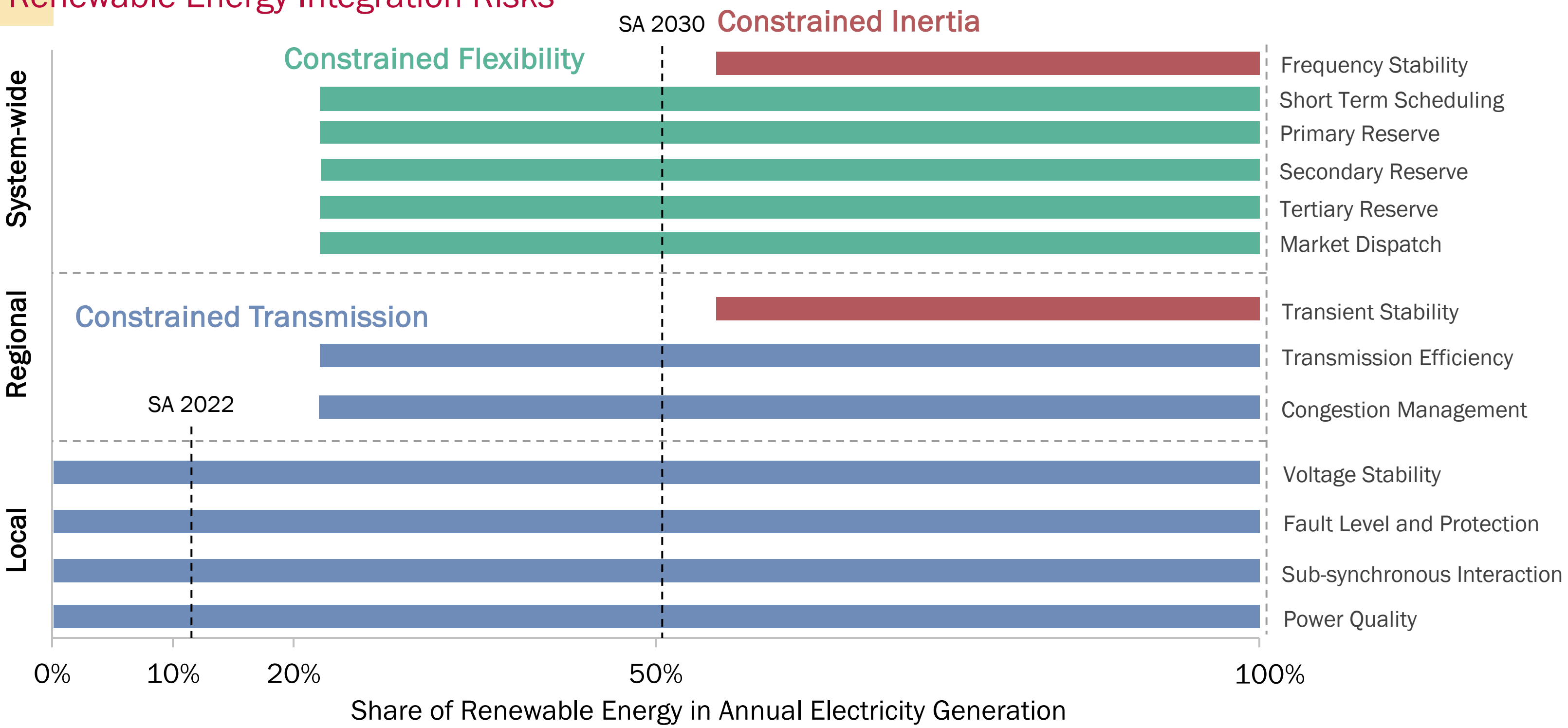
# Renewable Energy Integration Risks

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**Source:** Mararakanye & Bekker 2019 | Eskom 2022 (TDP 2023 – 32).

The diagram below shows the typical daily contribution in 2024 from the various South African generation plants towards meeting the system demand. It shows how solar PV only generates electricity during the day, how CSP continues to generate after sunset through build-in storage, the occurrence of load shedding in summer (unserved energy), and how pumped storage and diesel & gas are used to support the peak load in winter and mitigate load shedding in summer.

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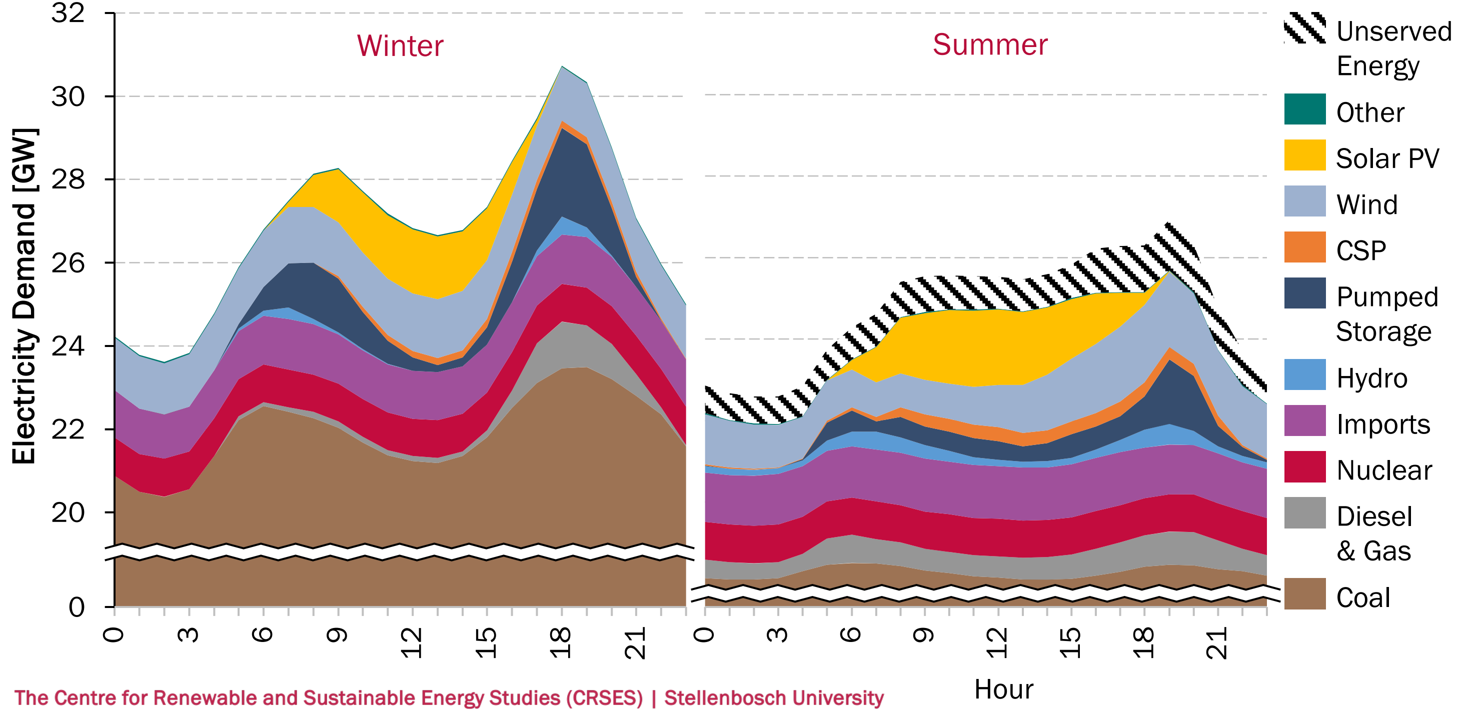
## Typical-Day Energy Production 2024

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**Source:** Eskom 2025a. **Notes:** Winter daily average uses data from June, July, and August; while summer uses data from December, January, and February.

The introduction of solar PV into the electricity system (both on a utility scale and as embedded generation) will result in increased ramping being required from the rest of the system in the morning and evening. This phenomenon is commonly referred to as the duck curve. This can become a problem when the size of the required ramp starts to strain the system's ramping capabilities. The red lines show the drastic difference between 2024 and 2030 evening residual demand ramping.

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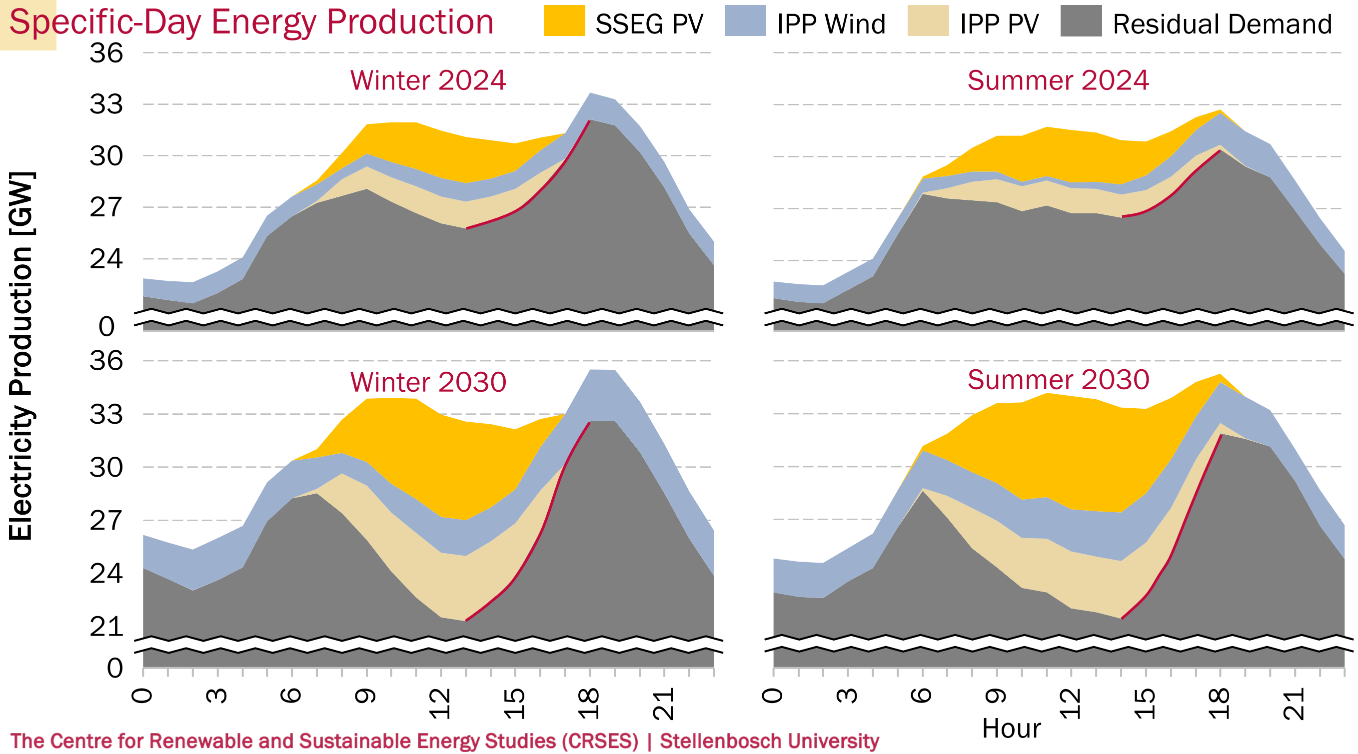
## Specific-Day Energy Production

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**Source:** DMRE 2023. **Notes:** Red lines show the evening residual demand ramping.

SSEG: Small-Scale Embedded Generation; IPP: Independent Power Producer.

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