South Africa Power Transition Outlook

Scenarios until 2040

November 17, 2023

Bloomberg Philanthropies

BloombergNEF

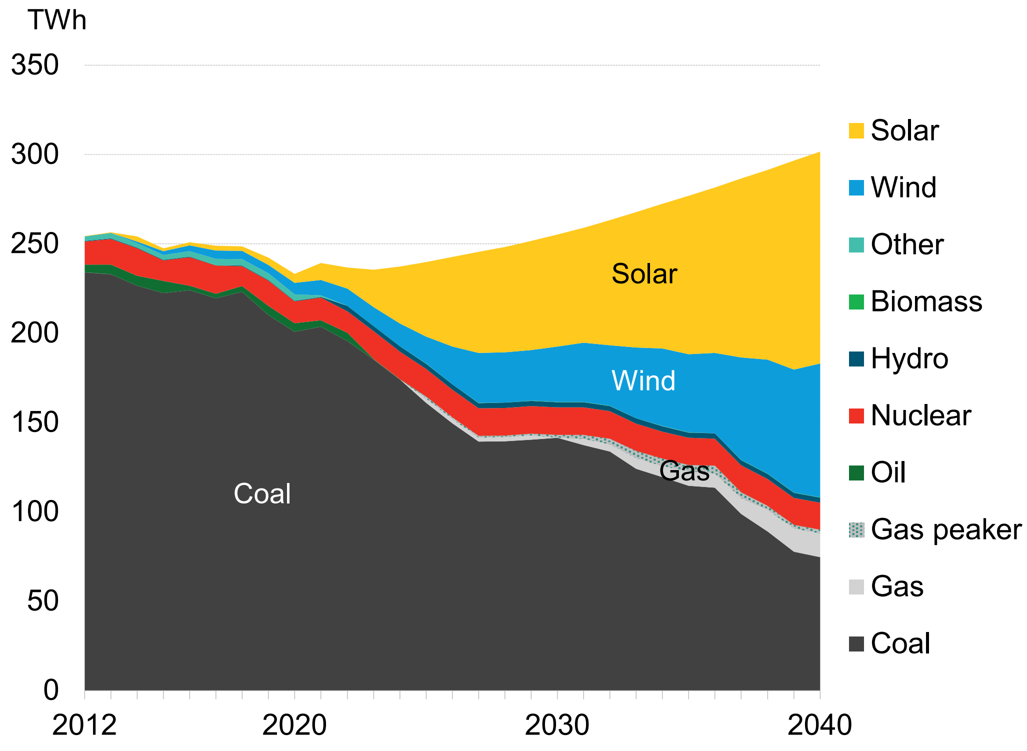
Contents

Executive summary

South Africa's coal-heavy power system faces a rapid transformation. This report, produced by BloombergNEF in partnership with Bloomberg Philanthropies, models three possible pathways for a future power system until 2040: a least-cost base case, a coal extension scenario, and a more ambitious clean power scenario. By 2030, renewables supply over a third of power in all scenarios, and new-build solar becomes cheaper than running even the most efficient coal units. The electricity system needs at least an average $5.9 billion of investment in power generation per year over 2021-2040, and up to $7.1 billion per year to move towards a net-zero power system by 2050.

- Small-scale solar installations are currently booming amid rolling power cuts, which reduces demand for coal generation by 28% by 2030 from 2022 levels. However, new backup capacity is still needed to replace retiring coal plants and ensure system adequacy.
- BNEF finds that battery storage and flexible gas plants are the most cost-efficient solution to complement growth in solar and wind generation and guarantee supply. Under our least-cost Economic Transition Scenario batteries and gas plants reach 37GW by 2040, almost the capacity of today's coal fleet.
- Even if coal plant closures were to be delayed, there is still a need for investment in new power generation capacity. Wind and solar in our Coal Extension Scenario reach 43GW by 2030 and 79GW by 2040, and at least 2GW of battery storage is also needed in 2030. There is also a risk of higher fuel costs and cost overruns to lifetime extensions.
- A more ambitious Clean Power Scenario, that would align the power sector to a net-zero trajectory, reaches 57GW of wind, solar and storage by 2030, and 105GW by 2040. This requires a cumulative $136 billion in investment in new generating capacity over the next two decades. Such a scenario would get South Africa 80% of the way to the lower bound of its 2030 climate targets, if appropriate policies are put in place.
- *(IRP 2030 coal capacity was corrected to 33GW in the chart on slide 17 on January 11, 2024.)*

Electricity generation in South Africa, Economic Transition Scenario



Source: BloombergNEF.

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Context

Power sector overview

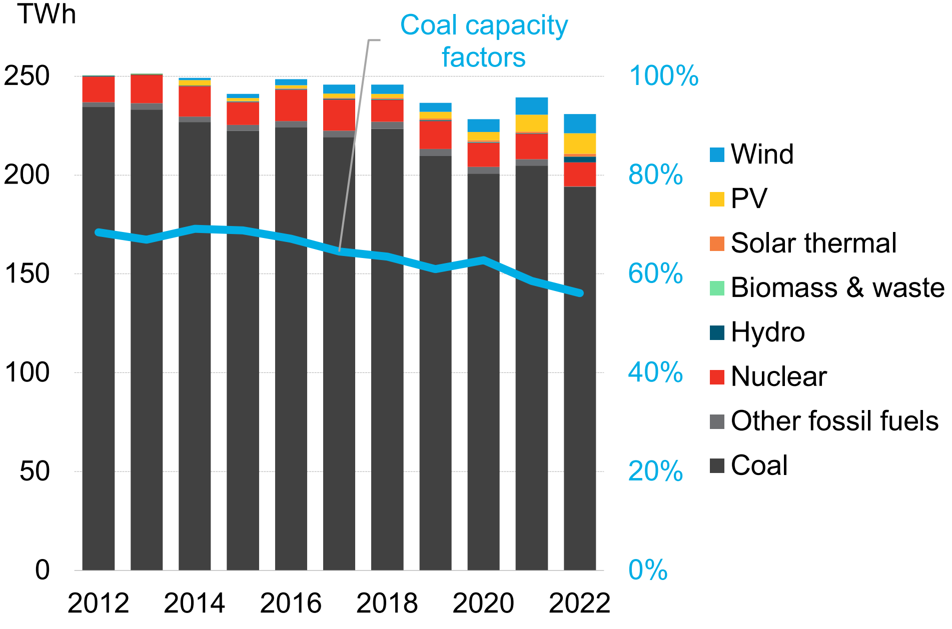
Context

Poor reliability of ageing coal plants is worsening the supply crisis

South Africa's power sector is dominated by 43GW of coal plants, which comprised 69% of total installed capacity and supplied 84% of generation in 2022. However, national utility Eskom's aging coal fleet has reduced output over the last decade due to plant maintenance issues and operational failures. Coal generation fell to 198TWh in 2022, its lowest level in over a decade and a 17% decline from 2012 levels. Coal plant capacity factors have worsened, averaging just 56% in 2022, down from 68% in 2012.

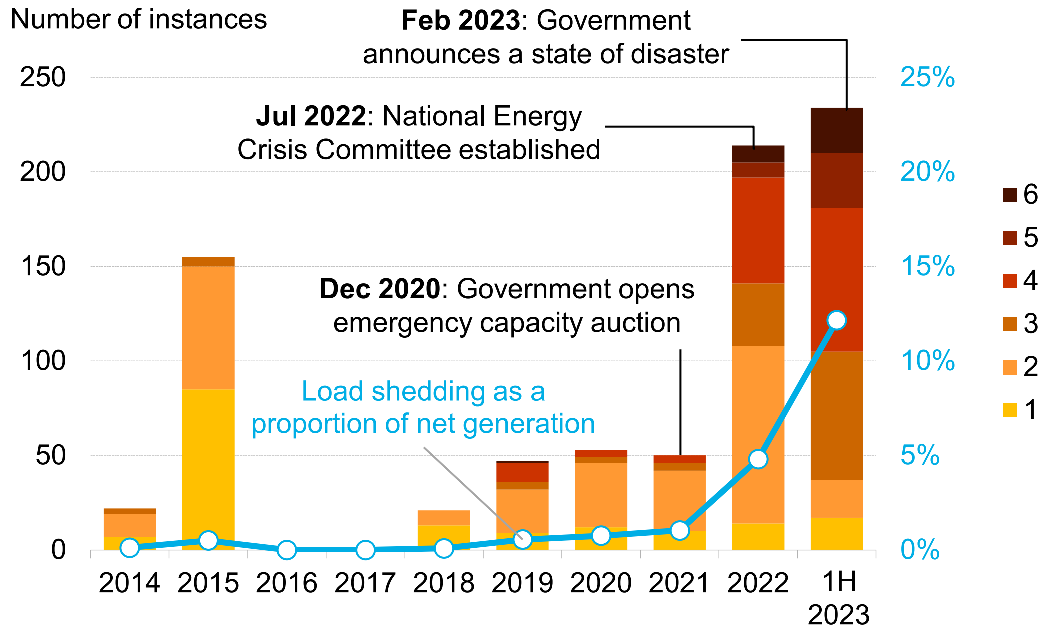
Poor availability, weak output, and delays in delivering new-build capacity have exacerbated the supply gap. Severe scheduled outages have ensued. The load shedding (rolling blackouts) exceeded 14TWh over January-June 2023 alone, the equivalent of 12% of net generation. In all of 2022 it was 10.9TWh, or 5% of net generation. The average availability of the coal fleet fell to just 54%, down from 58% in 2022.

Annual gross generation by technology and coal capacity factors



Source: BloombergNEF, Nersa. Note: 'Other fossil fuels' includes oil and diesel. Coal capacity factors are the fleet-wide average and not de-rated for availability.

Load shedding instances by stage and as a proportion of net generation



Source: BNEF, EskomSePush. Note: 2023 data until June 26. Load shedding 'stage' refers to the severity of blackouts. Stage 1 equates to Eskom temporarily reducing supply for up to 1,000MW of instantaneous load on the national grid, stage 2 is 2,000MW, and so on.

Context

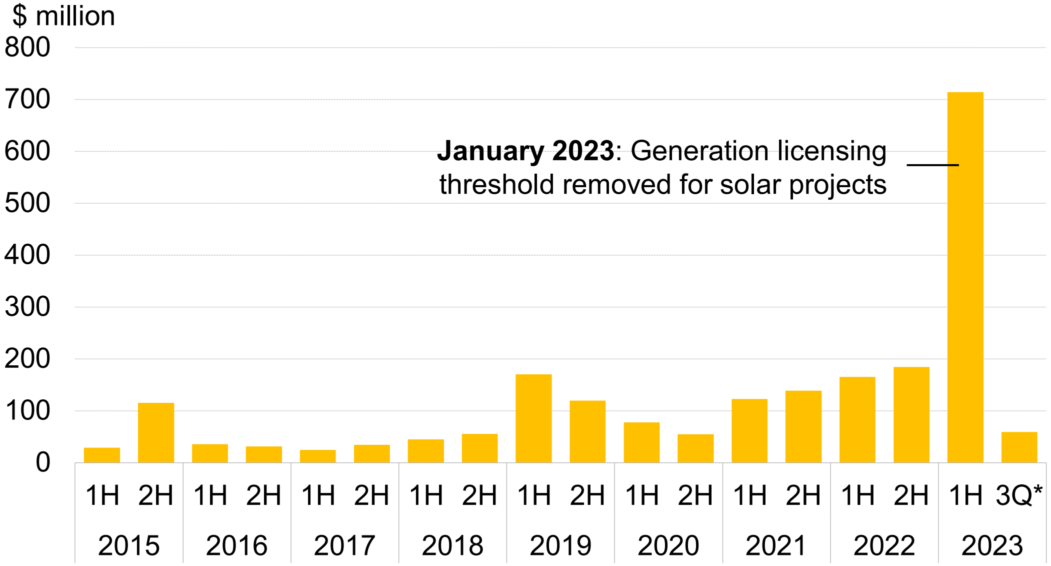
Residential and commercial solar is booming as the energy crisis worsens

Solar installations grew rapidly in the first half of 2023, driven by the power crisis and regulatory support. In 2021, the government allowed private generators under 100MW to connect to the grid without a generation license. In January 2023, this threshold was removed entirely, allowing businesses to add their own solar for local self-consumption, or sell it through the grid (“wheeling”) with a connection agreement.

As of March 2023, businesses in South Africa can reduce their taxable income base by 125% of the cost of an investment in renewables. Residential consumers can claim a one-off tax rebate of 25% of the cost of the panels on their 2023/24 tax liability, up to a maximum of 15,000 rand ($822). This tax incentive is valid for only one year. Anecdotally, the main driver for residential solar is to avoid blackouts. Many local firms are selling reliable power services from a rooftop solar and battery system, for a monthly payment.

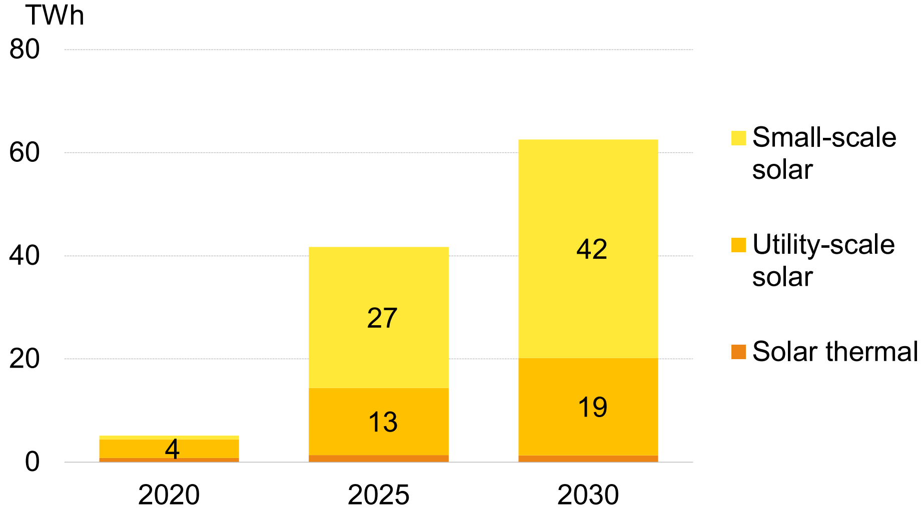
Good data for the rooftop solar market in South Africa is hard to obtain in the rush to install. Eskom publishes estimates of rooftop solar capacity in its weekly system adequacy reports, and these show that about 2.3GW has been commissioned over January-September 2023. Export data for solar cells and modules from China shows a surge in 1H 2023, with $773 million or about 3GW directed to South Africa. BNEF expects 3.5-5GW of residential and commercial solar to be added annually from 2023 to at least 2025, or until the load shedding crisis ends, despite a slowdown in the second half of 2023 due to better conditions.

Exports of solar panels from China to South Africa



*Source: SinoImex, BloombergNEF. Note: *3Q 2023 data includes July-September only.*

Solar generation by segment, Economic Transition Scenario



Source: BloombergNEF.

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Coal retirements are due to accelerate in the mid-2020s

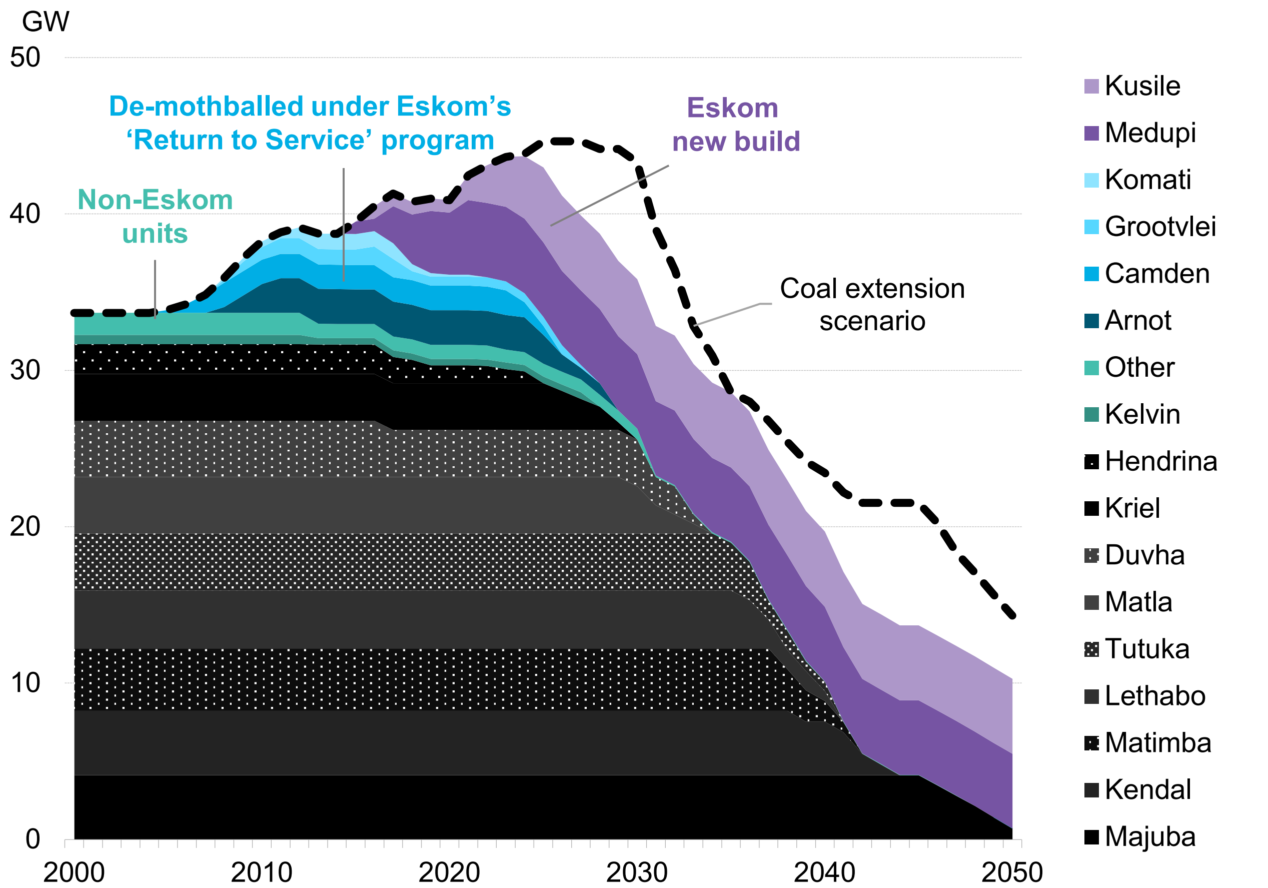
South Africa's coal capacity is due to peak in 2024 followed by a long-term decline as closures exceed new-build capacity additions. The power supply crisis has increased pressure on Eskom to resolve operational issues affecting plant availability, and to deliver the final new-build units at Kusile, which the utility aims to have operational by 2024.

The crisis has also called into question the coal decommissioning schedule. Eskom plans to close most of its coal plants, which are built for a 50-year lifetime, by 2040, starting with the oldest units first.

Eskom has put some of its schedule into action, for example decommissioning one of its oldest plants, Komati, in 2022, but is now considering extensions for other units. Grootvlei, Camden and Hendrina were due to decommission by 2020, but Eskom delayed plans for closure until 2023-27. Further delays to the decommissioning plans for these plants, as well as Arnot, Kendal, Kriel and Lethabo, are under discussion, according to news reports.

Delays or not: South Africa must plan for rapid coal retirements in the long term. New plants Medupi and Kusile could remain online beyond 2050 (the first units of these began operating in 2015 and 2016, respectively), but without investment in lifetime extensions the majority will need to close by the end of the 2030s.

Coal capacity by plant and retirement schedule

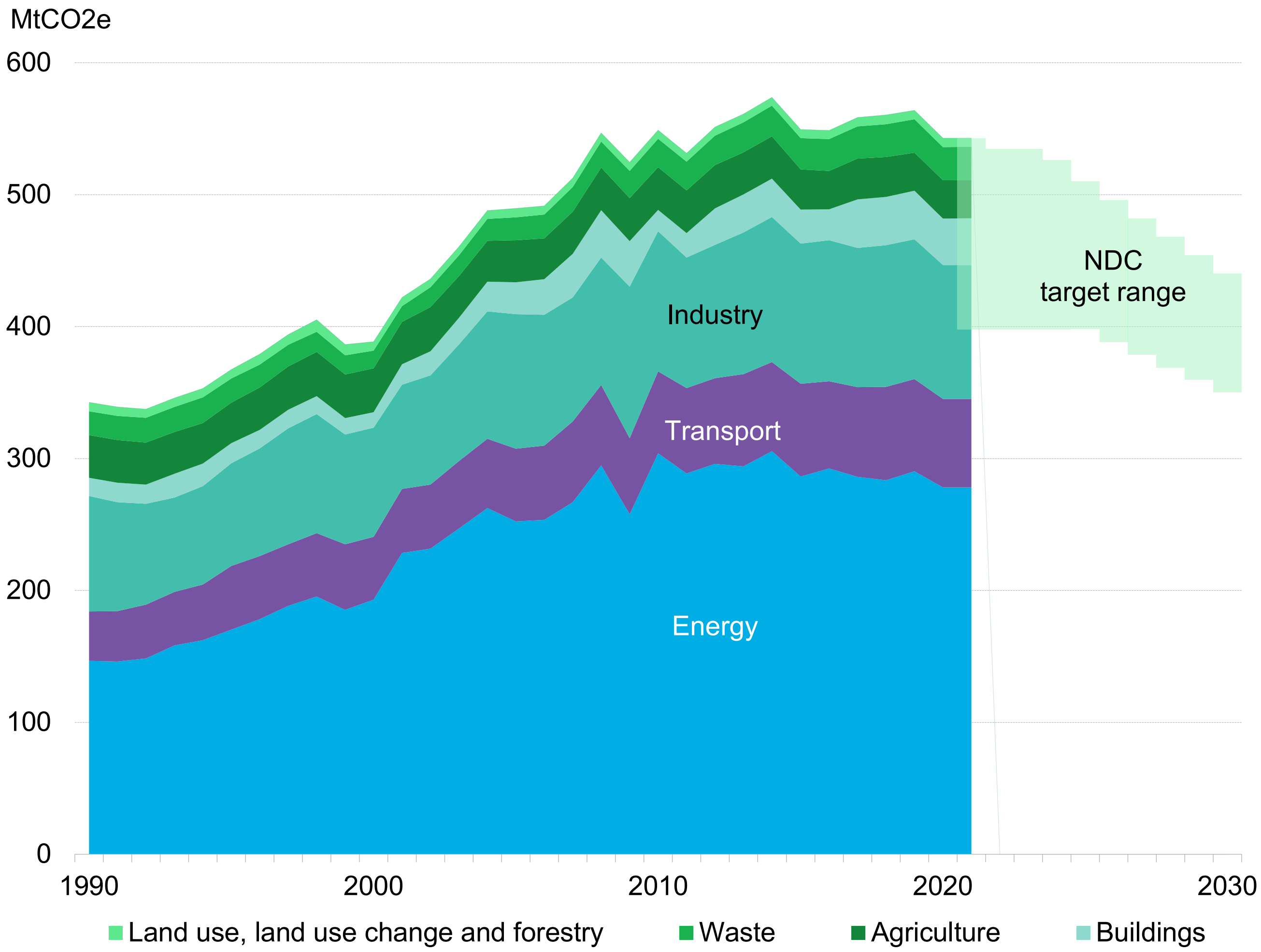


Source: BloombergNEF, Eskom. Note: Capacity is not derated for availability. Retirements based on Eskom's June 2020 decommissioning schedule and updates. Kusile delivery is based on BNEF estimates of construction timelines, with units 5-6 commissioning over 2024-25, but could face further delays in reaching full capacity after of a chimney failure in November 2022 took 2.4GW of the plant offline. Kelvin and 'other' are non-Eskom coal units. 'Extended fleet' scenario is based on assumed lifetime extensions.

Context

Climate targets rely on reducing emissions from power supply

Greenhouse gas emissions by sector and target, South Africa



Source: South Africa Nationally Determined Contribution, UNFCCC, Climate Watch, BloombergNEF.

The coal-dominated power sector emitted over half (52%) of South Africa's emissions over the last decade. Industry and transport represented another third. South Africa ranks 14th in the world for total greenhouse gas emissions, making emissions reductions in the country vital to global climate targets.

In its Nationally Determined Contribution (NDC) under the Paris Agreement, updated in 2021, the government targets economy-wide greenhouse gas emissions in 2030 to fall within the range of 350-440MtCO2e. Reducing emissions in line with this goal will rely on accelerating the process of replacing coal power supply with zero-carbon alternative sources, of which there are already mature, scalable, and economic solutions including solar and wind. Even without additional policy interventions, the deployment of new clean energy capacity in the power system based on economics could reduce emissions by 46MtCO2 by 2030, based on BNEF's Economic Transition Scenario.

The government has also laid out longer-term intentions to decarbonize the economy with a net-zero target for 2050, under its Low Emission Development Strategy published in 2020. This aligns with Eskom's net-zero target for 2050.

Scenario results

BNEF outlook for South Africa’s power sector

Scenarios: Overview

This report builds on the scenarios presented in BNEF's *New Energy Outlook 2022* (web | terminal). It includes three scenarios that describe an economics-led transformation of South Africa's power system between today and 2040. These scenarios are modeled with BNEF's proprietary New Energy Forecast Model (NEFM), which optimizes for a least-cost capacity mix to meet hourly demand, accounting for both capital and operational costs of different generation technologies. For detailed assumptions and our modeling methodology, see Appendix.

Economic Transition Scenario

The Economic Transition Scenario (ETS) shows the development of South Africa's power mix, optimized for the lowest system cost. We only include current policies with a clear implementation mechanism, such as the solar tax breaks, carbon tax and auctions. BNEF's forecast for wind, solar and storage build is delivered over 2023-27. We do not force government targets to be met.

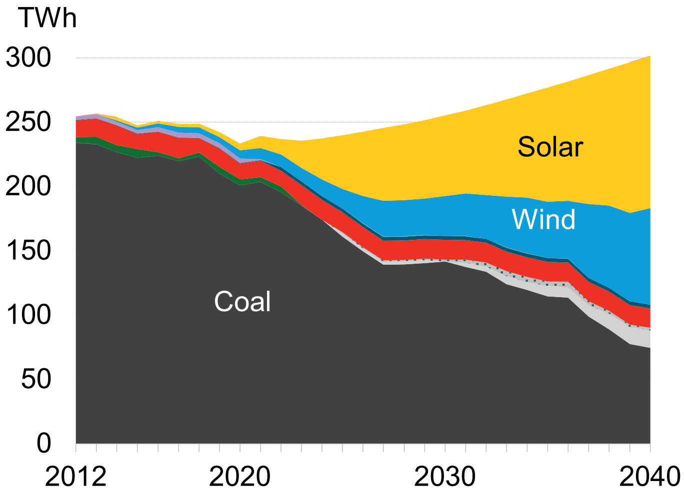
Coal Extension Scenario

The Coal Extension Scenario (CES) uses the same least-cost approach and assumptions as the ETS, but delays coal closures. Units that are due to retire during the 2020s, including Arnot, Camden, Grootvlei and Kriel, run for an additional 5-6 years. Later on, Lethabo and Kendal, which are due to retire during the 2030s, are extended for 10 years.

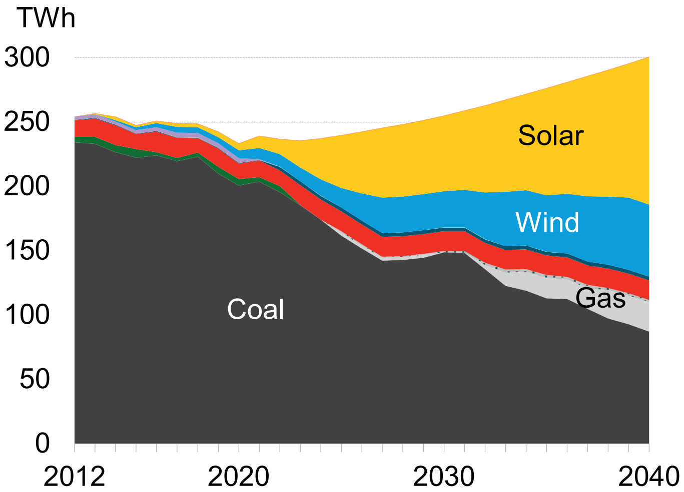
Clean Power Scenario

The Clean Power Scenario (CPS) shows a more ambitious power decarbonization scenario, aligned with a trajectory towards net zero by 2050. It uses the same assumptions as the ETS, including electricity demand and costs, and allows economic build of other zero-emission dispatchable technologies to meet a carbon budget. It also excludes carbon tax deductions after 2025.

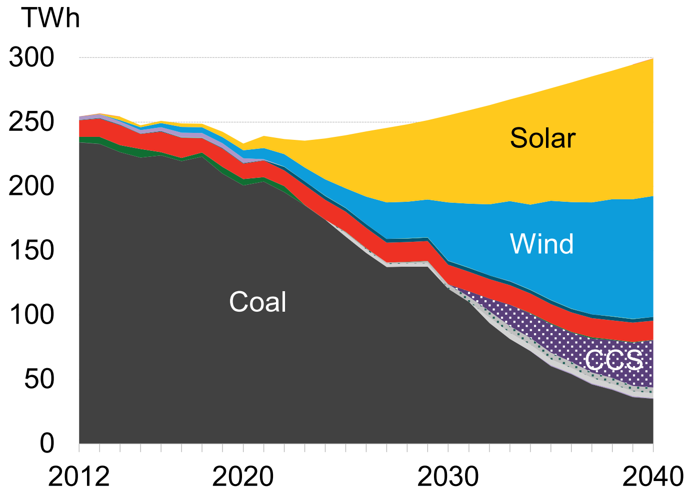
Electricity generation, ETS



Electricity generation, CES



Electricity generation, CPS



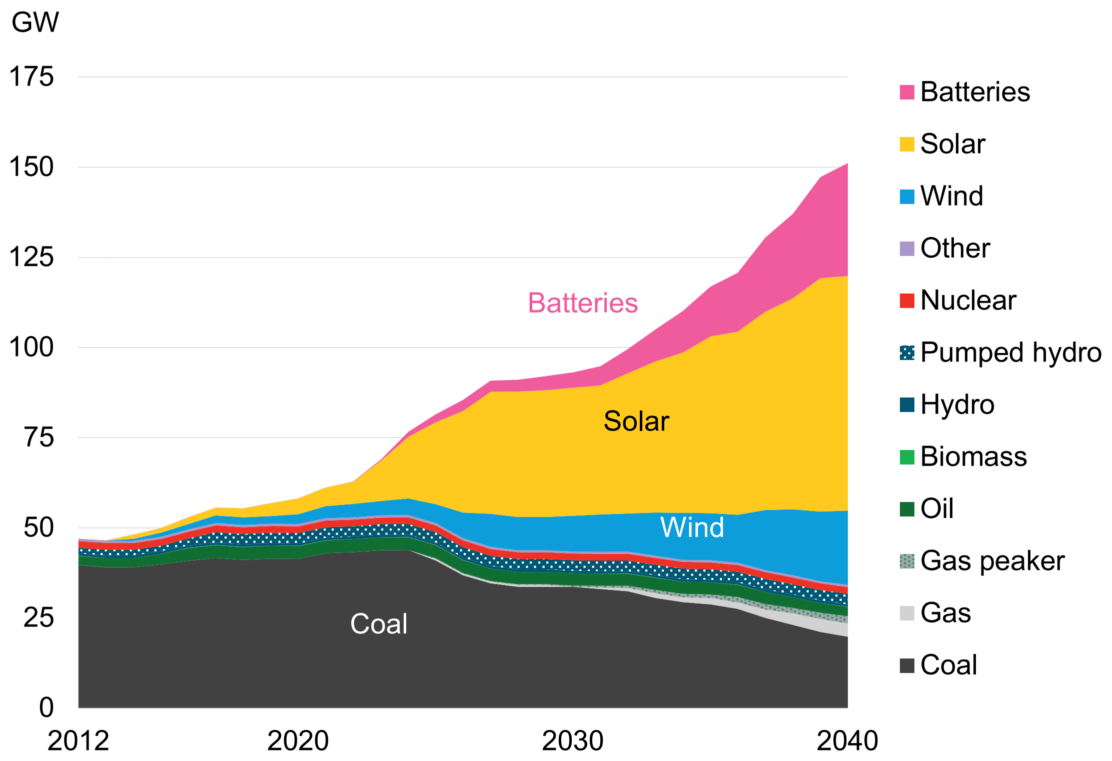
Coal | Oil | Gas | Gas peaker | Gas CCS | Hydrogen | Nuclear | Hydro | Biomass | Other | Wind | Solar

Source: BloombergNEF.

Economic Transition Scenario:
Solar boom eases supply gap

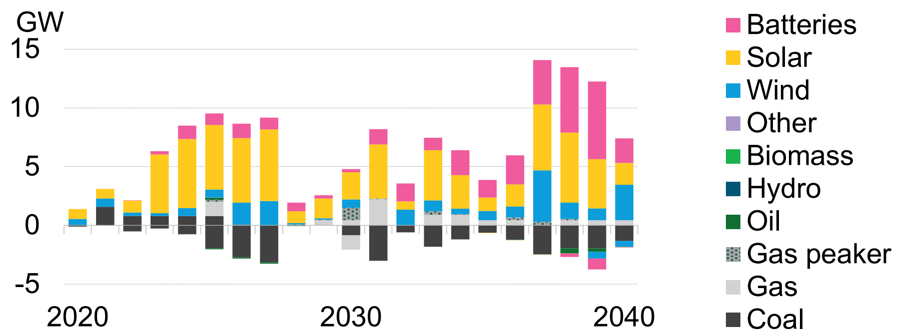
In our base case, solar supplies 63TWh by 2030, a more than five-fold increase from 2022 levels, while coal generation declines by 28% over 2022-2030. South Africa has 50GW of renewable energy capacity by 2030, including 10GW of wind and 36GW of solar, which displace some of the oldest and least efficient coal plants, several of which are closed a few years ahead of schedule on economic grounds. Renewables supply 38% of generation in 2030, an almost five-fold increase from just 8% in 2021. As demand grows and coal retirements accelerate, with 14GW closing in the 2030s, some 41GW of additional new solar, wind and battery storage is deployed, alongside 5GW of new gas plants. By 2040, renewables supply 65% of generation, with solar capacity reaching 65GW, complemented by a 31GW fleet of grid-scale battery storage assets, while wind hits 21GW by 2040.

Installed capacity

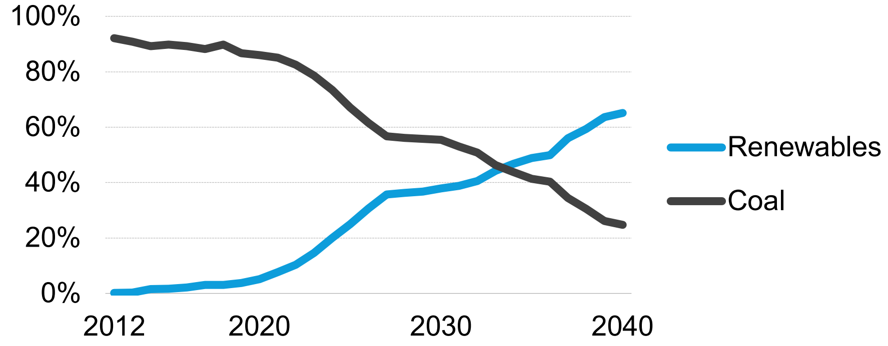


Source: BloombergNEF.

Capacity additions and retirements



Share of generation

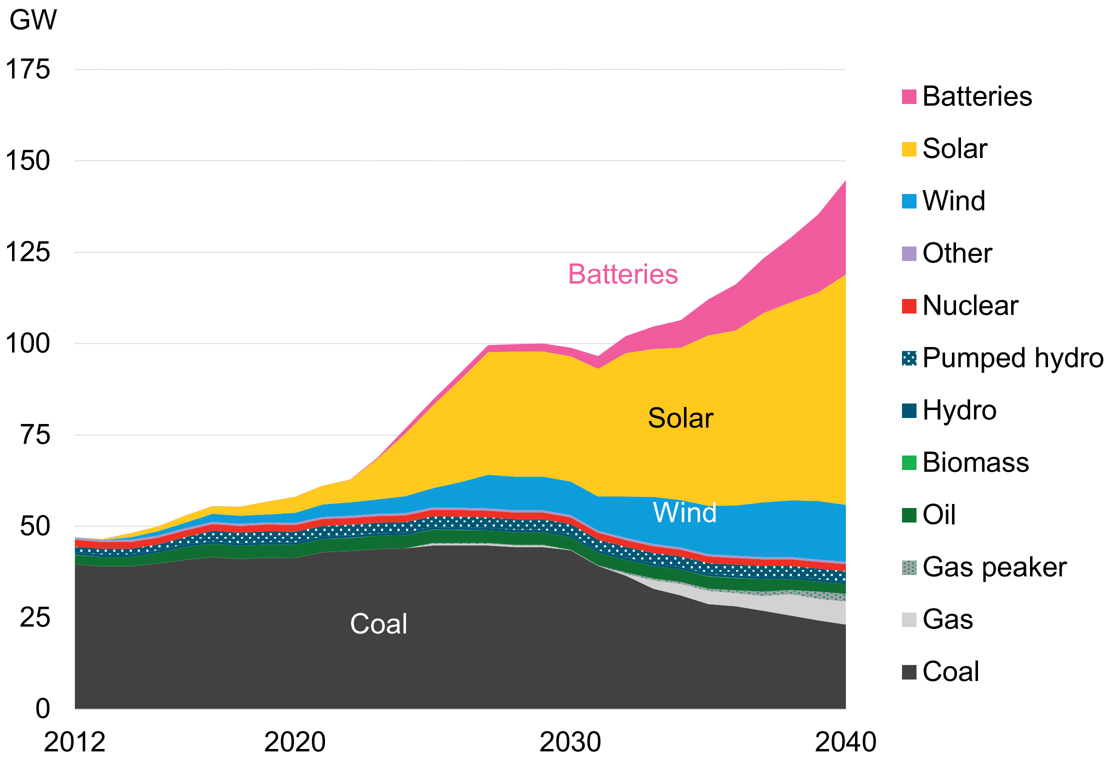


Source: BloombergNEF. Note: 'Renewables' includes wind, solar, biomass, and hydro.

Coal Extension Scenario:
Renewables still displace thermal output

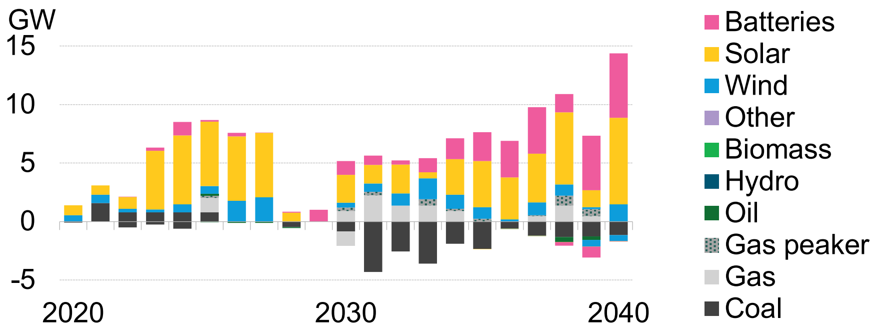
The Coal Extension Scenario results in slower build-out of renewables, particularly wind, and storage after BNEF's near-term forecast for capacity additions is delivered, as several coal plants run for longer. Coal retains a 58% share of generation in 2030, the highest of all three scenarios, limiting the deployment of wind and, to a lesser extent, solar. However, once coal retirements pick up pace again over 2030-2040, 8GW of new gas and 25GW of battery storage, alongside 36GW of new wind and solar are installed. By 2040, coal supplies 29% of South Africa's electricity, down from 86% in 2020. Meanwhile, renewables grow steadily after an early acceleration, reaching 34% of generation in 2030 and 58% in 2040, up from 8% in 2021.

Installed capacity

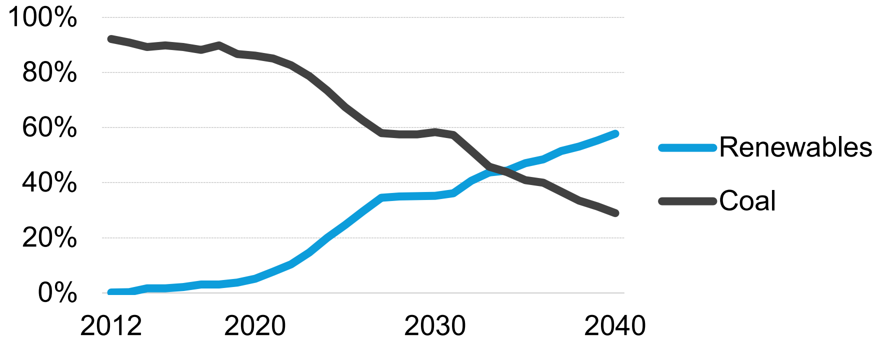


Source: BloombergNEF.

Capacity additions and retirements



Share of generation



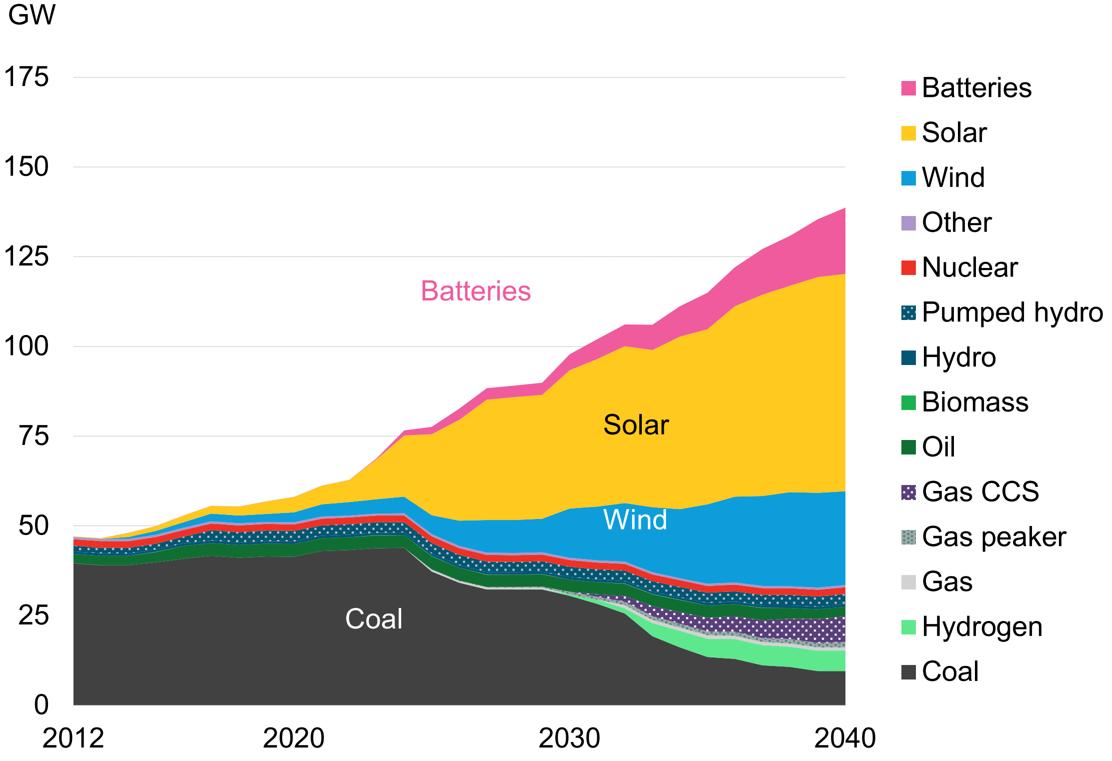
Source: BloombergNEF. Note: 'Renewables' includes wind, solar, biomass, and hydro.

Scenario results

Clean Power Scenario:
Wind grows as coal output halves by 2030

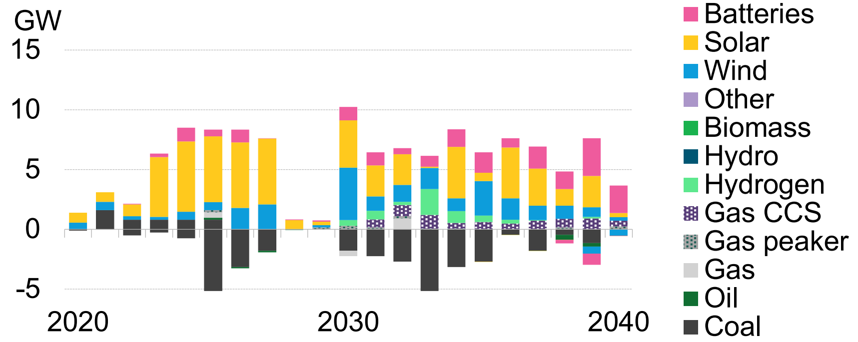
The Clean Power Scenario accelerates the phase-out of coal power in South Africa, by. Coal is replaced by a combination of wind, solar and storage, as well as lower-carbon thermal capacity. Renewables grow fastest in this scenario and supply half of all generation by 2032, a milestone reached four years earlier than in the Economic Transition Scenario. Wind grows more in this scenario, reaching 13GW by 2030 and 26GW by 2040, as it helps to lower emissions from coal power during the night. A larger wind fleet, in turn, slightly reduces the need for solar during the day compared to the other scenarios. Phasing out coal faster – with 32GW of retirements over 2023-2035, double the closures in the ETS – means accelerated build of clean dispatchable capacity, with 13GW of gas plants, with carbon capture and storage or fueled by hydrogen, installed by 2040.

Installed capacity

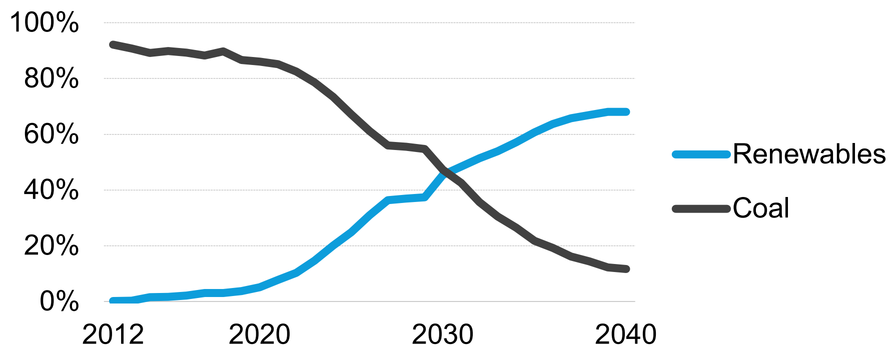


Source: BloombergNEF. Note: CCS is carbon capture and storage.

Capacity additions and retirements



Share of generation



Source: BloombergNEF. Note: 'Renewables' includes wind, solar, biomass, and hydro.

Scenario drivers and comparison

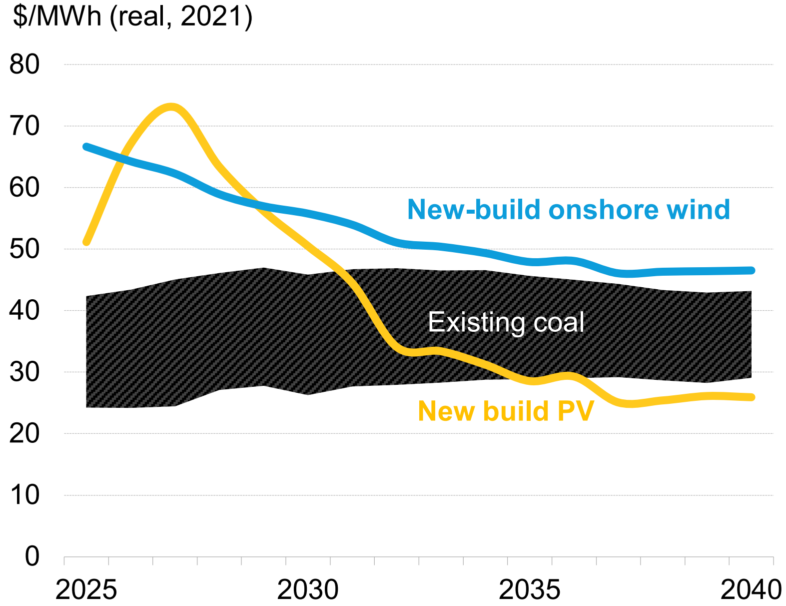
Implications for the power system and investment

Cheaper solar and wind grow rapidly, replacing the bulk of retiring coal

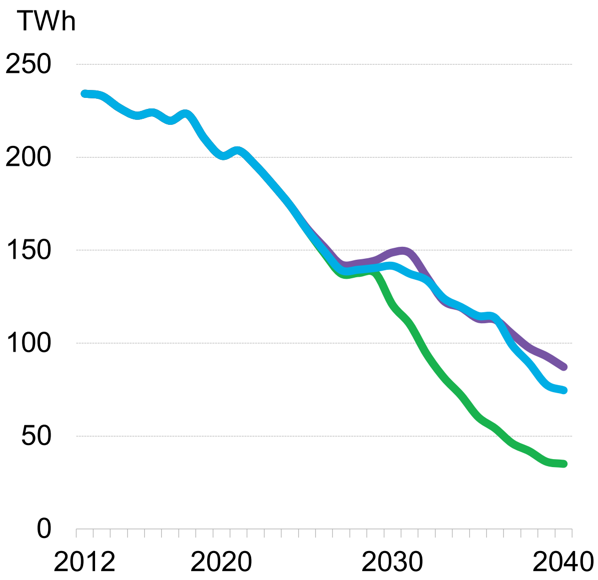
A 22GW boom in small-scale solar deployment, along with 5.5GW of wind capacity over 2023-2030, drives down demand for coal generation. In the longer term, solar and wind step in to replace a large portion of the output from retiring coal plants and become increasingly competitive with the running costs of the remaining coal fleet. Solar remains the cheapest technology in South Africa even after accounting for adjustments in the realized capacity factors of the technology, and benefits in the long-run from growth air conditioning demand.

Solar and wind grow to supply 94TWh by 2030, equivalent to over a third of total supply, in the Economic Transition Scenario. Even in the Coal Extension Scenario, coal generation continues to fall. The near-term influx of wind and solar reaches 87TWh by 2030, driving coal output down to 149TWh in 2030, 24% below 2022 levels. Wind and solar deployment is accelerated in the Clean Power Scenario, with these technologies producing more power than coal from 2031 onwards, compared to the Economic Transition Scenario reaching this threshold by 2034.

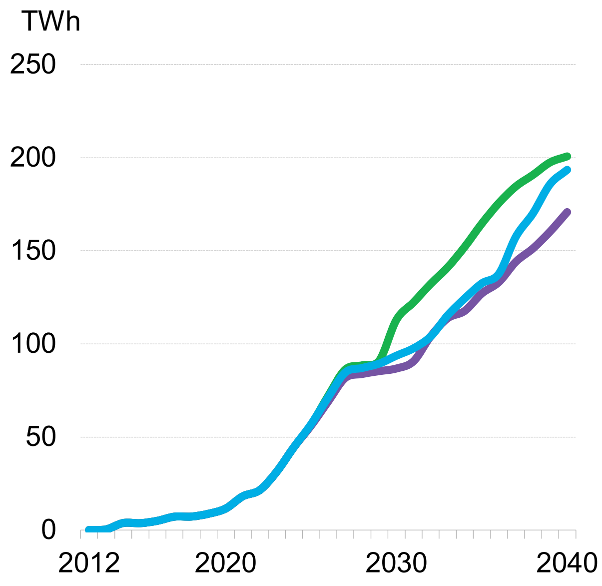
Marginal cost of new wind and solar, compared to coal running costs



Coal generation



Wind and solar generation



Source: BloombergNEF. Note: 'Marginal cost of new wind and solar' uses the Economic Transition Scenario and reflects the marginal cost of electricity of building an additional unit of capacity per technology, considering the capacity mix and realized capacity factors per technology of that given year.

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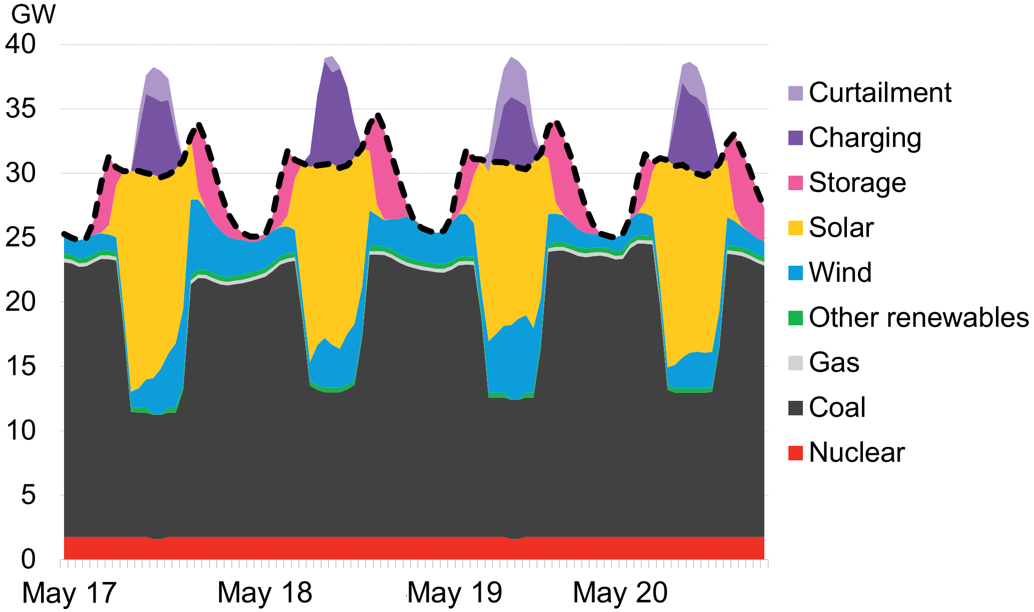
Batteries support solar buildout, but more firm capacity is needed to replace coal

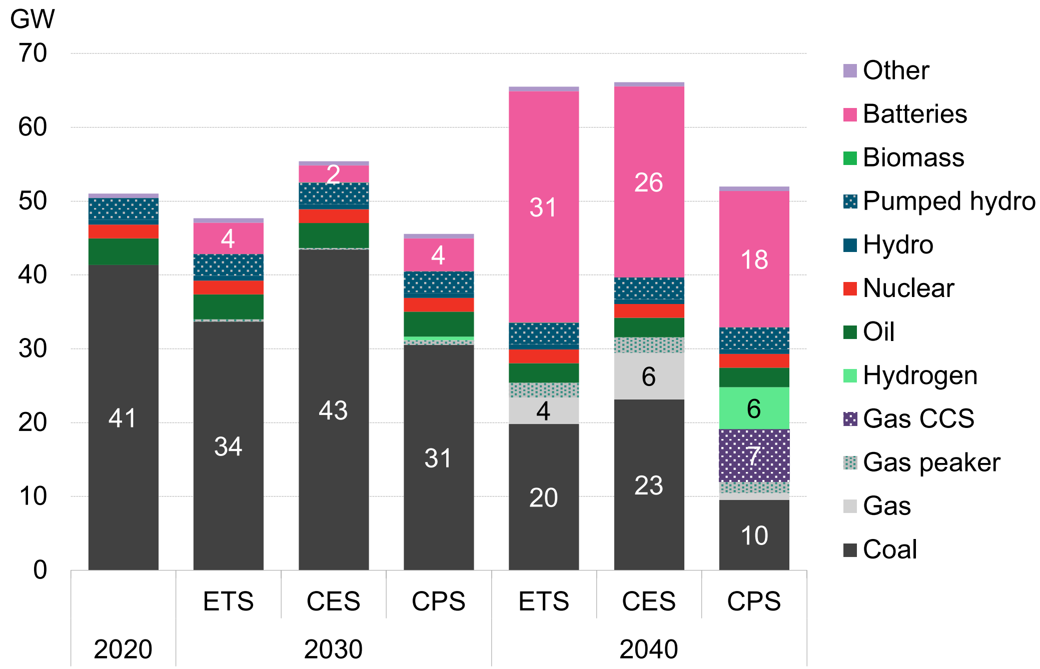
Our modeling shows battery storage grows to support the integration of variable renewables – particularly solar – and helps to meet evening peak demand. By 2030, some 2-4GW of battery storage is deployed across scenarios, driven by favourable economics and supporting 34-39GW of installed solar capacity. Batteries grow to 18-31GW by 2040 as total installations of wind and solar reach 79-87GW.

As more coal plants retire, South Africa also builds additional new dispatchable capacity to ensure system adequacy, including new gas power plants. There is a small but important role for more flexible peaking gas plants in the longer term, which grow to 2GW of the 6GW total installed gas capacity by 2040 in the Economic Transition Scenario and ramp up during longer periods of low renewable energy output. In the Clean Power Scenario, this role is filled by a growing fleet of low-carbon dispatchable capacity, including 6GW of hydrogen-fired power plants and 7GW of gas plants with carbon capture and storage by 2040, supplying around 15% of total generation in 2040. Battery deployment is lower in the Clean Power Scenario, driven by more demand-side flexibility to take advantage of high-renewables hours.

Hourly generation during May 2030, Economic Transition Scenario



Installed dispatchable capacity



Source: BloombergNEF. Note: Coal capacity is not de-rated. 'CCS' is carbon capture and storage. 'Hydrogen' is gas-fired power plants capable of running on hydrogen.

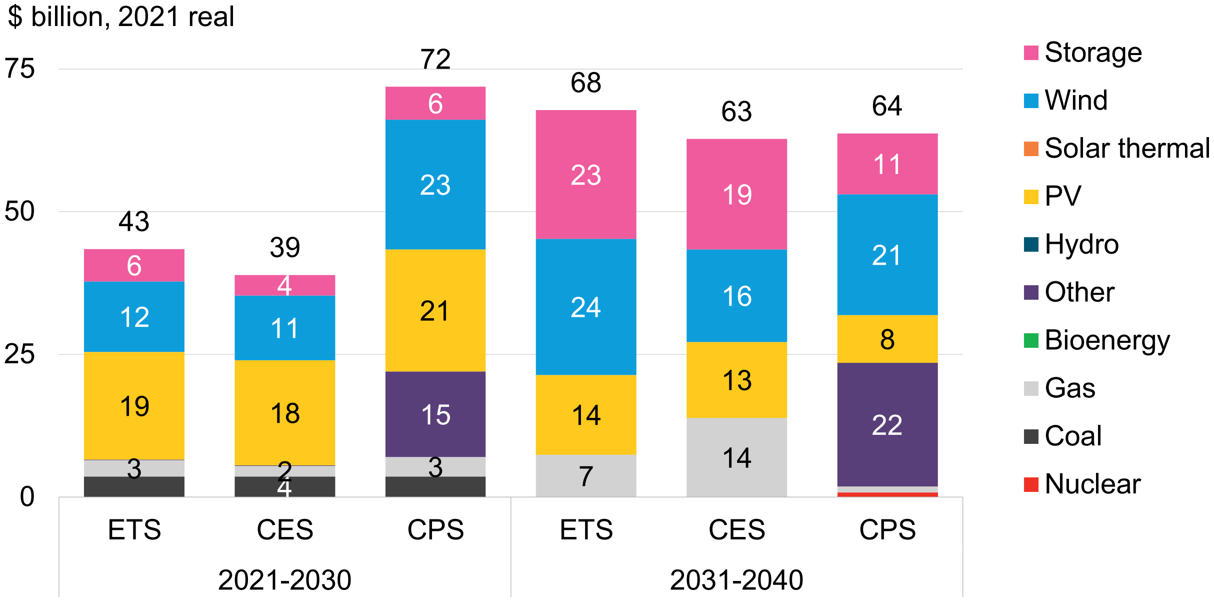
Coal extensions delay clean energy investment and increase fuel costs by 4%

BNEF tracked $34 billion of investment into renewable energy projects, primarily solar and wind, in South Africa over 2004-2022. Over the next two decades, the power system transition requires continued investment in new capacity. Our base case Economic Transition Scenario requires $111 billion of investment in new generating capacity over 2021-2040, of which 87% goes to zero-carbon plants, tripling the historical investment rate.

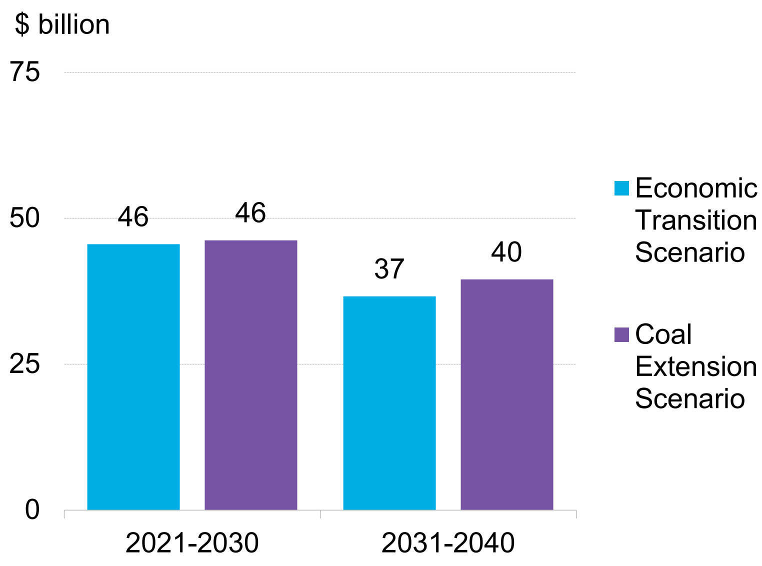
The Coal Extension Scenario has similar requirements, with investment in new generating capacity reaching $102 billion over 2021-2040. Running costs add an additional $3.8 billion more (4.4%) spent on fuel and carbon costs over 2021-2040 than the Economic Transition Scenario. However, coal unit extensions have a high degree of uncertainty both from a cost and viability perspective, and there is a risk that retrofits of existing coal plants make this scenario more expensive in practice. If lifetime extension costs, including the need to install filters and other equipment to meet emissions standards, were to exceed $620,000/MW (or $387,000/MW after adjusting for running costs), the Coal Extension Scenario is more costly.

A more ambitious decarbonization path for South Africa's power mix requires front-loading investment in new clean energy supply, to accelerate the transition away from coal. The Clean Power Scenario requires $136 billion over 2021-2040, of which 94% goes to zero-carbon technologies.

Investment in new generating capacity



Fuel and carbon costs



Source: BloombergNEF. Note: Investment totals reflect year of final investment decision, accounting for lead times of capacity delivery. As a result, some nuclear capacity financed in the 2030s is not online until after 2040. 'Other' includes oil, gas-fired power plants with carbon capture and storage and gas power plants fueled by hydrogen.

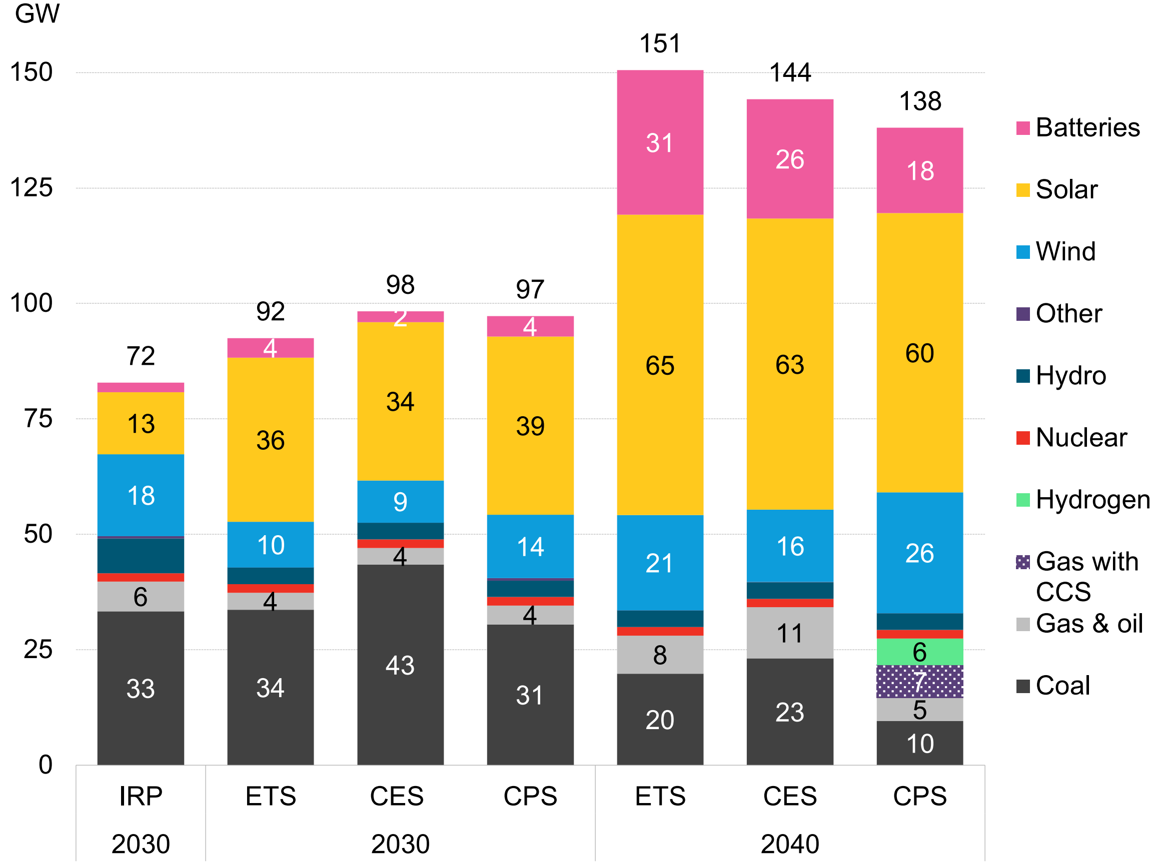
Government targets are short on solar and storage, and optimistic on wind

South Africa's 2019 Integrated Resource Plan (IRP) does not reflect rapidly changing adoption rates of small-scale solar today. The IRP reaches 13GW of installed solar and 2GW off battery storage capacity by 2030, well below the expected 39GW of solar and 4GW storage deployed by 2030 in BNEF's Economic Transition Scenario. Even if coal plants have an extended lifetime, BNEF finds that an economically-optimized capacity mix would reach 34GW for PV and 2GW for battery storage by 2030. However, the BNEF scenarios do not assume the delivery of additional pumped hydro before 2030, while the IRP 2019 does.

The IRP is much more optimistic on wind than BNEF's scenarios, with 18GW installed by 2030. Due to the relatively high costs of new-build wind compared to solar, our scenarios only reach economic deployment 18GW of wind by 2038 in the Economic Transition Scenario, although the Clean Power Scenario reaches this point in the early 2030s, and wind grows to 26GW by 2040.

Gas power plants are featured in the IRP as a source of dispatchable capacity to replace retiring coal. BNEF finds that South Africa needs 6GW of new gas and gas peaker plants, but only by 2040 in our Economic Transition Scenario. If coal plants get extended, gas capacity is higher, at 8GW in 2040, as less wind in the system requires additional evening generation. Additional policy considerations around the route to market for new-build dispatchable capacity is essential in supporting the evolving needs of the grid.

Installed capacity in the 2019 Integrated Resource Plan compared to BNEF scenarios



Source: BloombergNEF, 2019 Integrated Resource Plan (IRP). Note: Eskom's coal retirement schedule has changed since the IRP 2019 was published. 'Hydro' includes pumped hydro, for assumptions in BNEF scenarios please refer to Appendix; 'Other' includes biomass, hydrogen, and gas with CCS. 'Solar' for IRP stack includes PV, solar thermal and embedded generation.

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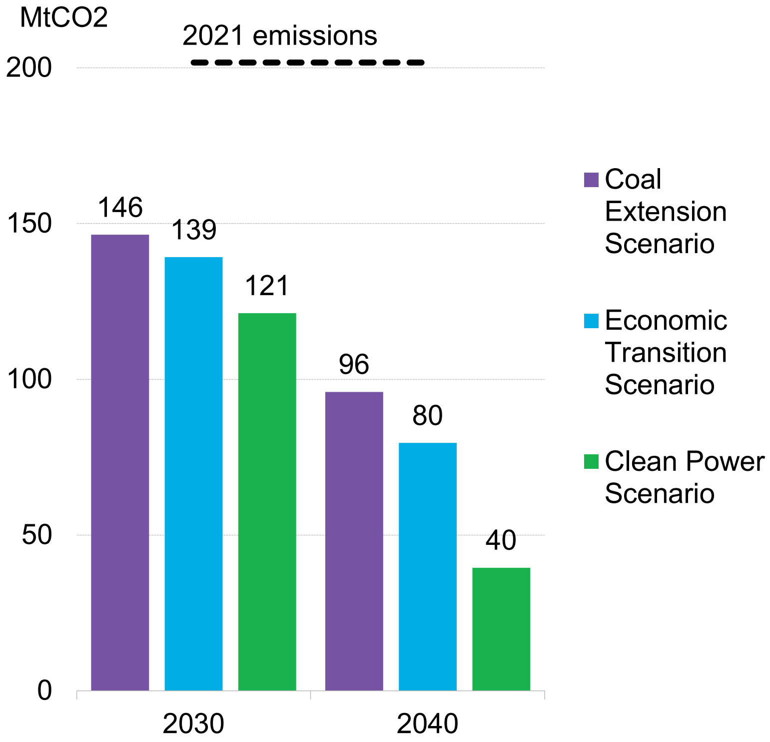
The power sector can deliver almost 80% of South Africa's 2030 climate targets

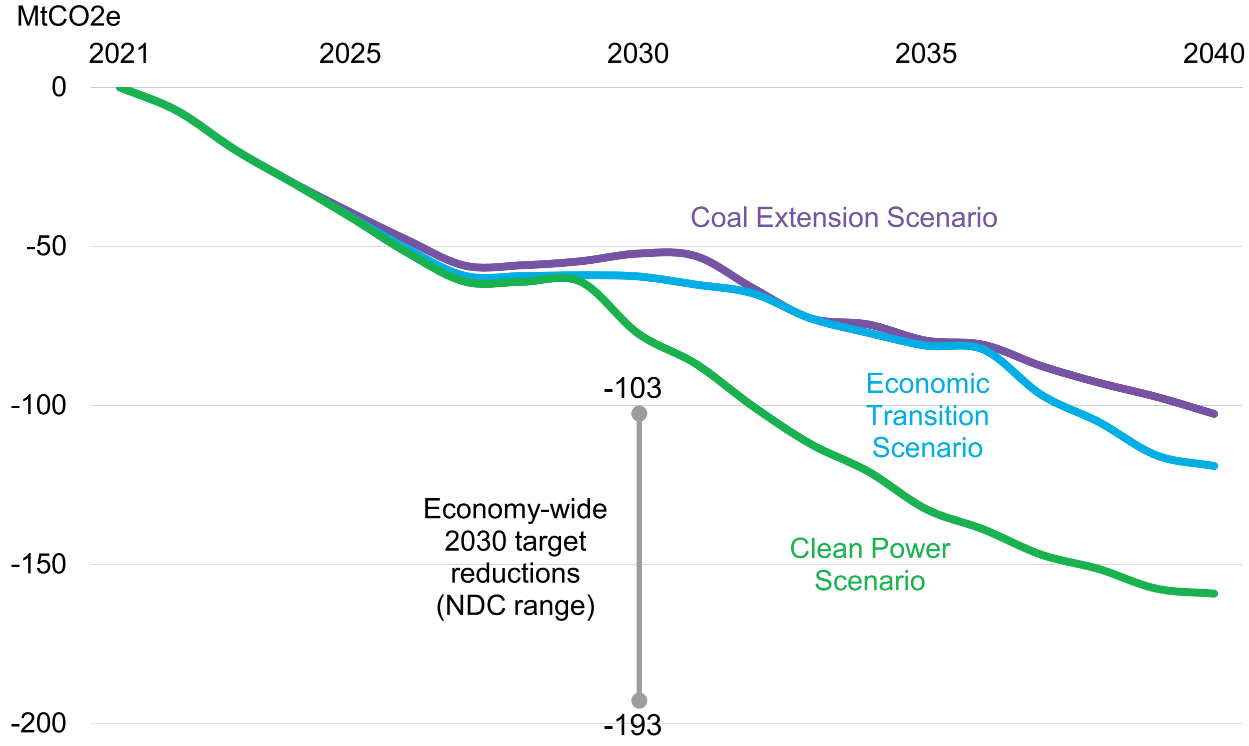
BNEF estimates that South Africa's power sector emitted 198MtCO2 in 2022, down 15% from 233MtCO2 in 2012. In all scenarios, emissions from electricity generation continue to decline as coal output drops. Carbon emissions fall fastest in the Clean Power Scenario to 122MtCO2 by 2030, contributing to 78% of the abatement needed to reach the lower bound of South Africa's climate targets. In the other scenarios, emissions fall more slowly as coal supplies the system for longer. Delaying coal closures results in the least progress towards 2030 climate targets, with power sector emissions remaining around 146MtCO2 in 2030, 5% higher than the Economic Transition Scenario. The Coal Extension Scenario would contribute to half of the total abatement needed to reach the lower bound of South Africa's NDC goal, presenting a high risk of overshoot if other end-use sectors – including industry and transportation – do not reduce their emissions faster.

Annual power sector emissions



Source: BloombergNEF.

Power sector emissions reductions from 2021 levels



Source: BloombergNEF, South Africa Nationally Determined Contribution.

Appendix

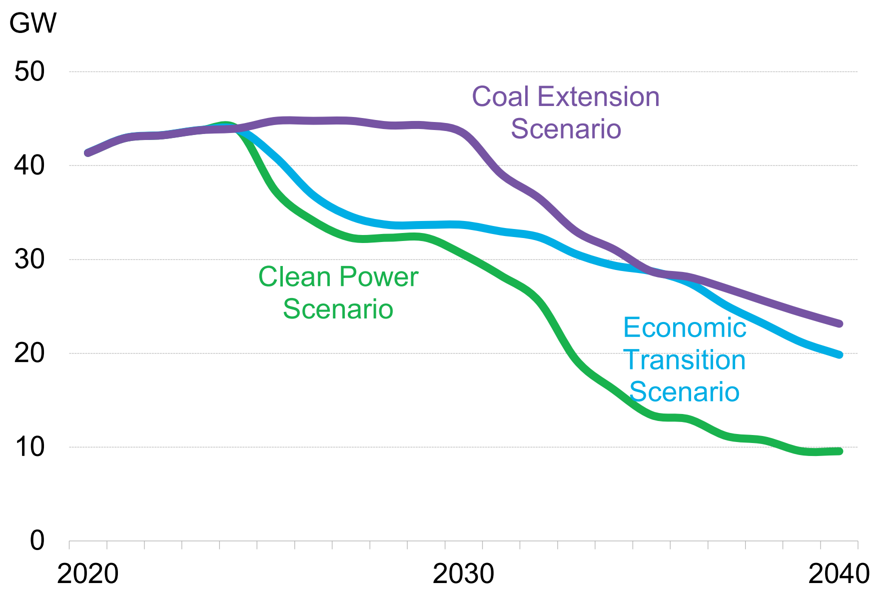
Modeling approach and assumptions

Methodology: Future power system scenario modeling at BloombergNEF

This research forms part of the library of energy transition scenarios at BloombergNEF, building on the analysis of our New Energy Outlook (NEO). NEO is BNEF's long-term scenario analysis on the future of the energy economy covering electricity, industry, buildings and transport and the key drivers shaping these sectors until 2050. As part of NEO, we use our in-house NEFM-2 power model to determine a least-cost system that can reliably meet electricity demand for every hour of the year. NEFM does not model import-export dynamics with neighbouring countries, but import capacity is modeled to help meet peak demand.

The core scenario used in BNEF research is our Economic Transition Scenario (ETS). This scenario employs a combination of near-term market analysis, least-cost modeling, and consumer uptake to describe the deployment and diffusion of commercially-available technologies, in the absence of new policy regimes, and uncover the underlying economic fundamentals of the energy transition. Scenarios are future-focused simulations combining a number of uncertain parameters into an internally consistent narrative. They are predominantly used for medium- to long-term investigative studies and may also include sensitivities to key variables. Scenarios differ from forecasts, which are shorter-term predictions.

Coal capacity by scenario, South Africa



Source: BloombergNEF.

Methodology and data inputs

This outlook for South Africa builds on results from our *New Energy Outlook 2022* (web | terminal) to explore additional scenarios for the power market only.

This outlook uses the Economic Transition Scenario (ETS) as a baseline. This scenario draws on updated assumptions about policy and capacity deployment, including adjusted commissioning timelines for new-build capacity and retirements.

The Coal Extension Scenario (CES) and Clean Power Scenario (CPS) are based on the ETS, but with additional assumptions to test different policy outcomes. The CES delays coal retirements, in line with ongoing policy discussions at the time of modeling. Such delays are not approved or confirmed as of November 2023.

The CPS puts South Africa on an accelerated path to a zero-carbon power system by 2050. The logic of cost-optimization and modeling approach remain the same in all scenarios.

Appendix

Methodology: Scenario assumptions

	Economic Transition Scenario	Coal Extension Scenario	Clean Power Scenario
Coal additions and retirements	Kusile units 5 and 6 are delivered over 2024-25 in line with Eskom announcements. Eskom's schedule of retirements are delivered in time (see Slide 6), and the model is allowed to build and close additional units on an economic basis. Tutuka is allowed to remain operational until each unit reaches 50 years of age.	This scenario takes an optimistic view on coal lifetime extensions. Arnot, Camden (units 4-8), Grootvlei (units 1-3), Hendrina (units 2, and 4-7) and Kriel, run for an additional 5-6 years. Lethabo and Kendal are extended for 10 years. Kusile units 5 and 6 are delivered over 2024-25. The model can only close additional units on an economic basis after 2030.	Kusile units 5 and 6 are delivered over 2024-25. Coal retirements are driven by a economics and need too meet an annual carbon budget. This results in more aggressive economic coal closures, ahead of current schedules. Most of Eskom's older units (36.6GW) are retired by 2035.
Gas additions and retirements	The model is allowed to build new units on an economic basis in all scenarios. Delivery of proposed gas plants currently remains uncertain, including for capacity contracted in the Risk Mitigation auction in 2021. We assume that the project pipeline from this auction, inclusive of the one 450MWW of gas-fired power ship that has secured an environmental permit, gets delivered over 2025-30.		
Wind, solar and storage	We incorporate BNEF's short-term forecast over 2023-27 for new wind, solar and battery storage capacity as of October 2023, which is based on bottom-up project pipeline data, policy measures and market-based drivers. This includes small-scale solar.		
Nuclear and hydro	We assume Koeberg operates until the end of its extended lifetime, retiring over 2044-45. No additional new nuclear or pumped hydro (including Tubatse) gets built, as decisions around procurement and delivery are still at too-early stages.		Same pipeline assumptions as ETS and CES. The model is allowed to build small modular reactors.
Carbon tax	The carbon tax is applied to electricity generators from 2025 until the end of the modeling period. Carbon tax deductions are included.		Same assumptions as ETS and CES, but we exclude carbon tax deductions.
Carbon budget	No carbon budget is forced in this scenario.	No carbon budget is forced in this scenario.	A carbon budget is applied, that aligns with a net-zero power system by 2050.
Load shedding	We allow some demand-side flexibility to simulate load shedding, in line with observed totals in South Africa over 2015-2023. The model then solves for total capacity build requirements to end load shedding by the end of 2025.		Same assumptions as ETS and CES, but some demand-side flexibility is reintroduced over 2030-2040.
Hydrogen	No hydrogen production from electrolyzers is modeled in this report, however BNEF tracks projects and produces forecasts for electrolyzer deployment. Announced projects in South Africa mostly plan to co-locate with renewables, and not be supplied by the grid.		

Appendix

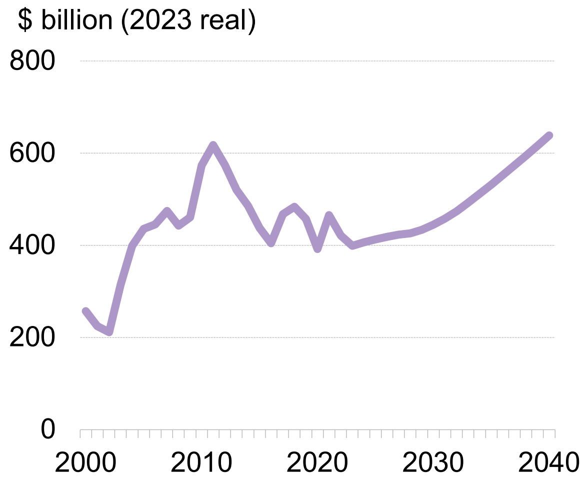
Methodology: Economic inputs and limitations

General electricity demand growth, including adoption of electric vehicles and air conditioning, are based on the methodology in BNEF's *New Energy Outlook 2022* (web | terminal). The underlying gross domestic product inputs used to produce our electricity demand outlook were updated in October 2023 with IMF and OECD forecasts. GDP growth averages -0.5% in South Africa over 2021-2030 and 4.4% over 2031-2040.

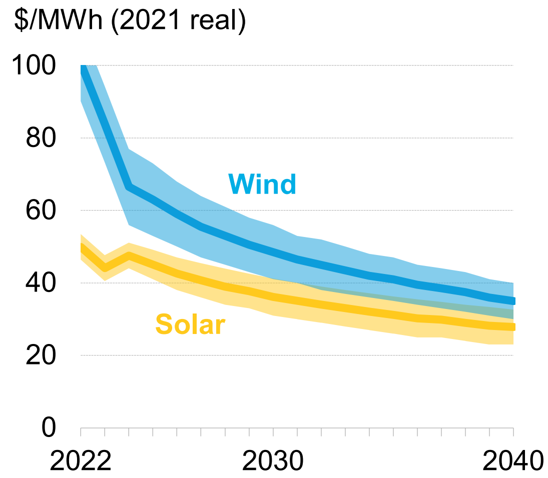
Our scenarios use BNEF forecasts for the evolution of technology costs, as well as gas and coal price forecasts for the region. These are based on BNEF's *Levelized Cost of Electricity* analysis (web | terminal) from 1H 2022. National carbon tax inputs are based on the disclosed rates and deductions for electricity generators scheduled under the Carbon Tax Act. In our modeling, the carbon tax is fed into the hourly operational cost of running unabated fossil fuel plants.

There are limitations to our modeling approach. Grid costs are not part of our least cost optimization. Near-term capacity pipelines are forced online as minimum build for all technologies, using the best information available at the time of modeling, but are subject to a high degree of uncertainty in delivery in the real world. We also assume that coal units at Medupi and Kusile are fully operational by end 2025, and that projects from the Risk Mitigation auction are commissioned by end 2025, both of which have a risk of non-delivery. Similarly, the adoption of small-scale solar in our modeling may slow down in the near term, if scheduled outages or broader economic conditions change.

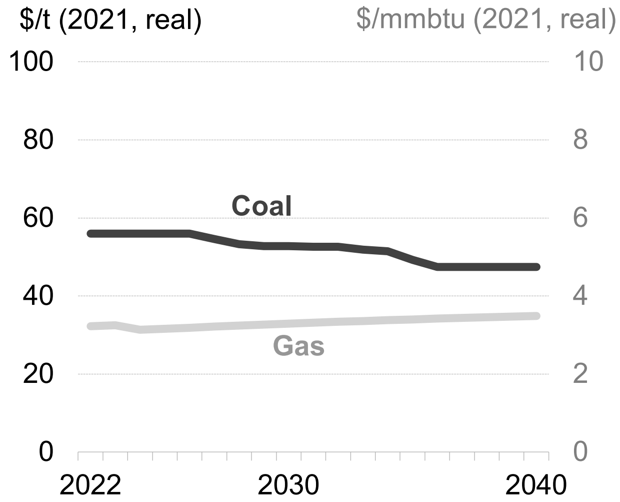
Gross domestic product



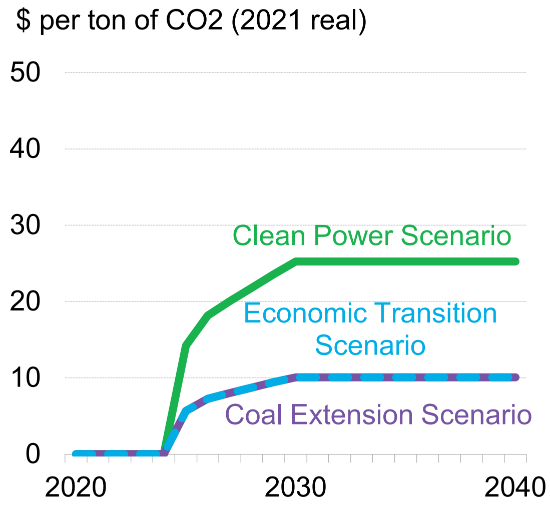
Levelized cost of electricity



Fuel prices



Carbon tax on electricity



Source: BloombergNEF, Carbon Tax Act. Note: All three scenarios use the same LCOEs and fuel prices.

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