Climate Action Tracker

Wind and Solar benchmarks for a 1.5°C world

SOUTH AFRICA

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CLIMATE ANALYTICS
NEW CLIMATE INSTITUTE

Executive Summary

Context

- South Africa has an abundant potential for wind and solar deployment. However, at present the electricity system is dominated by coal, which provided 83% of electricity generation in 2023.
- After the 2024 elections, a new South African government can set a new direction for the South African energy transition. This direction will also be needed as countries are requested to submit new 2035 climate targets to the UNFCCC in early 2025.
- In this report, we explore the level of wind and solar that South Africa would need to install as part of a global 1.5°C compatible pathway. Our benchmarks are also compatible with tripling renewables capacity by 2030.

Key findings

- South Africa's wind and solar generation needs to grow six to ten times by 2030 to align with 1.5°C, reaching 80–145 TWh of wind and solar.
- Almost 70 GW of wind and solar would be needed by 2030 (49 GW of solar and 16 GW of wind).
- A rapid rollout of renewables could help meet electricity demand and provide reliable, zero-carbon electricity to South Africans.
- However, it will require large-scale investment to help phase down coal power, accelerate renewables deployment, and drive grid expansion. International support will be key in supporting the energy transition via climate finance, some of which could be provided by the JETP.

Wind & solar
1.5°C benchmarks

Generation capacity in **2022**	Generation capacity in **2030**
9 GW	**65 GW**
3 GW Wind	**16 GW** Wind
6 GW Solar	**49 GW** Solar

Context

At COP28, governments agreed to triple global renewable capacity by 2030 globally to stay in line with 1.5°C. This report highlights the potential implications of this COP28 decision at the national level, focusing on **South Africa**.

Wind and solar deployment is accelerating around the world. However, expected wind and solar capacity deployment under current policies falls short of what is needed for 1.5°C, and is concentrated mainly in a few regions.

Research is needed to understand the pace of wind and solar deployment that aligns with the highest plausible ambition and is compatible with 1.5°C

This project aims at answering the following questions:

- **How much wind and solar generation is needed (TWh) at the national level?**
- **How much wind and solar needs to be built (GW of capacity)?**
- **When does it need to be built by, and how quickly?**

Policy context

South Africa's 2030 NDC is to cut emissions to the 350–420 $MtCO_2e$ range by 2030, a 19-32% reduction on 2010 levels excluding LULUCF. The country does not yet have a formal net zero target but has stated its intention to commit to a net zero CO_2 target for 2050.

South Africa's current renewable targets are to reach **8 GW of solar and 18 GW of wind by 2030**, as of the Integrated Resource Plan published in 2019.

Under current policies and market conditions, the IEA estimates that **solar capacity will reach 36 GW in 2030**, up from 6.4 GW of solar in 2022. Meanwhile, **wind capacity is projected to reach 10 GW in 2030**, up from 3.5 GW in 2022.

International support

The key analytical elements (high ambition country-level studies and downscaled 1.5°C compatible global pathways, see Methods) do not consider financing requirements.

Significant global resource transfers will be required in line with 'common but differentiated responsibilities and respective capabilities' to achieve these benchmarks.

We do not quantify the technical and financial support needed to achieve the wind and solar rollout presented in this report. This should be a country-driven exercise and some governments have already initiated such processes, including under the JETP umbrella.

High-income countries will need to provide substantially increased climate finance to support emissions reduction abroad, in line with their 'fair share' of climate action.

Achieving these benchmarks in lower-income countries is therefore a global responsibility, rather than a domestic responsibility. Therefore, ambitious climate finance commitments and delivery are essential to support high ambition at the national level.

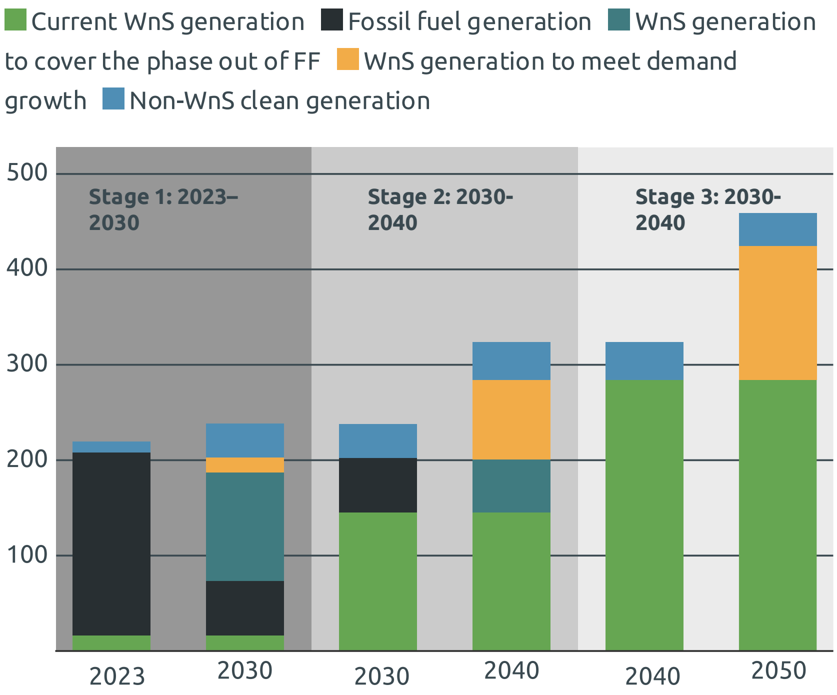
National enabling factors

Key enabling factors for ambitious wind and solar rollout include:

- **Institutional capacity.** A rapid build-out of wind and solar will require the governance and institutional capacity to develop, implement and enforce policy frameworks.
- **Just transition.** A just transition will be needed to take along all stakeholders, particularly those employed by the fossil economy.
- **Grid development.** Substantial increases in both transmission and distribution grid infrastructure will be necessary to integrate large-scale new wind and solar generation into the power system.
- **Fossil fuel phase-out.** Existing fossil fuel infrastructure often will need to be retired earlier than its economic lifetime. Policies need to be developed to achieve the early phase out of fossil fuel plants.
- **System flexibility.** Energy storage (diurnal and seasonal), flexible generation technologies such as hydro and geothermal, and increased demand side flexibility will all be crucial.
- **Market design.** Reform of market designs and regulation adapted to RE-based systems that incentivise and mobilise investments to install renewable energy at the scale needed (e.g., minimise cost of capital, ensure revenue certainty, etc).

Results

Stages of power sector decarbonisation



The stages of the electricity system transition in South Africa

WnS = Wind and Solar

Figure 1 – Electricity generation in each stage in TWh

In a 1.5°C pathway, countries must add solar, wind, and other clean technologies to meet rising power demand while replacing phased-out fossil fuels. The evolution of the power capacity mix over successive decades varies across countries.

From now until 2030, Australia would need to add 1.4 GW of wind and 4.9 GW of solar capacity to meet growing demand alone. Another 9.8 GW of wind and 35 GW of solar will be needed to displace the share of fossil fuels in the electricity generation mix.

Power sector transformation and the increasing participation of variable renewable energy (VRE) – mainly wind and solar – in a country's power mix gives rise to a set of technical challenges linked to the integration of VRE sources. Six phases can be distinguished here, from phase 0 (pre-development with negligible amount of VRE shares) to phase E (with over 80% VRE shares). More information about these phases can be found in Annex A.

Meeting the benchmarks for 2030 will put South Africa in Phase D, with wind and solar making up 61% of the generation mix. Periods in which VRE availability exceeds demand occur more frequently than in earlier phases. Ensuring system stability while continuing to increase renewable penetration requires additional measures, such as expanded demand response, stronger interconnections and large-scale energy storage. Market design and regulatory frameworks become increasingly important to enable these solutions. Although particularly critical in this phase, many of these measures should begin in earlier phases (B and C) to provide long-term investment signals and facilitate a smoother system transformation.

Figure 1 and Table 1 both show the stages of the transition to a decarbonised power sector in terms of the volumes of existing wind and solar and what is needed to displace fossil fuels and meet demand increases. Figure 1 shows the stages in terms of electricity generation, and Table 1 shows it in terms of generation, capacity and share of the electricity mix.

Table 1: Stages of the electricity system transition detailing how much generation capacity of wind and solar will be needed to displace fossil fuels in the system and meet growing electricity demand

	2023		2030		2040		2050
Grid integration phase (share of variable renewable energy in total electricity generation)							
Phase	Phase A		Phase D		Phase E		Phase E
Share of VRE	**< 15%**		**< 70%**		**> 85%**		**> 85%**
Share of electricity generation							
Wind & Solar	**7.5 %**		**61 %**		**88 %**		**93 %**
Other renewables	5.1 %		15 %		12 %		7.4 %
Fossil Fuels	**88 %**		**24 %**		**0 %**		**0 %**
Generation capacity							
To displace fossil fuels		**+45 GW**		**+32 GW**		**+0 GW**	
Wind & Solar	**15 GW**	**+6.7 GW/yr**	**66 GW**	**+8.9 GW/yr**	**140 GW**	**+12 GW/yr**	**220 GW**
To meet demand increase		**+6.2 GW**		**+ 48 GW**		**+77 GW**	
Generation							
Total	**220 TWh**	9%	**240 TWh**	33%	**320 TWh**	44%	**460 TWh**
Wind & Solar	16 TWh		150 TWh		280 TWh		420 TWh
Generation Capacity of VRE (variable renewable energy)							
To displace fossil fuels			9.8 GW		6 GW		0 GW
Wind capacity	**5.1 GW**		**16 GW**		**31 GW**		**39 GW**
To meet demand increase			1.4 GW		9 GW		7.2 GW
To displace fossil fuels			35 GW		26 GW		0 GW
Solar capacity	**9.5 GW**		**49 GW**		**110 GW**		**180 GW**
To meet demand increase			4.9 GW		39 GW		69 GW

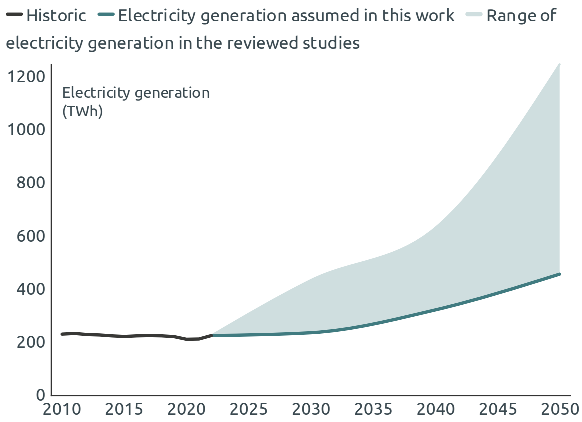
Note: Numbers are rounded to two significant figures, which may contribute to minor differences in totals. The calculations assume that wind, solar, and other renewables contribute equally and proportionally to displacing fossil fuels and meeting demand growth.

Future electricity demand

Electricity demand is taken from the University of Cape Town's Energy Systems Research Group (ESRG) study exploring net zero pathways for South Africa. We take demand from the most ambitious pathway, which achieves net zero CO_2 emissions by 2050, and limits cumulative GHG emissions in South Africa to 6 $GtCO_2e$ over 2021-2050.

Total electricity generation in South Africa doubles by 2050 relative to 2022 levels, reaching 460 TWh. This is driven by economic development and increased electrification.

However, there is a significant range in the studies in terms of the expected electricity generation in 2050 ranging from 460 TWh to 750 TWh. This would affect the necessary growth of wind and solar significantly. Our demand estimate is at the lower end of that estimated by country-level studies. It was chosen partly the basis of stakeholder feedback, and partly because it represents the most recent study from a group of researchers inside South Africa, who have the best understanding of the demand context in the country*.



Electricity generation doubles in South Africa by 2050

The solid line shows the electricity generation projection used to develop the benchmarks

Figure 2 – Total electricity generation in TWh

Pace of fossil fuel phase-out needed

The rate of fossil fuel phase-out is set by the overlap between country-level studies, downscaled 1.5°C compatible global pathways and the global milestones of the IEA's Net Zero roadmap, in which South Africa achieves a clean power system by 2045.

To align with 1.5°C, fossil fuels must exit the South African power sector before 2045. The CAT recommends aiming for the strongest ambition where South Africa phases out coal by 2040.

Fossil fuel generation falls by 38 to 71% between 2022 and 2030.

Phasing out fossil fuels while simultaneously meeting growing electricity demand will require substantial international support, including climate finance to help with the early retirement of existing coal-fired power plants

The fastest rate of fossil phase-out is set by the ESRG study.

* Some other country-level studies reviewed are conducted by research groups from outside South Africa. While these still provide valuable information on the energy transition in South Africa, we prioritise the results from in-country modelling groups. For a full list of reviewed studies, see the Annex.

To align with 1.5°C, fossil fuels must exit the South African power sector by 2045, even as electricity demand grows

South Africa would need to achieve clean electricity by 2045

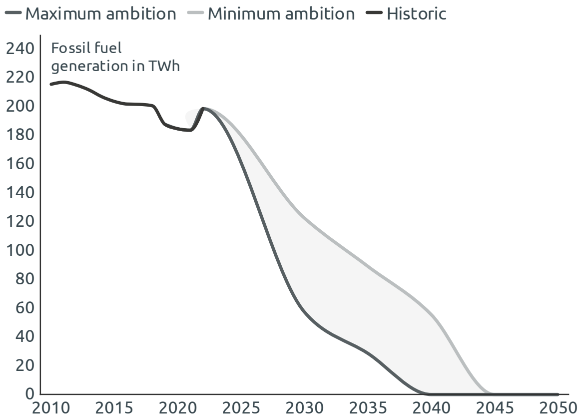


Figure 3 – Fossil fuel generation in TWh

Coal and gas phase-out in South Africa

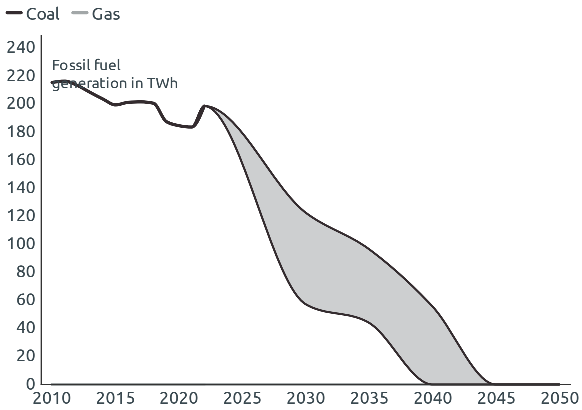


Figure 4 – Fossil fuel generation by fuel type in TWh

The role of other clean electricity generation

While wind and solar will be the workhorse of the energy transition, other clean electricity generation may play a role. We estimate the role of non-wind and solar clean technologies* (largely hydro, biomass, nuclear and geothermal) from country-level studies.

In our modelling, we assume that generation from clean technologies other than wind and solar in South Africa would reach 35 TWh by 2030 and 34 TWh by 2050. This is provided by a mix of nuclear, biomass and hydro-power.

Total wind and solar generation needed to align with 1.5°C

The wind and solar rollout is then calculated by combining projected electricity demand growth, the fossil phase-out necessary to align with 1.5°C, and the assumed generation from other clean technologies.

To align with 1.5°C, wind and solar generation in South Africa would need to reach between 80 and 145 TWh by 2030. Generation in 2022 was 14 TWh. This is therefore a 6 to 10-fold growth in wind and solar.

Wind and solar provides 34–61% of overall electricity generation in 2030, and 93% of overall generation in 2050. A grid powered almost entirely be wind and solar would requires substantial rollout of batteries and energy storage, support from dispatchable generation such as hydro and geothermal, flexible demand and grid extension to ensure reliability of the system.

* We do not consider CCS in the power sector, as we do not consider CCS a viable source of large-scale emissions reductions in the power sector.

To align with 1.5°C, wind and solar generation would need to grow rapidly in South Africa

Wind and solar generation needs to grow 6-10x by 2030 relative to 2022 in South Africa

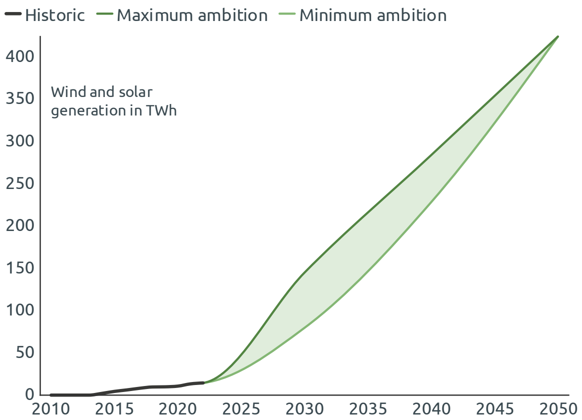


Figure 5 – Wind and solar electricity generation in TWh

Wind and solar would need to provide over 90% of electricity in South Africa by 2050

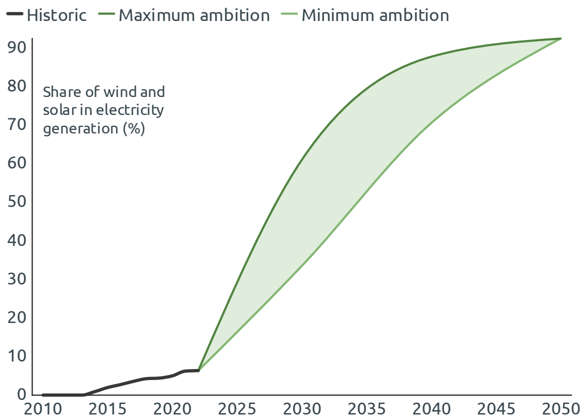


Figure 6 – Wind and solar electricity generation share (%)

Possible splits between wind and solar

The relative share of wind and solar deployment will vary depending on how various factors develop in the future. We explore one key uncertainty, the relative cost of solar and wind electricity generation (see methods). When accounting for this uncertainty, we see a range of possible future generation mixes between wind and solar.

We highlight the median of the range as our **central benchmark**, but do not suggest that this is the only possible breakdown into wind versus solar. In the central benchmarking scenario, solar becomes the main source of generation, providing on average twice as much generation as wind in the electricity mix by 2050. This will require a rapid uptake of non-fossil flexibility options.

In this scenario, **South Africa would need to deploy almost 70 GW of wind and solar by 2030 to align with 1.5°C**. By 2050, total wind and solar capacity would need to reach towards 220 GW. Due to its higher capacity factor, greater wind deployment would reduce total capacity requirements.

South Africa needs to reach almost 70GW of wind and solar installed capacity by 2030 to align with 1.5°C

Solar capacity would reach 49 GW in South Africa by 2030 in a 1.5°C-aligned scenario

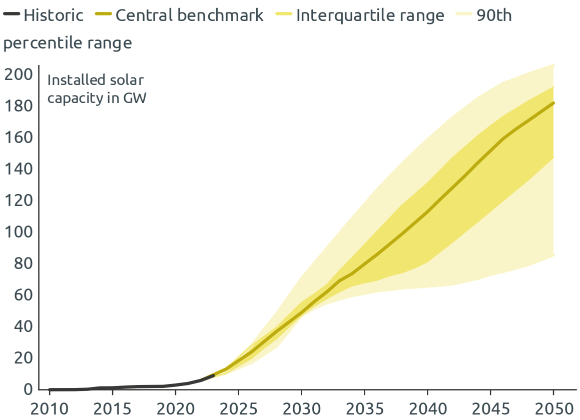


Figure 7 – 1.5°C compatible capacity benchmarks for solar in GW

Wind capacity would reach 16 GW in South Africa by 2030 in a 1.5°C-aligned scenario

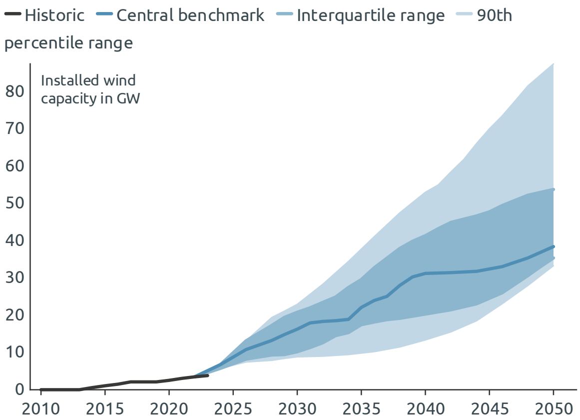


Figure 8 – 1.5°C compatible capacity benchmarks for wind in GW

Note: The benchmarks assume action from 2022.

The following table shows the wind and solar deployment needed to align with the central 1.5°C compatible benchmark produced. 2022 is historical data. All benchmark data from 2030 onwards is reported to two significant figures.

Table 2: Wind and solar electricity generation and capacity (2022–2050)

Scenario	Variable	Unit	2022	2030	2035	2040	2050
Central 1.5°Cbenchmark	Solar generation	TWh	8	59	100	150	290
Central 1.5°Cbenchmark	Wind generation	TWh	10	56	79	110	140
Central 1.5°Cbenchmark	Solar capacity	GW	6	49	80	110	180
Central 1.5°Cbenchmark	Wind capacity	GW	3	16	22	31	39

Table 3: Benchmarks translated into CAT format

Variable	Ambition	Unit	2030	2035	2040	2045	2050
Share of coal	Minimum	%	52	34	17	0	0
	Maximum	%	24	16	0	0	0
Share of gas	Minimum	%	0	0	0	0	0
	Maximum	%	0	0	0	0	0
Share of renewables	Minimum	%	42	61	79	98	99
	Maximum	%	70	79	96	98	99
Share of wind and solar	Minimum	%	34	52	71	90	93
	Maximum	%	61	71	88	90	93

Note: The benchmarks show a 0-17% share of coal in 2040, but the CAT recommends aiming for the strongest ambition due to the climate, economic, and health benefits of phasing out fossil fuels. In this case, South Africa should aim for a coal phaseout by 2040.

Comparison to current rollout and country target

We compare the IEA's capacity forecast for wind and solar to the benchmarks presented in this report. Under current policies and market conditions, deployment of solar PV in South Africa broadly aligns with the minimum level required to align with 1.5°C. However, to achieve the highest rates of fossil fuel phaseout, more wind and solar would need to be built, **with the most ambitious scenario installing over 70 GW of solar alone by 2030.** In comparison to the government's solar targets, at least 6 times more capacity needs to be build out.

Meanwhile, the target in the 2019 IRP of 18 GW of onshore wind is broadly 1.5°C aligned, but rollout is falling behind this level. Further action will be needed to drive wind deployment in South Africa at the pace needed.

There is strong support from businesses for high ambition from the government to phase out fossil fuels and transition the electricity system to be powered by renewables, with 95% of executives in South Africa polled in the Global Business Poll supporting renewables for jobs and economic growth and 86% in favour of phasing out the use of coal in electricity generation by 2035.

South Africa's solar rollout is broadly aligned with 1.5°C, but wind rollout needs to accelerate

Current rollout of solar in South Africa comes close to aligning with 1.5°C, but targets need updating

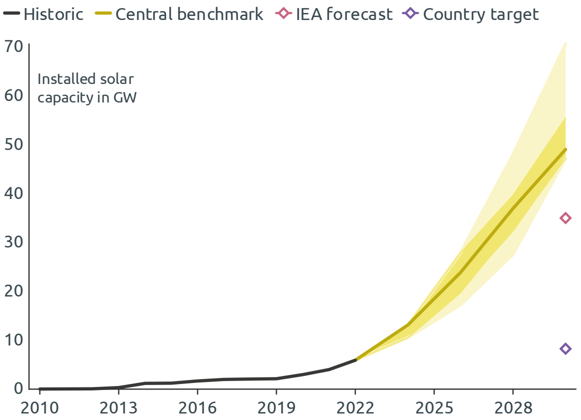


Figure 9 – Installed solar capacity in 2030 compared to targets and current policy projections in GW

The current wind capacity target in South Africa aligns with 1.5°C, but current rollout lags behind

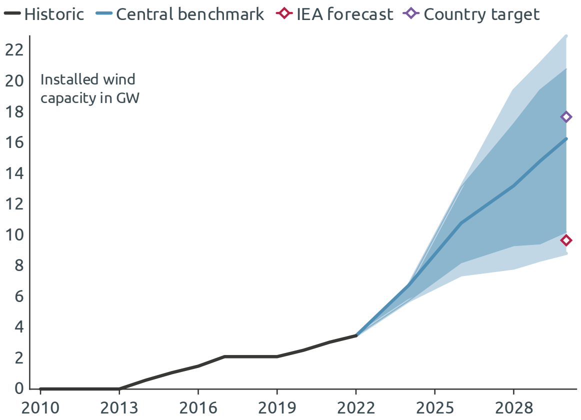


Figure 10 – Installed wind capacity in 2030 compared to targets and current policy projections in GW

Note: The target data was last pulled from Ember in January 2025. The current policies data was last pulled from the IEA in June 2025.

Wind and solar capacity additions in South Africa need to accelerate to align with 1.5°C

South Africa would need to add on average 5.2 GW/yr of solar capacity until 2030, and 6.8 GW/yr by over 2030–2050

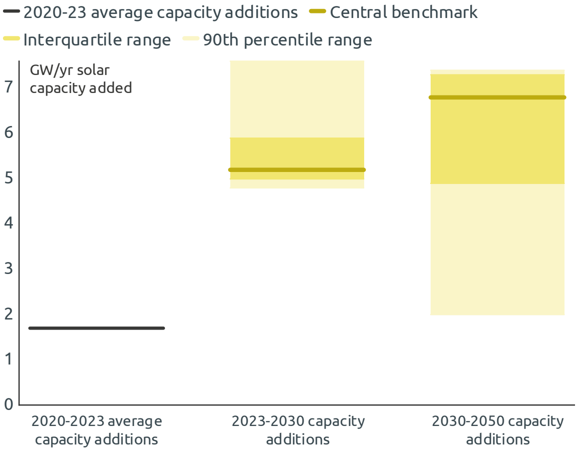


Figure 11 – Solar capacity additions per year in GW/y

South Africa would need to add on average 1.4 GW/yr of wind capacity until 2030, and 1.3 GW/yr by over 2030–2050

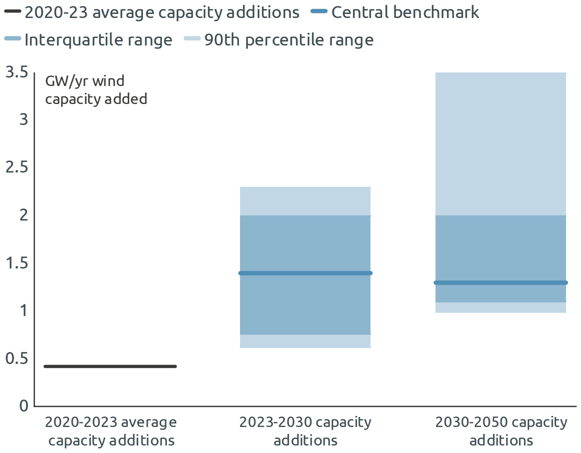


Figure 12 – Wind capacity additions per year in GW/y

Comparison with other studies

We compare the wind and solar generation seen in our analysis to that in the literature review of country-level studies. In particular, we highlight the results of modelling from the University of Cape Town, exploring [net zero pathways for South Africa](#).

We see that the solar generation that our method produces is broadly within the range of the national literature, while the central wind generation benchmark is slightly below the range of national literature.

Our analysis currently shows higher solar generation and less wind generation than the study highlighted from University of Cape Town, particularly by 2050. Wind capacity deployment in South Africa likely faces greater challenges than solar capacity, due to grid constraints which are particularly strong in areas of high wind potential.

Our benchmarks are broadly aligned with the literature

Electricity generation from solar: comparison with literature in South Africa

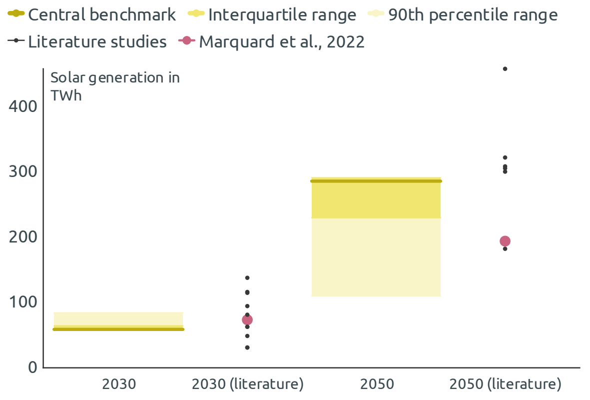


Figure 13 – Solar electricity generation in TWh

Electricity generation from wind: comparison with literature in South Africa

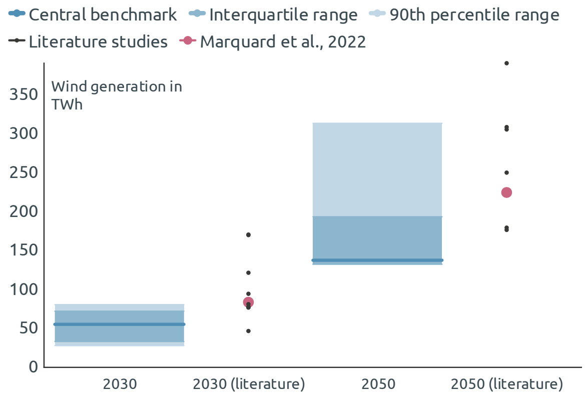


Figure 14 – Wind electricity generation in TWh

In South Africa, our benchmarks generally suggest that solar will provide more generation than wind

Share of wind and solar generation that comes from solar: comparison with literature in South Africa

The area above the blue dashed line represents a power system in which solar provides more electricity generation than wind

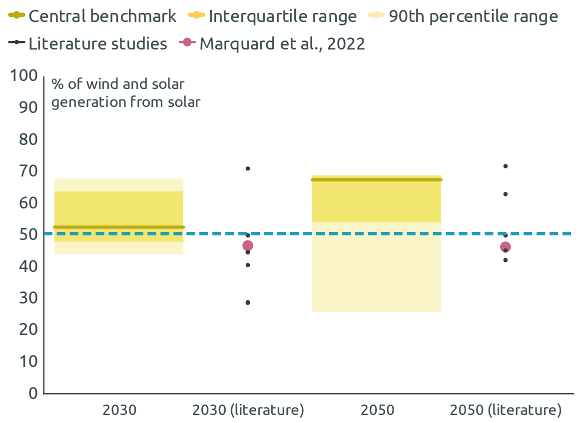
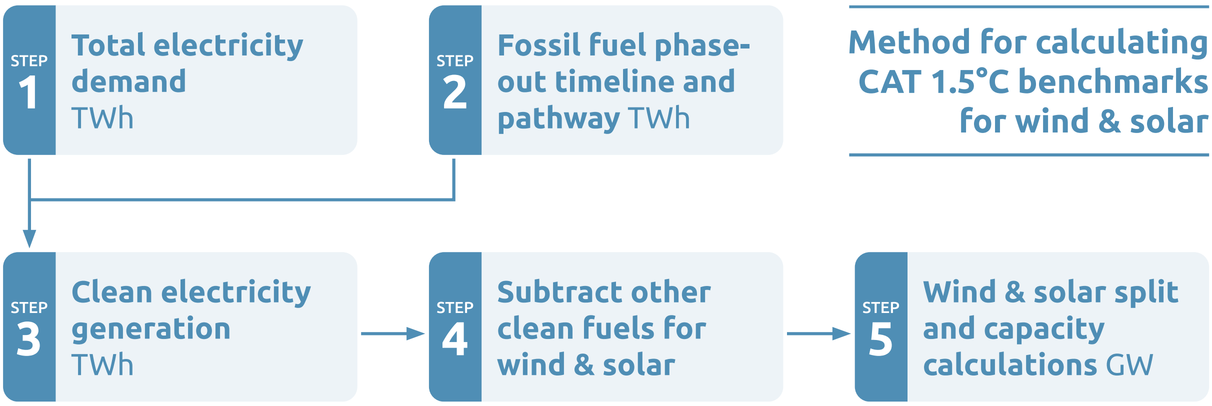


Figure 15 – Generation split between wind and solar (%)

Methodology

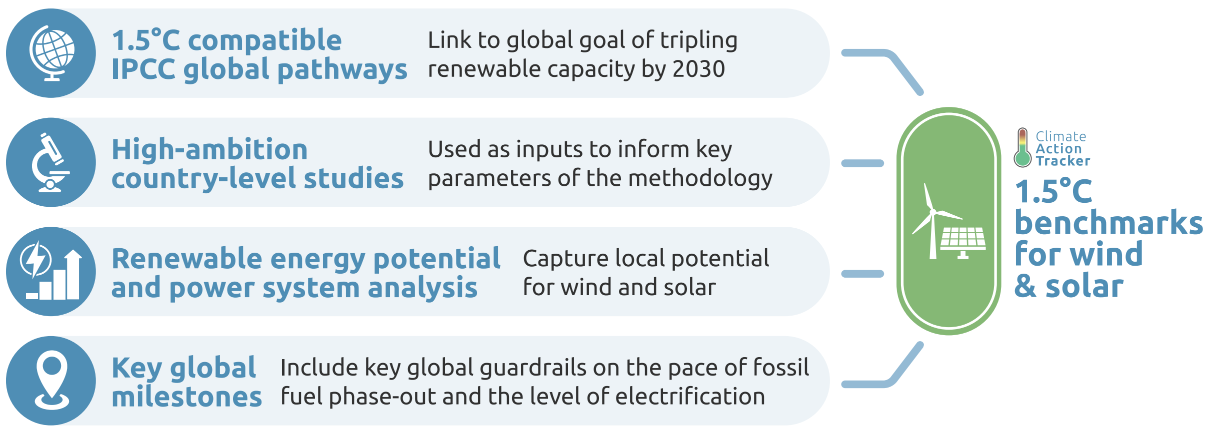
Summary of our method



Our method takes a series of steps to calculate the wind and solar generation needed for 1.5°C, and the resulting capacity deployment. The key methodological steps are highlighted below.

1. We project future electricity demand in the country.
2. We calculate the pace of fossil fuel phase-out needed to align with 1.5°C.
3. Bringing these trajectories together defines the level of clean electricity generation required to meet electricity demand growth while phasing out fossil fuels in the power sector.
4. We project non-wind and solar clean electricity generation based on country-level literature. This allows us to identify the wind and solar generation necessary to align with 1.5°C.
5. Having produced this wind and solar generation trajectory, we feed it into a simplified electricity system model (PyPSA), which calculates for a given set of cost assumptions around wind and solar, a split into wind versus solar and the associated capacity requirements.

Overlap of different elements



Our method focuses on the overlap between different elements. By looking at the range of fossil fuel phase-out which is outlined in both high ambition country-level studies and downscaled 1.5°Ccompatible global pathways, and is informed by key global milestones, we identify benchmarks which are both consistent with a global least cost pathway to limiting warming to 1.5°C but are also aligned with national–level modelling.

Combining multiple different analytical elements can help identify the most robust path to achieving a zero-carbon energy system.

For more details see the Methods Annex.

List of scenarios selected

Table 4: Country level studies for South Africa

Study	Publication	Scenario selected
Oyewo *et al.*, 2019	Pathway towards achieving 100% renewable electricity by 2050 for South Africa	Best Policy Scenario
Hanto *et al.*, 2021	Effects of decarbonization on the energy system and related employment effects in South Africa	2°C scenario
IRENA, 2020	Renewable Energy Prospects: South Africa	REmap case
IEA, 2022	Africa Energy Outlook 2022	Sustainable Africa Scenario
CSIR, 2017	Long-term electricity sector expansion planning: A unique opportunity for a least cost energy transition in South Africa	Decarbonised (conservative costs)
Marquard *et al.*, 2022	Exploring net zero pathways for South Africa - An initial study	Net Zero – 6 Gt GHG budget – 45 MtCO_2 /yr sink
Teske *et al.*, 2023	Net-zero 1.5°C sectorial pathways for G20 countries: energy and emissions data to inform science-based decarbonization targets	1.5°C

Annex A

Phases of grid integration

The grid integration phase is adapted from a de Vivero et al. report detailing a qualitative assessment framework for power system transformation and an IEA report on integrating solar and wind. We use the share of VRE sources in electricity generation to classify countries into a phase. More information about the characteristics and key challenges of each phase can be found in the report.

Phase 0 (less than 5% annual VRE share): we assign this phase when wind and solar make up 0-5% of a country's electricity generation mix. Installed VRE capacity is limited, and the impact on power system operation is negligible. Integration does not require significant operational or structural changes.

Phase A (between 5% and 15% annual VRE share): we assign this phase when wind and solar make up 5-15% of a country's electricity generation mix. Conventional power system operation remains largely sufficient for day-to-day system management. However, system planning must anticipate higher future VRE shares. This includes improving forecasting tools, integrating forecasting into dispatch decisions and moving toward shorter scheduling intervals and more real-time system operation.

Phase B (between 15% and 25% of annual VRE share): we assign this phase when wind and solar make up 15-25% of a country's electricity generation mix. The contribution of VRE varies significantly over time, with periods of very low output and periods of high penetration. This variability increases the need for operational flexibility. Enhanced coordination between system operators, network operators, and distribution system operators becomes critical to maintain system efficiency and security.

Phase C (between 25% and 40% of annual VRE share): we assign this phase when wind and solar make up 25-45% of a country's electricity generation mix. Periods in which VRE dominates system behaviour become increasingly frequent. A key operational challenge is maintaining system stability during sudden disruptions in supply or demand. Curtailment of VRE may become necessary to preserve system security. Without structural adjustments, integration constraints of VRE into the system may slow further increases in renewable energy shares despite additional installed capacity.

Phase D (between 40% and 70% of annual VRE share): we assign this phase when wind and solar make up 45-80% of a country's electricity generation mix. Periods in which VRE availability exceeds demand occur more frequently than in earlier phases. Ensuring system stability while continuing to increase renewable penetration requires additional measures, such as expanded demand response, stronger interconnections and large-scale energy storage. Market design and regulatory frameworks become increasingly important to enable these solutions. Although particularly critical in this phase, many of these measures should begin in earlier phases (B and C) to provide long-term investment signals and facilitate a smoother system transformation.

Phase E (more than 70% share of annual VRE share): we assign this phase when wind and solar make up 80-100% of a country's electricity generation mix. The power system reaches very high VRE penetration. The primary challenge becomes ensuring adequacy during extended periods of low wind and solar availability. Addressing this requires long-duration energy storage, sector coupling allowing for export and import of power between economic sectors in the same country and extensive electricity trade both within regions and between countries.

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The Consortium

The Climate Action Tracker (CAT) is an independent scientific analysis produced by three research organisations tracking climate action since 2009. We track progress towards the globally agreed aim of holding warming well below 2°C, and pursuing efforts to limit warming to 1.5°C.

climateactiontracker.org

Climate Analytics is a non-profit institute leading research on climate science and policy in relation to the 1.5°Climit in the Paris Agreement. It has offices in Germany, the United States, Togo, Australia, Nepal and Trinidad and Tobago.

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NewClimate Institute is an independent non-profit organisation that develops solutions to tackle climate change and drives their implementation worldwide. Through research, policy advice and knowledge sharing, we aim to raise the ambition for climate action and support sustainable development.

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