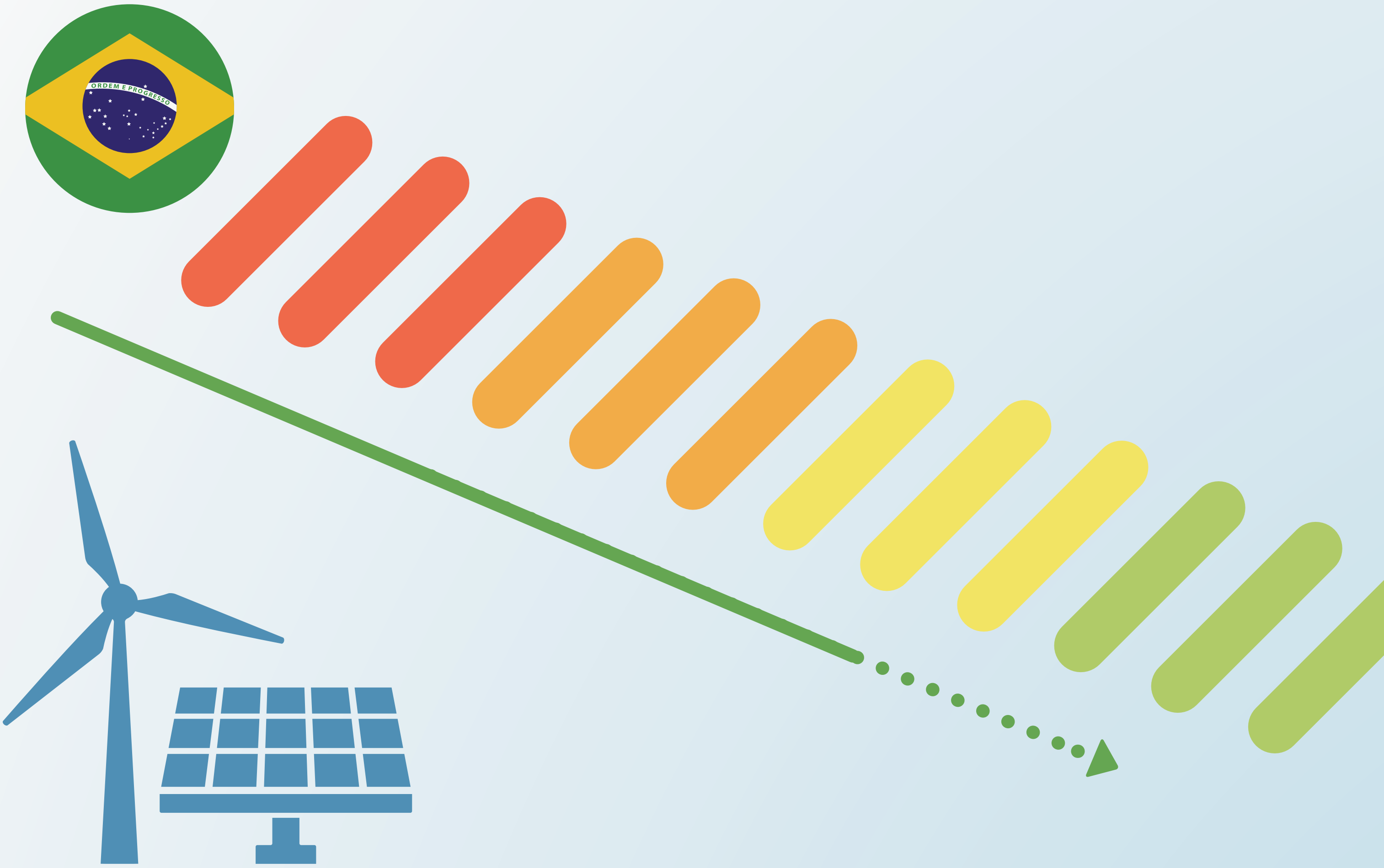
Climate Action Tracker



Climate Action Tracker

Wind and Solar benchmarks for a 1.5°C world

BRAZIL

January 2026

CLIMATE ANALYTICS

NEW CLIMATE INSTITUTE

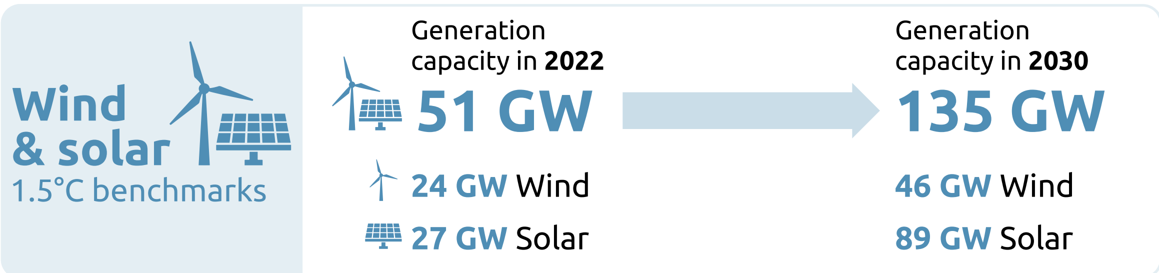
Executive Summary

Context

- Brazil generates most of its electricity from clean sources, 91% in 2023. Hydropower dominates the mix (60%).
- Wind and solar deployment is already underway, positioning the country at the forefront of wind energy in the region. Wind and solar contributed to 21% of the power mix in 2023, well above the global average (13%)
- While only 9% of Brazil's power supply came from fossil fuels in 2023, it fluctuates annually due to hydro availability.
- Despite having one of the cleanest power systems in the world, an increase in wind and solar power can reduce its vulnerability to droughts, while meeting growing electricity demand – in 2023, annual electricity demand grew by 5%
- To decarbonize other sectors, Brazil must increase its electrification levels, which is currently below 20%. This will require greater deployment of wind and solar.

Key findings

- Although Brazil does not need to triple renewables to stay on the 1.5°C pathway, our analysis suggests that solar capacity would need to triple and wind capacity double by 2030 compared to 2022 levels to meet growing demand.
- Brazil's current wind and solar rollout broadly aligns with the 1.5°C compatible benchmarks set out in this report.
- To stay aligned with the 1.5°C target, Brazil must maintain at least the same pace of annual wind and solar capacity additions over the remainder of this decade as in recent years.
- It is essential that Brazil avoids deploying new fossil fuel capacity. A dash for fossil gas in the power sector is an economic and climate risk that can, and should, be avoided.
- Our modelling envisages that wind will generate more electricity than solar in next decades in a 1.5°C compatible transition, in line with country-level studies and developments in the last decade.



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 **Brazil**.

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

Brazil's current NDC limits net GHG emissions to 1.2 $GtCO_2e$ by 2030, a 15% reduction below 2010 levels excluding LULUCF. The country announced "climate neutrality" target by 2050 but has incomplete information regarding GHG emission coverage and its legal status.

Brazil has already surpassed its target of reaching 84% renewable electricity by 2030. Brazil plans to reach **47 GW of solar and 31 GW of wind by 2030**, as of ten-year Energy Expansion Plan (PDE) (2022-2031) prepared by the Energy Research Office (EPE) in 2022.

Under current policies and market conditions, the IEA estimates that deployment of both wind and solar will far exceed the EPE's plans for 2030. According to the IEA, **solar capacity will reach 131 GW in 2030**, up from 27 GW in 2022. Meanwhile, **wind capacity is projected to reach 46 GW in 2030**, up from 24 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 countries have already initiated such processes.

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 phaseout.** 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

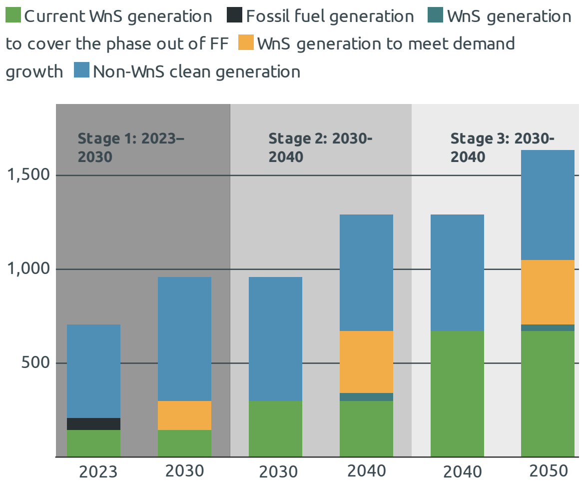


Figure 1 – Electricity generation in each stage in TWh

The stages of the electricity system transition in Brazil

This figure 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. This figure shows the stages in terms of electricity generation and Table 1 shows it in terms of generation, capacity and share of the electricity mix.

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, Brazil would need to add 20 GW of wind and 57 GW of solar capacity to meet growing demand.

Power sector transformation is a gradual, phased process. Different levels of wind and solar penetration in the generation mix present distinct challenges for the power system, and these challenges grow more complex as penetration increases. Meeting the benchmarks for 2030 will put Brazil in Phase C*, with variable renewable energy sources (VRES) making up 31% of the generation mix.

* The grid integration phase is adapted from a de Vivero et al. report detailing a qualitative assessment framework for power system transformation. We use the share of VRES in electricity generation to approximate the load coverage share, which is often lower, and classifying countries into a phase. More information about the characteristics and key challenges of each phase can be found in the report.

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							
Phase	Phase B		Phase C		Phase D		Phase D
VRES load coverage	**< 25 %**		**< 40 %**		**< 70 %**		**< 70 %**
Share of electricity generation							
Wind & Solar	**21 %**		**31 %**		**52 %**		**64 %**
Other renewables	71 %		69 %		48 %		36 %
Fossil Fuels	**8.7 %**		**0 %**		**0 %**		**0 %**
Generation capacity							
To displace fossil fuels		**+0 GW**		**+15 GW**		**+15 GW**	
Wind & Solar	**58 GW**	**+12 GW/yr**	**140 GW**	**+13 GW/yr**	**270 GW**	**+17 GW/yr**	**440 GW**
To meet demand increase		**+77 GW**		**+120 GW**		**+160 GW**	
Generation							
Total	**710 TWh**	41%	**1000 TWh**	30%	**1300 TWh**	23%	**1600 TWh**
Wind & Solar	150 TWh		300 TWh		670 TWh		1000 TWh
Generation Capacity of VRE (variable renewable energy)							
To displace fossil fuels			0 GW		6.9 GW		3.4 GW
Wind capacity	**26 GW**		**46 GW**		**110 GW**		**150 GW**
To meet demand increase			20 GW		55 GW		36 GW
To displace fossil fuels			0 GW		7.9 GW		11 GW
Solar capacity	**32 GW**		**89 GW**		**160 GW**		**290 GW**
To meet demand increase			57 GW		62 GW		120 GW

Note: Numbers are rounded to two significant figures, which may contribute to minor differences in totals.

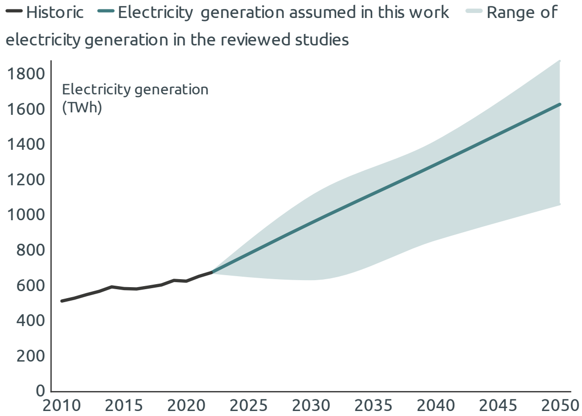
Future electricity demand

Electricity demand is taken from the *National Energy Plan 2050* of the Energy Research Office (EPE). This study includes a scenario with 100% renewable expansion for Brazil. This scenario achieves full decarbonization of the power sector by 2050, with the most significant progress occurring between 2030 and 2040.

Total electricity generation in Brazil more than doubles by 2050 relative to 2022 levels, reaching 1,635 TWh. This is driven by economic development and, to lesser extent, electrification. However, there is a significant range in the studies in terms of the expected electricity generation in 2050 ranging from 1,070 TWh to 1,880 TWh. Our demand estimate is in the middle of that range estimated by country-level studies.

The reference study projects a 24% electrification rate by 2050, much lower than the 52-55% global average indicated by international studies on global net zero pathways (IEA and IRENA).

A higher electrification rate in Brazil would significantly impact the anticipated growth of renewable energy in the country.



Electricity generation more than doubles in Brazil over 2022–2050

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

Figure 2 – Electricity demand in TWh

Pace of fossil phaseout needed

The rate of fossil 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 2023, just 9% of Brazil's electricity supply came from fossil fuels. **Our analysis suggests that electricity generation from fossil fuels should drop to 0-2% by 2030**, consistent with national studies showing 0-5% by 2030.

To align with 1.5°C, Brazil should phase out fossil fuels during the 2030s, even as electricity demand grows rapidly

Brazil would need to achieve clean electricity by 2045

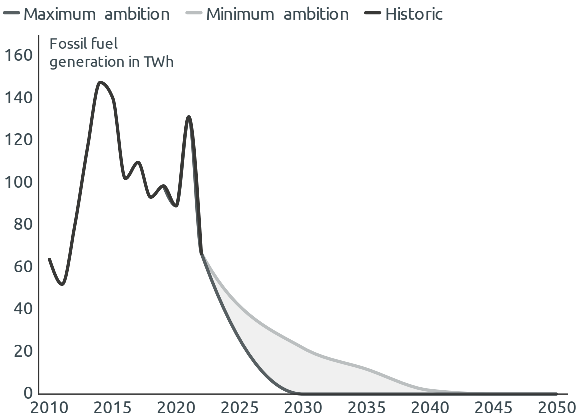


Figure 3 – Fossil fuel generation in TWh

Coal and gas phaseout in Brazil

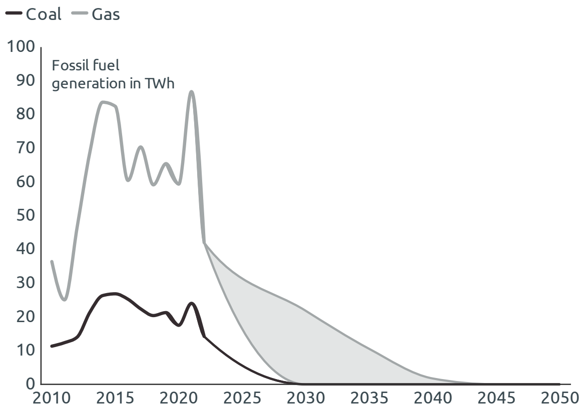


Figure 4 – Fossil fuel generation by fuel type in TWh

The role of other clean electricity generation

In 2023, Brazil generated 91% of its electricity from clean sources, with hydropower contributing 60% of the total. Although wind and solar will play a greater role in the future than they do today, other clean electricity generation will still play a key role in future electricity supply. We estimate the role of non- wind and solar clean electricity generation* (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 Brazil would reach 660 TWh by 2030 and 600 TWh by 2050. This is provided mostly by hydropower, alongside a small contribution from nuclear and biomass.

Scaling up wind and solar capacity to meet growing energy demand can also reduce the country's vulnerability to droughts, ensuring a more resilient and diverse energy supply.

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

Wind and solar expansion in Brazil will be crucial to meet the growing electricity demand, beyond enabling the phase out of fossil fuels. We also recognize the key role of other non-wind-and-solar clean technologies (mainly hydropower, biomass, nuclear), which is informed from country-level studies.

To align with 1.5°C, wind and solar generation in Brazil would need to reach between 270 and 300 TWh by 2030. Generation in 2022 was 122 TWh. This represents an increase in wind and solar generation of 2.5-2.6 times.

Our analysis shows that **wind and solar will contribute 29–31% of total electricity generation in 2030, and 64% in 2050**. This is broadly in line with the most ambitious scenarios in the *National Energy Plan 2050* of the Energy Research Office (EPE), which show a 26-28% share of electricity generation from wind and solar by 2030, and 62-66% share by 2050.

To align with 1.5°C, Brazil's wind and solar generation would need to grow 2.5-2.6x over 2022-2030

Wind and solar generation needs to more than double by 2030 relative to 2022 in Brazil

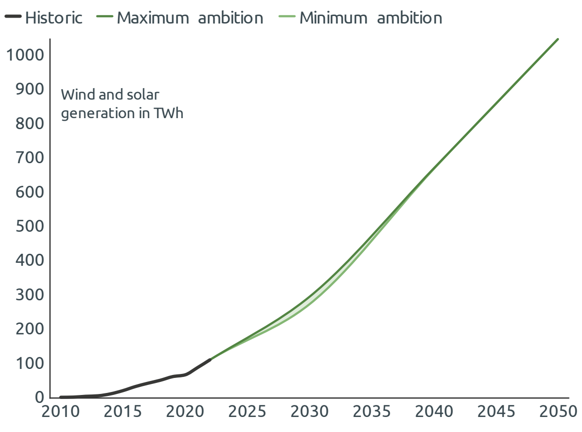


Figure 5 – Wind and solar electricity generation in TWh

Wind and solar would need to provide almost two-thirds of electricity generation in Brazil by 2050

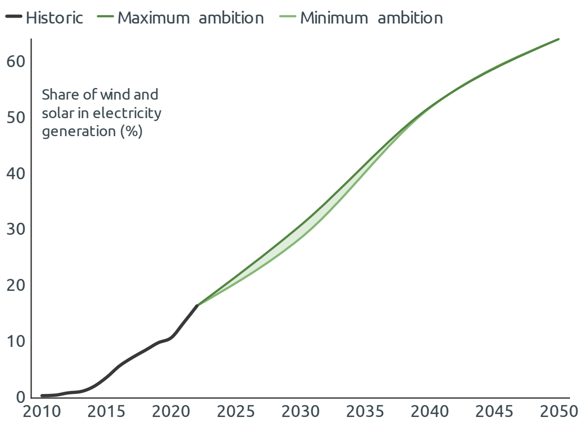


Figure 6 – Wind and solar electricity generation share (%)

* 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.

Possible splits into 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 vs. solar. In the central benchmark scenario, wind is the main source of generation, providing on average about 40% more electricity than solar in the generation mix by 2050. The significant contribution of hydropower will be key to providing system flexibility and enabling the rapid uptake of wind and solar.

In this scenario, **Brazil would need to deploy around 135 GW of wind and solar by 2030 to limit warming to 1.5°C**. By 2050, total wind and solar capacity would need to reach towards 440 GW. Due to its higher capacity factor, greater wind deployment would reduce total capacity requirements.

Brazil needs to install reach 135 GW of wind and solar installed capacity by 2030 to align with 1.5°C

Solar capacity would reach 89 GW in Brazil by 2030 in a 1.5°C-aligned scenario

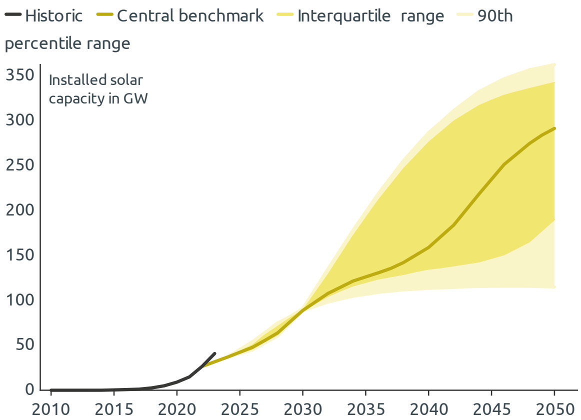


Figure 7 – 1.5°C compatible capacity benchmarks for solar in GW

Wind capacity would reach 46 GW in Brazil by 2030 in a 1.5°C-aligned scenario

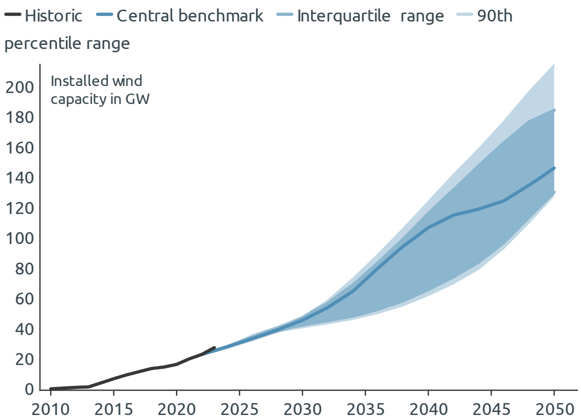


Figure 8 – 1.5°C compatible capacity benchmarks for wind in GW

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	37	130	180	230	420
Central 1.5°Cbenchmark	Wind generation	TWh	84	180	290	440	630
Central 1.5°Cbenchmark	Solar capacity	GW	27	89	130	160	290
Central 1.5°Cbenchmark	Wind capacity	GW	24	46	73	110	150

Comparison to current rollout and country target

Under current policies and market conditions, Brazil's rapid wind and solar deployment aligns with the 1.5°C pathway, exceeding national targets. **Solar deployment in Brazil is on track to surpass 1.5°C compatible pathways by 2030, while wind rollout aligns with the benchmark.**

To stay on track, Brazil must build on the momentum of recent years to **maintain annual capacity additions at least at the same pace over remainder of the decade**.

The rapid deployment of wind and solar in Brazil towards 2030-2050 is driven primarily by the need to meet growing electricity demand and, to a lesser extent, to phase out fossil fuels from the electricity.

However, a full decarbonization of the economy will require action in other sectors, for which end-use electrification is a key solution. Higher electrification rates will further increase electricity demand, requiring even greater deployment of wind and solar. This is not considered in the benchmarks presented here.

Targets need to be updated to reflect the projected rollout of wind and solar. 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 89% of executives in Brazil polled in the Powering Up study wanting to see this transition by 2035.

Brazil's solar rollout exceeds 1.5°C, while wind rollout broadly aligns

Current solar rollout of solar in Brazil could go beyond 1.5°C-aligned levels, driving an even faster fossil phaseout

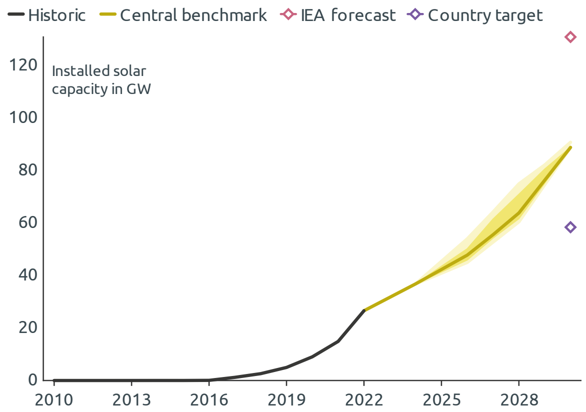


Figure 9 – Installed solar capacity in 2030 compared to targets and current policy projections in GW

Current rollout of wind in Brazil aligns with 1.5°C, but targets need updating

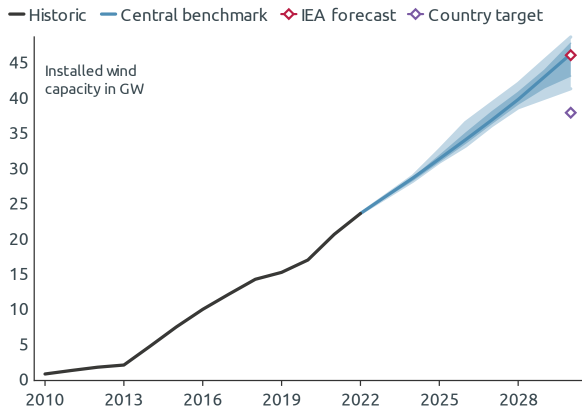


Figure 10 – Installed wind capacity in 2030 compared to targets and current policy projections in GW

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.

To stay aligned with 1.5°C, Brazil must maintain its current pace of annual wind and solar capacity additions over the remainder of this decade

Brazil would need to add on average 8.5 GW/yr of solar capacity until 2030, and 10.0 GW/yr by over 2030–2050

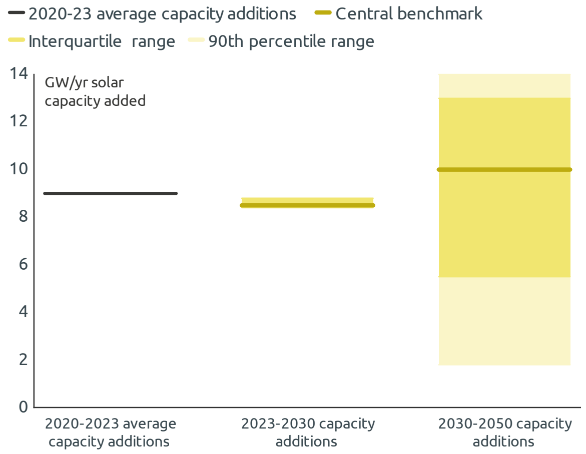


Figure 11 – Solar capacity additions per year in GW/y

Brazil would need to add on average 3.1 GW/yr of wind capacity until 2030, and 5.9 GW/yr by over 2030–2050

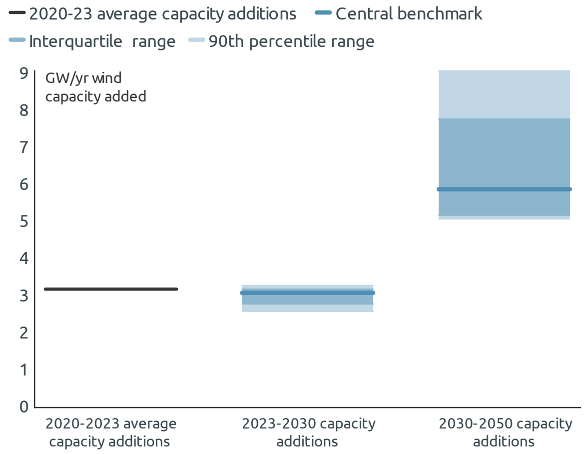


Figure 12 – Wind capacity additions per year in GW/y

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 *National Energy Plan 2050* of the Energy Research Office (EPE), exploring full decarbonization pathways for Brazil. We see that the combined wind and solar generation from our analysis is broadly within the range of the national literature.

Both our modelling and country-level studies see wind as providing the largest share of generation in 2030, 2040 and 2050. For wind, our analysis is generally on the lower end of the range of the national studies.

Conversely, our analysis show higher generation form solar than in national studies. Our analysis shows a slight lean towards solar generation compared to the scenarios in the EPE study, which presents a larger role for wind.

Our benchmarks are broadly aligned with the literature

Electricity generation from solar: comparison with literature in Brazil

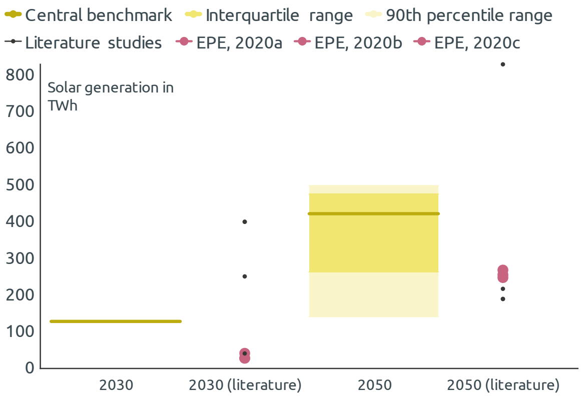


Figure 13 – Solar electricity generation in TWh

Electricity generation from wind: comparison with literature in Brazil

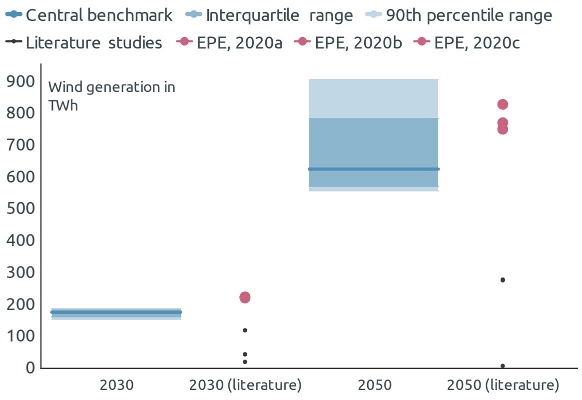


Figure 14 – Wind electricity generation in TWh

In Brazil, our benchmarks generally suggest that wind will provide more electricity than solar

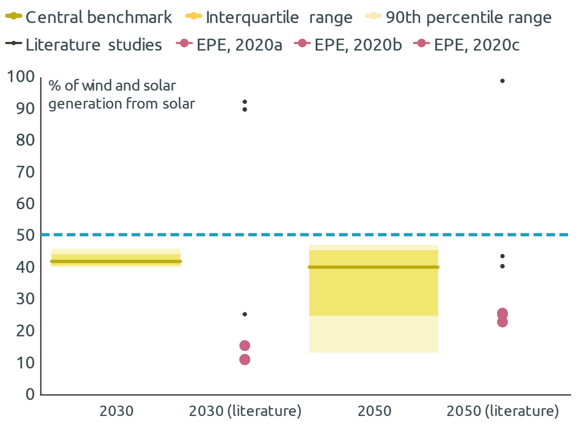


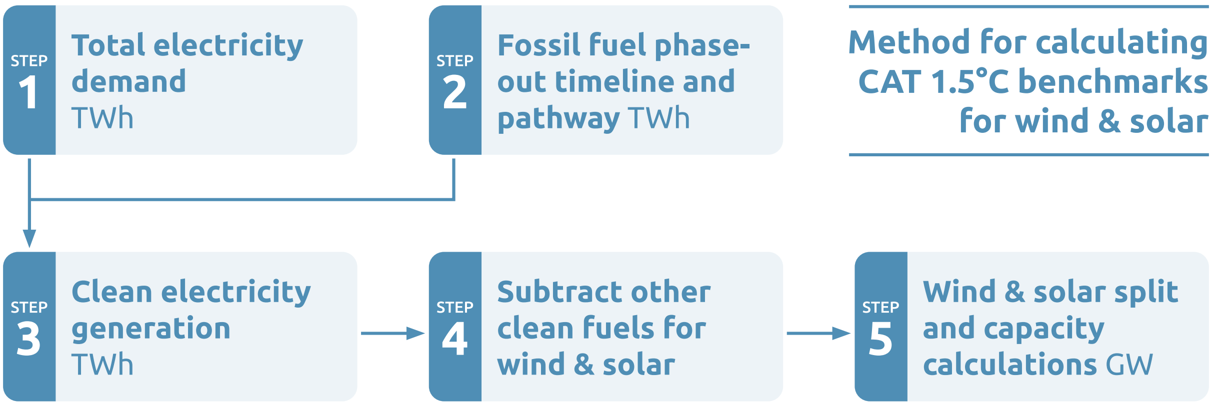
Figure 15 – Generation split between wind and solar (%)

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

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

Methodology

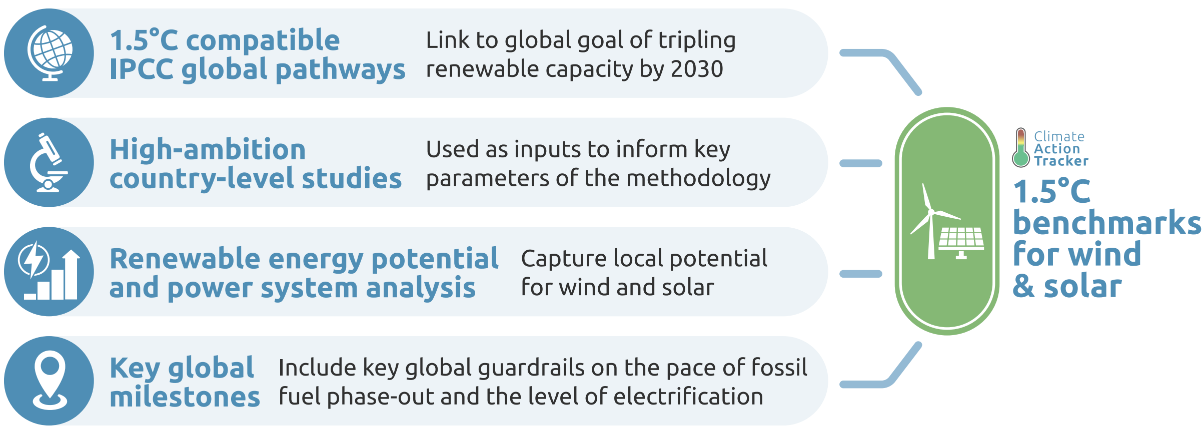
Summary of our method



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 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 3 – Country level studies for Brazil

Study	Publication	Scenario selected
Barbarosa *et al., 2016*	Hydropower and Power-to-gas Storage Options: The Brazilian Energy System Case	Integrated Scenario
Breyer *et al.*, 2017	Solar photovoltaics demand for the global energy transition in the power sector	
EPE (Ministry of Mining & Energy), 2020	PNE 2050 – Plano Nacional de Energia	• Matriz Elétrica com expansão 100% renovável • Matriz Elétrica com expansão a partir de tecnologias não emissoras de GEE • Efeitos das Mudanças Climáticas (redução de disponibilidade hídrica) sem emissões • Frota de veículos leves integralmente elétrica em 2050
IEA, 2023	World Energy Outlook 2023	Announced Pledges Scenario (APS)
Gils *et al.*, 2017	100% Renewable Energy Supply for Brazil – The Role of Sector Coupling and Regional Development	Base
Luz *et al.*, 2019	100% Renewable energy planning with complementarity and flexibility based on a multi-objective assessment	

Luz *et al.*, 2019	Power generation expansion planning with complementarity between renewable sources and regions for 100% renewable energy systems	Regional
Ramos *et al.*, 2019	CENÁRIOS PARA A MATRIZ ELÉTRICA 2050	SATC-FEE
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

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Acknowledgments
We would like to thank the wider CAT team for their work on country assessments, which contributed to this briefing.

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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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