Climate Action Tracker

Wind and Solar benchmarks for a 1.5°C world

INDIA

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CLIMATE ANALYTICS

NEW CLIMATE INSTITUTE

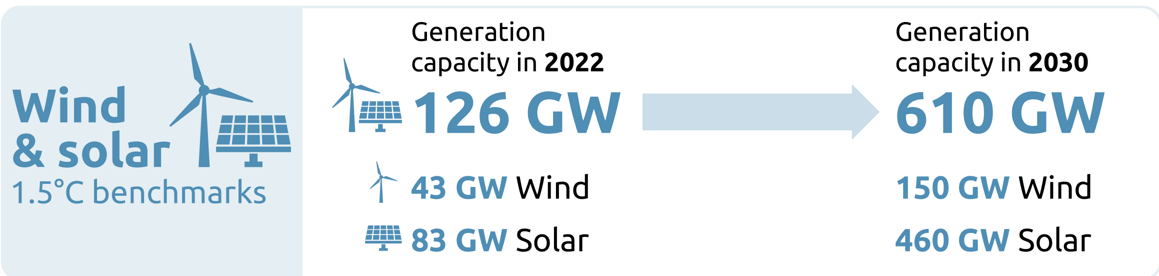
Executive Summary

Context

- Wind and solar are accelerating in India. However, electricity demand is growing even faster. As a result, wind and solar are still growing alongside coal, rather than displacing fossil fuels from the mix.
- India's power sector remains heavily dependent on coal, which provided 75% of electricity generation in 2023. Further action will be necessary to transform the Indian electricity system into one powered predominantly by renewables.
- In this report, we explore the level of wind and solar that India 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

- India's wind and solar generation needs to grow five to six times by 2030 to align with 1.5°C, reaching 900–1200 TWh of wind and solar.
- Just over 600 GW of wind and solar installed capacity would be needed by 2030 (460 GW of solar and 150 GW of wind).
- Current rollout of wind and solar would need to further accelerate to align with 1.5°C. At the current pace of rollout, India would fall short of the needed capacity in 2030 by almost 90 GW of solar and just over 60 GW of wind.
- India 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.



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 **India**.

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

India's 2030 NDC is to cut emissions intensity by 45% below 2005 levels in 2030. This is estimated to represent an emissions level of ~4.6 $GtCO_2e$ in 2030 excluding LULUCF. The country has pledged to become net zero by 2070.

India's current renewable targets are to reach **319 GW of solar and 110 GW of wind by 2030**, as of the Indian National Electricity Plan 2022-32.

Under current policies and market conditions, the IEA estimates that **solar capacity will reach 371 GW in 2030**, up from 83 GW of solar in 2022. Meanwhile, **wind capacity is projected to reach 86 GW in 2030**, up from 42 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.

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.

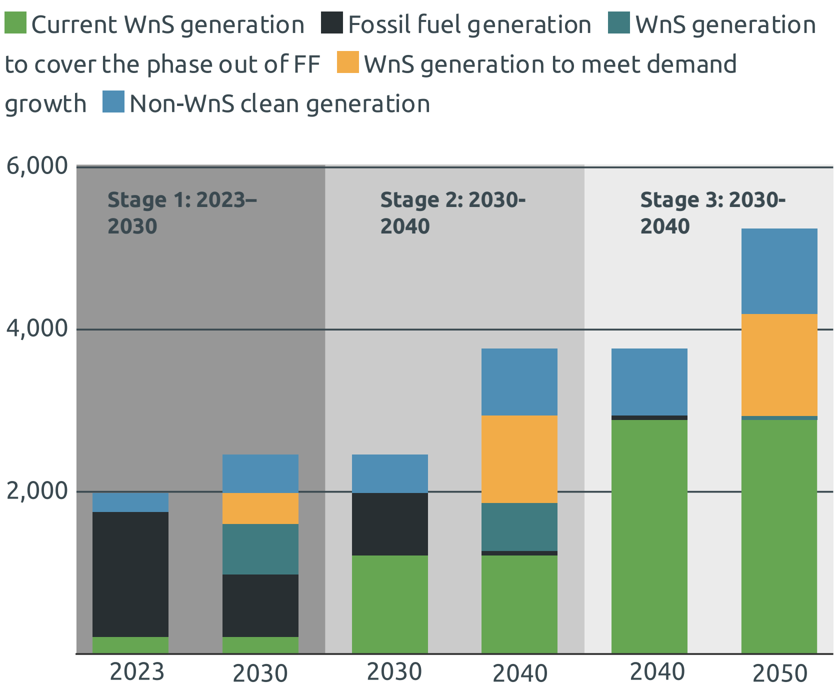
National enabling factors

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 India

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, India would need to add 40 GW of wind and 130 GW of solar capacity to meet growing demand alone. Another 63 GW of wind and 220 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 India in Phase D, with wind and solar making up 49% 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 D		Phase D
Share of VRE	**< 15%**		**< 70%**		**< 70%**		**< 70%**
Share of electricity generation							
Wind & Solar	**11 %**		**49 %**		**77 %**		**80 %**
Other renewables	12 %		19 %		22 %		20 %
Fossil Fuels	**78 %**		**31 %**		**1.5 %**		**0 %**
Generation capacity							
To displace fossil fuels		**+280 GW**		**+410 GW**		**+31 GW**	
Wind & Solar	**160 GW**	**+66 GW/yr**	**620 GW**	**+120 GW/yr**	**1800 GW**	**+80 GW/yr**	**2600 GW**
To meet demand increase		**+170 GW**		**+750 GW**		**+830 GW**	
Generation							
Total	**2000 TWh**	25%	**2500 TWh**	52%	**3800 TWh**	37%	**5200 TWh**
Wind & Solar	210 TWh		1200 TWh		2900 TWh		4200 TWh
Generation Capacity of VRE (variable renewable energy)							
To displace fossil fuels			63 GW		40 GW		14 GW
Wind capacity	**53 GW**		**150 GW**		**270 GW**		**640 GW**
To meet demand increase			40 GW		73 GW		360 GW
To displace fossil fuels			220 GW		370 GW		18 GW
Solar capacity	**112 GW**		**460 GW**		**1500 GW**		**2000 GW**
To meet demand increase			130 GW		670 GW		470 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 TERI's study exploring India's electricity transition pathways out to 2050. This conducts a detailed estimate of future electricity demand in India, based on a bottom-up review of electrification trends by sector, and economic and demand-growth.

In this study, total electricity generation in India almost triples by 2050 relative to 2022 levels, reaching 5200 TWh. However, there is a significant range in the studies in terms of the expected electricity generation in 2050 ranging from 5200 TWh to 9200 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.

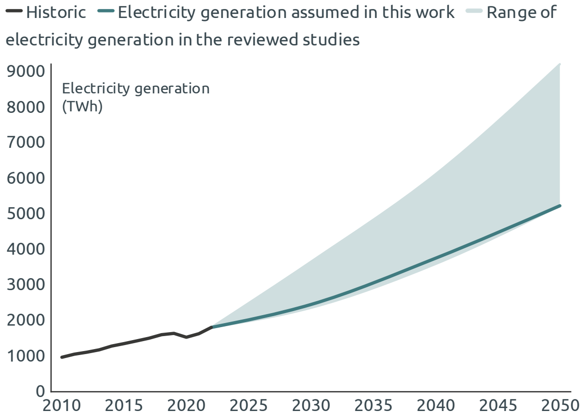


Figure 2 – Total electricity generation in TWh

Electricity generation almost triples in India over 2022–2050

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

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 India achieves a clean power system by 2045.

To align with 1.5°C, fossil fuels must exit the Indian power sector before 2045

Fossil fuel generation falls by 20 to 44% between 2022 and 2030 in our benchmarks. Phasing out fossil fuels while simultaneously meeting rapidly 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 Teske et al., 2019's 1.5°C aligned pathway for India.

To align with 1.5°C, fossil fuels must exit the power sector in India by 2045, even as electricity demand grows rapidly.

India would need to achieve clean electricity by 2045

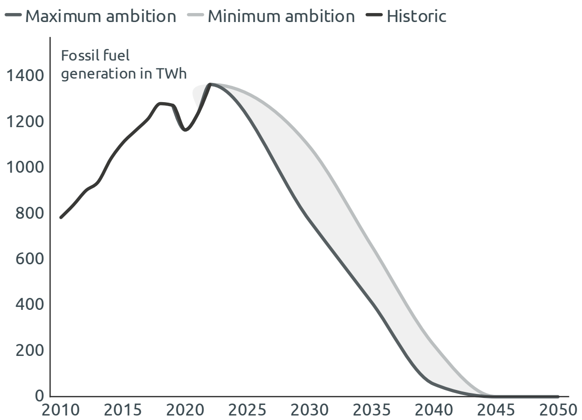


Figure 3 – Fossil fuel generation in TWh

Coal and gas phase-out in India

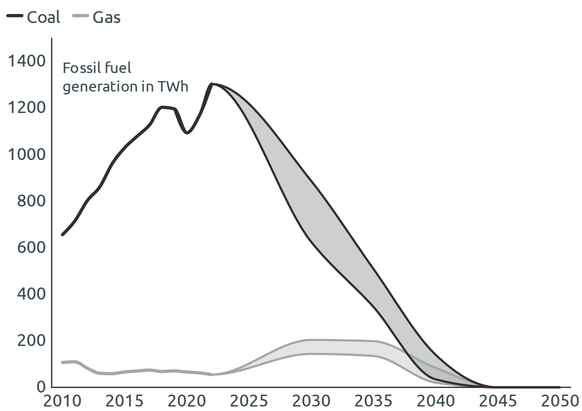


Figure 4 – Fossil fuel generation by fuel type in TWh

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 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 India would reach almost 500 TWh by 2030 and over 1000 TWh by 2050. This is provided largely by a mix of hydropower, biomass and geothermal, with limited nuclear generation.

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 India would need to reach between 900 and 1200 TWh by 2030. Generation in 2022 was 191 TWh. This is therefore a 5 to 6-fold growth in wind and solar over 2022–2030.

Wind and solar provides 36–49% of overall electricity generation in 2030, and 80% of overall generation in 2050.

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

Wind and solar generation needs to grow 5-6x by 2030 relative to 2022 in India

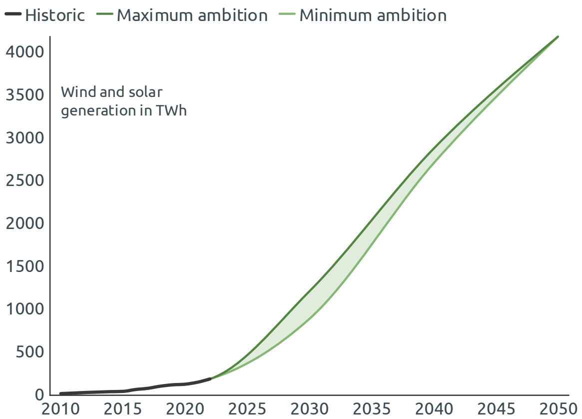


Figure 5 – Wind and solar electricity generation in TWh

Wind and solar would need to provide around 80% of electricity generation in India by 2050

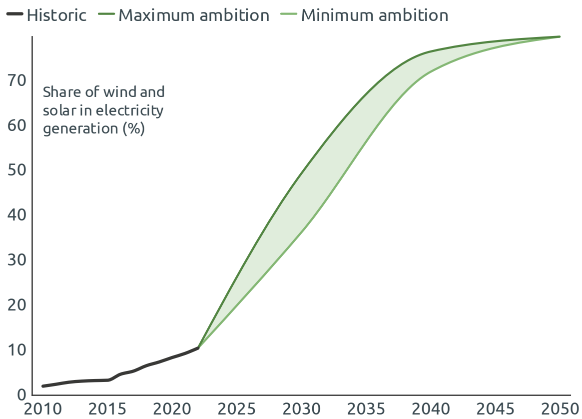


Figure 6 – Wind and solar electricity generation share (%)

* 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 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.

In India, the level of uncertainty seen in our benchmarks across wind and solar costs is small. This does not mean that there is no uncertainty in the possible split of wind and solar, as a range of other uncertainties could also impact on the split, including grid capacity, supply chains, national policies and more.

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 benchmarking scenario, solar becomes the main source of generation, providing on average 70% more generation as wind in the electricity mix by 2050. This will require a rapid uptake of non-fossil flexibility options.

In this scenario, **India would need to deploy around 600 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 2.6 TW. Due to its higher capacity factor, greater wind deployment would reduce total capacity requirements.

India needs to reach around 600 GW of wind and solar installed capacity by 2030 to align with 1.5°C

Solar capacity would reach 460 GW in India by 2030 in a 1.5°C-aligned scenario

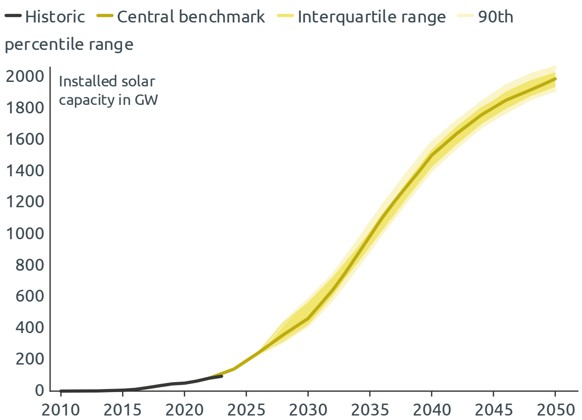


Figure 7 – 1.5°C compatible capacity benchmarks for solar in GW

Wind capacity would reach 150 GW in India by 2030 in a 1.5°C-aligned scenario

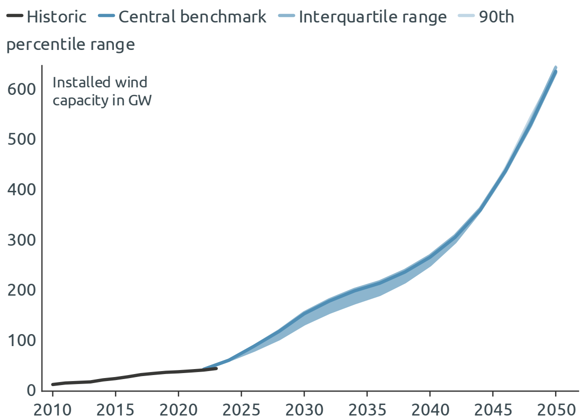


Figure 8 – 1.5°C compatible capacity benchmarks for wind in GW

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	121	690	1400	2100	2600
Central 1.5°Cbenchmark	Wind generation	TWh	75	390	530	690	1500
Central 1.5°Cbenchmark	Solar capacity	GW	83	460	990	1500	2000
Central 1.5°Cbenchmark	Wind capacity	GW	43	150	210	270	640

Table 3: Benchmarks translated into CAT format

Variable	Ambition	Unit	2030	2035	2040	2045	2050
Share of coal	Minimum	%	36	17	4	0	0
	Maximum	%	26	12	1	0	0
Share of gas	Minimum	%	8	6	2	0	0
	Maximum	%	6	4	1	0	0
Share of renewables	Minimum	%	52	74	91	98	98
	Maximum	%	65	82	96	98	98
Share of wind and solar	Minimum	%	36	56	72	79	80
	Maximum	%	49	64	77	79	80

Comparison to current rollout and country target

Under current polices and market conditions, India is on track to achieve its 2030 target for solar of just over 300 GW but is not on track to install the 110 GW of wind targeted in the National Electricity Plan 2022-2032.

Both current targets and current policy rollout would need to be further accelerated to align with the 1.5°C compatible benchmarks presented in this report.

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 84% of executives in India polled in the Global Business Poll wanting to see this transition by 2035.

India's rollout of wind and solar is lagging behind 1.5°C- aligned level

In India, current rollout of solar is lagging behind 1.5°C-aligned levels

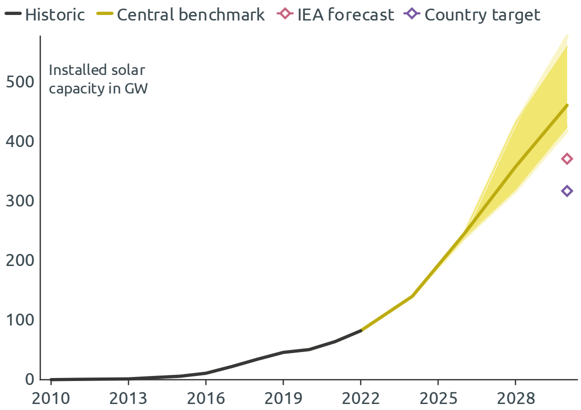


Figure 9 – Installed solar capacity in 2030 compared to targets and current policy projections in GW

In India, current rollout of wind is lagging behind 1.5°C-aligned levels

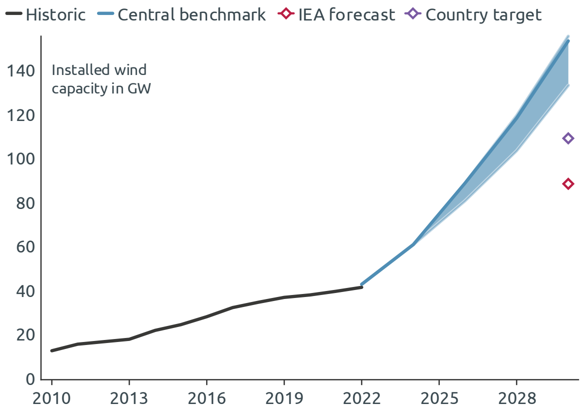


Figure 10 – Installed wind capacity in 2030 compared to targets and current policy projections in GW

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. The benchmarks assume action from 2022.

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

India would need to add on average 44 GW/yr of solar capacity until 2030, and 75 GW/yr by over 2030–2050

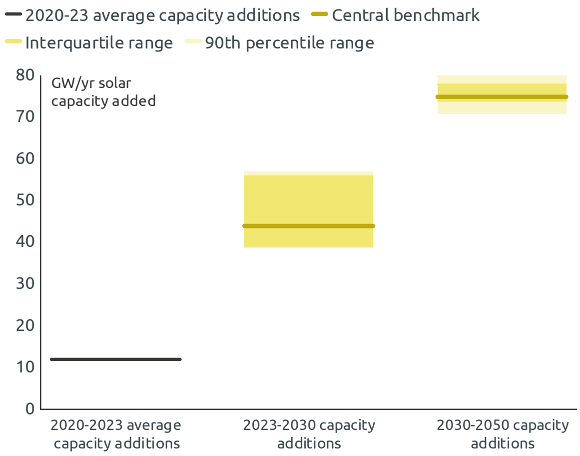


Figure 11 – Solar capacity additions per year in GW/y

India would need to add on average 13 GW/yr of wind capacity until 2030, and 25 GW/yr by over 2030–2050

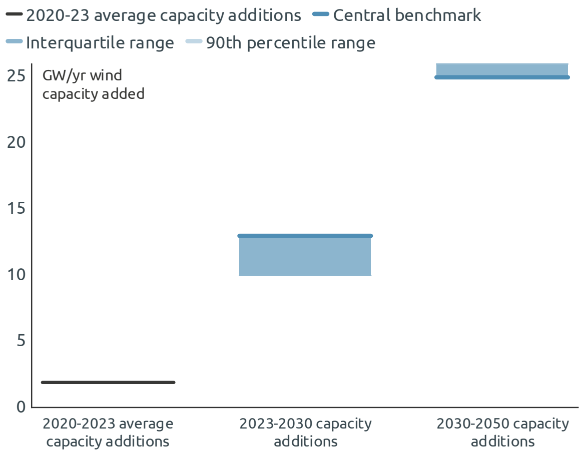


Figure 12 – Wind capacity additions per year in GW/y

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 from TERI's modelling of a net zero power sector in which there is no new fossil fuel capacity added after 2025.

Our modelling suggests that **solar will be the dominant source of electricity generation** in future zero-carbon electricity grids for India. The majority of the literature agrees with this, with solar providing the majority of electricity generation in most country-level studies exploring deep decarbonization of the Indian power sector.

In general, our analysis is broadly aligned with the results of country-level studies, although is at the lower end of solar generation in 2050.

Our benchmarks are broadly aligned with the literature

Electricity generation from solar: comparison with literature in India

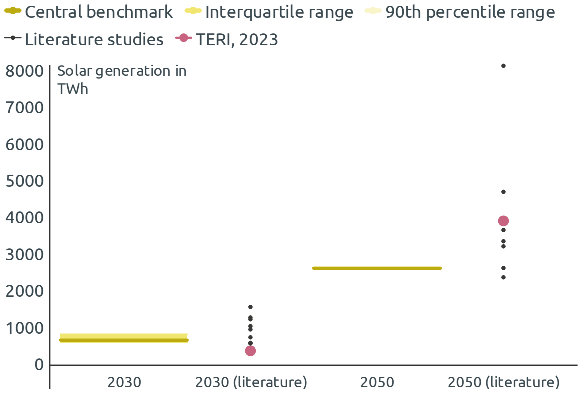


Figure 13 – Solar electricity generation in TWh

Electricity generation from wind: comparison with literature in India

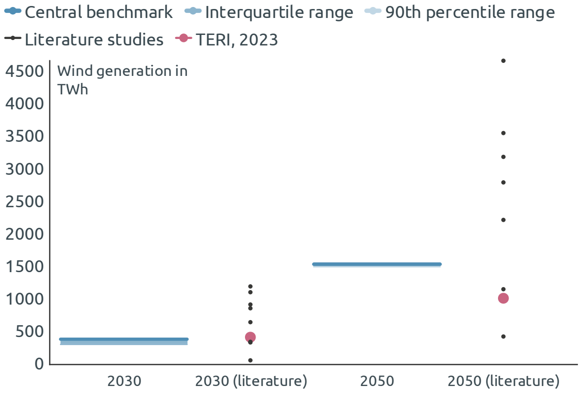


Figure 14 – Wind electricity generation in TWh

In India, 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 India

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

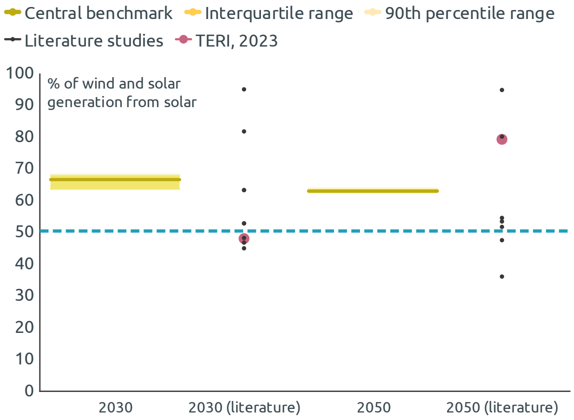
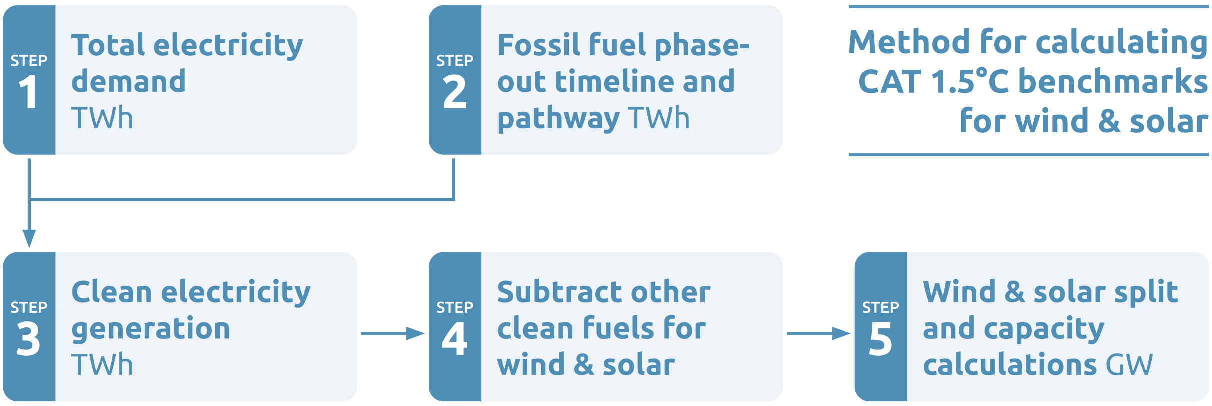


Figure 15 – Generation split between wind and solar (%)

Methodology

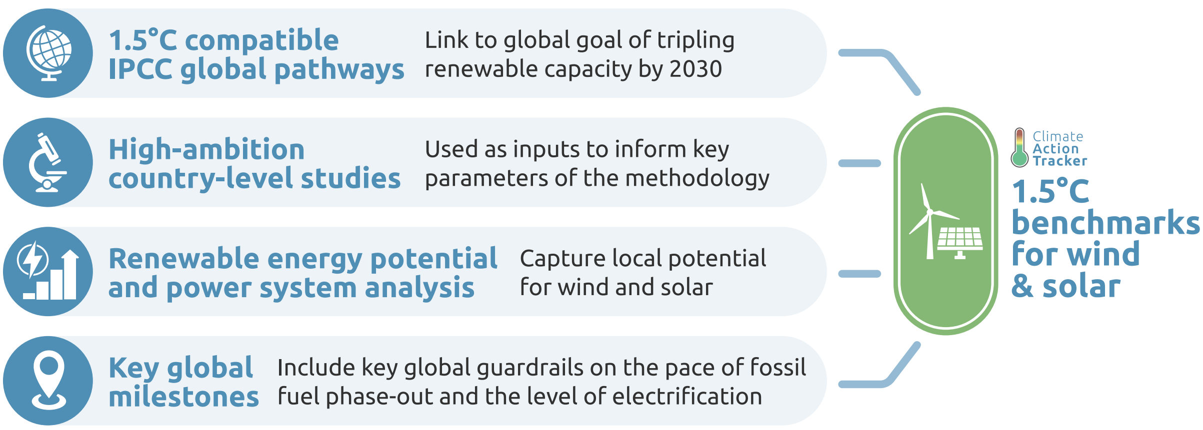
Summary of our method



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 India

Study	Publication	Scenario selected
Gulagi et.al., 2017	The role of storage technologies in energy transition pathways towards achieving a fully sustainable energy system for India	Integrated scenario
Lawrenz et.al., 2019	Exploring energy pathways for the low-carbon transformation in India--A model-based analysis	limited emissions only (LEO)
Teske, 2015	A Sustainable World Energy Outlook 2015	Advanced Energy [r]evolution scenario
Teske, 2015	A Sustainable World Energy Outlook 2015	Energy [r]evolution scenario
IEA, 2021	India Energy Outlook 2021	Sustainable Development Scenario
Teske, 2019	Achieving the Paris Climate Agreement Goals	1.5 °C
Teske, 2019	Achieving the Paris Climate Agreement Goals	2 °C
TERI, 2023	India’s Electricity Transition Pathways to 2050: Scenarios and Insights	No fossil fuel scenario
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.

climateanalytics.org

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