Wind and solar benchmarks for a 1.5°C world

Developing national-level benchmarks to achieve renewables deployment in line with the Paris Agreement

Australia

NEW CLIMATE INSTITUTE

CLIMATE ANALYTICS

Executive Summary

Context:

- Australia has abundant potential for wind and solar. At the same time, it is heavily dependent on coal, which still provided almost two-thirds of electricity generation in Australia in 2023.
- The Australian Government has set a target of achieving 82% renewable electricity by 2030.
- In this report, we look at national studies and global energy system models to assess how much Australia's wind and solar capacity needs to grow to align with the global goal to triple renewables by 2030 and the Paris Agreement's 1.5°C warming limit.

Key findings:

- Australia's wind and solar generation needs to grow between four and five times by 2030 to align with 1.5°C. This equates to 280–330 TWh of wind and solar generation in 2030, up from 64 TWh in 2022.
- Almost 170 GW of new wind and solar would be needed by 2030 (120 GW solar, 45 GW wind).
- Australia's current rollout of wind and solar is not progressing fast enough to achieve this. Under current policies and market conditions, only half of the solar and 60% of the wind needed to align with 1.5°C will be installed by 2030.

Context

At COP28, governments agreed to triple global renewable capacity by 2030 globally. This slide deck highlights the potential implications of this COP28 decision at the national level, focusing on **Australia**.

Wind and solar deployment is accelerating around the world. However, expected wind and solar capacity deployment under current policies falls short, 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?**

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, which calculates for a given set of cost assumptions around wind and solar, a split into wind versus solar and the associated capacity requirements.

Our method is focused on including multiple different analytical elements

NEW CLIMATE INSTITUTE
CLIMATE ANALYTICS

Integrating multiple different elements

High-ambition country-level studies

Use ambitious country-level studies as inputs to inform key parameters of the methodology

1.5°C compatible IPCC global pathways

Link to global goal of tripling renewable capacity by 2030

Renewable energy potential and power system analysis

Capture local potential for wind and solar

Key global milestones

Include key global guardrails on the pace of fossil phase-out and the level of electrification

For more details see the Methods Annex

Overlap of different elements

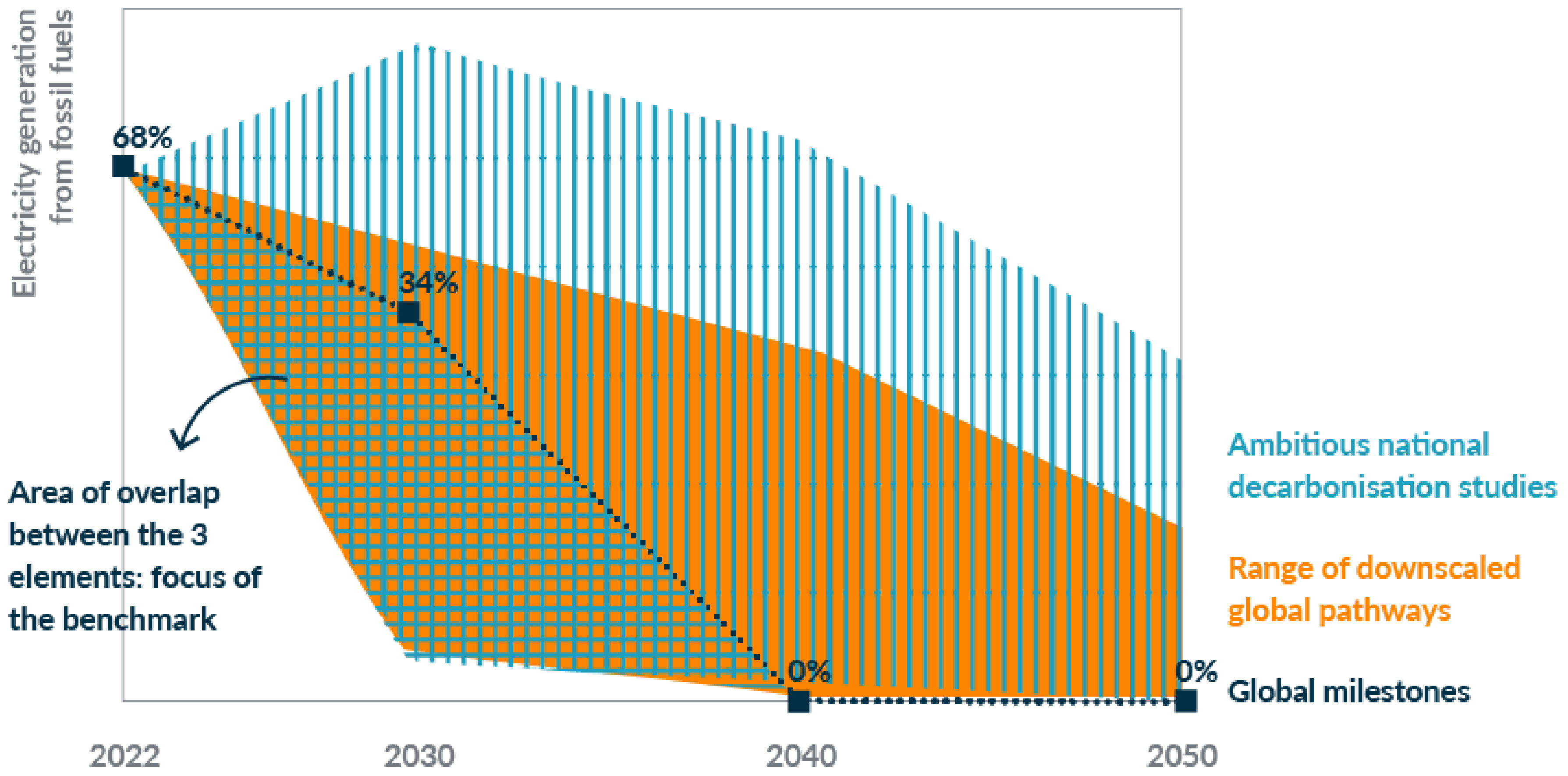
Our method focuses on the overlap between different elements. By looking at the range of fossil phase-out which is outlined in both high ambition country-level studies and downscaled 1.5°C compatible global pathways, and is informed by key global milestones, we identify benchmarks which are both consistent 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.

Overlapping multiple analytical elements can provide more robust benchmarks

NEW CLIMATE INSTITUTE

CLIMATE ANALYTICS



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 to incentivize and mobilise investments to install renewable energy at the scale needed (e.g., minimise cost of capital, ensure revenue certainty, etc)

Policy context

Australia's current NDC is to cut emissions 43% below 2005 levels including LULUCF. The country aims to reach net zero GHGs by 2050.

Australia also aims to reach 82% of renewables in electricity generation by 2030, but under current policies, will only reach a 63% share in 2030.

Under current policies and market conditions, the IEA estimates that **solar capacity in Australia will reach 57 GW in 2028**, up from 32 GW of solar in 2023. Meanwhile, **wind capacity is projected to reach 23 GW in 2028**, up from 12 GW in 2022.

Results

Future electricity demand

Electricity demand is taken from Net Zero Australia's study exploring net zero pathways for Australia. We take demand from the rapid electrification pathway, which achieves nearly full electrification of transport and buildings by 2050, and has large-scale renewables build out.

In this scenario, total electricity generation in Australia more than quadruples by 2050 relative to 2022 levels, reaching 1200 TWh. This is driven by increased electrification of the Australian economy, and demand for electricity to produce clean fuels for export (particularly green hydrogen and ammonia derivatives). Over half of electricity demand would be used to for clean fuel export demand.

However, there is a significant range in the studies in terms of the expected electricity generation in 2050 ranging from 436 TWh to 1265 TWh. This would affect the necessary growth of wind and solar significantly. Our demand estimate is at the higher end of that estimated by country-level studies.

Pace of fossil phaseout needed

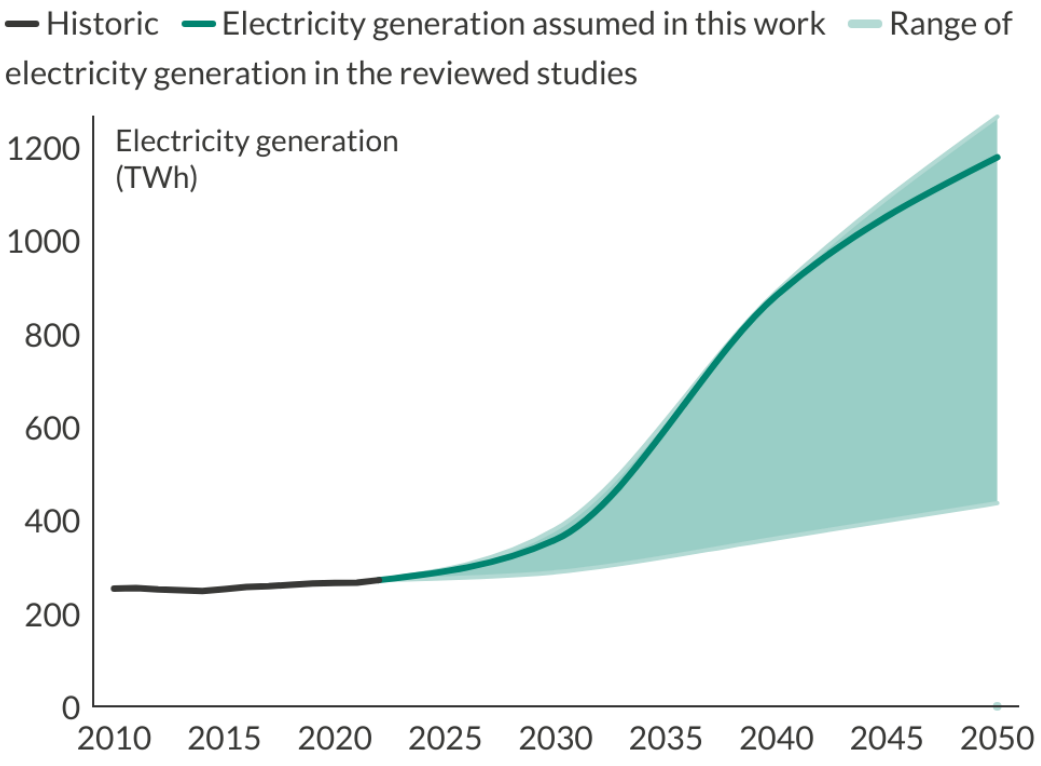
The rate of fossil phase-out is set by the overlap between country-level studies, downscaled 1.5°C compatible global pathways and the global milestones of the IEA's Net Zero roadmap, in which Australia achieves a clean power system by 2035.

To align with 1.5°C, fossil fuels must exit the Australian power sector before 2035.

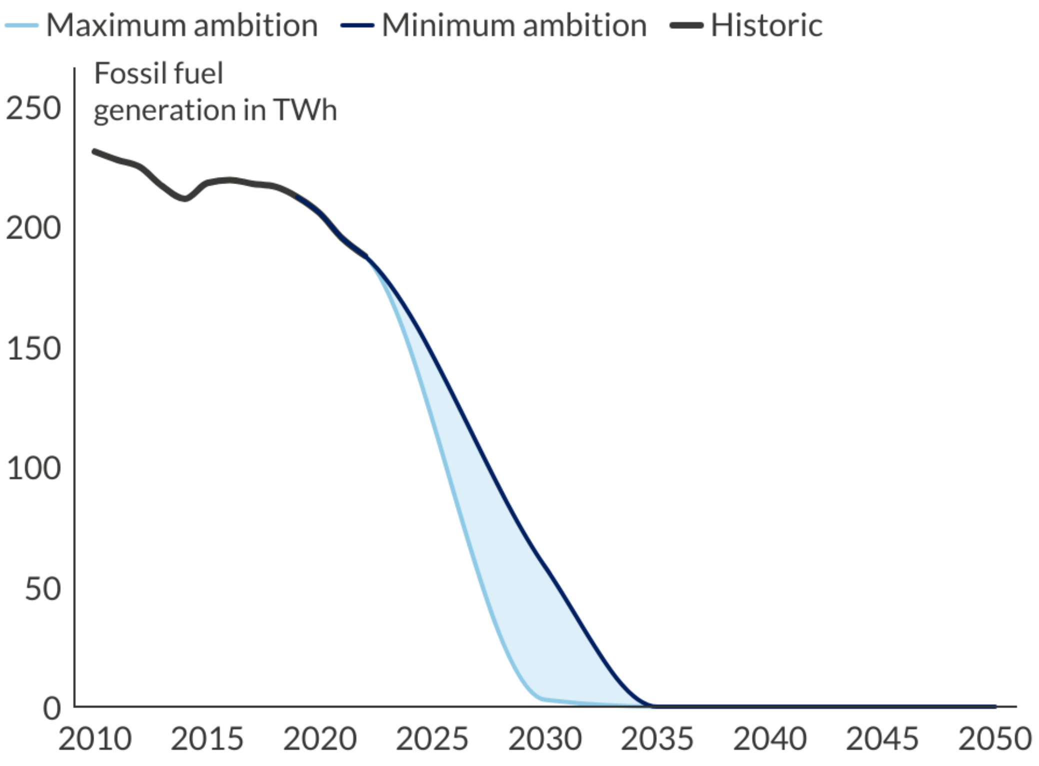
Fossil fuel generation falls by 69 to 98% between 2022 and 2030.

To align with 1.5°C, fossil fuels must exit the power sector in Australia by 2035, even as electricity demand grows rapidly.

Electricity generation grows 4x in Australia, partly to meet demand for clean exports



Australia would need to achieve clean electricity by 2035



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, particularly in certain countries. 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 non-wind and solar clean technologies in Australia would remain around 20 TWh over 2030 to 2050. This generation is provided largely from hydropower (around 15 TWh), with a small amount of biomass (3-4 TWh). The benchmarks do not assume any deployment of nuclear in the Australian power sector.

* 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.

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

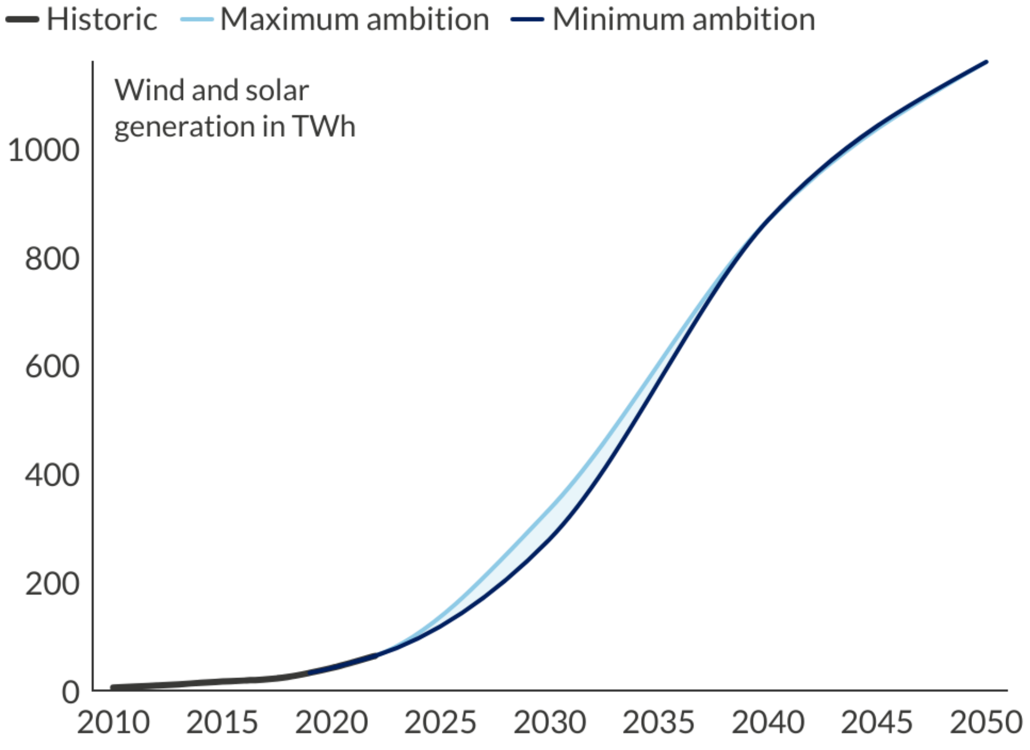
The wind and solar rollout necessary is then calculated by combining projected electricity demand growth, the fossil phase-out necessary to align with 1.5°C, and the assumed generation from other clean technologies.

To align with 1.5°C, **wind and solar generation in Australia would need to reach between 280 and 330 TWh by 2030**. Generation in 2023 was 64 TWh. This is therefore a 4 to 5-fold growth in wind and solar.

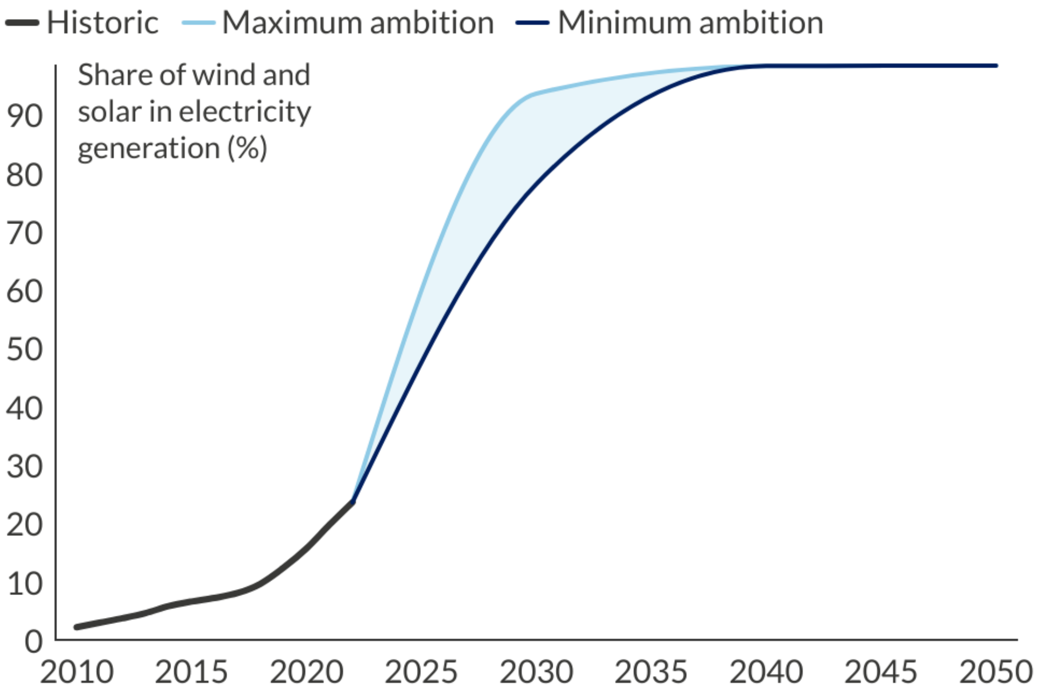
Wind and solar provides 78–94% of overall electricity generation in 2030, and 98% of overall generation in 2050. A grid powered almost entirely by wind and solar would require substantial rollout of batteries and energy storage, flexible demand and grid extension to ensure that supply can always match demand.

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

Wind and solar generation needs to grow 4-5x by 2030 relative to 2022 in Australia



Wind and solar would need to provide over 95% of electricity generation in Australia by 2050



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 benchmarking scenario, there is a relatively balanced contribution of wind and solar in the electricity mix by 2050. However, solar ramps up faster in the near-term, providing almost twice the electricity generation as wind in 2035.

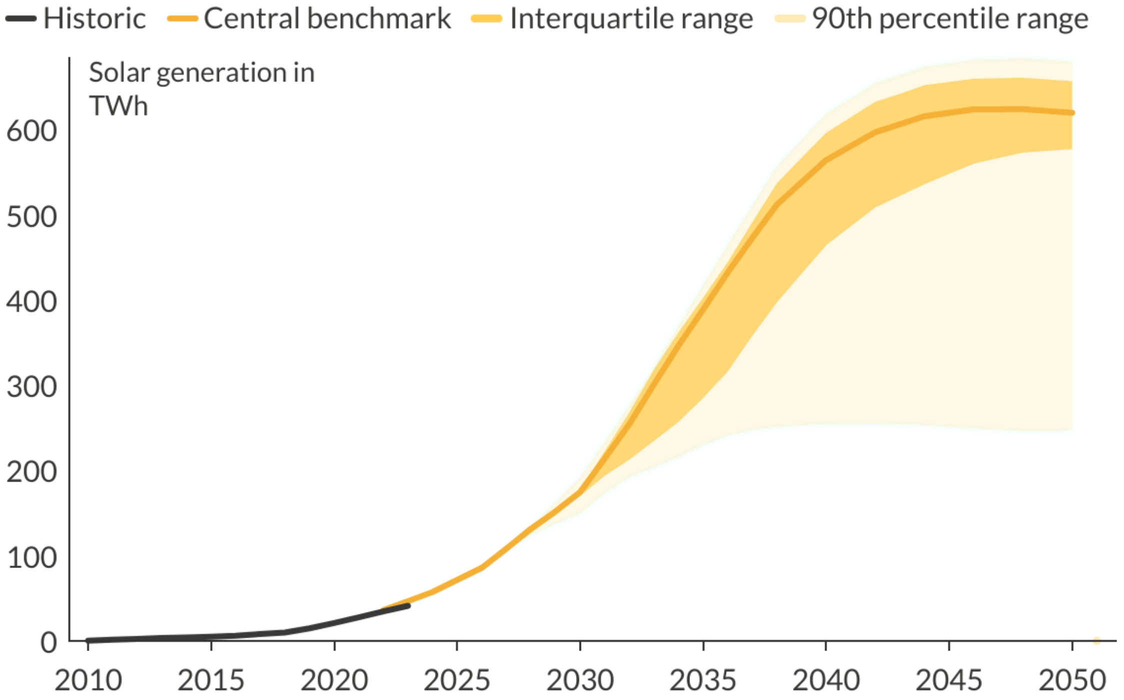
In this scenario, **Australia would need to deploy almost 170 GW of wind and solar by 2030 to align with the 1.5°C temperature limit**. By 2050, total wind and solar capacity would need to reach to over 500 GW.

On average, solar provides 100 TWh more electricity than wind by 2050 in Australia

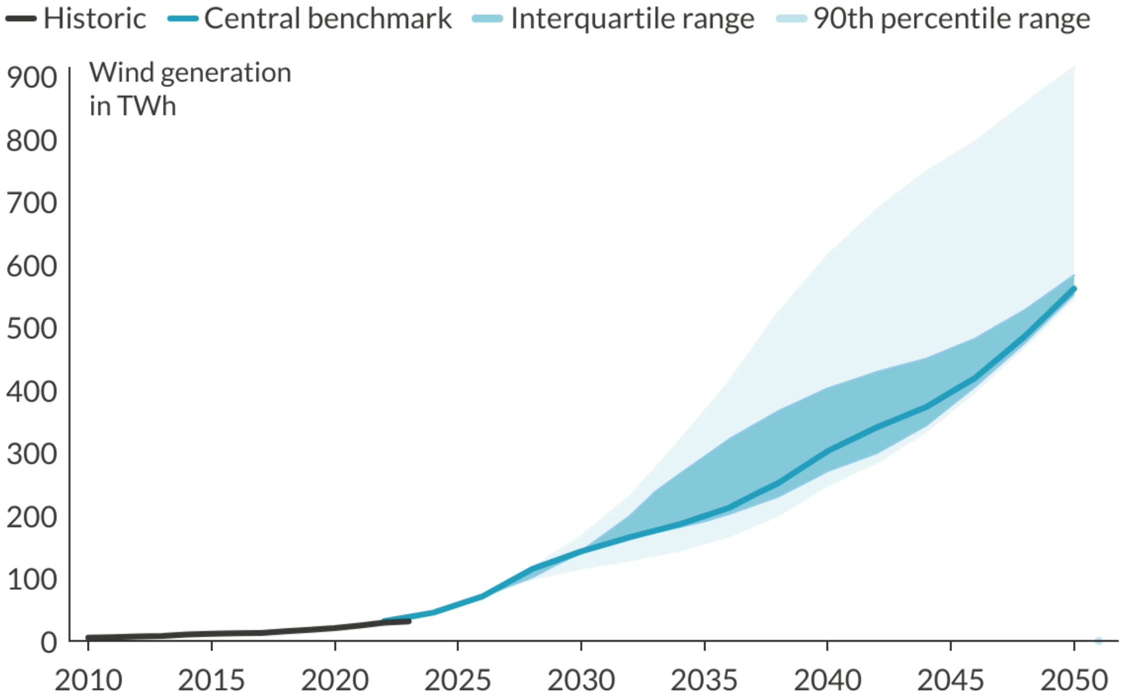
NEW CLIMATE INSTITUTE

CLIMATE ANALYTICS

Solar generation in Australia would reach almost 600 TWh by 2050 in a 1.5°C-aligned transition

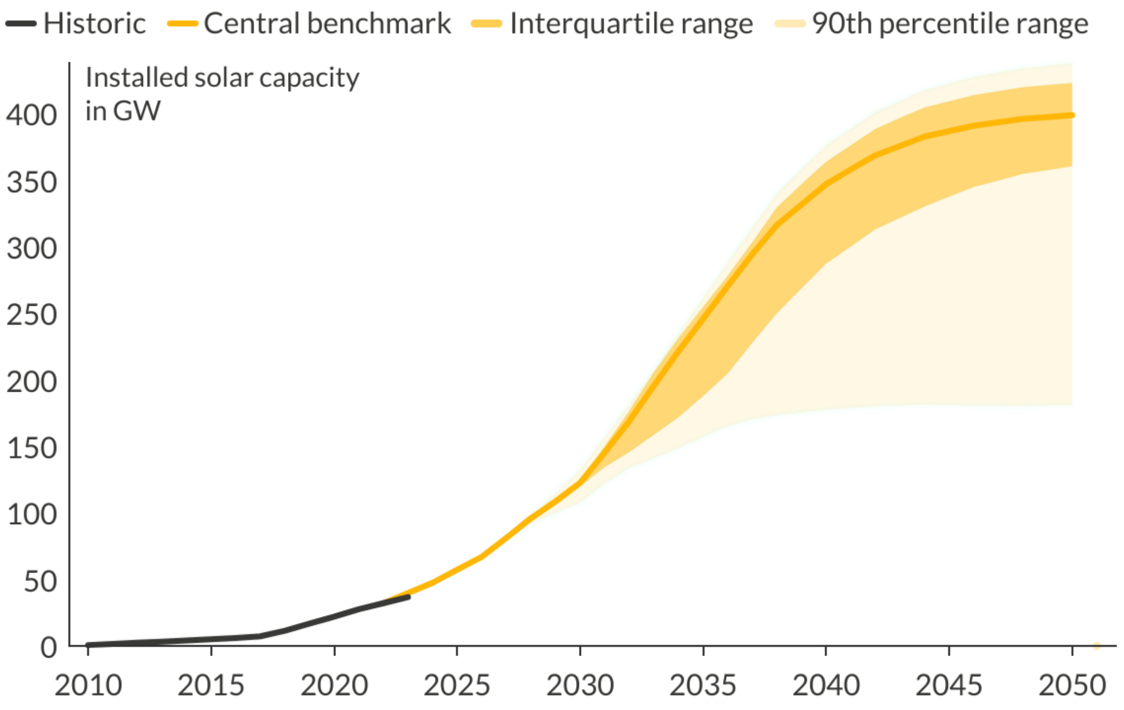


Wind generation in Australia would reach over 500 TWh by 2050 in a 1.5°C-aligned transition

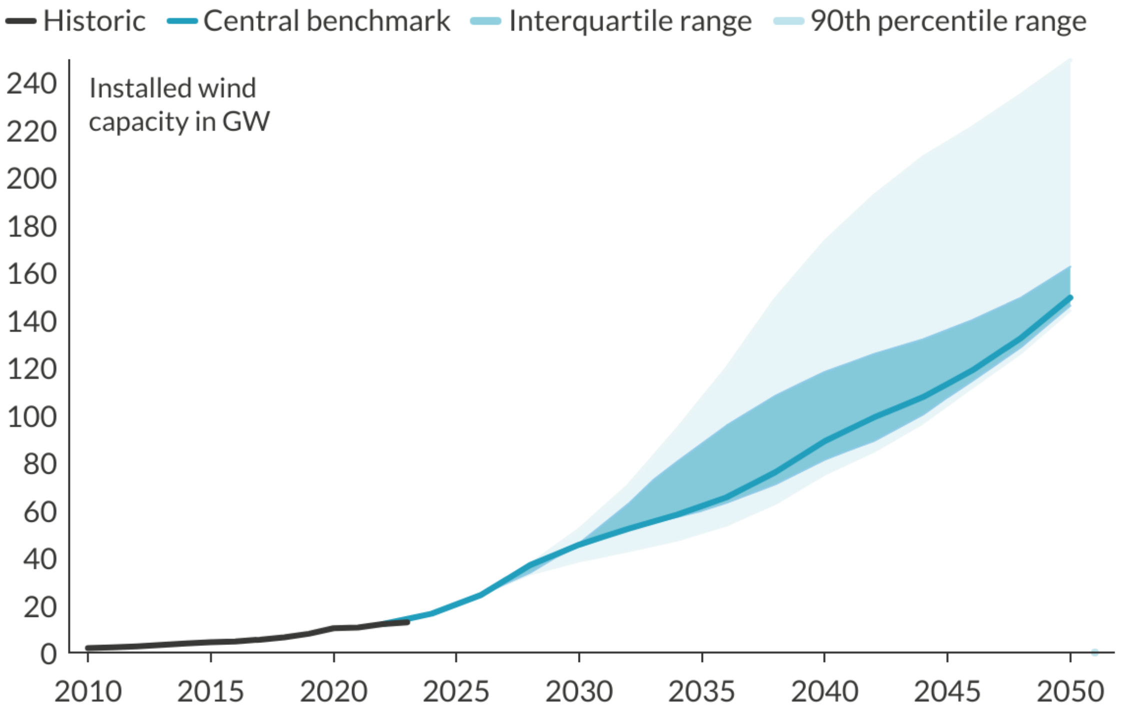


Australia needs to install almost 170 GW of wind and solar by 2030 to align with 1.5°C

Solar capacity would reach 120 GW in Australia by 2030 in a 1.5°C-aligned scenario



Wind capacity would reach 45 GW in Australia by 2030 in a 1.5°C-aligned scenario



Comparison to current rollout

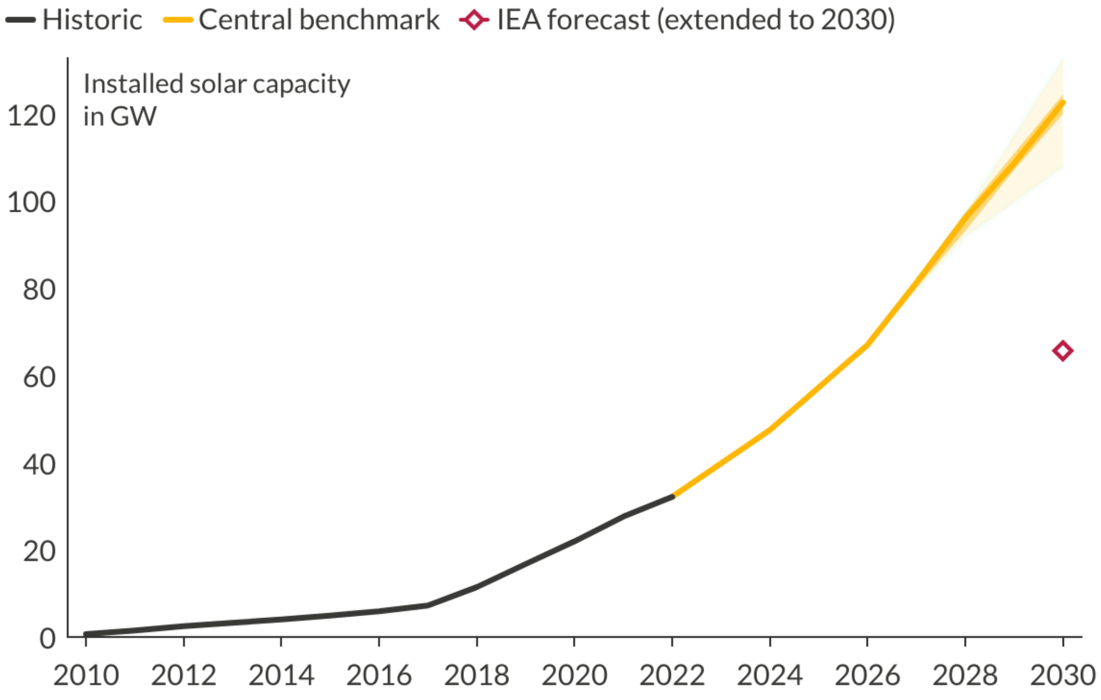
We extend the IEA's capacity forecast for wind and solar (which is provided out to 2028) to 2030 and compare to the benchmarks presented in this report.

Under current policies and market conditions, deployment of wind and solar PV in Australia would not align with 1.5°C. There would be a capacity gap of **57 GW of solar PV** and **18 GW of wind** missing in 2030 between current rollout and the 1.5°C compatible benchmarks highlighted here.

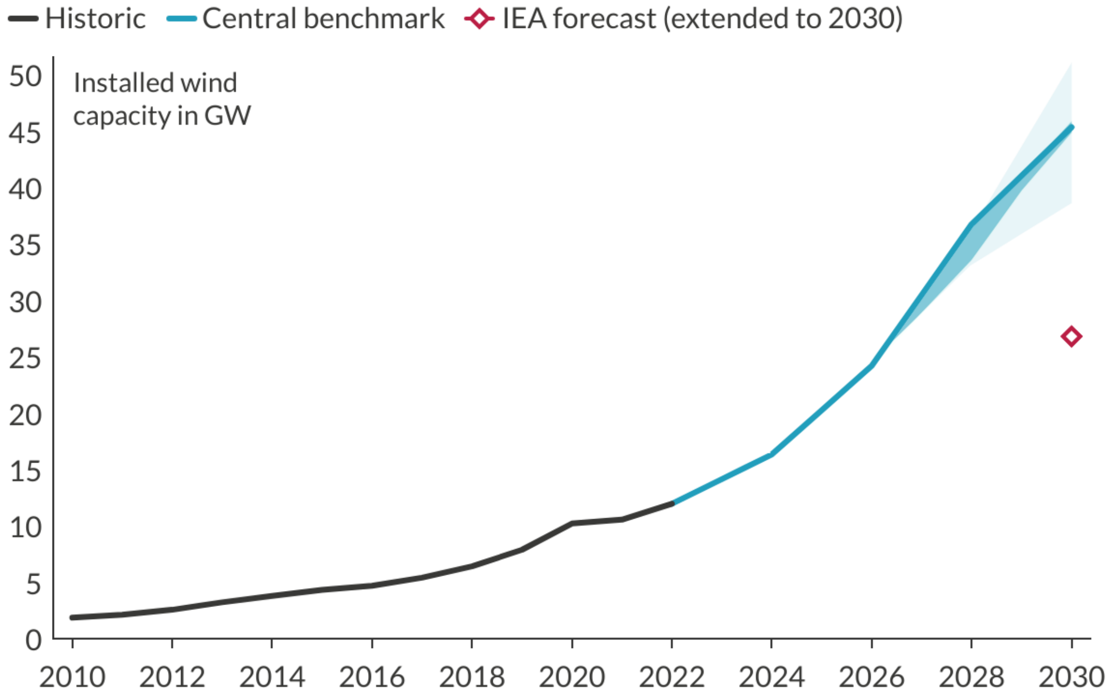
Australia's rollout of wind and solar needs to accelerate to align with 1.5°C

NEW CLIMATE INSTITUTE | CLIMATE ANALYTICS

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



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

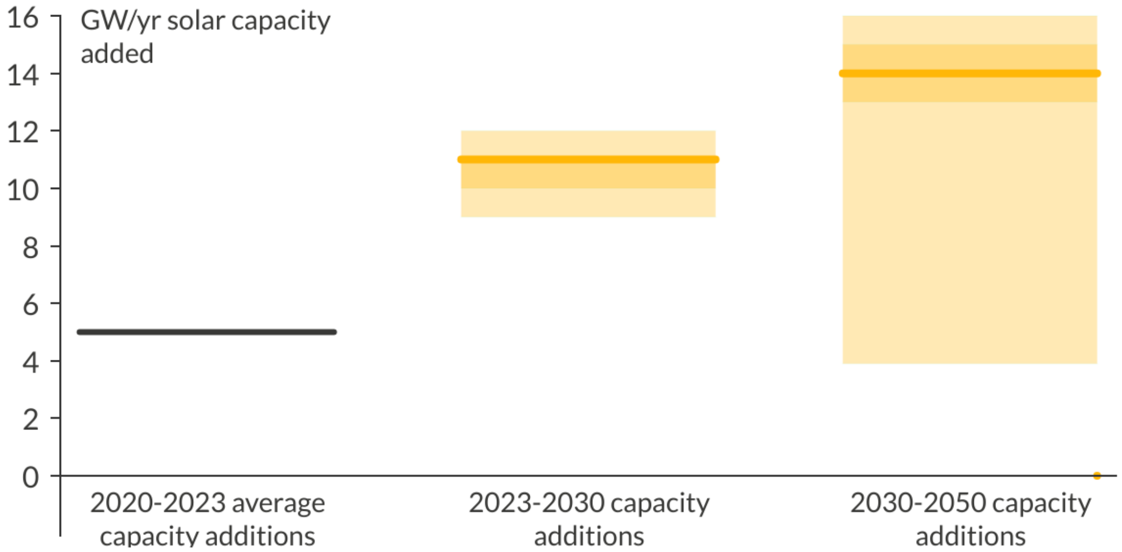


Wind and solar capacity additions in Australia need to accelerate to align with 1.5°C

NEW CLIMATE INSTITUTE | CLIMATE ANALYTICS

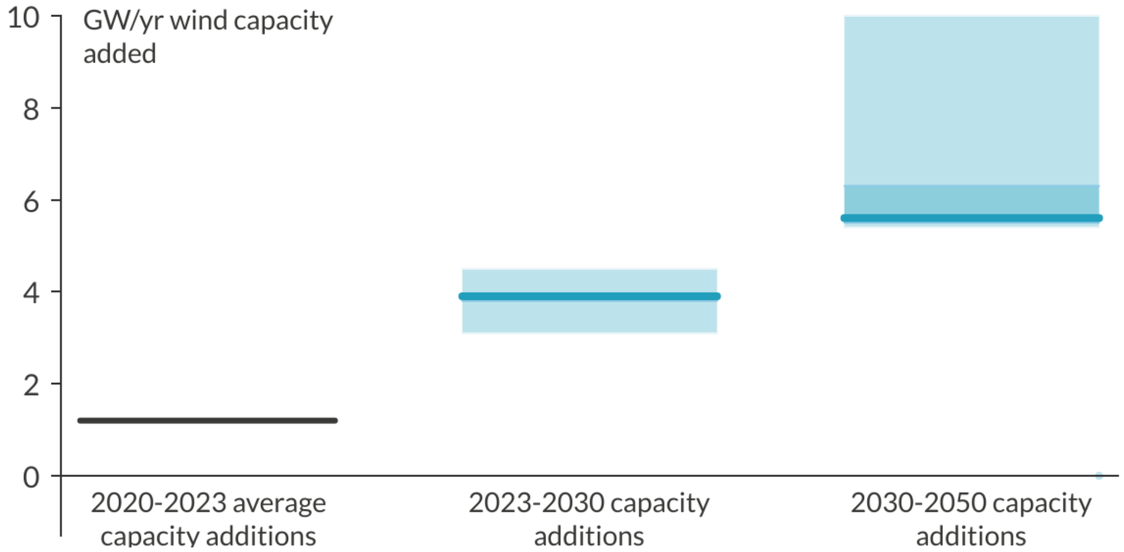
Australia would need to add on average 11.0 GW/yr of solar capacity until 2030, and 14.0 GW/yr by over 2030–2050.

— 2020-23 average capacity additions — Central benchmark — Interquartile range — 90th percentile range



Australia would need to add on average 3.9 GW/yr of wind capacity until 2030, and 5.6 GW/yr by over 2030–2050

— 2020-23 average capacity additions — Central benchmark — Interquartile range — 90th percentile range



Comparison with other studies

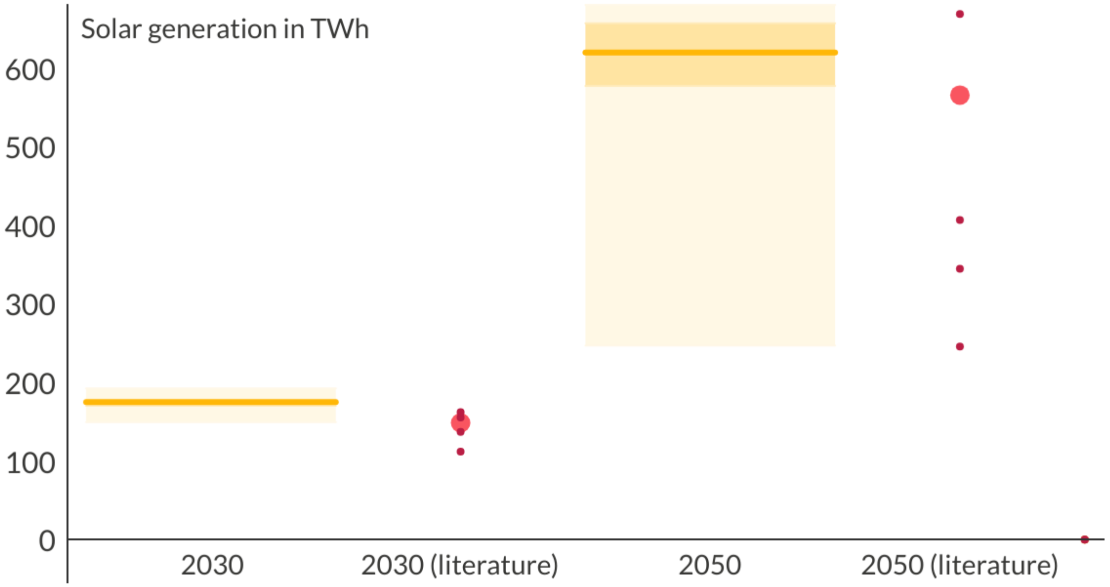
We compare the wind and solar generation seen in our analysis to that in the literature review of country-level studies. We highlight the results of modelling from the Net Zero Australia, exploring net zero pathways for Australia, where we particularly highlight the results from the *Rapid Electrification* scenario (E+).

We see that the wind and solar generation that our method produces is broadly comparable to the Net Zero Australia modelling in 2050. However, our benchmarks envisage a faster rollout of solar in the 2030s and a slower rollout of wind than the Net Zero Australia modelling.

Our benchmarks are broadly aligned with the literature

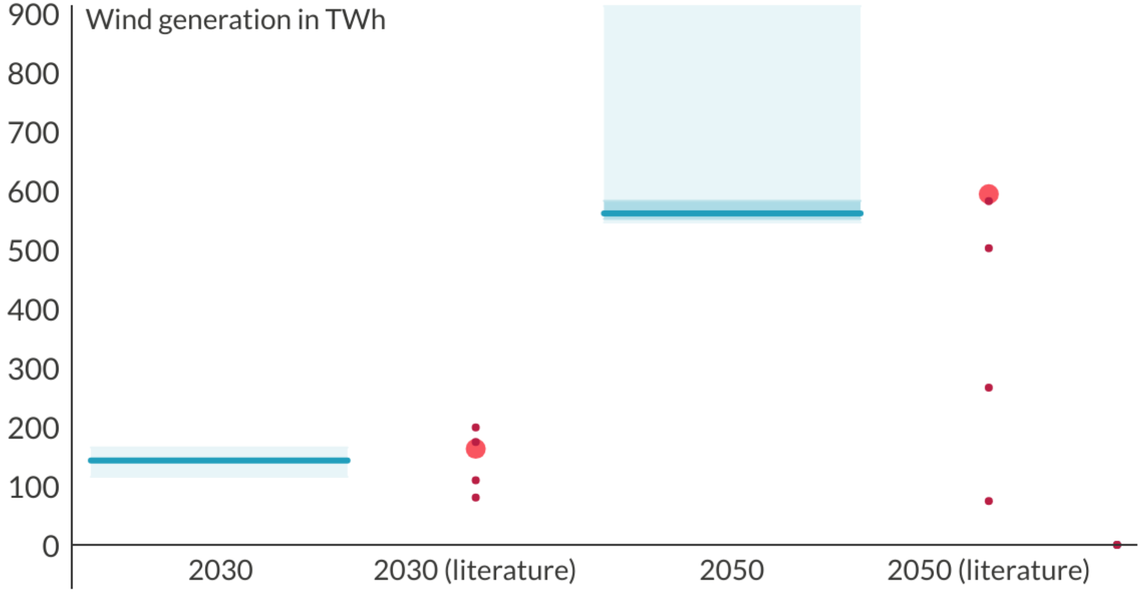
Electricity generation from solar: comparison with literature in Australia

Central benchmark · Interquartile range · 90th percentile range · Literature studies · Net Zero Australia, 2021 (E+)



Electricity generation from wind: comparison with literature in Australia

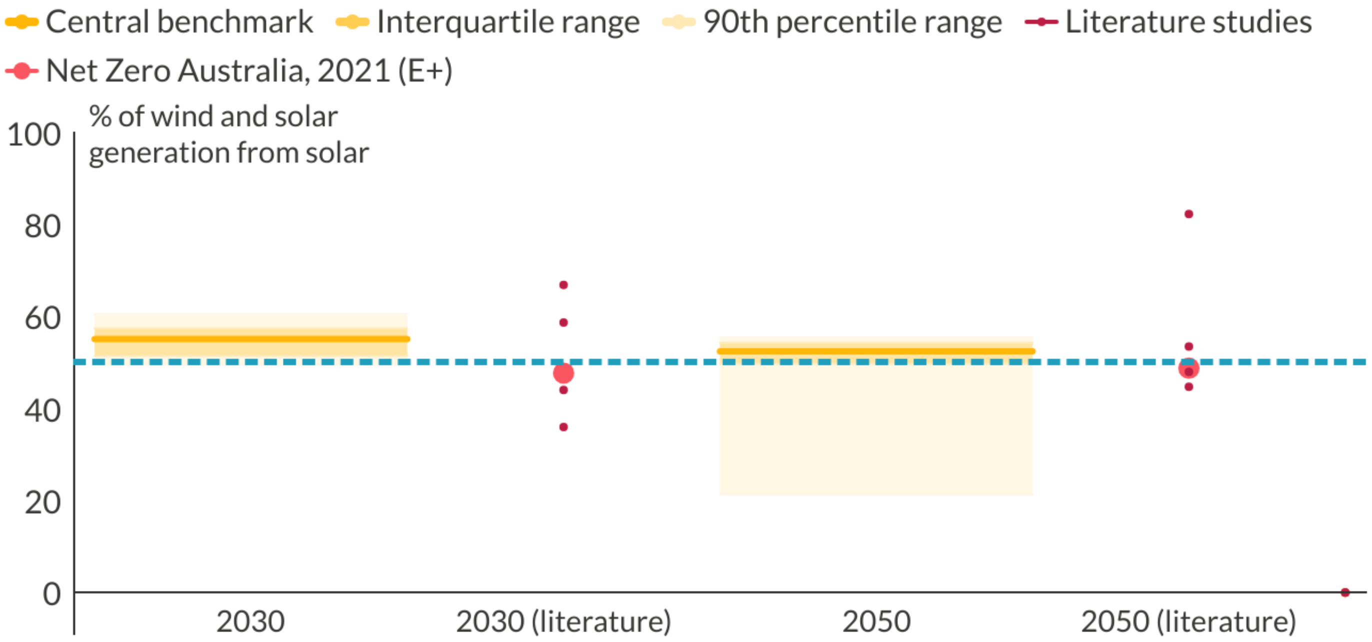
Central benchmark · Interquartile range · 90th percentile range · Literature studies · Net Zero Australia, 2021 (E+)



In Australia, our benchmarks generally suggest that relatively even contribution of wind and solar

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

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



Summary data

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.

Scenario	Variable	Unit	2022	2030	2035	2040	2050
Central 1.5°C benchmark	Solar generation	TWh	36	180	390	560	620
Central 1.5°C benchmark	Wind generation	TWh	31	140	200	300	560
Central 1.5°C benchmark	Solar capacity	GW	32	120	250	350	400
Central 1.5°C benchmark	Wind capacity	GW	12	45	62	89	150

Annex 1

Overview of analytical elements

Different analytical elements

Our method takes multiple different analytical elements to try and understand a possible 1.5°C aligned wind and solar rollout that is informed by both bottom-up approaches and top-down perspectives.

The integration of multiple different analytical elements can help compensate for the limitations of any individual perspective, and provide a more robust and better-informed ultimate set of results.

In the following section, we provide some further detail on three of the main analytical elements. For more detail, please see the Methodology Report.

Global pathways

We use the global 1.5°C compatible pathways to bring a link back between national level action and the global goal of limiting warming to 1.5°C. All our benchmarks are consistent with pathways which achieve this goal at the global level, and in which renewable capacity triples by 2030 relative to 2022.

We focus on a set of 24 pathways from the IPCC's Sixth Assessment Report which avoid unsustainable levels of CDR deployment, as defined by the literature, and in which high-income countries take the lead in reducing emissions faster than low and middle-income countries. For more details see here.

Having selected these pathways, we then downscale them from the regional level (e.g. Sub-Saharan Africa) to the national level. We do this using the SIAMESE tool, which provides a cost-effective breakdown of energy consumption and emissions at the national level.

Country-level studies

We use national-level studies, whether conducted by in-country actors (preferable), or otherwise external studies, to help provide national context. These studies help to ground-truth the top-down evidence being provided by the global downscaled pathways.

Studies are then filtered based on level of

- **Ambition**: We select studies which full decarbonise the power sector by the 2050s at the latest
- **Scope**: We prioritise studies with energy-wide sectoral representation, high levels of electrification and that provide data out to 2050
- **Robustness**: We focus on detailed power system modelling studies, avoiding simple heuristics

The resulting set of filtered studies are used to help inform future electricity demand, the future fossil fuel phase-out schedules in the country, and the level of non-wind and solar clean electricity generation that could be deployed out to 2050.

Country-level studies

List of scenarios selected

Study	Publication	Scenario Selected
Aboumahboub et al., 2020	Decarbonization of Australia's energy system: Integrated modeling of the transformation of electricity, transportation, and industrial sectors	P1.5C
University of Melbourne, 2021	Net Zero Australia	E+
University of Melbourne, 2021	Net Zero Australia	E+RE+
Climateworks Centre, 2023	Climateworks Centre decarbonisation scenarios 2023: Australia can still meet the Paris Agreement	1.5 °C
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

Global milestones

As well as the high-ambition country-level studies and the downscaled global pathways, we ensure that our benchmarks are compatible with the milestones identified in the IEA's net zero scenario, which sees:

- Advanced economies achieving net zero power sector emissions in 2035
- China achieving this milestone in 2040
- All other economies achieving this in 2045

Annex 2

Step-by-step method

Summary of our method

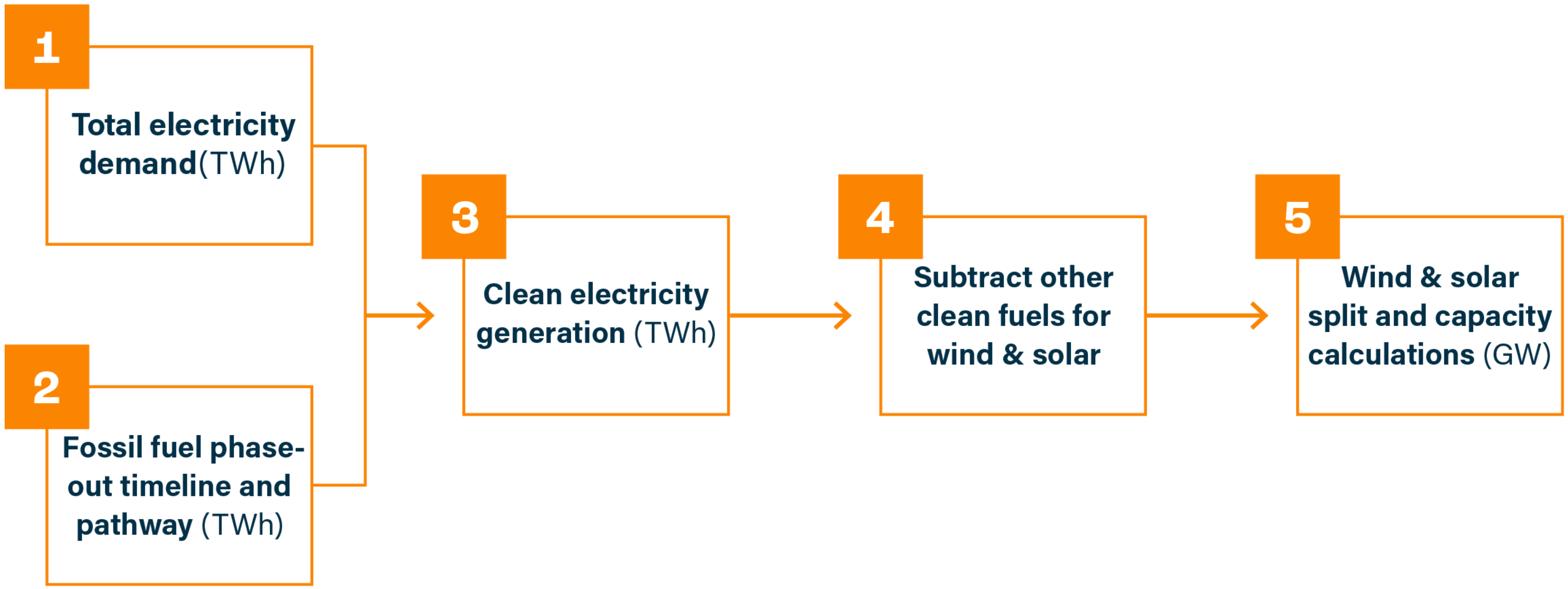
Our method takes a series of steps to calculate the wind and solar generation needed for 1.5°C, and the resulting capacity deployment.

First, we project future electricity demand. We then calculate the pace of fossil fuel phase-out needed to align with 1.5°C. Bringing these data points together, we can calculate the level of clean electricity generation required. We subtract non-wind and solar generation to calculate the wind and solar generation necessary to meet electricity demand growth and phase out fossil fuels in line with 1.5°C.

Having produced this wind and solar generation trajectory, we feed it into an electricity system model (PyPSA), which can then calculate for a given set of cost assumptions around wind and solar, a split into wind versus solar and the associated capacity requirements.

The following section further summarises the method. For a detailed overview, please see the methodology paper released in 2023.

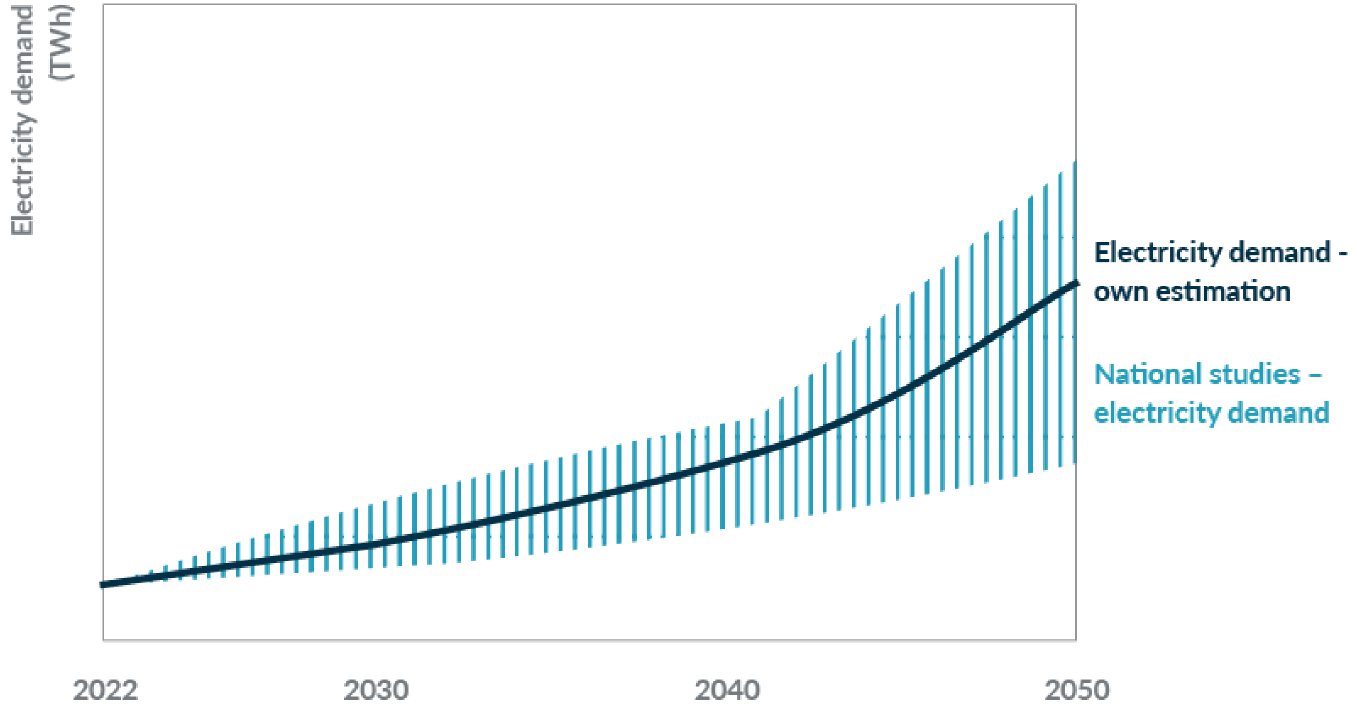
We use a step-by-step method to calculate our benchmarks



For more details see the Methods Annex

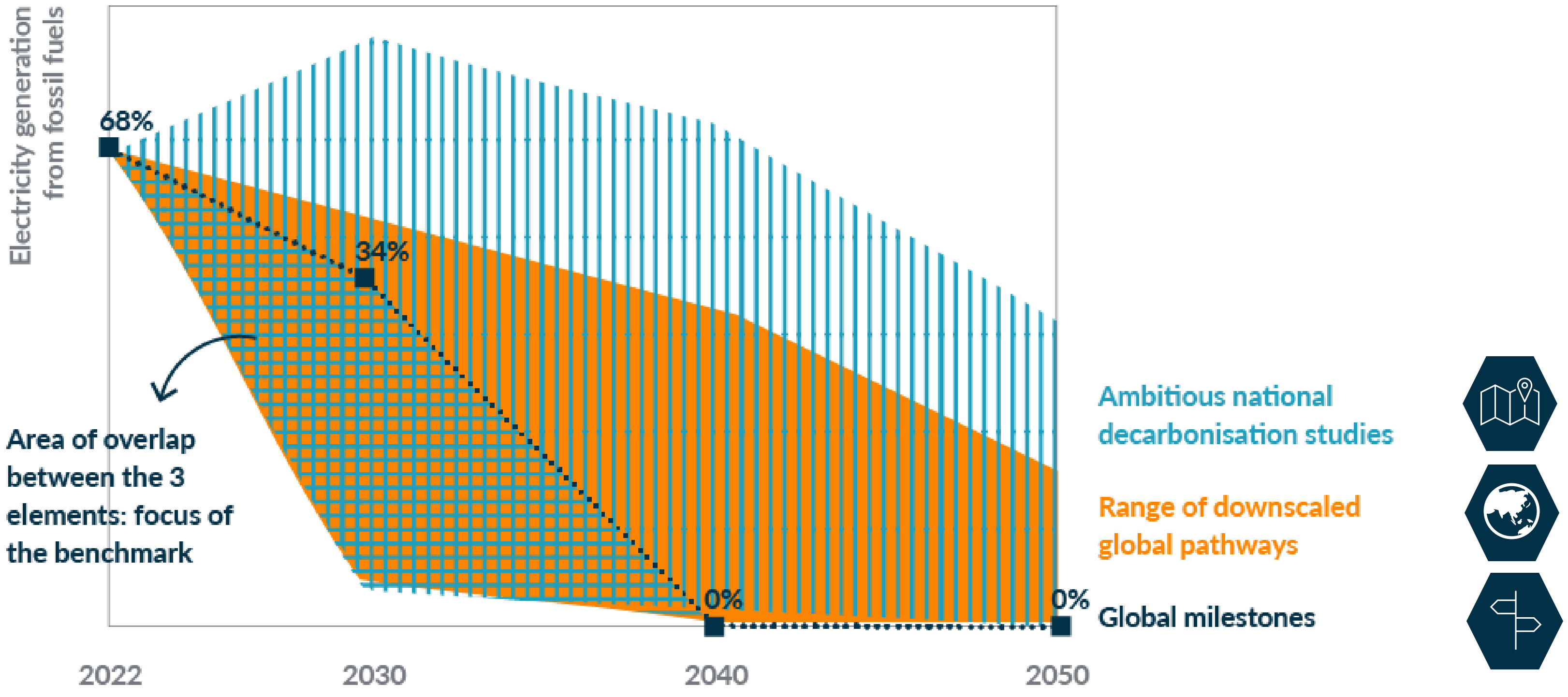
1 Total electricity generation

1. We extract electricity generation projections for 2030, 2040, and 2050 from **ambitious country-level studies**.
2. We then identify an electricity generation projection from a scenario to use for our analysis. We focus on identifying studies which capture key elements of the transition, including **high electrification**, and which have been conducted using **detailed energy system models** by **country-level experts**. We incorporate feedback from stakeholders to identify these studies which inform the electricity demand trajectory.



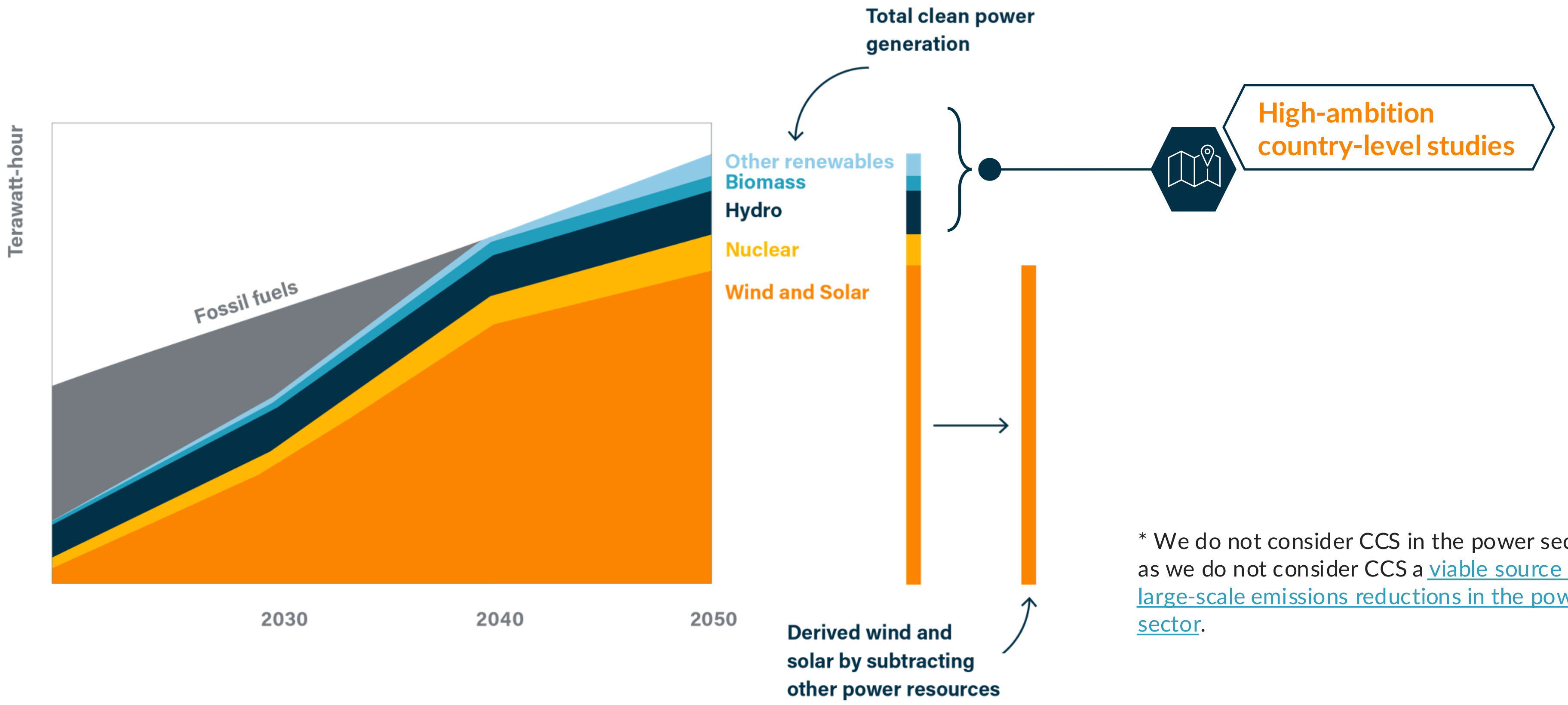
2 Fossil fuel phase-out

1. We calculate a range of electricity generation pathways from fossil fuels based on ambitious country-level studies.
2. We produce a similar range from downscaled 1.5°C compatible global scenarios.
3. We identify the intersection of these two ranges, representing the speed and scale of decarbonisation pathways that aligns with the goals of the Paris Agreement while capturing local circumstances in countries.
4. We integrate differentiated timelines for phasing out fossil fuel electricity generation, applied as global milestones (2035 for advanced economies, 2040 for China, and 2045 for emerging economies).



3 4 Calculate wind and solar generation

1. We obtain electricity generation from carbon-free resources: from total electricity generation (step 1), subtracting fossil-fired generation (step 2).
2. We then subtract estimates of electricity generation attributed to hydroelectricity, biomass, other renewable resources, and nuclear power – informed from **country-level studies'** estimates – from the total clean electricity generation* to infer the wind and solar generation.

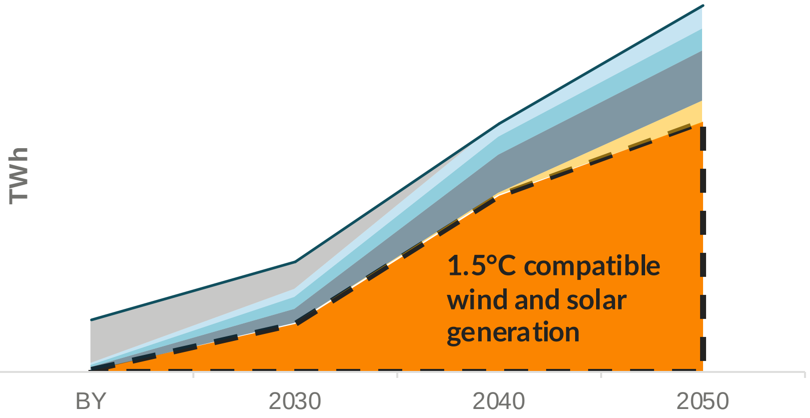


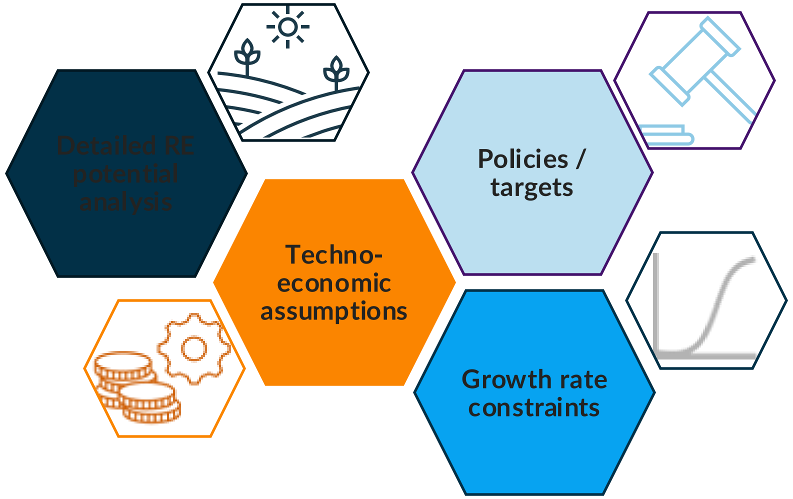
* We do not consider CCS in the power sector, as we do not consider CCS a viable source of large-scale emissions reductions in the power sector.

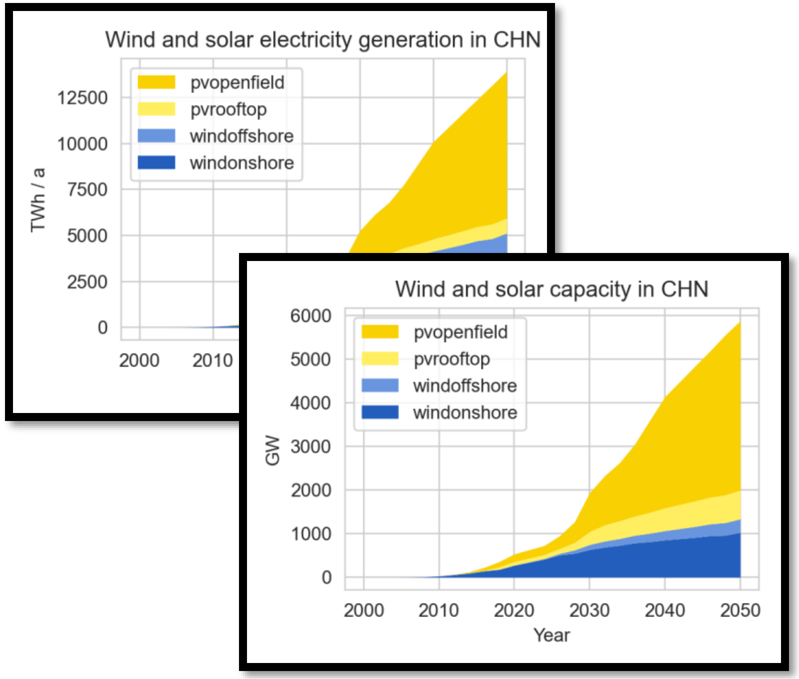
5 Wind and solar breakdown

1. We use a detailed geospatial **renewable potential analysis** to calculate the technical potential of each technology in the country. We then feed the wind and solar generation required into a power system model calibrated to these potentials.
2. We force the model to deploy at least the level of solar and wind seen in countries' **current targets and pledges**.
3. The power system model then gives a split of wind and solar in the country and the resulting capacity requirements.

1.5°C compatible wind and solar generation (steps 1-4) → **RE potential and power system analysis** / **Current targets and pledges** → **Generation and capacity of wind and solar**







Key modelling parameters in the analysis

The following table highlights some of the most relevant parameters which influence the PyPSA modelling used to help estimate the split into wind versus solar

Model feature	Details
Cost resolution	Detailed cost curve for wind and solar produced based on geospatial weather data.
Growth rates	Solar and wind growth rates constrained to technology specific growth rates set based on analysis of past technology rollout. Current default growth rates are set as: • Wind = 16% per year • Solar = 33% per year These constraints are applied to both total capacity and capacity additions.
Adequacy factor	In addition to the total annual electricity generation from wind and solar having to be met, we require that at a certain proportion of the hourly load is always met by wind and solar. The default value for this constraint in Australia is 50%. This factor captures the level of storage and dispatchable generation available to meet electricity demand. A higher factor means that wind and solar need to more closely match hourly loads, without the use of storage/dispatchable generation to smooth out mismatches between generation and demand. This would generally lead to an overbuild of wind and solar to ensure adequate power supply at all times, and greater curtailment. Meanwhile a factor of 0% would mean that wind and solar generation can fall to zero for significant periods of time, as long as over the whole year, total wind and solar generation needed is provided. This would imply that there is greater availability of batteries and other dispatchable zero-carbon generation to meet demand in times of low wind and solar output.
Wind and solar costs	We produce a range of different cost curves for wind and solar in each country, based on IRENA data. For more details see the technical annex.