Wind and solar benchmarks for a 1.5°C world

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

Mexico

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Executive Summary

Context

- Power supply is Mexico's largest GHG emitting sector.
- Mexican electricity supply is highly dependent on fossil fuels (77% in 2023). Natural gas is the dominant fuel (58%), followed by oil (9%). Coal (8%) is already phasing out.
- To meet the 1.5°C target, Mexico needs to significantly reduce the use of fossil fuels while coping with electricity demand growth. Wind and solar power will play a key role.
- Recent policies have increased support for gas-fired electricity generation and discontinued RE support mechanisms such as tenders, causing a slowdown in new wind and solar installations.
- A change in government could reinstate RE support policies, although it is likely that support for gas generation will continue, maintaining policies from the previous administration.

Key findings

- This report examines the wind and solar capacity installation Mexico needs for a 1.5°C compatible pathway, aligning with the goal of tripling renewables by 2030.
- Future electricity expansion should focus on wind and solar. Wind and solar generation in Mexico need to increase around 6x by 2030, compared to 2022 levels, to be 1.5°C compatible.
- Projected wind and solar rollout in Mexico falls short of benchmarks, with a 2030 capacity gap of nearly 58 GW for solar and 11 GW for wind under current policies. Both need significant growth to align with benchmarks.
- Mexico would require around 97 GW of wind and solar to be installed by 2030 (19 GW and 78 GW, respectively) according to our benchmarks.
- Despite its current low levels, our model sees solar energy surpassing wind in power generation in 2030, 2040 and 2050, in line with country-level studies.

Context

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

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 possible 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

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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

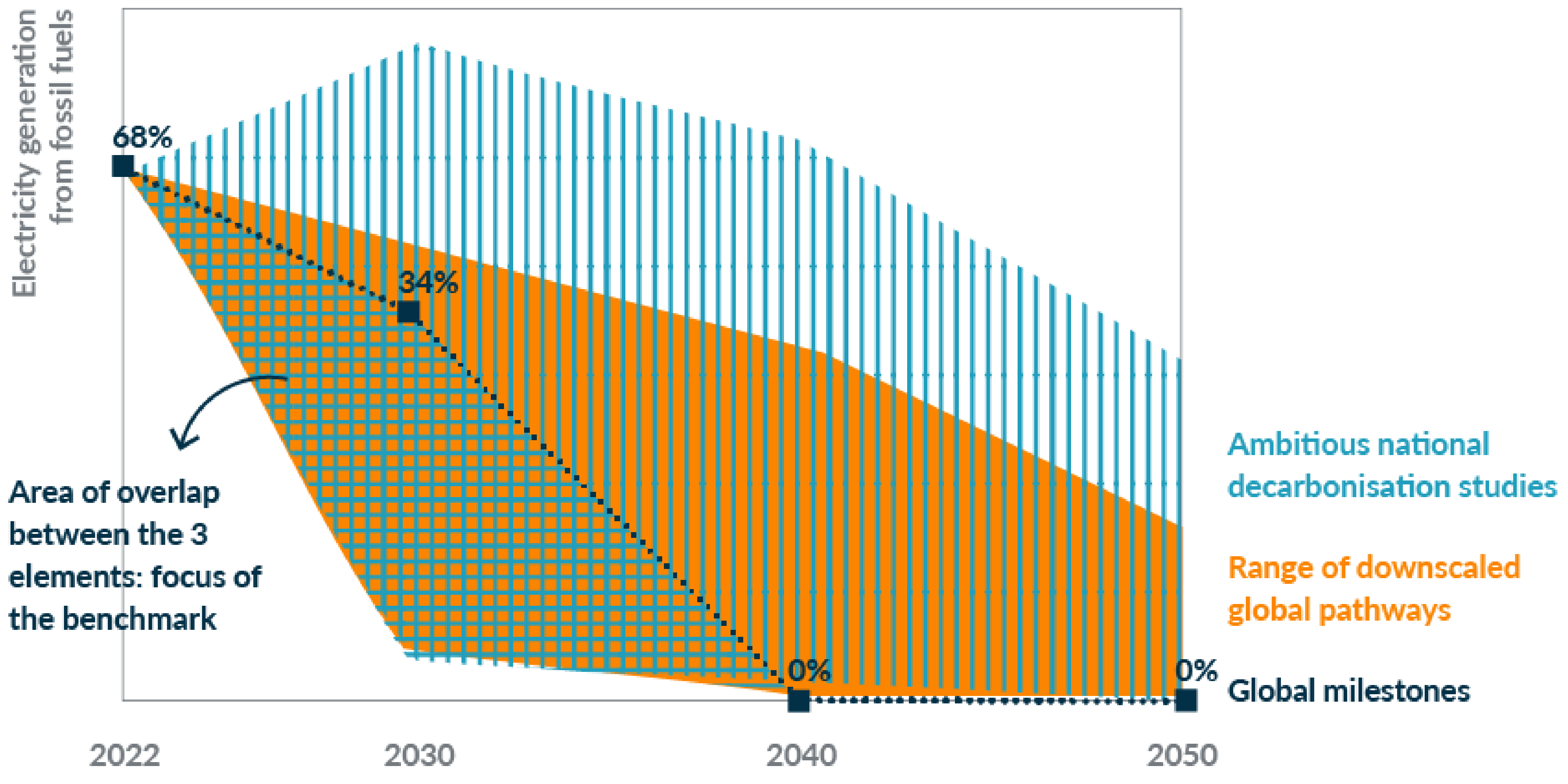
For more details see the Methods Annex

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



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)

International support

The key analytical elements (high ambition country-level studies and downscaled 1.5°C compatible global pathways) 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, 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.

Policy context

Mexico's current NDC aims to reduce emissions by up to 35% below a BAU baseline by 2030, which is equivalent to **11-22% above 2010 levels** excluding LULUCF. The country does not yet have a formal net zero target for 2050.

Mexico's current renewable targets are to **reach 23 GW of solar and 13 GW of wind by 2030**, as of the National Electric System Development Program 2023-2037 (PRODESEN).

Under current policies and market conditions, the IEA estimates that **solar capacity will reach 19 GW in 2028**, up from 10.8 GW in 2022. Meanwhile, **wind capacity is projected to reach 8 GW in 2028**, up from 6.9 GW in 2022.

Recent policy developments have prioritized gas-fired electricity generation, discontinuing RE support mechanisms like RE auctions, which have slowed new wind and solar installations. While a change in government could restore RE policies, continued support for gas generation is expected to persist.

Results

Future electricity demand

Electricity demand is taken from the Iniciativa Climática de México (ICM)'s study exploring net zero pathways for Mexico. We take demand from the most ambitious pathway, which achieves net zero Greenhouse Gases (GHG) emissions by 2060, which is aligned with a GHG emissions reduction pathway of 30% by 2030.

Total electricity generation in Mexico almost doubles by 2050 relative to 2021 levels, reaching 620 TWh. This is driven by economic development and increased electrification, while being partly offset by energy efficiency measures.

However, there is a significant range in the studies in terms of the expected electricity generation in 2050 ranging from 620 TWh to 1800 TWh. Our demand estimate is at the lower end of that estimated by country-level studies. Assuming higher electricity demand would affect the expected growth of RE significantly.

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 Mexico achieves a clean power system by 2045.

To align with 1.5°C, Mexico should start displacing fossil fuels now, phasing them out completely by 2045 while simultaneously addressing the growth in electricity demand. Wind and solar deployment will play a central role in achieving this goal.

Electricity generation from fossil fuels falls by 34-41% by 2030, compared to 2022 levels.

The fastest rate of fossil phase-out is set by Teske's study on Net-zero 1.5°C sectorial pathways for G20 countries.

To align with 1.5°C, Mexico should phase out fossil fuels by 2045 and expand renewables to meet growing demand

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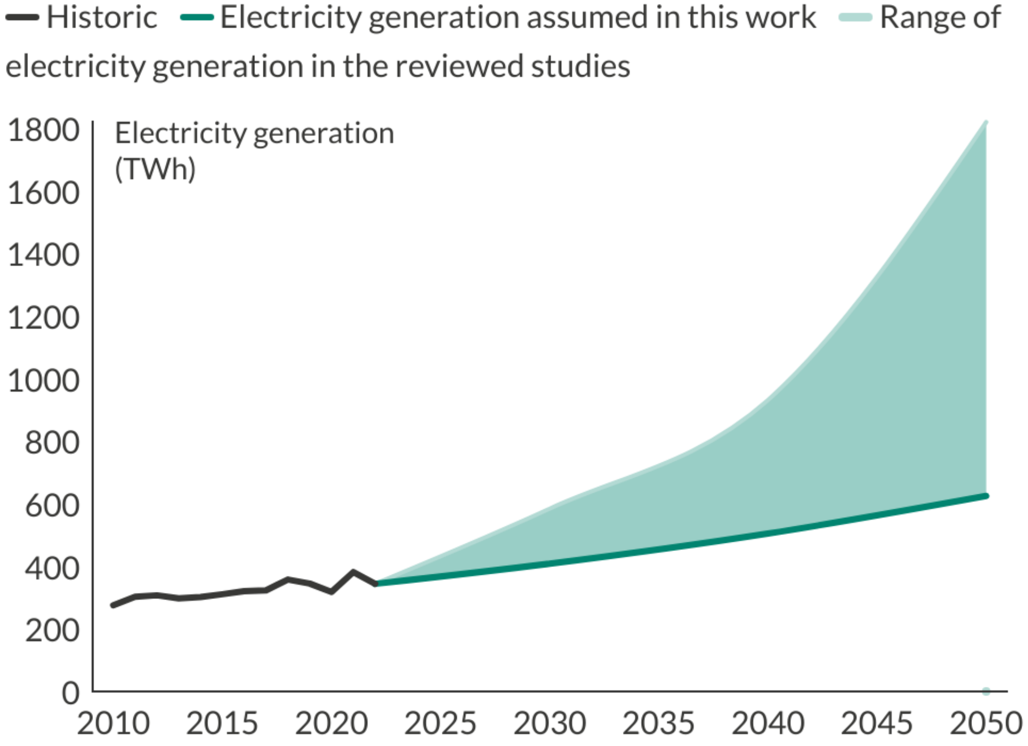
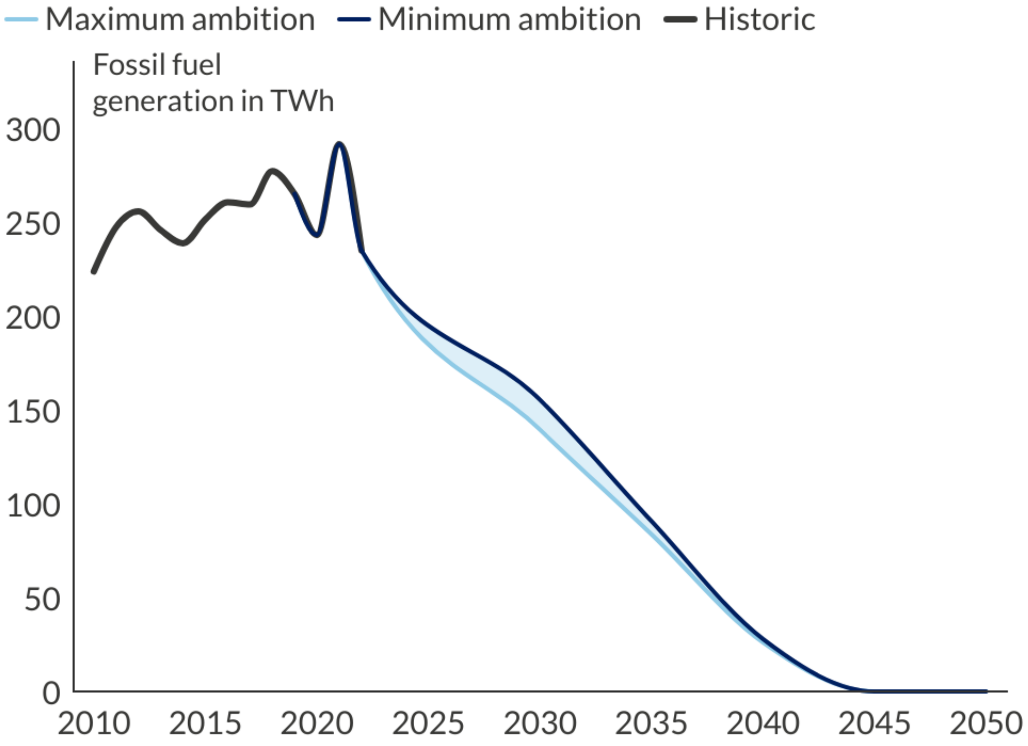
Electricity generation almost doubles in Mexico over 2022–2050



Mexico would need to achieve clean electricity by 2045



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 Mexico would reach 57 TWh by 2030 and 82 TWh by 2050. This is provided by hydropower, nuclear, biomass, and other renewable technologies.

* 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

Wind and solar is then needed to meet electricity demand growth and to drive the phaseout of fossil fuels. We estimate the role of non-wind and solar clean technologies (largely hydro, biomass, nuclear and geothermal) from country-level studies.

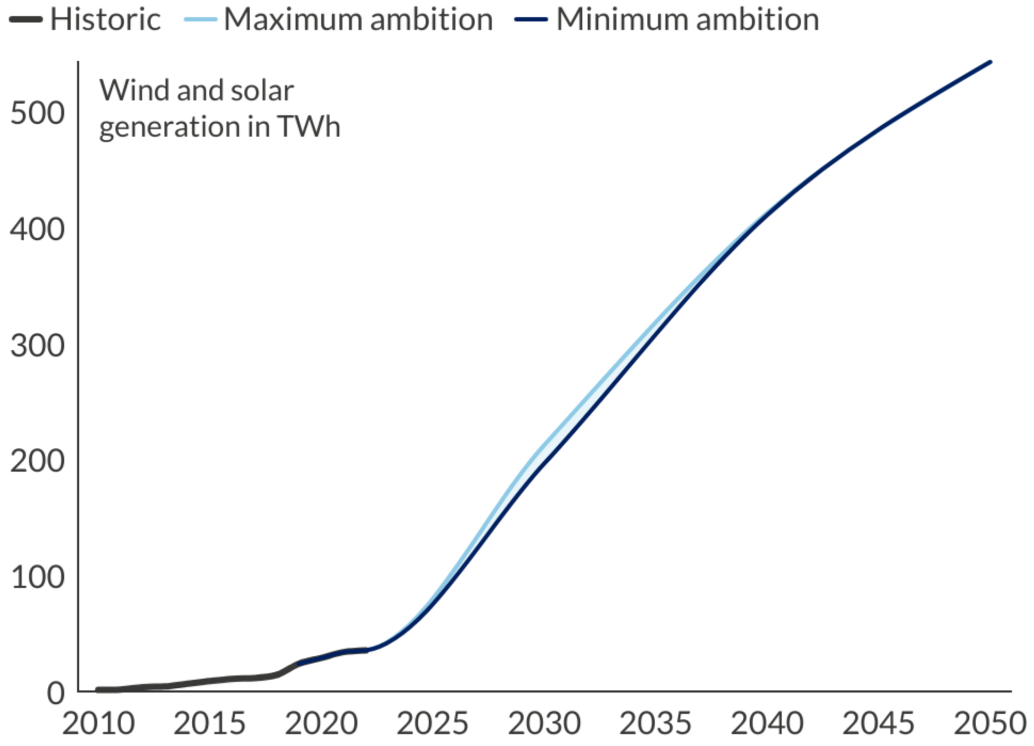
To align with 1.5°C, wind and solar generation in Mexico would need to reach between 200 and 210 TWh by 2030. Generation in 2022 was 35 TWh. This is therefore a roughly six-fold growth in wind and solar.

Wind and solar provides around 50% of overall electricity generation in 2030, and 87% of overall generation in 2050.

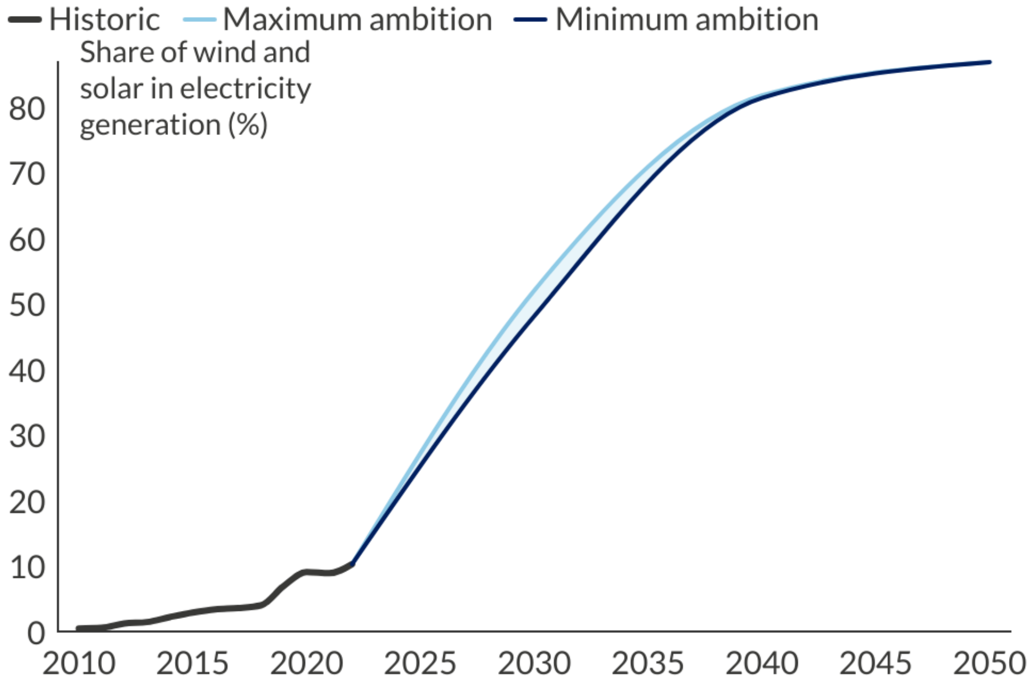
This is in line with two of the most ambitious scenarios in terms of the pace of fossil phase-out in the 2020s/2030s among the national studies considered (Teske et al., Buira et al.), leading to accelerated wind and solar rollout. The net-zero scenario in the ICM modelling for Mexico yields a 35% share of electricity generation from wind and solar by 2030, with a still dominant share of natural gas at almost 50%.

To align with 1.5°C, wind and solar generation in Mexico needs to grow around 6x from 2022-2030

Wind and solar generation needs to grow 6x by 2030 relative to 2022 in Mexico



Wind and solar would need to provide over 80% of electricity generation in Mexico 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, solar becomes the main source of generation, providing on average 2.3x 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, **Mexico would need to deploy almost 100 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 270 GW. Due to its higher capacity factor, greater wind deployment would reduce total capacity requirements.

On average, solar will contribute more than twice as much as wind in Mexico by 2050

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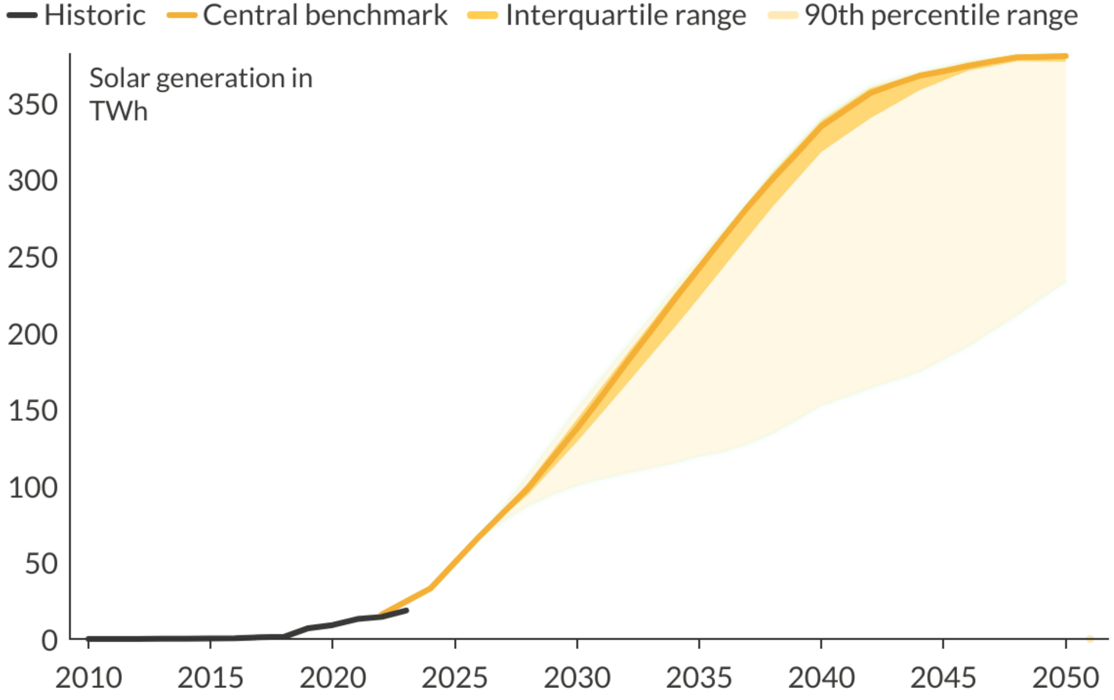
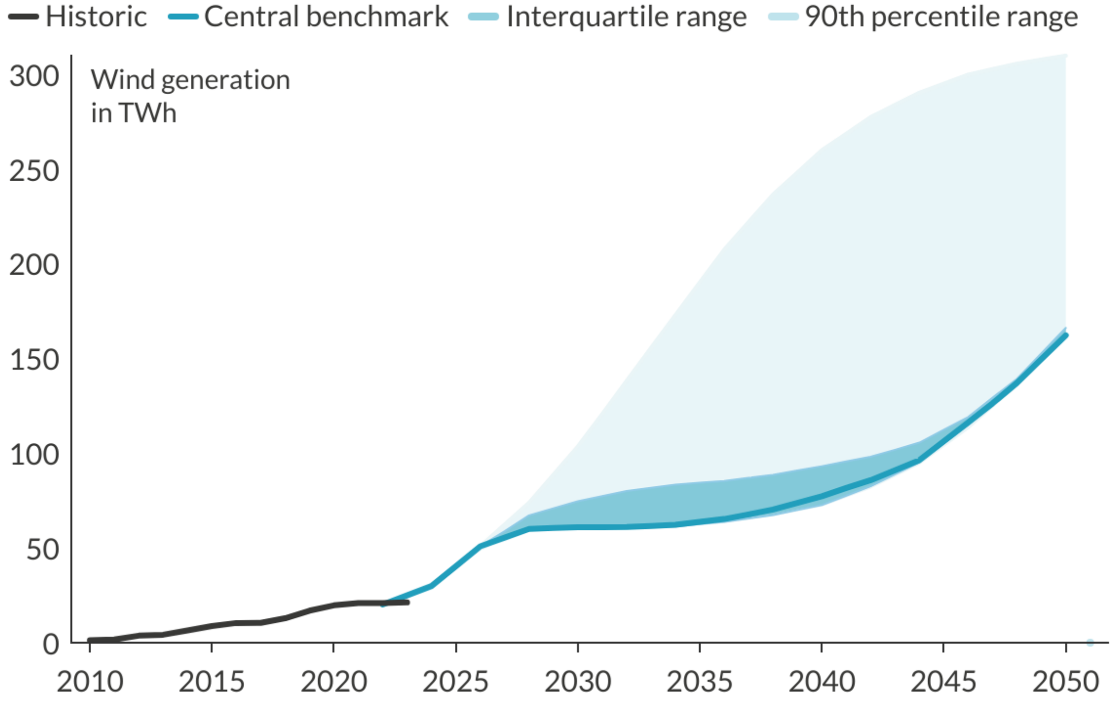
Solar generation in Mexico would reach around 380 TWh by 2050 in a 1.5°C-aligned transition

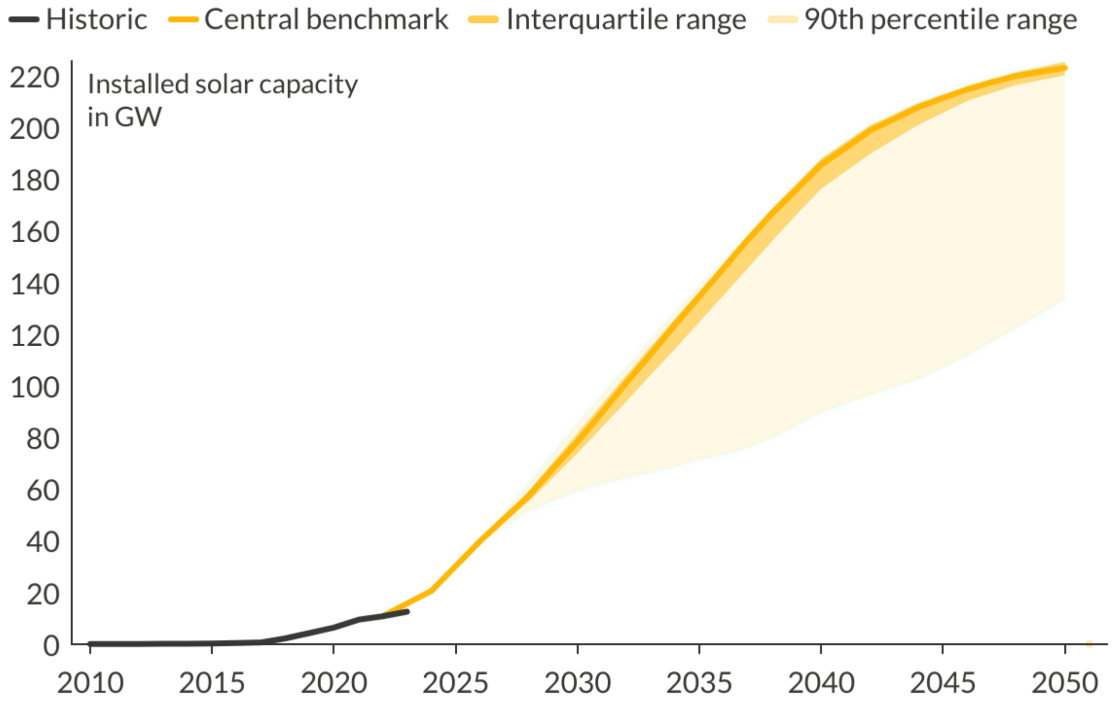


Wind generation in Mexico would reach around 160 TWh by 2050 in a 1.5°C-aligned transition

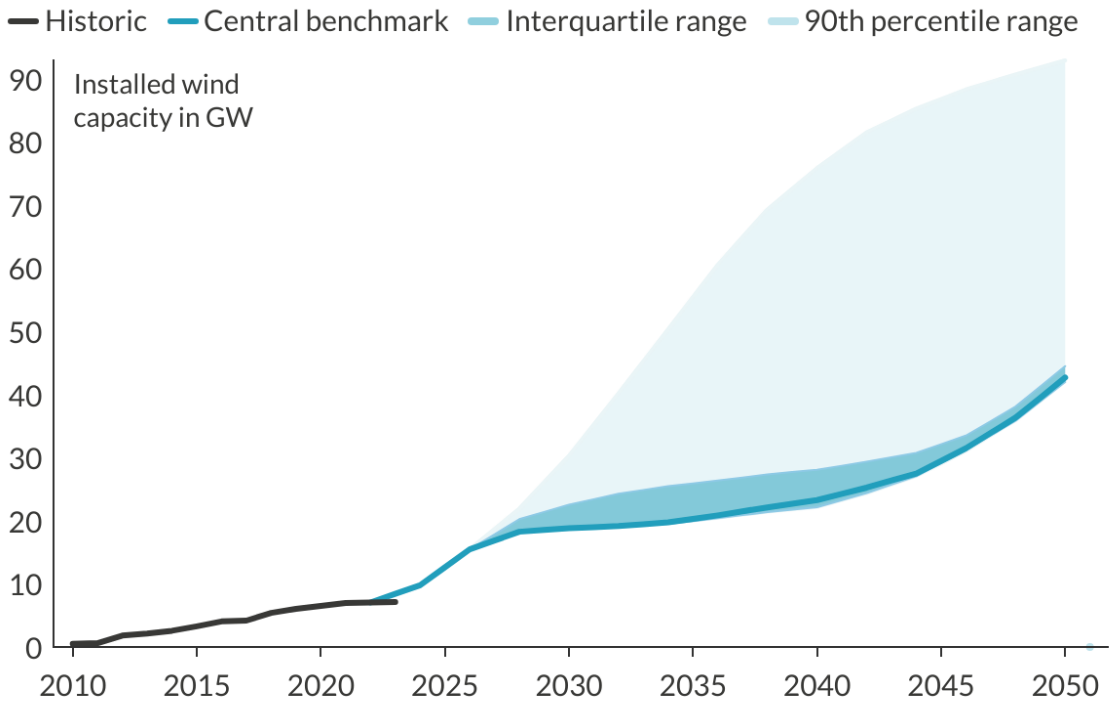


Mexico needs to install almost 100 GW of wind and solar by 2030 to align with 1.5°C

Solar capacity would reach 78 GW in Mexico by 2030 in a 1.5°C-aligned scenario



Wind capacity would reach 19 GW in Mexico by 2030 in a 1.5°C-aligned scenario



Comparison to current rollout

Under current policies and market conditions*, deployment of solar and wind power in Mexico is well below the minimum level required to align with 1.5°C. To achieve the high pace of fossil fuel phaseout, **more wind and solar would need to be installed, about 80 GW of solar alone by 2030**.

While the current deployment of solar power is broadly on track to meet the government's 2030 targets, wind deployment must increase by at least 1.5 times to align with the wind targets.

However, **both wind and solar targets need a significant ramp-up to be aligned with a 1.5°C pathway**: solar and wind capacity targets must increase by 3.4 and 1.5 times, respectively.

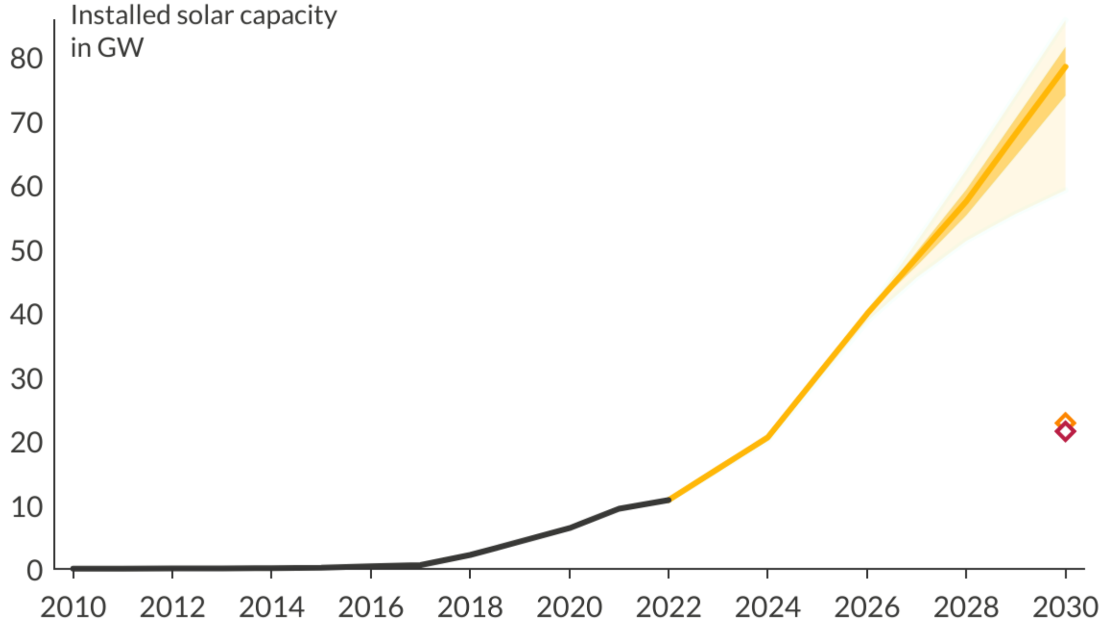
Further action will be needed to drive wind deployment in Mexico at the pace needed.

(*) 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.

Mexico’s wind and solar rollout falls far short of alignment with a 1.5°C pathway

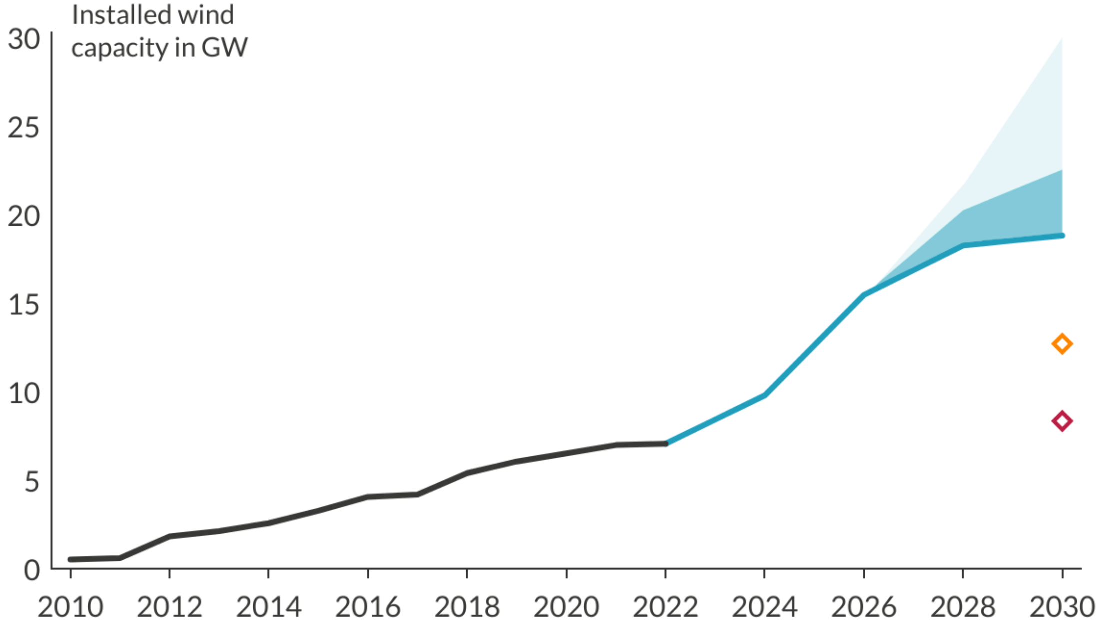
In Mexico, current rollout of solar is lagging behind 1.5°C-aligned levels

Historic — Central benchmark — IEA forecast (extended to 2030) — Country target



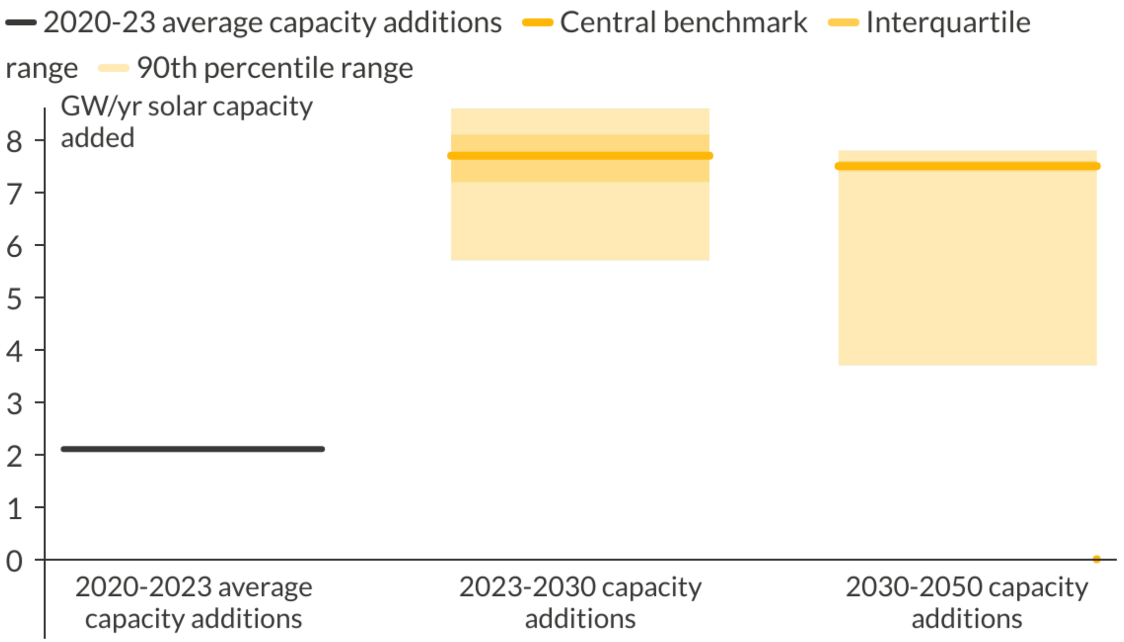
In Mexico, current rollout of wind is lagging behind 1.5°C-aligned levels

Historic — Central benchmark — IEA forecast (extended to 2030) — Country target

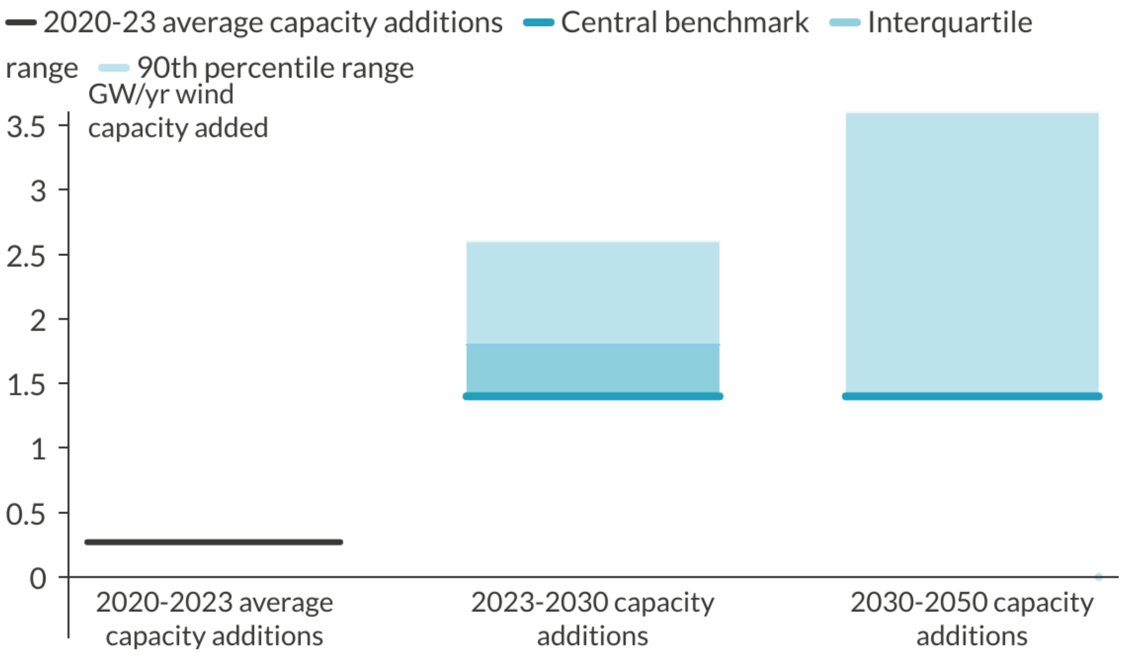


Wind and solar annual capacity additions in Mexico need to accelerate to align with 1.5°C, requiring international financial support

Mexico would need to add on average 7.7 GW/yr of solar capacity until 2030, and 7.5 GW/yr by over 2030–2050.



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



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 Iniciativa Climática de México (ICM), exploring net zero pathways for Mexico.

Our analysis shows solar generation broadly within the range of the national literature, particularly towards 2030/2040. The results from national studies vary widely toward 2050 due to differing underlying assumptions.

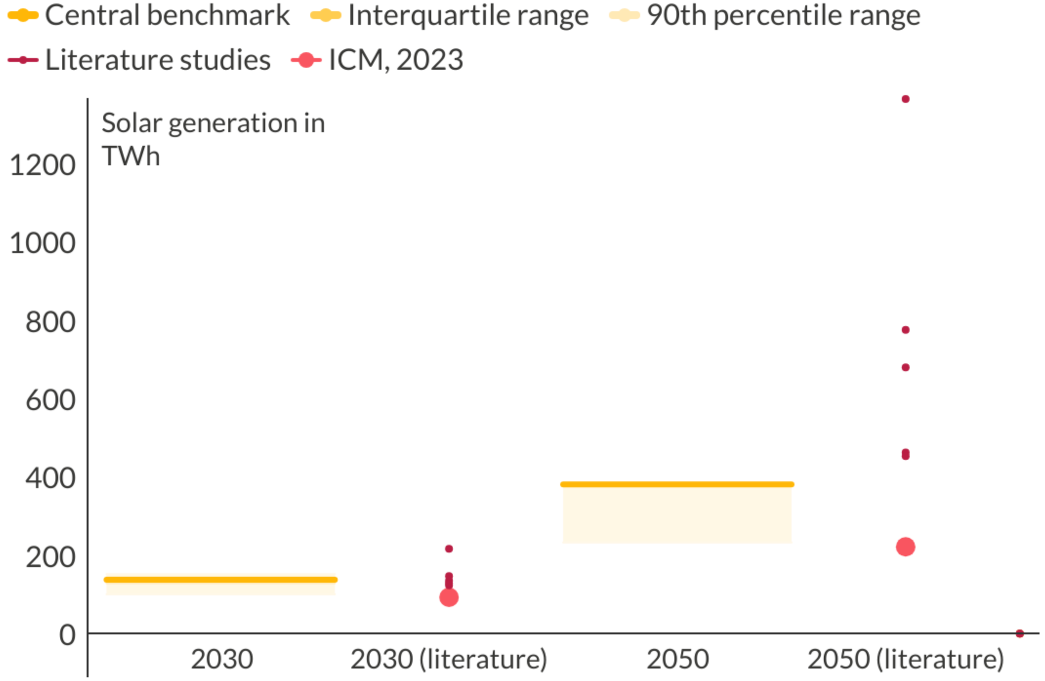
For wind, our analysis is generally on the lower end of the wind generation range of the national studies.

Our analysis shows higher generation from both wind and solar than the ICM study, largely due to the greater share of natural gas in this scenario in the 2030 energy mix and a delayed fossil fuel phase-out by 2060.

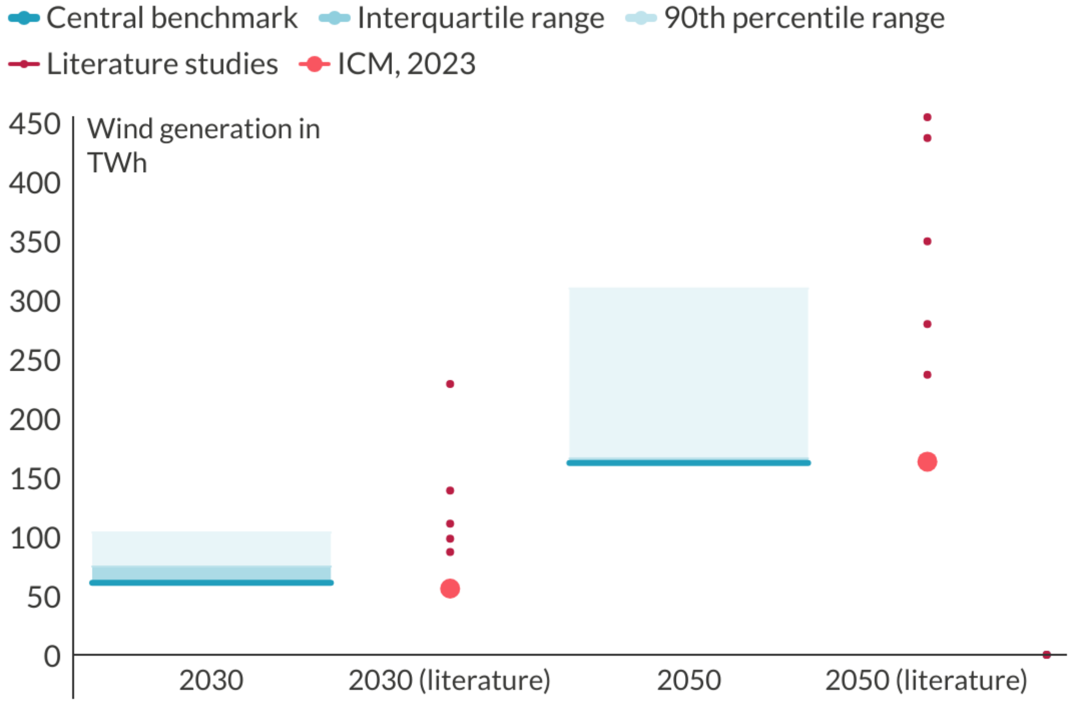
Both country-level studies and our modelling sees solar will provide more power generation than wind in 2030, 2040 and 2050.

Our benchmarks are broadly aligned with the literature

Electricity generation from solar: comparison with literature in Mexico



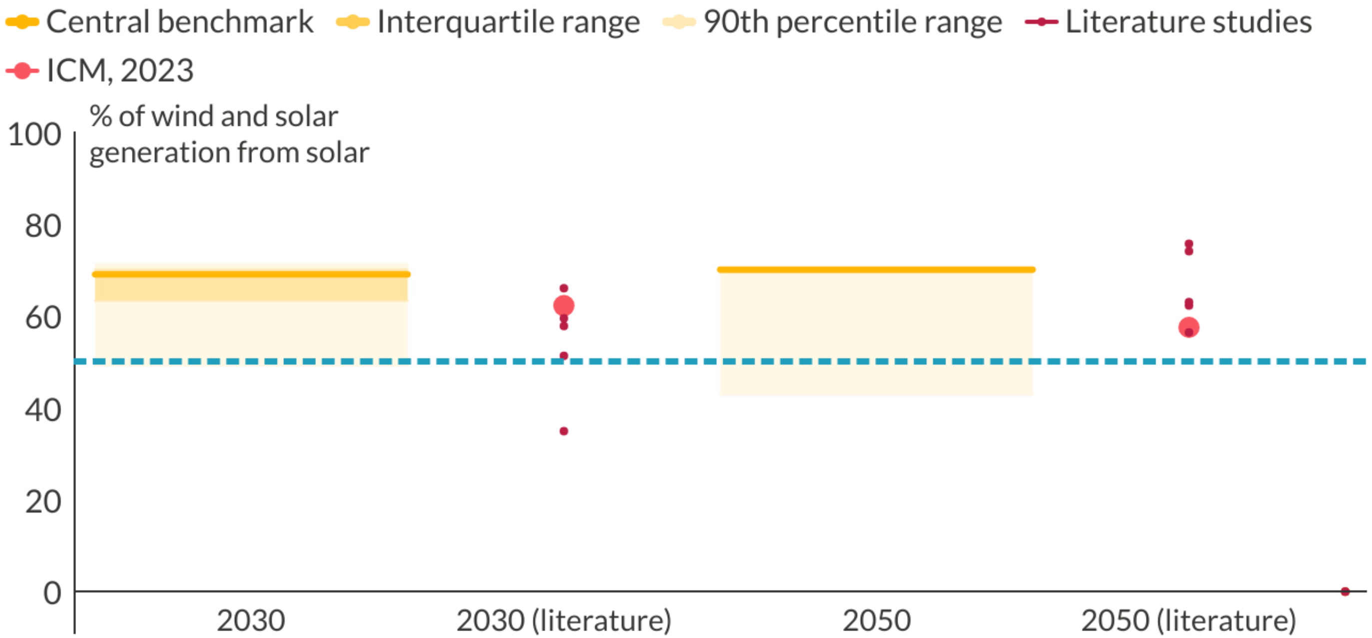
Electricity generation from wind: comparison with literature in Mexico



In Mexico, our benchmarks suggest that solar will provide 2.4x more electricity than wind

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

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	16	140	240	330	380
Central 1.5°C benchmark	Wind generation	TWh	20	61	64	77	160
Central 1.5°C benchmark	Solar capacity	GW	11	78	130	190	220
Central 1.5°C benchmark	Wind capacity	GW	7	19	20	23	43

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
ICM, 2023	Rutas sectoriales para el escenario nacional emisiones netas cero de México	Net Zero Emissions
Buira *et al.*, 2021	A whole-economy Deep Decarbonization Pathway for Mexico	Deep Decarbonization Pathway
Sarmiebto *et al.*, 2019	Analyzing Scenarios for the Integration of Renewable Energy Sources in the Mexican Energy System – An Application of the Global Energy System Model (GENeSYS-MOD)	• Climate Goals • 100% Renewables
Simon *et al.*, 2018	Transformation towards a Renewable Energy System in Brazil and Mexico – Technological and Structural Options for Latin America	Energy [R]evolution
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

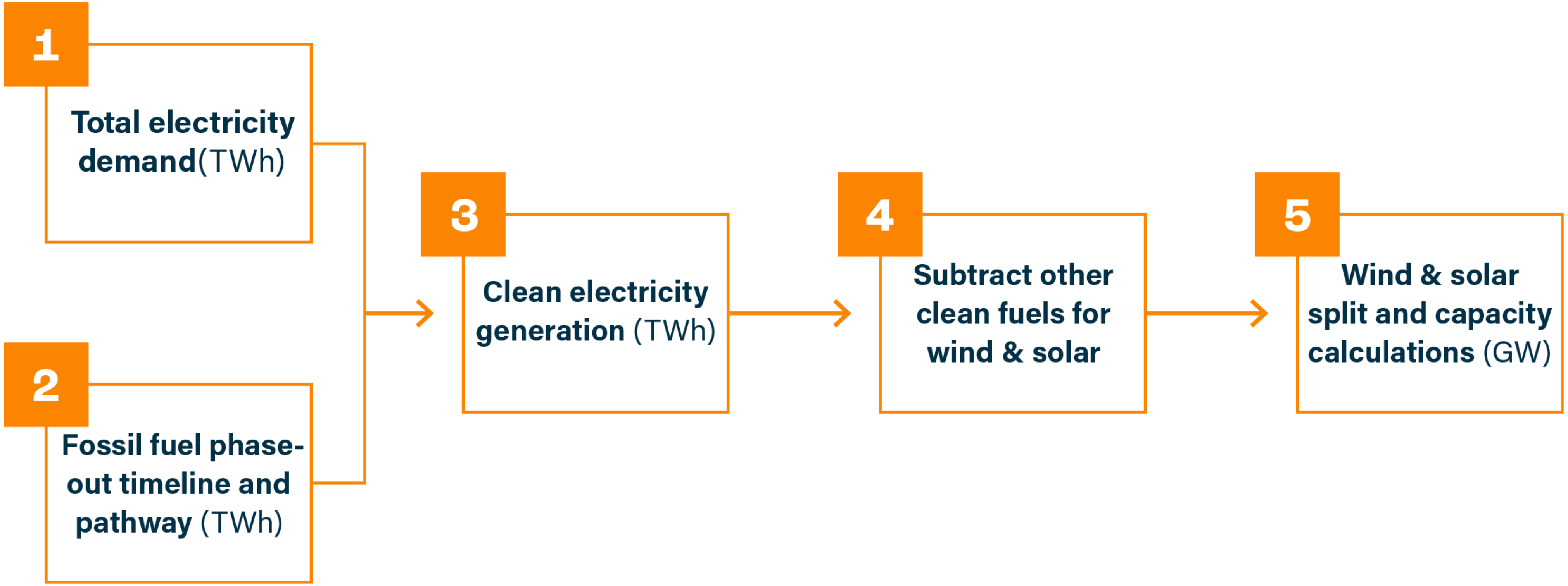
Our method takes a series of steps to calculate the wind and solar generation needed for 1.5°C, and the resulting capacity deployment.

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

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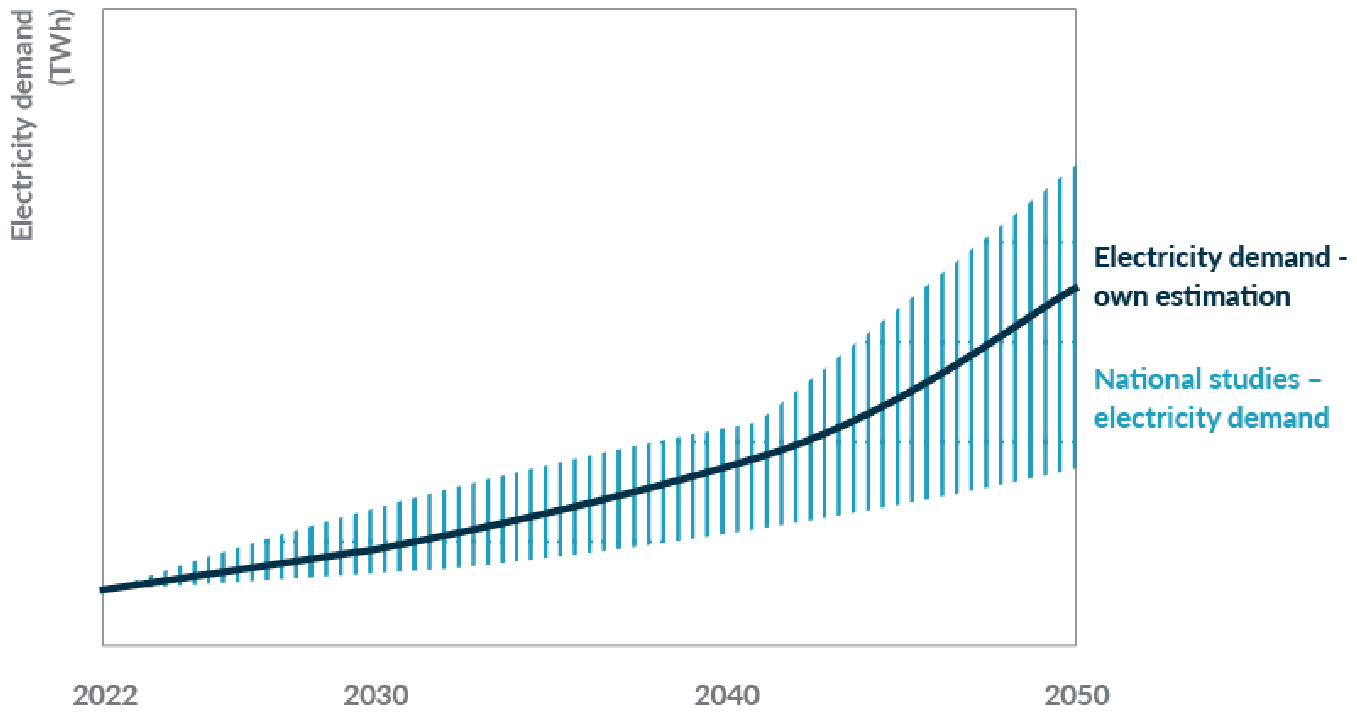
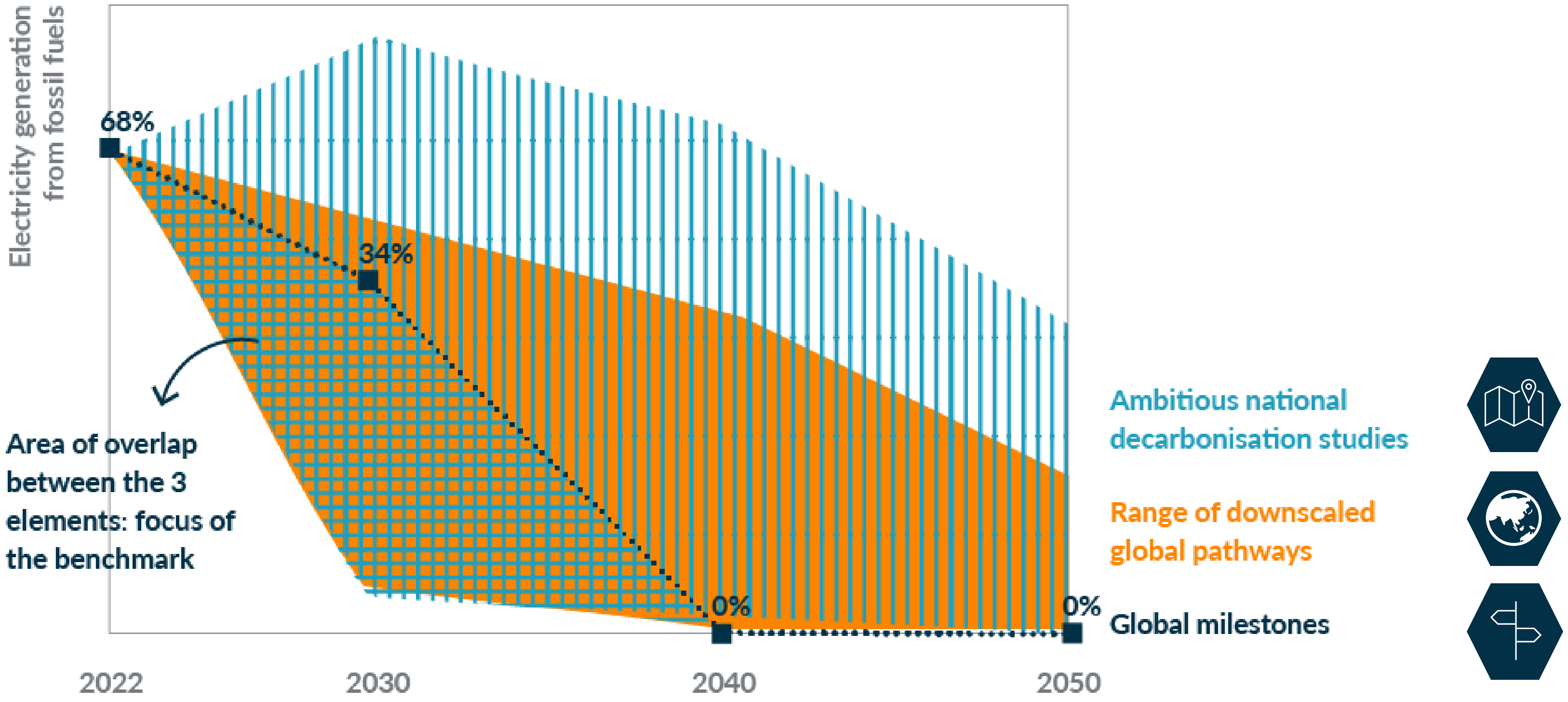
1. We extract electricity generation projections for 2030, 2040, and 2050 from **ambitious country-level studies**.
2. We then identify an electricity generation projection from a scenario to use for our analysis. We focus on identifying studies which capture key elements of the transition, including **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.



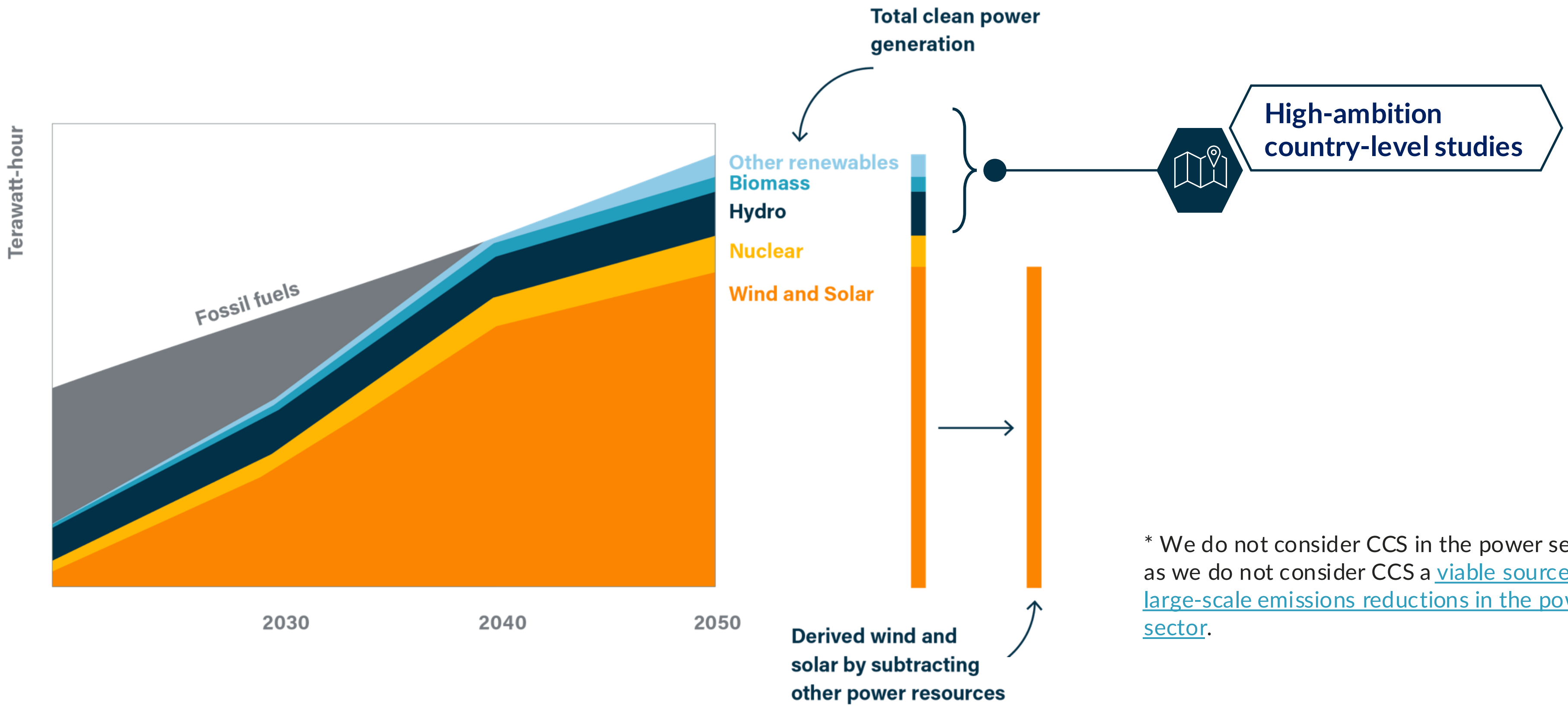
2 Fossil fuel phase-out

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

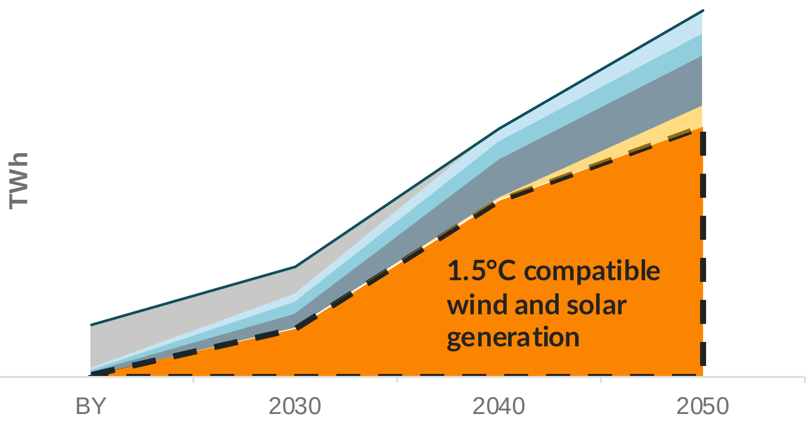
1. We use a detailed geospatial **renewable potential analysis** to calculate the technical potential of each technology in the country. We then feed the wind and solar generation required into a power system model calibrated to these potentials
2. We force the model to deploy at least the level of solar 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.

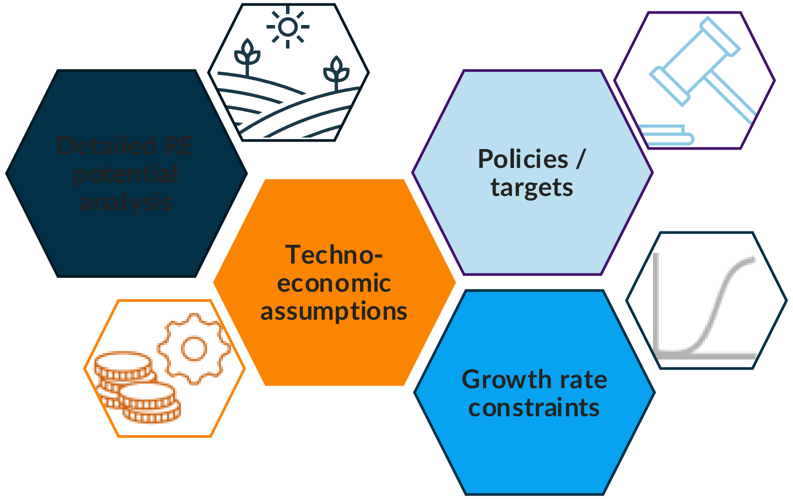
1.5°C compatible wind and solar generation (steps 1-4)

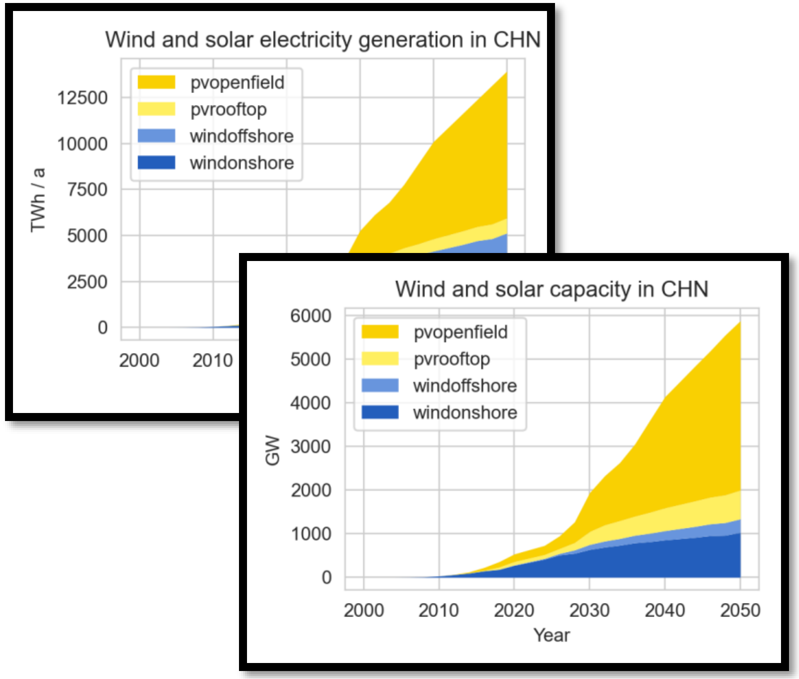
RE potential and power system analysis

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 is 25%. 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.