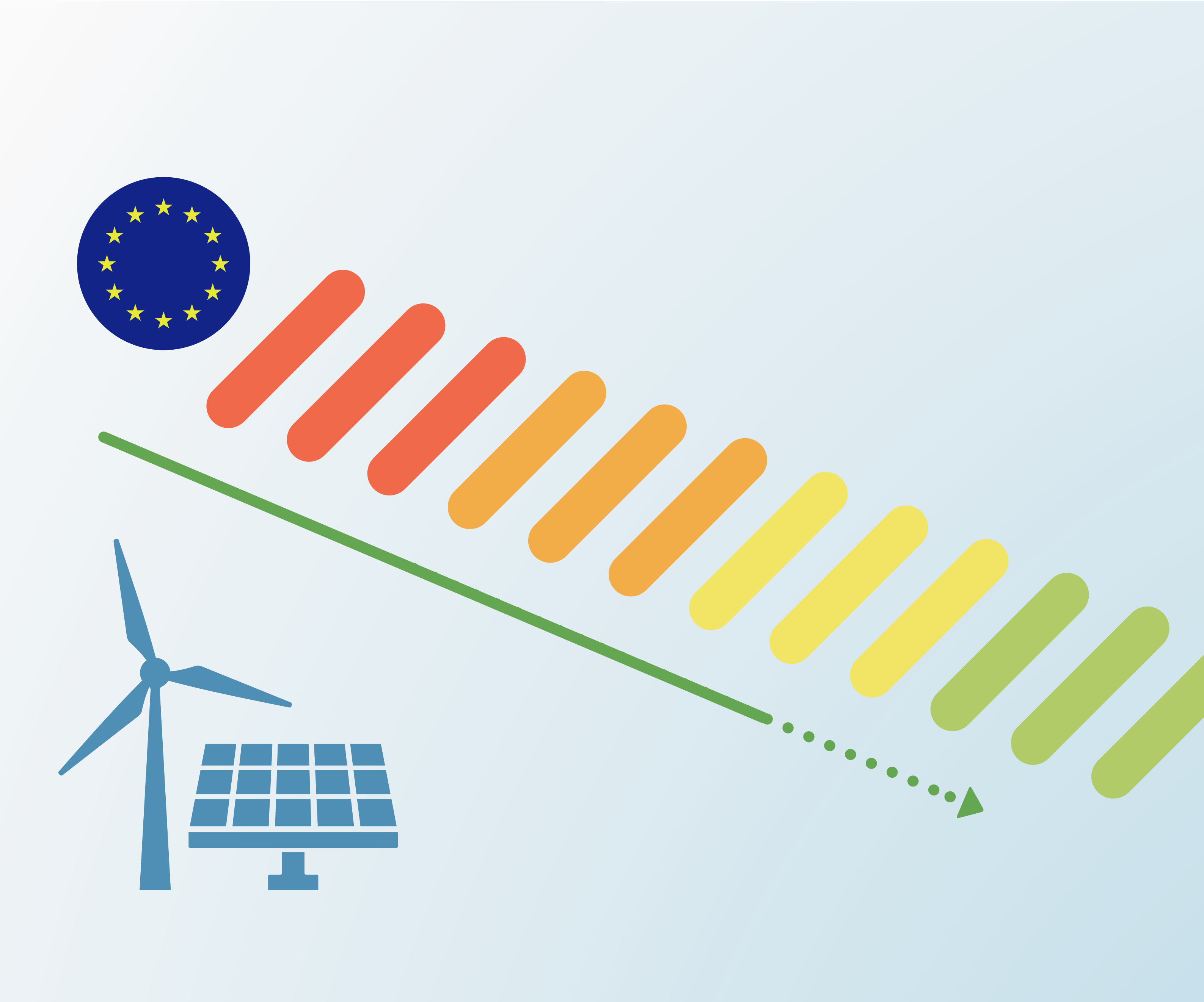
Climate Action Tracker



Climate Action Tracker

Wind and Solar benchmarks for a 1.5°C world

EUROPEAN UNION

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CLIMATE ANALYTICS

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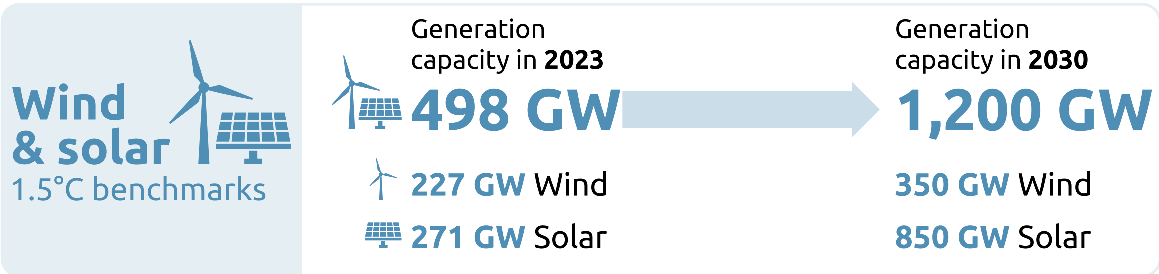
Executive Summary

Context

- The European Union has experienced a consistent upward trend of wind and solar for the last 10 years, accelerating in the past five years. At the same time the share of fossil fuels in the electricity mix has been decreasing. According to electricity production estimations for 2025, wind and solar has produced more power in the EU than fossil fuels for the first time.
- The EU has set a target to achieve 42.5% of renewable share in the EU's energy mix across all sectors by 2030 and has an additional indicative ambition to reach 45% by 2030.
- In this report, we look at national studies and global energy system models to assess how much the EU'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

- EU's wind and solar generation needs to grow by a factor of around two to two and a half by 2030 to align with a 1.5°C-consistent pathway. This equates to 1,618–1,861 TWh of wind and solar generation in 2030, up from 731 TWh in 2023.
- Almost 700 GW of new installed capacity of wind and solar would be needed by 2030 (580 GW of solar and 120 GW of wind). This would require average annual capacity additions of 78 GW/yr of solar and 20 GW/yr of wind from 2023-2030.
- EU's current rollout of solar is not progressing fast enough to achieve this. Under current policies and market conditions 81% of the solar capacity needed to align with 1.5°C will be installed by 2030. By contrast, projected wind capacity additions are broadly consistent with the levels required to align with a 1.5°C by 2030 under the same assumptions.



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 the **European Union (EU)**.

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

The EU's 2030 National Determined Contribution (NDC) commits to reducing net greenhouse gas (GHG) emissions by at least 55% below 1990 levels by 2030 (including LULUCF). The EU's 2035 NDC commits to reducing GHG emissions by 66.25%-72.5% below 1990 levels by 2035 (including LULUCF). These emissions targets seek to achieve the net zero GHG target set for 2050 under the European Green Deal strategy and made legally binding through the European Climate Law.

Under the revised Renewable Energy Directive, the EU has a binding target of 42.5% of renewable energy share in final energy consumption across all sectors by 2030, with an indicative ambition to reach 45% by 2030. This directive was revised to align it with the emissions reductions targets set under the European Climate Law and to phase out Russian fossil fuel import dependency after the Russian invasion of Ukraine, as set out under the REPower EU plan.

Under the REPower EU package, the European Commission has indicated that achieving EU's energy-independence objectives would require renewables to account for around 69% of electricity generation by 2030.

Under current policies, the IEA estimates that renewables will reach 63% of share generation in 2030 and that **solar capacity in the EU will reach 692 GW in 2030**, up from 271 GW of solar in 2023. Meanwhile, **wind capacity is projected to reach 369 GW in 2030**, up from 226 GW in 2023.

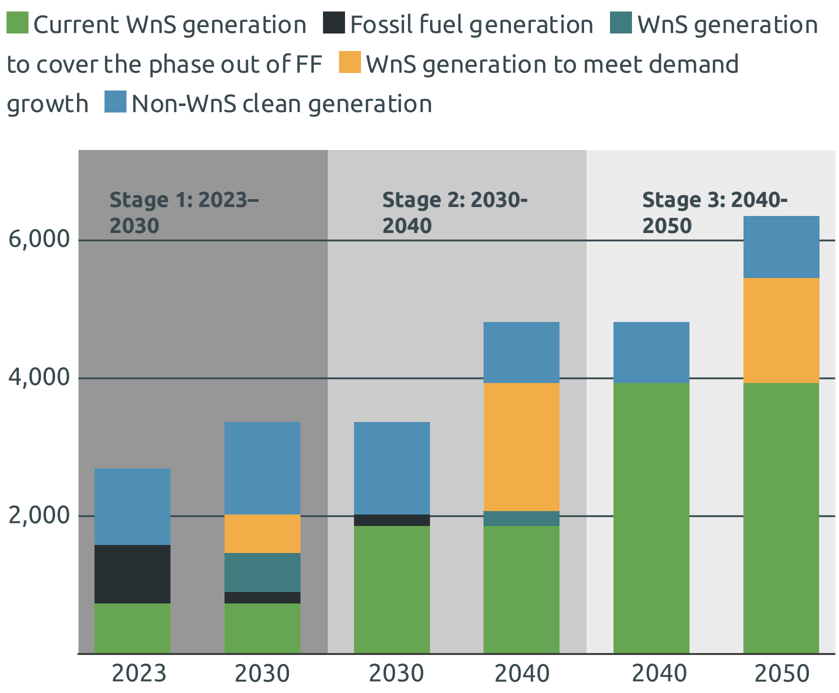
National enabling factors

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



The stages of the electricity system transition in the EU

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, the EU would need to add almost 59 GW of wind and 286 GW of solar capacity to meet growing demand alone. Another 61 GW of wind and 293 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 the EU in Phase D, with wind and solar making up 55% 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 1and 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 for the EU. 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 C		Phase D		Phase E		Phase E
Share of VRE	**< 40%**		**< 70%**		**> 85%**		**> 85%**
Share of electricity generation							
Wind & Solar	**27 %**		**55 %**		**82 %**		**86 %**
Other renewables	41 %		40 %		18 %		14 %
Fossil Fuels	**32 %**		**4.9 %**		**0 %**		**0 %**
Generation capacity							
To displace fossil fuels		**+350 GW**		**+140 GW**		**+0 GW**	
Wind & Solar	**500 GW**	**+100 GW/yr**	**1200 GW**	**+130 GW/yr**	**2500 GW**	**+60 GW/yr**	**3100 GW**
To meet demand increase		**+350 GW**		**+1200 GW**		**+560 GW**	
Generation							
Total	**2700 TWh**	26%	**3400 TWh**	41%	**4800 TWh**	33%	**6400 TWh**
Wind & Solar	730 TWh		1900 TWh		3900 TWh		5500 TWh
Generation Capacity of VRE (variable renewable energy)							
To displace fossil fuels			61 GW		20 GW		0 GW
Wind capacity	**230 GW**		**350 GW**		**540 GW**		**1100 GW**
To meet demand increase			60 GW		170 GW		560 GW
To displace fossil fuels			290 GW		120 GW		0 GW
Solar capacity	**270 GW**		**850 GW**		**2000 GW**		**2000 GW**
To meet demand increase			290 GW		1000 GW		8.7 GW

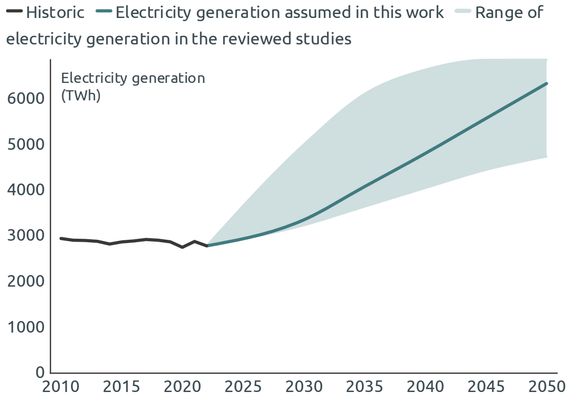
Note: Numbers are rounded to two significant figures, which may contribute to minor differences in totals. The calculations assume that wind, solar, and other renewables contribute equally and proportionally to displacing fossil fuels and meeting demand growth.

Future electricity demand

Electricity demand is taken from the European Commission's Impact assessment on a 2040 Climate Target. The aim of this assessment is to propose an EU-wide 2040 climate target to achieve climate neutrality by 2050. We take the electricity demand from the LIFE scenario developed in the assessment, which assumes sustainable lifestyles and a move towards a more circular and shared economy, translating into a different evolution of demand patterns for energy use in different sectors. This scenario was developed to illustrate how demand-side driven actions can complement the supply-side technology deployment required.

In this scenario, electricity generation in the EU doubles by 2050 relative to 2021 levels, reaching 6,354 TWh. This is driven by increased electrification across end-use sectors and demand for electricity to produce renewable fuels of non-biological origin (RFNBOs) such as green hydrogen.

Across the broader literature reviewed here, projected EU electricity generation in 2050 ranges from 4,753 TWh to 6,875 TWh. This wide range has major implications for the required deployment of wind and solar capacity. The demand estimate adopted here lies toward the upper end of country-level studies.



Electricity generation grows 2.4 times in the EU, partly to meet electrification across end-use sectors and production of RFNBOs

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

Figure 2 – Total electricity generation in TWh

Pace of fossil fuel phase-out needed

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

To align with 1.5°C, our modelling results show that fossil fuel generation falls by 52% to 81% between 2021 and 2030 and that fossil fuels must exit the EU power sector by 2035 while expanding renewables to meet growing demand.

To align with 1.5°C, the EU should phase out fossil fuels by 2035 and expand renewables to meet growing demand.

The EU would need to achieve clean electricity by 2035

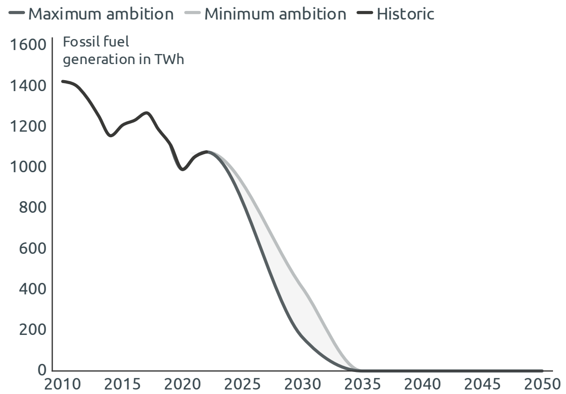


Figure 3 – Fossil fuel generation in TWh

Coal and gas phase-out in the EU

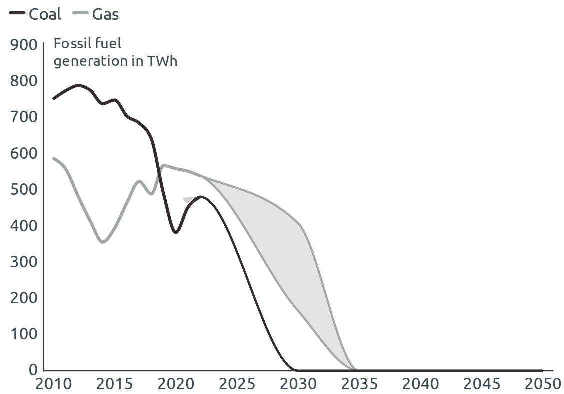


Figure 4 – Fossil fuel generation by fuel type in TWh

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 non-wind and solar clean technologies in the EU would reach 1,336 TWh by 2030 (40% of total generation) and 893 TWh by 2050 (14% of generation). This generation is provided largely from nuclear and hydro in 2030. In 2050, the generation comes mainly from hydro.

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 the EU would need to reach between 1,618 and 1,861 TWh by 2030**. Generation in 2023 was 731 TWh. This is therefore a two to two and a half-fold growth in wind and solar.

Wind and solar provides 48–55% of overall electricity generation in 2030, and 86% of overall generation in 2050. A grid powered almost entirely by wind and solar would require a substantial rollout of batteries and energy storage, support from dispatchable generation such as hydro and geothermal, flexible demand and grid extension to ensure reliability of the system.

To align with a 1.5°C pathway, EU wind and solar generation would need to at least double by 2030 relative to 2023 levels

Wind and solar generation in the EU needs to grow 2-2.5x by 2030 above 2023 levels.

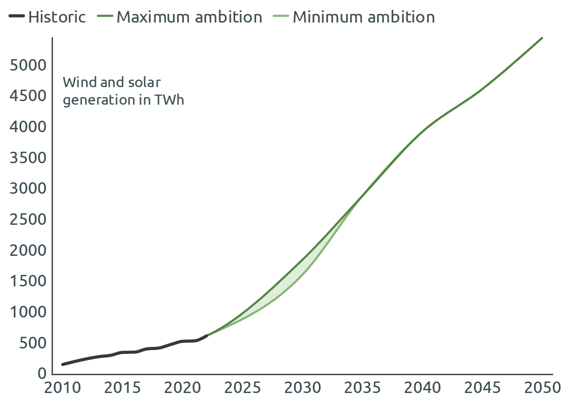


Figure 5 – Wind and solar electricity generation in TWh

Wind and solar need to provide over 86% of the EU's electricity generation by 2050.

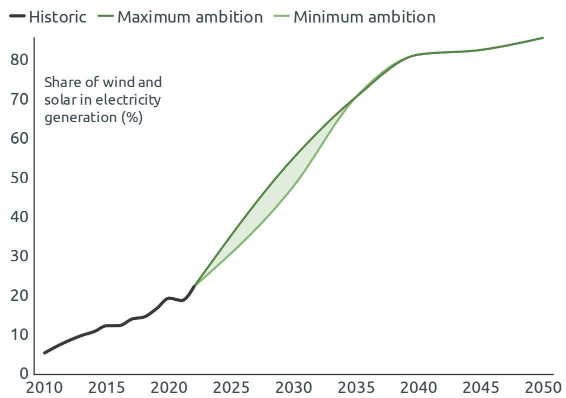


Figure 6 – Wind and solar electricity generation share (%)

* 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 split between wind and solar

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

We highlight the median of the range as our **central benchmark**, but do not suggest that this is the only possible breakdown between wind vs. solar. In the central benchmarking scenario, solar becomes the main source of electricity generation by 2030 across all generation technologies. It continues to grow until reaching its peak in electricity generation by 2040, and declines slowly after. By then, solar provides around 1.5 times as much generation as wind in the electricity mix. By 2050, wind overtakes solar to become the dominant source of generation across all technologies, delivering roughly 1.5 times as much electricity as solar.

In this scenario, **the EU would need to deploy almost 700 GW of new wind and solar capacity by 2030 to align with the 1.5°C temperature limit**. By 2050, total wind and solar capacity would need to reach over 3100 GW.

Importantly, these are cost-optimised modelled pathways that give a useful indication of the pace and scale of wind and solar deployment needed for 1.5°C, but they cannot fully the capture real-world context, where industry development, supply chains, workforce, and infrastructure will require stable and sustained development.

Sustaining this scale of deployment throughout the modelling period implies a profound acceleration of electrification across the EU economy. Such structural transformation would not only enable high renewable penetration but also strengthen regional energy sovereignty by reducing reliance on imported fossil fuels.

The EU needs to install almost 700 GW of wind and solar by 2030 to align with 1.5°C

Solar capacity in the EU would reach 850 GW by 2030 in a 1.5°C-aligned scenario

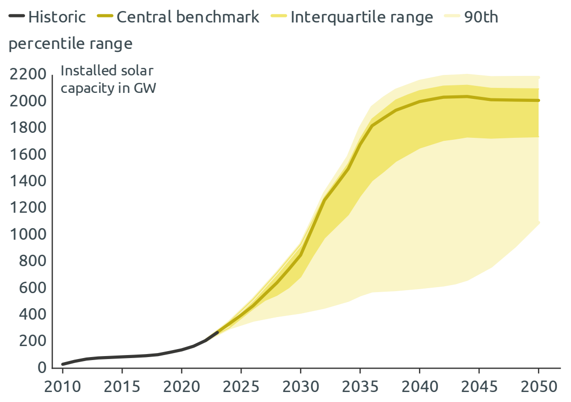


Figure 7 – 1.5°C compatible capacity benchmarks for solar in GW

Wind capacity in the EU would reach 350 GW by 2030 in a 1.5°C-aligned scenario

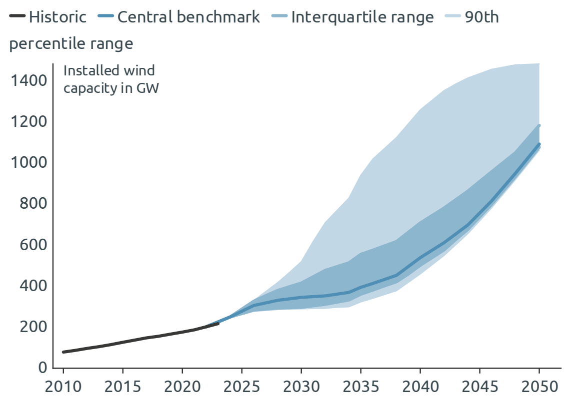


Figure 8 – 1.5°C compatible capacity benchmarks for wind in GW

The following table shows the wind and solar deployment needed to align with the central 1.5°C compatible benchmark produced. 2023 is historical data. All benchmark data from 2030 onwards is reported to two significant figures.

Table 2: Wind and solar electricity generation and capacity (2023–2050)

Scenario	Variable	Unit	2023	2030	2035	2040	2050
Central 1.5°Cbenchmark	Solar generation	TWh	293	1000	2000	2400	2300
Central 1.5°Cbenchmark	Wind generation	TWh	488	790	950	1500	3600
Central 1.5°Cbenchmark	Solar capacity	GW	271	850	1700	2000	2000
Central 1.5°Cbenchmark	Wind capacity	GW	227	350	400	540	1100

Table 3: Benchmarks translated into CAT format

Variable	Ambition	Unit	2030	2035	2040	2045	2050
Share of coal	Minimum	%	0	0	0	0	0
	Maximum	%	0	0	0	0	0
Share of gas	Minimum	%	12	0	0	0	0
	Maximum	%	5	0	0	0	0
Share of renewables	Minimum	%	71	93	98	99	99
	Maximum	%	78	93	98	99	99
Share of wind and solar	Minimum	%	48	48	82	82	86
	Maximum	%	55	55	82	82	86

Comparison to current rollout and country target

Under current policies and market conditions, deployment of wind and solar in the EU would be broadly close to 1.5°C-aligned levels for wind and solar. For **solar there would be a capacity gap of almost 160 GW** and for **wind an overcapacity of almost 20 GW** in 2030.

When compared to the indicative capacity levels communicated by the European Commission under the REPowerEU strategy – which are not legally binding but signal the scale of deployment required to meet emissions reduction targets and the EU's energy-independence objective – alignment appears mixed. **To align with a 1.5°C-consistent level, the REPowerEU solar target would need to increase by almost 260 GW**. Conversely, the indicative **wind target would exceed the 1.5°C-aligned benchmark by around 160 GW**.

Discrepancies between the REPowerEU targets and our modelling can be explained by two main factors. First, the REPowerEU package assigns a larger role to wind compared to solar PV, while our modelling favours solar due to its higher cost-effectiveness under current assumptions – which do not fully capture transmission constraints, spatial effects, curtailment or detailed integration costs, and could influence the relative balance between solar and wind.

In the development of the REPowerEU targets, non-wind and solar renewable technologies (excluding nuclear) play a more limited role, accounting for around 16% of total electricity generation in 2030. In contrast, in our modelling these technologies contribute a larger share, reaching 23% of total electricity production in 2030.

Comparing current deployment trends directly with the REPowerEU indicative levels shows that solar deployment is broadly on track to meet the Commission's 2030 indicative level, with a projected overcapacity of 100 GW. In contrast, wind deployment would need to accelerate significantly, with an additional 140 GW required to meet the 2030 indicative level.

EU's rollout of wind and solar are broadly aligned with 1.5°C

In the EU, current rollout of solar lags behind 1.5°C-aligned levels

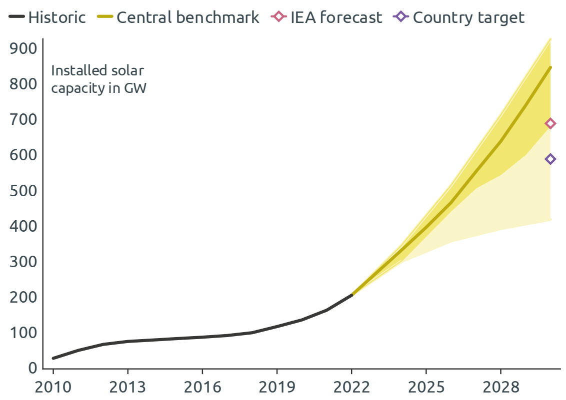


Figure 9 – Installed solar capacity in 2030 compared to targets and current policy projections in GW

In the EU current rollout of wind is consistent with 1.5°C-aligned levels

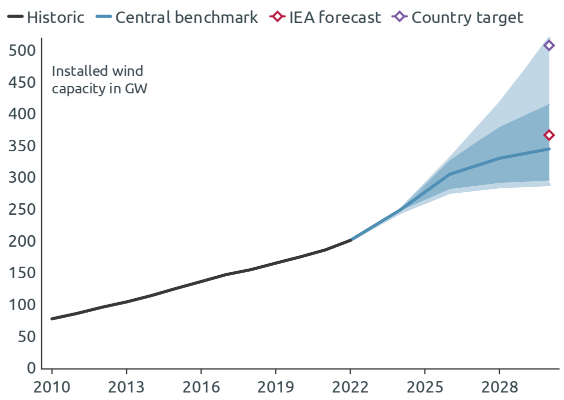


Figure 10 – Installed wind capacity in 2030 compared to targets and current policy projections in GW

Note: The target data was last pulled from Ember in January 2025. The current policies data was last pulled from the IEA in February 2026.

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

The EU would need to add, on average, 78 GW/yr of solar capacity by 2030, and 66 GW/yr over 2030–2050, compared to 35 GW/yr from 2020–2023

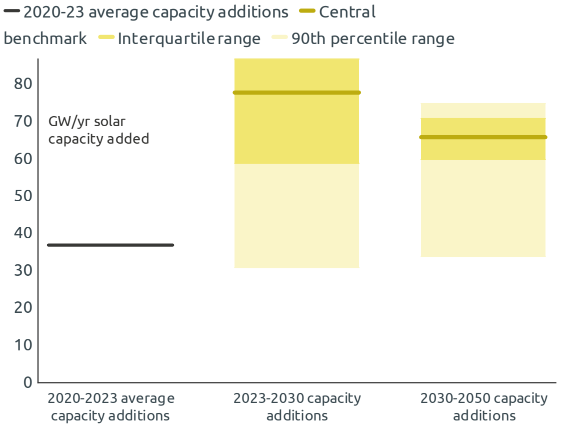


Figure 11 – Solar capacity additions per year in GW/y

The EU would need to add on average 20 GW/yr of wind capacity by 2030, and 44 GW/yr over 2030–2050y, compared to 13 GW/yr from 2020–2023

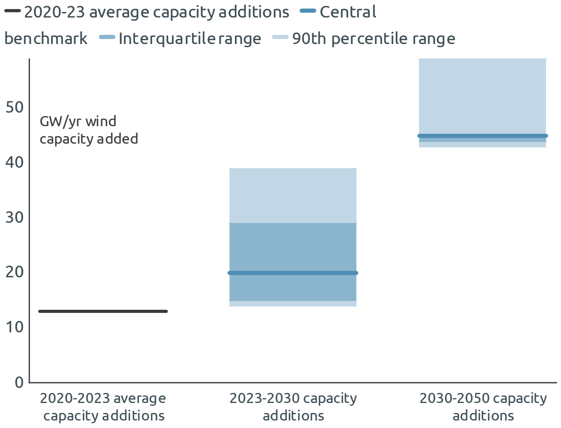


Figure 12 – Wind capacity additions per year in GW/y

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 Impact assessment on a 2040 Climate Target, exploring an EU-wide 2040 climate target aligned with the European Climate Law, which sets the goal to become climate neutral by 2050.

Our modelling results for wind and solar generation are broadly within the range reported in the national literature for solar, though towards the higher end of that range. In contrast, wind deployment in our modelling differs more noticeably from the literature, particularly in 2030, reflecting differences in cost assumptions, technology preferences and system constraints across studies.

Our benchmarks are broadly aligned with the literature

Electricity generation from solar: comparison with EU literature

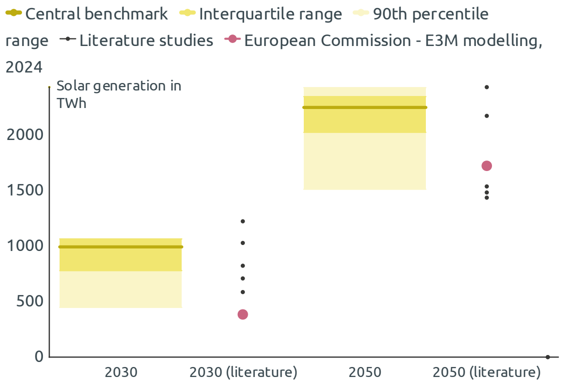


Figure 13 – Solar electricity generation in TWh

Electricity generation from wind: comparison with EU literature

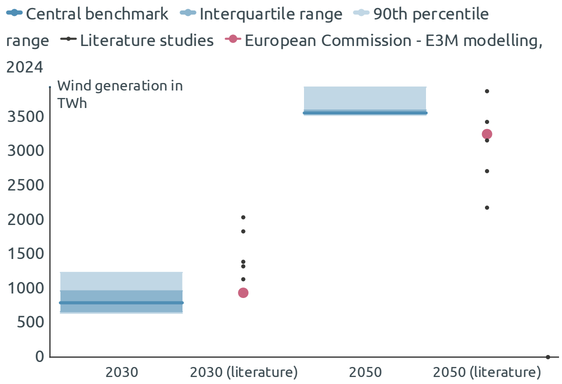


Figure 14 – Wind electricity generation in TWh

In the EU, our benchmarks generally suggest a relatively even contribution of wind and solar

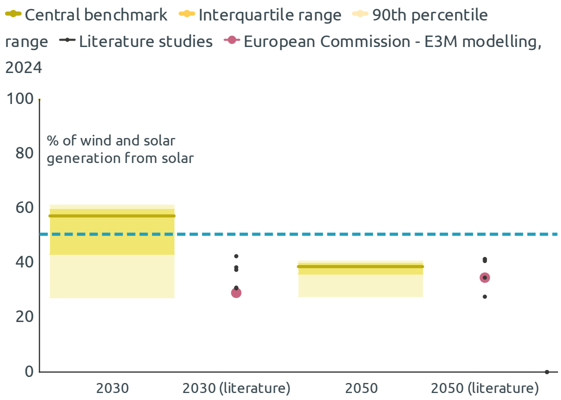


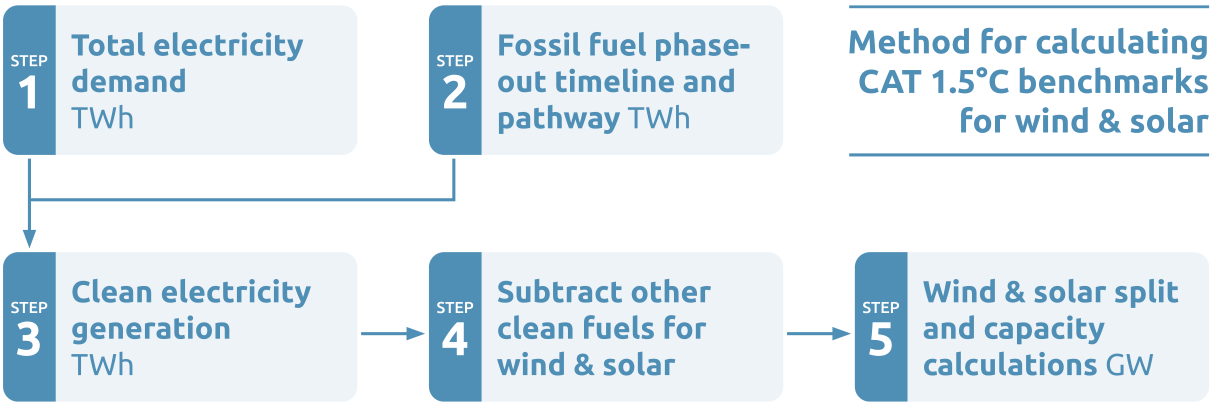
Figure 15 – Generation split between wind and solar (%)

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

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

Methodology

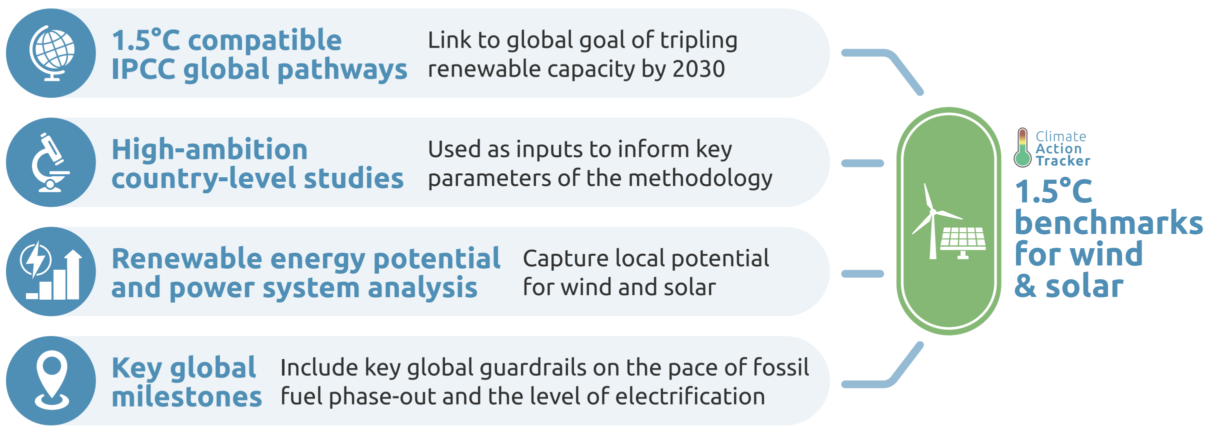
Summary of our method



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 4: Country level studies for the EU

Study	Publication	Scenario selected
CAN Europe & European Environmental Bureau, 2020	Building a Paris Agreement Compatible (PAC) energy scenario	PAC scenario
H. Auer et al., 2020	Development and modelling of different decarbonization scenarios of the European energy system until 2050 as a contribution to achieving the ambitious 1.5 ◦C climate target	• Societal commitment • Directed transition
Agora, 2023	Breaking free from fossil gas	EU gas exit pathway
Ember, 2022	Building a clean European electricity system by 2035	System change pathway
IRENA, 2025	Regional energy transition outlook	Decarbonising energy
European Commission, 2024	Impact assessment on a 2040 Climate target	Life

Annex A

Phases of grid integration

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

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

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

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

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

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

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

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The Consortium

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

climateactiontracker.org

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

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

newclimate.org