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Setting 1.5°C compatible wind and solar targets

Guidance for key countries

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Summary

At COP28, the world committed to tripling renewable capacity by 2030. This represents a key action that governments can take to cut emissions in line with the 1.5°C warming limit. All countries are also called upon to submit new 2035 climate targets by early next year. Providing ambitious targets, including for wind and solar rollout, can help turn the tripling goal into action and close the gap to 1.5°C, while also achieving universal electricity access by 2030.

To help guide national target setting, we have produced 1.5°C compatible wind and solar benchmarks for 11 key countries, responsible for over 70% of global wind and solar deployment. As wind and solar will be the backbone of the energy transition, setting specific targets for them could become the defining policy action in global efforts to limit warming to 1.5°C.

Key findings:

- → On average, wind and solar capacity needs to grow five times by 2030, and eight times by 2035, to align with 1.5°C.
- → To close the renewables capacity gap in 2030, countries need to install on average three times more wind and solar a year over 2023-2030 compared to the average pace achieved since 2020.
- → While solar grows faster than wind, wind provides more electricity than solar across the 11 countries until the mid-2030s. By 2050, solar provides around half of total electricity generation, and wind around a third.

National results

There is no single way to translate global goals to the national level. A country's wind and solar rollout depends on a range of factors, including forecast electricity demand, the pace of fossil phase-out needed, the availability of other renewable technologies like hydropower and geothermal, and the split between wind and solar. The benchmarks presented here offer one interpretation of global targets translated to the national level, drawing from both global and national evidence to capture the key factors mentioned above. → Table ES 1 highlights the total wind and solar capacity that needs to be installed by 2030 and 2035 in each country to align with our benchmarks.

Country	2022 levels (GW)	2030 benchmark (GW)	2035 benchmark (GW)
Australia	44	170	310
Brazil	50	140	200
China	794	4500	6600
Germany	133	400	510
Indonesia	<1	100	270
India	126	620	1200
Mexico	18	98	150
Nigeria	<1	54	120
Türkiye	22	91	150
South Africa	9	66	100
United States	281	1300	2000

Table ES 1 **Wind and solar benchmarks for a 1.5°C world**

Developed countries need to take the lead in phasing out fossil fuels and achieving a clean power sector by 2035. However, they often have smaller relative scale-up rates than other countries as they tend to start from a larger existing base of installed wind and solar and see lower levels of electricity demand growth.

Emerging markets and developing economies (EMDEs) have a slower rate of fossil phaseout, achieving clean power around 2040. However, they are often projected to have higher levels of future electricity demand, driven by faster economic growth and progress on energy access. Typically starting from a lower base of existing wind and solar, their relative scale-up rates are also higher.

Key country-level results:

→ **China needs to reach 4.5 TW of wind and solar by 2030 to align with 1.5°C.** This is needed to meet rapidly growing electricity demand in China, and to also displace large volumes of coal on the road to fossil-free power by 2040. The rollout of solar is broadly on track with 1.5°C in China, but wind deployment needs to accelerate further.

- India is set to more than triple wind and solar capacity by 2030 compared to 2022 but would need further international support, including climate finance, to **scale five-fold to over 600 GW to meet growing demand and move away coal dependence in line with 1.5°C.**
- **South Africa would need to reach almost 70 GW of wind and solar by 2030 to align with our benchmarks.** Shifting away from an ageing and unreliable coal-fired fleet could help meet South Africa's electricity needs, while also cutting emissions in line with the Paris Agreement. International support, including via the JETP, can help catalyse this transition.
- Australia's wind and solar generation under current policies is set to grow 2.5-fold by 2030, but instead **would need to grow four to five times by 2030 from 2022 to align with 1.5˚C:** almost 170 GW of wind and solar capacity would be needed by 2030.
- **The United States needs to grow wind and solar capacity almost five-fold by 2030, reaching almost 1400 GW of installed capacity** in the central benchmark presented here. The Inflation Reduction Act is helping to accelerate wind and solar deployment, but more would need to be done to ensure that the United States achieves its target of a clean power sector by 2035.
- Germany's targets for renewables rollout in 2030 are broadly aligned with 1.5°C, and could help phase out of fossil fuels in the power sector. **The government should make a clear commitment to fossil-free power by 2035 and would need over 500 GW of installed wind and solar capacity to achieve this.**
- Indonesia is only just beginning the transition to wind and solar. **To meet future electricity demand while phasing out coal power, almost 110 GW of wind and solar would be needed by 2030,** with the majority of this coming from solar. International support will be critical to delivering this.
- Brazil would need to reach almost 140 GW of wind and solar by 2030 to align with 1.5°C. **Brazil's current pace of wind and solar deployment puts it well on track to achieving this benchmark.** As such, investments in fossil gas power stations represent a needless economic and climate risk.

- Mexico's power sector transition has faltered in recent years, as policy support has shifted from renewables to fossil gas. To get back on track and align with 1.5°C, around **80 GW of solar and 20 GW of wind would need to be installed by 2030.** Current rollout is far behind this rate and needs accelerating.
- Nigeria has abundant wind and solar potential, but investment levels would need to scale up considerably to meet our benchmarks. International support, including concessional and grants-based finance, will be crucial. **To meet electricity demand growth while reducing reliance on diesel and gas in the power sector, over 50 GW of wind and solar would be needed by 2030.**
- **Türkiye would need to reach just over 90 GW of wind and solar by 2030 to align with 1.5°C.** This would be equivalent to achieving the 2035 targets set by the National Electricity Plan five years early. By 2035, 120 GW of solar and 30 GW of wind would be needed to align with these benchmarks.

For a deep dive into the wind and solar rollout of each country, see the country briefings that accompany this report.

Enabling conditions for achieving the benchmarks

These benchmarks are not just about deploying wind and solar – they are about a whole system transition at pace and scale. This will require grid expansion, deploying energy storage, demand-side management, early retirement of fossil assets, a just transition and more. The falling cost of batteries will be a key enabler of ambitious wind and solar rollout.

Achieving these benchmarks is a collective responsibility. International collaboration will be particularly important to address barriers to the renewables rollout in some EMDEs. There is no single silver bullet which can overcome these; a range of actions will be needed:

- While wind and solar are cost-effective technologies, EMDEs need access to low-cost capital to make investments viable. Advanced economies should provide concessional finance to bridge the gap to private capital, helping crowd-in investment and reduce capital costs.

- Grants-based financing and capacity building, including to develop and support institutional frameworks, will also be needed to help low-income developing countries navigate the broader system implications of transition, such as grid expansion and the early retirement of fossil assets.
- EMDE governments also have a responsibility to set clear and ambitious renewables targets, resist fossil interests, and revise energy sector governance frameworks – all will be essential to creating an enabling environment for wind and solar deployment.
- A just transition is essential to ensure that the global shift to renewables is equitable and inclusive. As investments in renewables reshape the energy landscape, we risk leaving the most vulnerable behind if the transition is not approached from a just perspective. Focusing on a just transition ensures that the benefits of decarbonization, such as new jobs, economic growth and cleaner air, are widely shared, while the burdens, such as job losses in fossil fuel sectors, are mitigated through targeted support and inclusive policies.

The race to wind and solar is just beginning to gather pace. By setting ambitious targets for wind and solar in the next set of climate targets, pairing this with credible implementation and delivery plans, and underpinning this with increased international collaboration, the world can deliver the step-change in action needed and help close the gap to 1.5°C.

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01 Introduction

At COP28, the world committed to tripling global renewable energy capacity by 2030 as part of a package of measures to bring climate action globally in line with the Paris Agreement's 1.5°C warming limit (UNFCCC 2023). This is crucial, as tripling renewables, alongside doubling energy efficiency, is one of the most powerful levers we have for cutting emissions at the pace needed this critical decade (IEA 2023). Together, these steps are the cornerstone of an energy transition which phases out fossil fuels in line with 1.5°C.

Wind and solar have emerged as the leading technologies in the energy transition. Enabling policies and technological advancement have driven rapid cost reductions, making wind and solar some of the most promising solutions for reducing greenhouse gas emissions, particularly in the power sector (IPCC 2022). They have consistently outperformed cost projections (Jaxa-Rozen and Trutnevyte 2021), making them not only key mitigation technologies but also the lowest–cost option for new electricity generation in most of the world (IEA 2024a). The scalability of wind and solar ensures they can meet the growing demand for electricity while displacing fossil fuels, offering a pathway to substantial emissions reductions.

Moreover, the clean energy transition presents a range of economic and social benefits. By investing in wind and solar power, countries can stimulate innovation, create jobs, improve energy security, enhance energy access, reduce local air pollution, and provide clean power for economic development. Wind and solar are critical to ensuring access to electricity for the estimated 775 million people without it by 2030, 600 million of whom are in Africa (IEA 2023). These technologies are key to decarbonising other sectors of the economy through electrification, powering everything from electric vehicles to green hydrogen production, while for poorer developing countries, they provide the central basis for clean economic development and growth.

Despite their promise, current deployment levels of wind and solar energy fall short of what is needed to stay below the 1.5°C warming limit. Their expansion remains concentrated in a limited number of countries and regions, such as China, the United States, Brazil and Europe, leaving many other parts of the world at risk of lagging behind (IRENA 2024, IEA 2024a).

According to the most recent assessments, only 15% of global clean energy investments are made in Emerging Market and Developing Economies (EMDEs) excluding China (IEA 2024d). The high cost of finance and a lack of appropriate financial instruments and modalities for highly indebted countries is one key barrier limiting the reach of these technologies (Climate Analytics 2022), as well as incumbent fossil interests, weak policy frameworks and a lack of clear understanding of how renewables can support national development priorities.

While the collective commitment to triple renewables represents high ambition, the success of this global goal depends on the actions of individual nations. Governments therefore need guidance to align their deployment of key technologies like wind and solar with their international commitments to both triple renewables and limit warming 1.5°C.

This report and its accompanying series of country briefings provides a roadmap for a 1.5°C-aligned rollout of wind and solar energy for 11 countries: Australia, Brazil, China, Germany, India, Indonesia, Mexico, Nigeria, South Africa, Türkiye and the United States. These benchmarks can be used to inform ambitious sectoral target setting, for instance as part of the upcoming Nationally Determined Contribution (NDC) updates, helping countries demonstrate climate leadership and commitment to the 1.5°C goal. Setting specific NDC targets on the renewables rollout would help action the tripling goal agreed at COP28.

The benchmarks in this report go beyond the goal to tripling renewable energy capacity by 2030 to ensure global warming is kept below 1.5°C by the end of the century. By translating global targets into national benchmarks, this report shows the levels of wind and solar generation, capacity and capacity additions needed by key dates in the energy transition for each of the selected countries.

The benchmarks provide clear pathways for countries to follow, adapted to their unique national circumstances. Grounded in national studies and global energy system modelling, they provide national energy transition roadmaps to show how countries can move away from economic reliance on fossil fuels, develop localised clean industries, create new jobs, and drive economic growth with renewable energy.

International collaboration will be essential to achieving the benchmarks

While the benchmarks offer a useful starting point, they should not be interpreted in isolation. They must also be viewed through the lens of equitable climate action, reflecting the principle of “common but differentiated responsibilities and respective capabilities.” Each country’s energy transition is shaped by its specific economic, social, and political context. Similarly, these benchmarks must be understood within the broader needs of the energy transition relevant to each country, such as industrial and economic development, energy affordability, overcoming energy poverty and the need for a just transition.

International collaboration will be essential to achieving these benchmarks. Current investments in wind and solar are largely concentrated in a few countries, mainly advanced economies and China (although some other countries including Kenya and Viet Nam have seen growth). Catalysing investment in other EMDEs outside China is crucial if the world is to leave no one behind in the transition to renewables. Increased private investment will be particularly important, as the scale of finance needed far exceeds available public resources. While wind and solar have proven themselves to be viable private sector investments in many contexts, in others they still face risks (real or perceived) which are hampering investment flows (IEA 2024b).

Addressing this will require joint action from both EMDE governments and the wider international community. EMDE governments have a key role to play in creating an enabling environment for public and private investment in renewables. This requires signalling a clear direction of travel, such as by setting ambitious renewable capacity targets in NDC updates, and clarity on the mix of technologies and timelines by which these targets will be achieved. It will also require revised energy sector governance and policy frameworks which align with the transition from fossil fuels to renewables, resisting incumbent fossil interests that seek to slow the transition to wind and solar, and addressing just transition needs.

In addition to the efforts of EMDE governments, the international community needs to take action to address key barriers to the energy transition. This includes catalysing investment in renewables and supporting EMDEs in navigating the broader systemic challenges associated with the rapid transition to clean electricity. Advanced economies play a key role in providing concessional finance, which can help mitigate investment risks, lower the cost of capital and attract private investment in renewable energy projects. There is also a need to develop novel green financing instruments that address some of the barriers to investment in EMDEs, such as green bonds, sustainability-linked loans and guarantee funds which can help mitigate risks.

However, boosting investment in renewables is just one part of the puzzle. Wind and solar deployment will need to be accompanied by grid expansion, the development of institutional frameworks, early retirement of fossil fuel assets, and planning for a just transition and new clean industry value chains. Crucially, all of this will need to happen at sufficient scale and pace in EMDEs. In this context, grant-based climate finance will be an essential part of the transition package.

Action on climate finance is central to driving the clean energy transition. With coordinated action from both EMDE governments and the wider international community, a global energy transition which leaves no one behind is achievable.

The benchmarks in this report lay out a path towards a power system dominated by wind and solar. Achieving this will require strategies that integrate large-scale variable renewables into the system via energy storage, grid expansion, demand-side management, and firm zero-carbon generation, such as hydropower and geothermal. In each country, decisions will need to be made on the basis of their own resources and infrastructure. This analysis does not explicitly model such strategies, however, they are indirectly captured via the integration of detailed country-level studies, where applicable. Additional research could further explore the infrastructure required in each country to support the scale of wind and solar deployment outlined in this report.

The 1.5°C-aligned national wind and solar benchmarks provided offer a clear and actionable pathway to accelerate the deployment of renewable energy and drive meaningful progress in the fight against climate change. The following section provides a brief overview of the methods used to produce the benchmarks. The results are presented in → Section 3 and → Section 4. → Section 5 explores how these benchmarks align with the tripling goal, while → Section 6 concludes.

02 Methods

The benchmarks presented in this report and the accompanying country briefings are produced using a step-by-step method to calculate the level of wind and solar deployment needed to meet electricity demand growth and phase out fossil fuels. This method has been fully documented elsewhere (NewClimate Institute and Climate Analytics 2023), and is summarised in brief here.

Multiple analytical elements are taken into account when producing these benchmarks. Bringing together different elements, each with their own strengths, can help derive robust benchmarks.

The analytical elements considered by the method are:

- → High ambition country-level studies which capture key elements of the power system transition and are performed using detailed energy system analyses. These help capture key elements of the power system transition in any given country and ensure that our benchmarks are based on a good understanding of power system dynamics and, where possible, in-country knowledge and modelling.
- → 1.5°C compatible pathways as assessed by the IPCC (IPCC 2022a), filtered to avoid unsustainable reliance on carbon dioxide removal (Climate Analytics 2023), and downscaled to the country-level (Climate Analytics 2024a). These help set the overall level of ambition of the benchmarks and ensure that they are aligned with the 1.5°C warming limit.
- → Key global milestones on power system transformation, taken from the IEA's net zero scenario (IEA 2023). This means that our benchmarks capture the central transformations seen in the IEA's modelling around fossil phaseout in the power sector.
- → Renewable energy potential and power system analysis. This ensures that the benchmarks are informed by the techno-economic potential for wind and solar in each country.
- → Stakeholder feedback. Where possible, we have taken into account feedback from in-country stakeholders and organisations to improve the underlying method and to guide its application in any given country.

→ **Figure 1** shows how the above aspects are considered in a step-by-step method to derive the benchmarks.

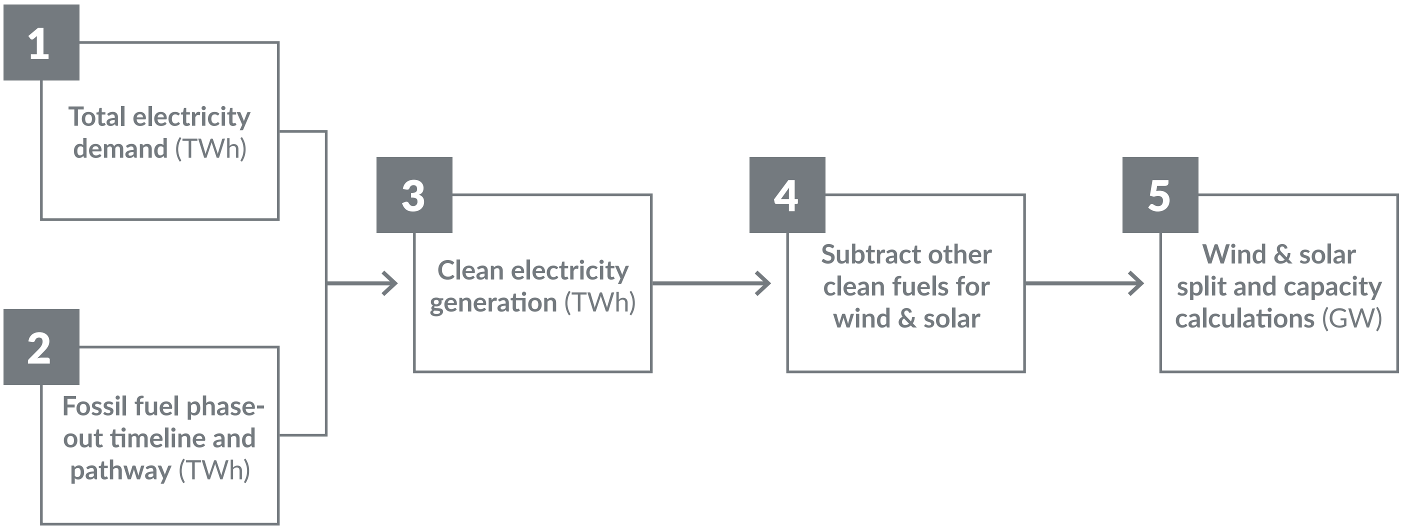

Figure 1 **Summary of the step-by-step method used in the analysis**
The figure shows the central benchmark per country. The dashed line separates wind and solar generation into pre- and post- 2022 (as the year against which the tripling target is generally measured). For more detail on individual country results, see the individual country briefings.

In the following section, we provide a brief summary of how each analytical element is used across the different steps. For more details see NewClimate Institute and Climate Analytics (2023).

1. An electricity generation projection up until 2050 is selected from a high ambition country-level study, using stakeholder feedback to identify the most robust assumptions around electricity demand growth.
2. The fossil fuel phase-out pathway is determined by an overlap of three different elements. These are the high-ambition country-level studies, downscaled 1.5°C compatible pathways, and key global milestones from the IEA's net zero scenario, in which advanced economies, China and emerging economies achieve clean power in 2035, 2040 and 2045 respectively. Our method focuses on a corridor of fossil fuel phaseout which is in line with all three elements. Using multiple different analytical elements can enhance the robustness of the analysis.

3 The level of clean electricity generation needed to meet electricity demand growth and phase out fossil fuels is obtained by subtracting the remaining future fossil generation from the future electricity generation.

4 Projections of clean electricity generation from non- wind and solar technologies (hydroelectricity, biomass, other renewable resources, and nuclear) are taken from country-level studies. These are subtracted from the total clean electricity generation to calculate the wind and solar generation needed.

5 A detailed geospatial potential analysis is used to calculate the technical potential of wind and solar. This wind and solar generation potential is then fed into a simplified power system model to determine a cost-optimal split of wind and solar in the country and provide the final generation and capacity requirements per technology. Where a country has existing targets for wind and solar deployment, these set the minimum deployment bounds in our model. However, our method determines the split between wind and solar primarily on cost assumptions. There are a range of other factors (e.g. policy preferences in country, permitting times, access to grid connections[1] and more) which could also influence the split between wind and solar, but are not fully included in this method.

1
We do not explicitly model the grid in our simplified model, with each country modelled as a single demand centre that can be met by wind and solar generation across the country. However, when selecting and reviewing high-ambition country-level studies, we prioritise those which explicitly model grid expansion, to capture this key transition dynamic where possible. Future work could explore the level of grid expansion required to achieve the benchmarks presented here in more depth.

03 Wind and solar benchmarks aligned with 1.5°C

3.1 The next decade is crucial for scaling up wind and solar generation

The wind and solar rollout needs to accelerate rapidly through to 2030, 2035 and beyond to limit warming to 1.5°C. Over the 11 countries analysed, on average wind and solar generation grows 5-6x by 2030 relative to 2022 levels, and 8x by 2035.

→ Figure 2 shows the level of wind and solar generation each of the analysed countries would need to reach to align with 1.5°C, and the breakdown into wind and solar. It also shows the aggregate results for all 11 countries summed together.

In this report, we focus on the central benchmark in each country. This is set by the median of a distribution of scenarios which explore a range of possible future costs for wind and solar technologies (NewClimate Institute and Climate Analytics 2023). The relative share of wind and solar deployment will vary depending on various factors, including resource potentials, cost assumptions, social acceptance and power system considerations (such as the spatial and temporal distribution of wind and solar and how this overlaps with existing and future load patterns). While this report focuses on a single number, we do not suggest that this is the only possible breakdown into wind and solar. There is a wide range of other possible splits into wind versus solar in each country. For more detail on individual country results, please see the individual country briefings.

The period with the most rapid growth rates is the path out to 2035, with wind and solar generation growing at an average rate of 17% per year from 2022–2035 in these benchmarks across the 11 countries. The pace of growth slows to 7% per year in the 2030s, and down to 3% per year in the 2040s. The next ten years remain the critical window for driving fossil fuels out of the power sector while meeting growing electricity demand.

The specific rollout required in our analysis for any given country is influenced by the availability of wind and solar resources, the pace at which fossil fuels need to phaseout, and the anticipated level of electricity generation growth. Thus, there is no single rate of scale-up of wind and solar that can be applied to all countries, and no single split into wind versus solar. In some countries,

Figure 2 **Wind and solar generation needed to align with 1.5°C for selected countries**

The figure shows the central benchmark per country. The dashed line separates wind and solar generation into pre- and post- 2022 (as the year against which the tripling target is generally measured). For more detail on individual country results, see the individual country briefings.

our benchmarks suggest a relatively even contribution of wind versus solar by 2050 (such as the USA or Australia), while in others either wind dominates (such as Brazil and Germany) or solar (such as South Africa or Türkiye).[2]

Translating global goals such as tripling renewables or limiting warming to 1.5°C to the national level requires careful consideration of country context. Each of the accompanying country briefings provides more detail on the power system transition in a given country and what this means for wind and solar rollout.

→ **Figure 3** shows the share of electricity demand which is met by wind and solar in each country.

Across the countries analysed as a whole, solar provides more electricity generation than wind in 2050, with roughly 50% of all electricity generation coming from solar, and 33% from wind.[3] This is a similar split in wind and solar generation to that seen in the IEA's net zero scenario (IEA 2023), although overall wind and solar provides more generation in 2050 (83%) in our benchmarks than the IEA scenario (72%). For more information on how our benchmarks compare to the IEA's modelling, see → **Section 5**. Across the 11 countries analysed in aggregate, while solar is the largest source of generation in 2050, until the mid 2030s, wind provides more electricity generation than solar. This highlights the critical role that wind plays in providing clean electricity generation to displace fossil fuels and drive electrification, particularly in the near-term.

These benchmarks chart a path to a power system in which wind and solar provide the majority of electricity generation by mid-century. Given the variable nature of wind and solar generation, there will need to be a corresponding deployment of a range of complementary solutions to enable large-scale integration of wind and solar. This includes transmission expansion, demand-side flexibility, sector coupling, flexible zero-carbon generation from other sources, and batteries and energy storage to enable the high penetration of wind and solar into electricity grids nationally and hence globally.

Deployment of storage capacity, particularly batteries, will need to increase at least six-fold by 2030 in order to achieve a tripling of renewable capacity (IEA 2023). Battery costs are dropping rapidly and batteries are becoming increasing cost effective in utility scale applications, with cost reductions of close to 50% expected by 2030 (Cole and Karmakar 2023). Battery manufacturing capacity could exceed 9 TWh by 2030 if the current project pipeline is successfully realised, 90% of the level required by the IEA's net zero pathway, and therefore close to what would be needed in the scenarios outlined here.

2
Our research focuses on finding a cost-effective split into wind versus solar in each country, based on the renewable potential in the country. Other considerations could influence this split into wind and solar.

3
The remaining 17% comes from other clean electricity sources, most notably hydropower, but also including biomass, geothermal, other renewables and nuclear.

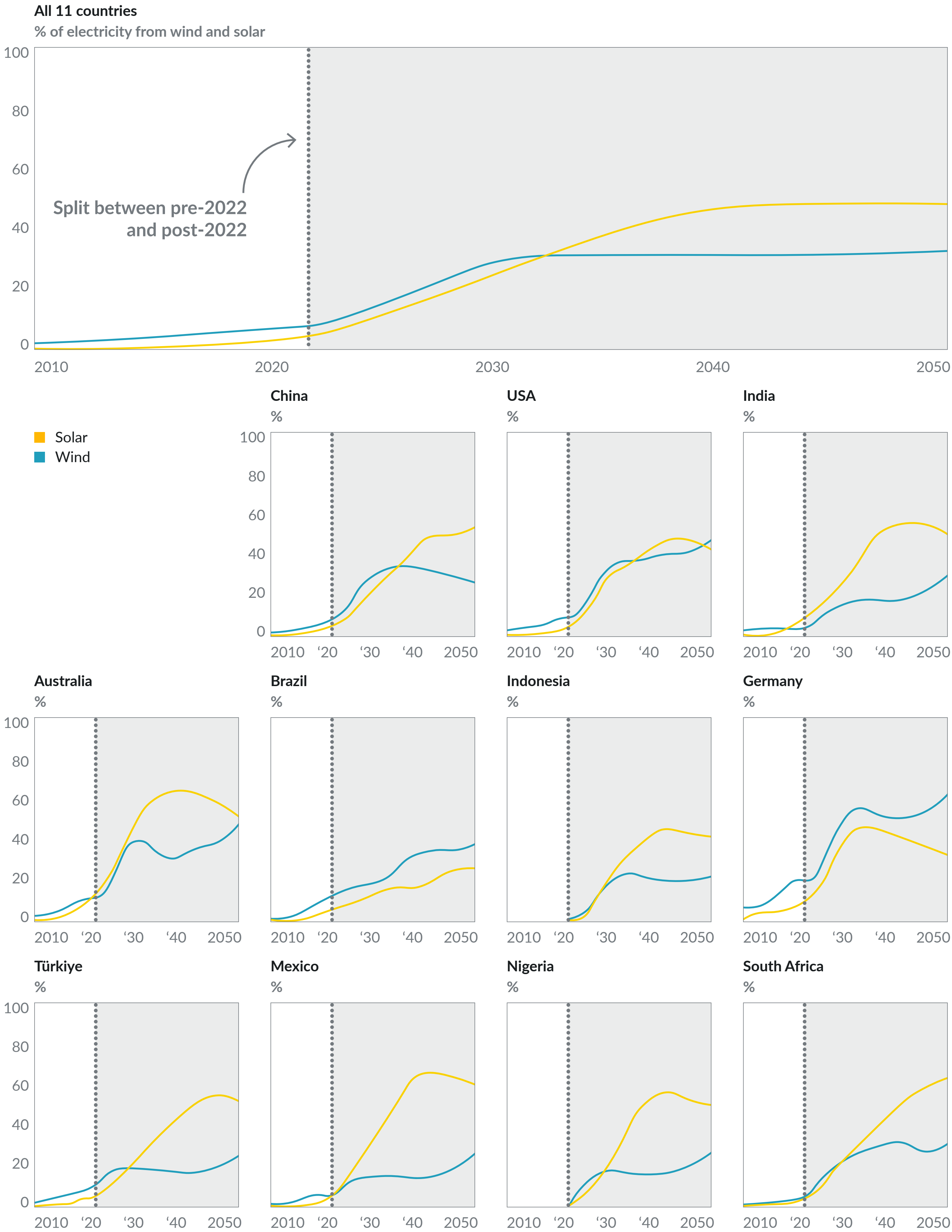

Figure 3 **The share of electricity generation from wind and solar in selected countries**

The figure shows the central benchmark per country. For more detail on individual country results, see the individual country briefings. The dashed line separates wind and solar generation into pre- and post- 2022.

3.2 All countries need to rapidly increase wind and solar capacity, but differences remain

To limit warming to 1.5°C and deliver at least a tripling of renewables, wind and solar capacity will need to scale around five-fold by 2030 and eight-fold by 2035. This will require a significant acceleration in the level of annual wind and solar capacity additions, which need to triple over the remainder of this decade.

→ Table 1 presents the wind and solar capacity that would need to be installed by 2030, 2035 and 2050 to align with 1.5°C. It also shows the scale-up of wind and solar capacity in 2030 relative to 2022 (as the year against which the tripling goal is measured). This national level roadmap for action can inform the renewable capacity targets which could be used to inform the next round of NDC updates.

In all countries assessed, rapid deployment of wind and solar electricity is a central part of ambitious emissions reductions in line with 1.5°C. While not all countries may need to triple renewable capacity by 2030 in order to deliver a cost-effective global tripling (Climate Analytics 2024b), all countries do need to accelerate wind and solar deployment. Even in Brazil, where renewables already provide around 88% of electricity generation, wind capacity doubles and solar capacity triples by 2030. This is to meet both growth in electricity demand and phase out the remaining fossil fuels in the power sector. By 2035, all countries scale wind and solar capacity by at least four times relative to 2022, while for the group of countries as a whole, wind and solar capacity grows eight times over 2022-2035.

However, while rapid wind and solar deployment is a consistent theme across all countries, there are differences in the relative scale-up rate between different countries (see the final column in → Table 1). These relate particularly to the **level of electricity demand growth expected, the pace of fossil phase out required, the level of reliance on other technologies to provide zero-carbon electricity, the level of wind and solar a country had already installed by 2022, and the split into wind versus solar in the country.** These issues are discussed in more depth below.

Growth in electricity demand

Electricity will largely power the clean energy system of the future. Demand for electricity will grow due to economic growth, but also as buildings, industry and transport are increasingly electrified. Wind and solar will be needed to meet this growing electricity demand and unlock emissions reductions across the economy. **The greater the rate of electricity demand growth, the faster wind and solar need to be deployed to meet this demand.**

In all 11 countries assessed, we see strong growth in electricity demand, with generation broadly set to double by 2050, or grow even faster. Our estimates of future electricity demand are set by national studies which capture the growing electrification of the energy system, as well as general growth in energy demand due to economic growth. On average, the direct electrification rate in our country-level scenarios rises from 19% today to 50% by 2050, as electricity displaces fossil fuels in industry, buildings and transport.

However, the level of growth in electricity demand by 2030 varies strongly across countries, as well as the underlying drivers for this growth. In some countries such as the United States and Germany, electricity demand only grows 7% and 11% over 2022–2030. These are high-income countries with slower rates of economic growth, where electricity demand has historically been broadly stable over recent years. While demand in these countries begins to grow (driven largely by electrification) the level of growth seen by 2030 is lower than in China, India, Indonesia and Nigeria, where electricity demand is currently growing rapidly (driven particularly by robust economic growth, as well as the emerging signal of electrification) and is set to continue to do so. The lower level of electricity demand growth seen in Germany and the United States reduces the level of wind and solar scale-up seen in these countries.

Pace of fossil phaseout

The pace of a country's phaseout of fossil fuels in the power sector is dependent on two factors – the existing level of fossil fuels in the mix in 2022, and the date by which a country needs to reach clean power. **The faster fossil fuels need to exit the power sector, the more rapidly wind and solar needs to be deployed to displace them.**

In our benchmarks, advanced economies lead the phaseout of fossil fuels in the power sector, achieving clean power by 2035. All else being equal, this would lead to them having greater rates of wind and solar scale-up than other countries. Meanwhile, Brazil has one of the lowest scale-up rates of wind and solar, largely because there are very little fossil fuels in the power system to displace in the first place.

Reliance on non- wind and solar electricity generation

These benchmarks map out a path to a fossil-free power sector. Wind and solar are the driving force of this transition but are not the only technologies used to displace fossil fuels. Other renewables such as hydropower, geothermal and (limited) biomass, as well as nuclear, can play a role. We estimate the role of non- wind and solar generation in each country using an in-depth review of high ambition national-level studies. **The greater the reliance on non- wind and solar technologies, the lower the scale-up rate of wind and solar.**

This is seen in for example Brazil, where hydropower plays a large role in existing generation. While in the future, the share of electricity from hydropower decreases in our benchmarks, as wind and solar grow to provide two-thirds of the electricity generation in the country by 2050, the large-scale hydropower generation in Brazil reduces the level of wind and solar rollout needed.

The level of wind and solar already installed in a country

Countries are not all starting from the same position in the transition to a power sector dominated by wind and solar. **When calculating the relative scale-up rate, the more wind and solar already installed by 2022, the lower the relative scale-up rate from 2022 onwards.**

This is clearly observable in those countries which have already been transitioning to wind and solar for a period of time. For example, Germany, Australia and Brazil have the highest shares of electricity generation coming from wind and solar in 2022 of the countries analysed at 32%, 24% and 16% respectively. This larger existing base means that the relative scale-up rate needed over 2022–2030 is lower, with these three countries exhibiting the lowest (although still ambitious) scale-up rates for total wind and solar capacity.

Equally, there are those countries for which the transition to wind and solar is only just beginning: Indonesia and Nigeria. In 2022, Indonesia had only 0.3 GW of solar and 0.15 GW of wind installed, while Nigeria had 0.1 GW of solar and only 6 MW of wind. This very low base is a key driver for the high scale-up rates observed in these countries. However, while the relative scale-up rate is very large, the absolute level of installed wind and solar capacity in 2030 (around 110 GW for Indonesia and 50 GW for Nigeria) is more modest. In these countries, international support for the energy transition will be key, such as concessional finance to catalyse private investment in wind and solar (IEA and IFC 2023), finance to support a just transition and unlock the early retirement of fossil fuel infrastructure, and institutional support and capacity building.

Split into wind and solar

Finally, the combined relative scale-up rate of wind and solar capacity is dependent on the ratio of wind to solar in the country. **Countries which rely more heavily on solar in the energy transition will have higher scale-up rates, because solar has a lower capacity factor than wind.**

Solar PV requires more installed capacity than wind to produce the same amount of electricity. On average, around twice as much solar capacity needs to be installed to produce the same amount of electricity over a year as wind (IEA 2024a). As a result, countries in which the cost-effective split of wind and solar involves greater levels of solar will see higher scale-up rates for total wind and solar capacity.

In our analysis, each country has a unique context in terms of projected electricity demand growth, fossil phase-out required, reliance on non- wind and solar generation, existing base of wind and solar, and the modelled split into different technologies. As a result, the wind and solar rollout is unique to each country, making it difficult to draw broad comparisons between the rollout in advanced economies and EMDEs, for example. However, the factors identified above can help explain the differences between wind and solar rollout between each country. This is illustrated in the case of Mexico and Australia.

In the 1.5°C compatible benchmarks presented here, Australia scales wind and solar capacity by 3.8x over 2022–2030, while in Mexico, wind and solar capacity grows 5.5x. Australia has higher electricity demand growth out to 2030 and a faster fossil phaseout by 2030 compared to Mexico in our analysis. Australia also relies less heavily on non- wind and solar generation to displace fossil fuels than Mexico, with only 6% of generation in 2030 coming from other clean generation (largely hydro). In Mexico this share is closer to 14% in 2030. This should result in Australia having a faster scale-up of wind and solar than Mexico. However, the opposite is true in our benchmarks.

This is particularly due to the existing base of wind and solar in Australia. The share of wind and solar in Australia in 2022 was twice the size of that in Mexico – and this larger existing base reduces the relative scale-up needed. Mexico also scales faster due the relative split into wind and solar in each country: while in Mexico there is over four times as much solar installed as wind in 2030, in Australia solar capacity only exceeds wind capacity by a factor of 2.5 in 2030. The greater role of wind in the Australian power sector reduces the overall scale-up rate needed.

The benchmarks are generally provided to two significant figures. Minor differences between the totals and the sum of wind and solar are due to rounding effects.

Region	**Capacity**	**2022 levels** (GW)	**2030 benchmark** (GW)	**2035 benchmark** (GW)	**2050 benchmark** (GW)	**2030** (relative to 2022 levels)
Australia	Solar	32	120	250	400	3.8
	Wind	12	45	62	150	3.8
	Wind and Solar	44	170	310	550	3.8
Brazil	Solar	27	89	130	290	3.3
	Wind	24	46	73	150	2
	Wind and Solar	50	140	200	440	2.7
China	Solar	429	2900	4600	8000	6.8
	Wind	365	1600	2100	2000	4.4
	Wind and Solar	794	4500	6600	10000	5.6
Germany	Solar	67	250	340	350	3.8
	Wind	66	150	170	230	2.2
	Wind and Solar	133	400	510	580	3
Indonesia	Solar	<1	77	210	590	300
	Wind	<1	29	59	150	190
	Wind and Solar	<1	110	270	730	250

Table 1 **Wind and solar capacity needed to align with 1.5°C**

Region	Capacity	2022 levels (GW)	2030 benchmark (GW)	2035 benchmark (GW)	2050 benchmark (GW)	2030 (relative to 2022 levels)
India	Solar	83	460	990	2000	5.6
	Wind	43	150	210	640	3.6
	Wind and Solar	126	620	1200	2600	4.9
Mexico	Solar	11	78	130	220	7.3
	Wind	7	19	20	43	2.7
	Wind and Solar	18	98	150	270	5.5
Nigeria	Solar	<1	37	100	230	380
	Wind	<1	17	21	61	2800
	Wind and Solar	<1	54	120	290	520
Türkiye	Solar	11	62	120	330	5.6
	Wind	11	27	30	69	2.4
	Wind and Solar	22	91	150	400	4
USA	Solar	140	890	1400	2700	6.4
	Wind	141	480	630	1200	3.4
	Wind and Solar	281	1400	2000	3900	4.8
South Africa	Solar	6	49	80	180	8.3
	Wind	3	16	22	39	4.7
	Wind and Solar	9	66	100	220	7
All countries analysed	**Solar**	**799**	**5000**	**8400**	**15200**	**6.2**
	Wind	**669**	**2600**	**3400**	**4800**	**3.9**
	Wind and Solar	**1472**	**7500**	**11600**	**20000**	**5.1**

Table 1 **Wind and solar capacity needed to align with 1.5°C**

Achieving this level of wind and solar capacity by 2030, and continuing the transition out to 2050, will require a vast amount of new wind turbines and solar panels to be installed.→ Figure 4 shows the level of wind and solar capacity additions needed to align with the 1.5°C temperature limit, for the assessed countries and their aggregate. As in the previous charts, we focus on the central benchmark per country. The chart also shows the average wind and solar capacity additions achieved over 2020–23, and the maximum rate of capacity additions achieved in a single year since 2000.

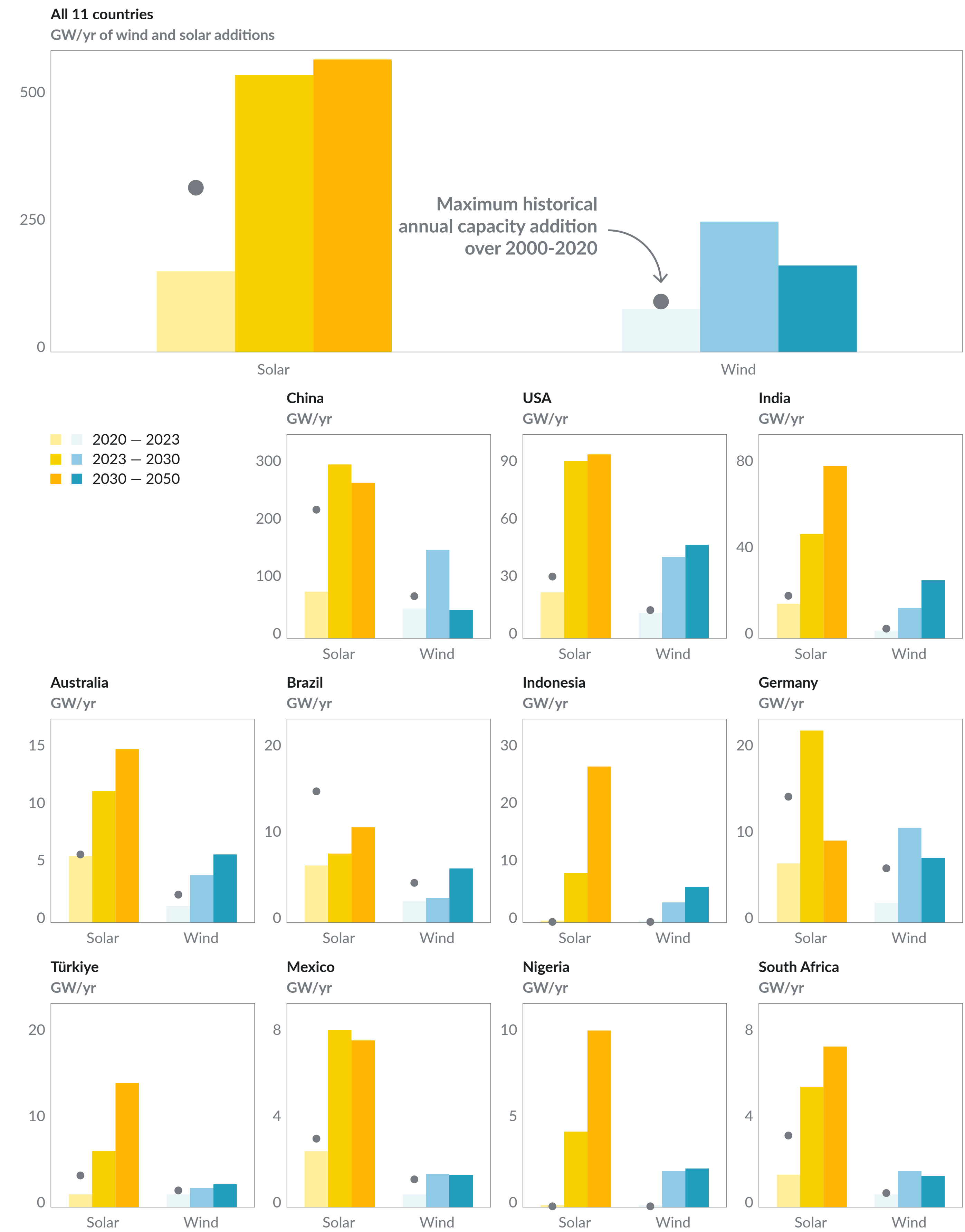

Figure 4 **Wind and solar capacity additions needed to align with 1.5°C for selected countries**

The figure shows the central benchmark per country. For more detail on individual country results, see the individual country briefings. The grey dot shows the maximum capacity installed in any single year since 2000 in each country.

Wind and solar capacity additions need to break historical precedents and set new records on the road to a power sector dominated by wind and solar. On average, the rate of wind and solar installations needs to triple over the 2023–2030 period, compared to the 2020–23 period. In all countries, average capacity additions over the period out to 2030 are larger than the average rate of additions achieved over 2020–2023. There are some countries, however, where the maximum rate of capacity additions achieved since 2000 in a single year exceeds or is almost aligned with the pace of rollout required to achieve the benchmarks. This is the case for Brazil (both wind and solar), China (solar rollout), Germany (wind rollout) and Türkiye (wind rollout).

In most countries, the level of capacity addition required continues to grow post-2030, with larger annual additions needed over 2030–2050. This is particularly the case for Nigeria and Indonesia, which are starting from a low base and therefore need more time to build momentum in their energy transitions. In some other countries, the greatest absolute rates of capacity additions are needed in the 2020s, after which average capacity additions can decline, which is the case for Germany and China.

For Germany, this is likely because fossil fuels need to exit the power sector by 2035 in order to be 1.5°C compatible. As a result, the level of additional wind and solar capacity required decreases as wind and solar additions are only needed to meet electricity demand growth and not to displace fossil fuels. For China, this is because our benchmarks assume very rapid growth in electricity demand out to 2030, after which demand growth begins to slow due to structural changes in the industrial sector, and a slowdown in the rate of demand growth in the buildings sector.

04 Is the world on track to achieve the benchmarks?

As seen above, renewable capacity additions need to accelerate rapidly to align with a 1.5°C compatible energy transition. This acceleration is beginning to occur. In 2023, over 380 GW of wind and solar were added globally, an increase of 70% compared to wind and solar capacity additions the year before (IEA 2024a). **However, under current policies, wind and solar are not on track to achieve the scale and pace of rollout set out by our benchmarks.**

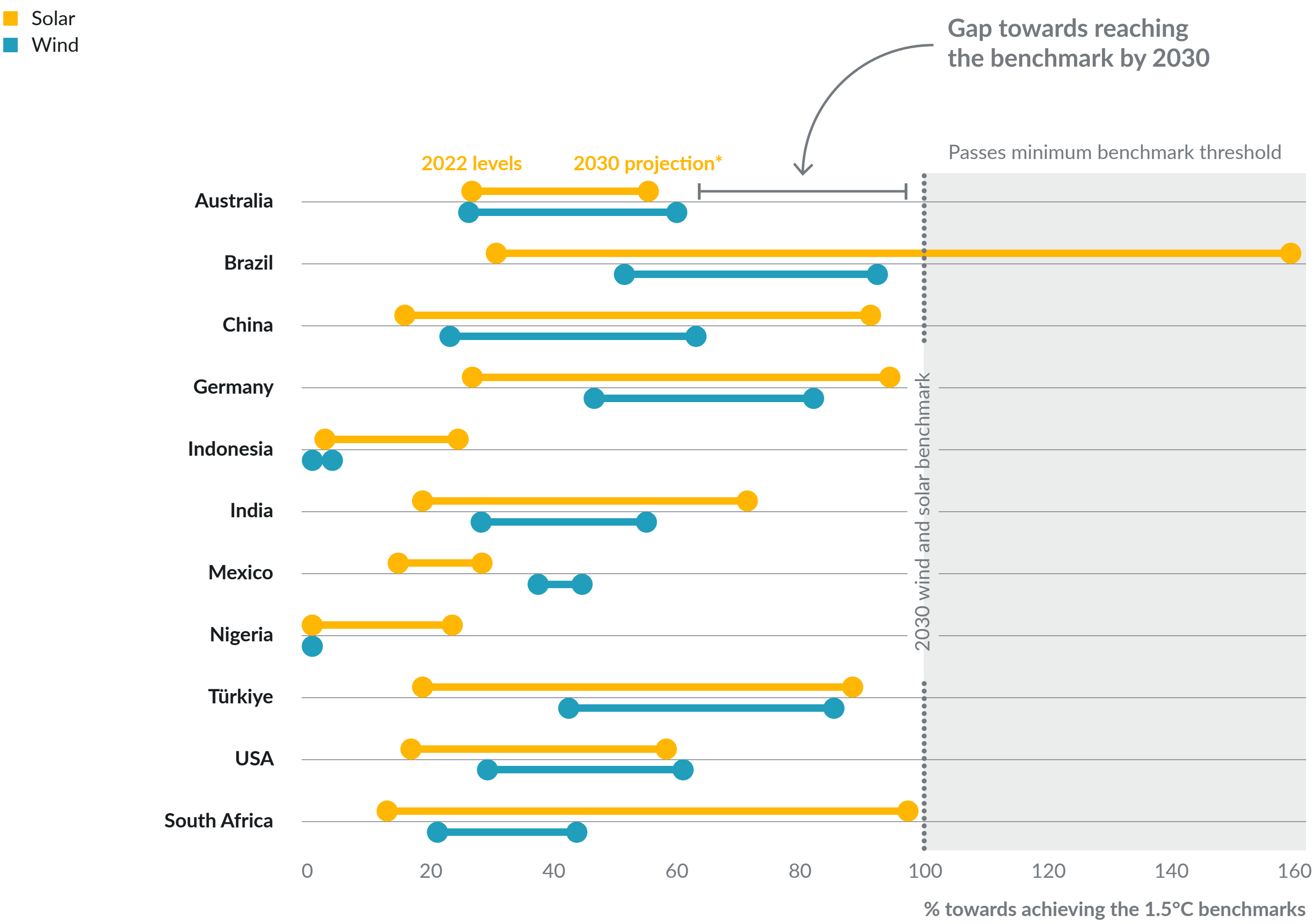

Figure 5 **Comparing the rollout of wind and solar under current policies to 1.5°C compatible benchmarks**

The figure shows the % of the 1.5°C compatible benchmark set to be achieved under current policies and market conditions in 2030. A figure of above 100% represents installing more capacity than required by the benchmarks.

* Projection taken from IEA (extended to 2030)

→ Figure 5 shows the level of capacity that is expected to be installed by 2030 across the 11 countries under current policies and market conditions. This uses projections from the IEA, which forecast capacity deployment out to 2028. We extend this forecast to 2030.[4]

More action is needed to accelerate wind and solar deployment across the world. Across the eleven countries and two technologies, there is only one case in which rollout is aligned with 1.5°C (rollout of solar in Brazil).

However, the need for further acceleration to align with 1.5°C is not distributed evenly across the world and across technologies. Wind deployment is lagging further behind 1.5°C compatible levels than solar. There are four countries in which the current rollout of solar would reach at least 90% of the 1.5°C compatible benchmark in 2030 (China, South Africa, Germany and Brazil). There is only one country in which wind rollout is close to aligning with 1.5°C (Brazil). Given the central importance of wind in providing clean electricity, particularly in the near term, more action is needed to support its deployment around the world.

The capacity gap in 2030 between the rollout under current policies and 1.5°C compatible levels also varies between country, with the largest gaps seen in Indonesia, Nigeria and Mexico. In these countries, the projected deployment of wind and solar in 2030 is less than half of the level required to align with 1.5°C. Closing this capacity gap is essential to ensuring that these countries can reap the benefits of the wind and solar rollout. This will require international support from advanced economies to help create a financial environment in which these technologies (which are already cost-effective), can be deployed.

International support should involve concessional finance, which can help reduce the cost of capital and crowd-in private investment in renewables. Climate finance is also needed to address the systemic challenges relating to a rapid energy transition (developing the supporting infrastructure and institutional frameworks, retraining workers, building new clean industries, expanding grids, and achieving early retirement of fossil assets). However, all countries need to act to set out a clear direction towards renewables, both in terms of targets and policy frameworks, and to prevent incumbent fossil interests blocking the energy transition to renewables.

4
To do this, we assume a quadratic growth in wind and solar capacity, which means that capacity additions grow linearly from 2028–2030 along the 2022–2028 trendline. This results in global renewable capacity reaching around 9 TW in 2030 under current policies and market conditions, which is in line with the IEA's own extrapolation of their forecast (IEA 2024a).

05 How do the benchmarks align with the tripling goal?

In this report and the accompanying country briefings, we have explored one possible translation of the 1.5°C temperature goal to the national level for 11 countries. While these countries do not provide global coverage of the power sector, they represented 62% of total electricity generation in 2022 (IEA 2024c), and 72% of total wind and solar generation (IEA 2024a, 2024c).

It is therefore possible to make a first estimate of what these benchmarks, if extended to cover the world as a whole, would mean for global renewables deployment. To do this, we compare our analysis to the IEA's net zero scenario (IEA 2023). This is a global scenario which triples renewable capacity relative to 2022 and has been a key line of evidence to support the global tripling goal.

As the IEA's analysis is for the globe as a whole, and our analysis currently covers 11 countries (albeit ones accounting for a significant proportion of global wind and solar generation), it is not possible to compare the analysis in absolute terms, only relative terms. The following section should be seen as a preliminary comparison, which will be further developed as we expand the number of countries covered by these benchmarks.

→ Table 2 highlights some of the key elements of the energy transition in our benchmarks, compared to the IEA's net zero scenario. It shows that our benchmarks are at least in line with tripling renewable capacity, and indeed go slightly beyond this. Tripling renewable capacity should be seen as an ambition floor, not a ceiling.

The difference between our analysis and the IEA's modelling is due to a range of factors.

Benchmark	**Our results** (11countries)	**IEA global analysis**
Growth in electricity demand from 2022-2030	35%	32%
Share of electricity coming from fossil fuels in 2030	21–29%	30%
Share of electricity coming from wind and solar in 2030	49-57%	40%
Share of electricity coming from other clean generation in 2030	22%	30%
Growth in wind capacity from 2022-2030	3.9x	3x
Growth in solar capacity from 2022-2030	6.2x	5.3x

Table 2 Comparing the energy transition in our modelling to the IEA's net zero scenario

First, our analysis for the 11 countries covered in this report demonstrates a slightly faster scale-up of electricity demand over 2022–2030 than in the IEA's modelling. This could be due to differences in assumptions around economic growth or electrification, or because the 11 countries covered here are not representative of global trends. However, it is difficult to fully identify the underlying reasons, as our analysis uses a set of country-specific bottom-up studies to estimate electricity demand on a country-by-country basis, while the IEA's approach is a top-down global modelling effort.

Second, our benchmarks exhibit a faster phaseout of fossil fuels, and lower reliance on other sources of non-fossil electricity generation such as nuclear, hydropower and biomass. The share of fossil fuels in the electricity mix falls from 61% in 2022 to 21–29% in 2030 across the 11 countries analysed. While the absolute level of electricity generation from hydropower, other renewables and nuclear grows 10% over the time period, this is slower than the rate of electricity demand growth. As a result, their share in the global electricity mix falls from 27% in 2022 to 22% in 2030. This contrasts with the net zero scenario, in which these other sources of clean electricity generation (and particularly nuclear and biomass) grow faster than electricity demand, and hence their overall share of generation rises from 27% to 30% in 2030.

As a result, our benchmarks see wind and solar providing 49-57% of total electricity generation in 2030 for the 11 analysed countries, substantially above the IEA's analysis for the global average. This is to achieve both a faster phase-out of fossil fuels and a reduced reliance on nuclear and biomass. This can help mitigate the significant risks associated with expanding biomass demand (Energy Transitions Committee 2021) or nuclear energy (WNISR 2023).

The scale-up rates of wind and solar obtained by our analysis are also therefore larger than the IEA's. Rather than wind and solar capacity growing roughly three-fold and five-fold in the countries analysed here, they grow approximately four-fold and six-fold over 2022–2030. If our 11 countries can be taken as a representative global sample, then this would imply an additional 1 TW of solar PV and 740 GW of wind installed by 2030 compared to the IEA's analysis. However, the slower growth in hydropower and other renewables could reduce capacity requirements for these technologies by around 400 GW. As a result, total renewable capacity in our benchmarks, if extended to the world as a whole, could be more than 1 TW higher than the IEA's analysis, at 12.4 TW in 2030. This would be a scaling of 3.4 times relative to 2022, instead of 3.0 times as in the net zero scenario.[5]

5 As highlighted in previous sections, the relative scale-up rate of wind and solar capacity varies strongly across different countries. It is therefore possible that once more countries are covered by these benchmarks, that the average scale-up rate in wind and solar capacity across all countries would be different to this preliminary finding.

While increasing country coverage of the benchmarks would enable a more fully informed comparison between our work and the IEA's, this first exploratory analysis suggests that our benchmarks are broadly aligned with the tripling goal and go slightly beyond it, for the reasons identified above. It is possible that global electricity demand grows faster than anticipated in the IEA's net zero scenario, we fail to scale biomass, nuclear and hydrogeneration at the pace anticipated, or we need to phase out fossil fuels faster than occurs in the IEA's modelling. In such a world, renewable capacity would need to more than triple. The North Star of the energy transition should remain the Paris Agreement's temperature goal. As evidence around electricity demand growth, fossil phaseout and technology development continues to emerge, the level of ambition required to meet this temperature goal can be monitored, and the roadmap adjusted where necessary.

06 Conclusions

The momentum of the energy transition is growing, led by the frontrunners of wind and solar. Their deployment is accelerating rapidly and is fuelling hope that the emissions curve can be bent downwards and towards zero.

However, there is no room for complacency. Almost a year on from the conclusion of the first Global Stocktake, the need for action remains as urgent as ever. Despite growth in wind and solar, today's rates of deployment are not sufficient to limit warming to 1.5°C. And, without a fundamental change in the geographical distribution of renewables investment and deployment and work to ensure an accompanied just transition, we risk a transition that leaves many behind on the road to a zero-carbon future.

This report and its accompanying country briefings provide one possible interpretation of what the 1.5°C temperature limit and the global tripling goal could mean at the national level. In doing so, it provides a roadmap for action at the level of implementation. This can help set ambition for renewables in updated NDCs. Ambitious targets for renewables need to be accompanied by ambitious delivery of finance to ensure that the energy transition is a truly global transition, and all can reap the benefits of renewables.

A rapid rollout of wind and solar can help deliver clean and affordable electricity by 2030 to the millions who currently lack it, will bring substantial benefits in terms of local job creation and reduced air pollution, and is one of the central levers to limiting warming to 1.5°C, which is key to safeguarding sustainable development, particularly in the most vulnerable parts of the world.

The benchmarks presented here are in line with evidence from national studies, as well as global energy and emissions pathways assessed by the IPCC. They are not the only possible translation of global goals to the national level and should be considered in combination with other information when setting targets and accelerating action. However, they can provide a key piece of evidence to guide the NDC update process in line with 1.5°C.

Achieving the benchmarks will require new records to be set in wind and solar deployment, with annual additions of wind and solar breaking historical precedents. In a world which is serious about limiting warming to 1.5°C, the future cannot look like the past. However, the current acceleration of wind and solar deployment seen around the world is grounds for optimism that this scale-up can be achieved.

Ambitious wind and solar deployment, accompanied by batteries, grid-expansion, flexible zero-carbon generation and demand-side management, can transform the power system into a new paradigm: fossil-free power, lower bills, cleaner air, and reduced dependency on volatile international fossil fuel markets. This future is achievable, but is not guaranteed. Only ambitious renewable targets, paired by rapid implementation and policy development and underpinned by international support, can usher in this new paradigm. It is time to translate the tripling goal into action to keep 1.5°C in reach.

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