Unlocking Investment to Triple Renewables by 2030

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BloombergNEF

Bloomberg Philanthropies

Contents

Executive summary

$1 trillion

Average annual investment required globally from 2024 to 2030 to enable a tripling of renewables, consistent with a net-zero emissions pathway

$623 billion

Total investment in renewable energy in 2023

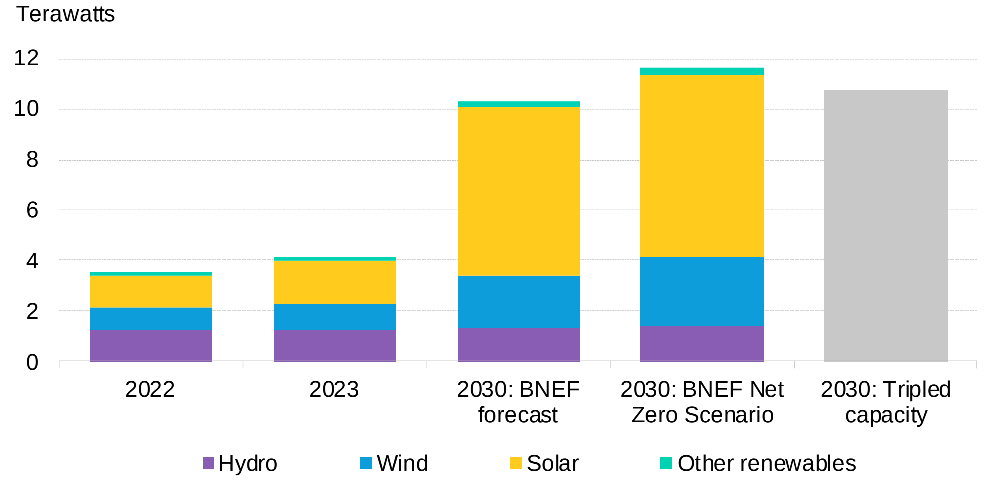
13%

Additional build needed relative to forecast 2030 global renewables capacity to reach the net-zero/tripling-renewables goal

The COP28 climate summit closed in December 2023 with a commitment from nearly 200 Parties to take action towards tripling global renewables capacity by 2030. Installations and investment have been ramping up, with the world pouring $300 billion into renewable energy in the 10 months since that agreement was reached. But further acceleration is needed to get on track for a net-zero emissions pathway.

- **Tripling renewables capacity aligns with net zero.** Achieving global climate commitments requires a rapid buildout of renewable energy this decade, equivalent to over 11 terawatts of installed capacity in 2030. The greater share of renewables in the power mix drives over 50% of emissions reductions this decade, according to BloombergNEF's Net Zero Scenario, which charts a pathway to net-zero emissions by 2050 while keeping global warming well below 2 degrees Celsius (Figure 2).
- **The world is not currently on track for the COP28 goal but is getting closer.** A total of 578 gigawatts of new renewables capacity was added in 2023, with a particular boom in solar. A continuation of this annual build would bring the world to 8.2 terawatts by 2030, still 29% below the net-zero pathway. However, BNEF expects annual installations to rise even further this decade based on current policies, announced project pipelines and economics. BNEF forecasts 10.3 terawatts of renewables capacity globally by the end of the decade, although that would need to rise 13% to meet the net-zero target (Figure 1).

Figure 1: Global installed renewable energy capacity versus BNEF's 2030 forecast and Net Zero Scenario, and tripling renewables target



Source: BloombergNEF Note: 'Other renewables' includes bioenergy, geothermal, solar thermal and marine. 'Tripled capacity' is compared with 2022.

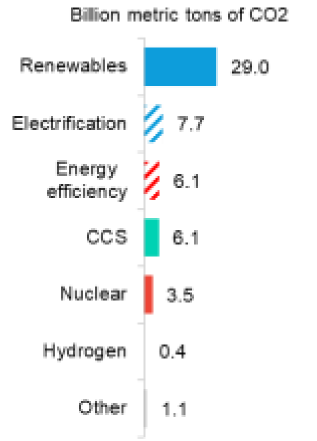
- **Investment needs to ramp up, especially in supporting areas**. BNEF's Net Zero Scenario requires an average of $1 trillion per year (in 2023 terms) to be invested in renewable energy between 2024 and 2030, plus an average of $193 billion per year in battery storage and $607 billion in the electricity grid (Figure 7). This is higher than current levels but not a step change; BNEF estimates $623 billion was invested in renewables worldwide in 2023, plus $36 billion in energy storage and $310 billion in the grid. In the first half of 2024, some $313 billion was went to renewables around the world.

- **Technologies beyond solar require a faster scale-up of capital.** Solar investment and buildout has been growing much faster than for wind, storage or grids. This could put climate targets at risk, as the same amount of solar capacity produces less electricity than wind and therefore displaces less fossil-fuel emissions.
- **Some regions need a lot more support and investment than others.** China and Brazil are broadly on track for a net-zero future, whereas Europe, the US and India have strong policy support for the energy transition but need to accelerate. Japan, Indonesia, the Middle East, North Africa, Turkey and sub-Saharan Africa are lagging well behind, both in terms of the volume of deployment and investment.
- This report has been produced by BNEF and was commissioned by Bloomberg Philanthropies. It was supported and reviewed by the Global Renewables Alliance and its members the Global Wind Energy Council, Global Solar Council, Long Duration Energy Storage Council, Green Hydrogen Organisation, International Hydropower Association and International Geothermal Association.

Section 1. Tripling capacity as a goal for 2030

Renewable power is critical for climate commitments

Figure 2: Cumulative emissions reductions in BNEF's Net Zero Scenario across 2024-2030, by measure



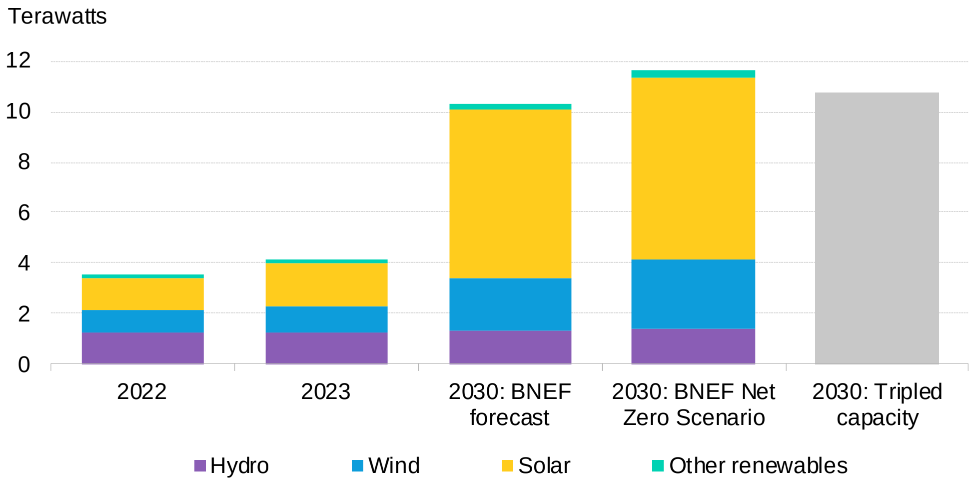
Source: BloombergNEF
Note: Reductions from fuel combustion by measure. CCS is carbon capture and storage.

The COP28 summit closed in December 2023 with an agreement between nearly 200 Parties to take action towards achieving a tripling of global renewable energy capacity by 2030. This landmark deal has turned into a rallying call across the industry and a guiding light for tracking progress across the sector.

Achieving global climate commitments requires a rapid buildout of renewable energy this side of 2030. Under BNEF's Net Zero Scenario – a pathway to net-zero emissions by 2050 that limits planetary warming to well below 2 degrees Celsius – expanding the share of renewables in the power mix accounts for over 50% of emissions reductions this decade (Figure 2). That is versus a 'no transition' counterfactual where no further decarbonization takes place. An additional 14% of emissions savings come from this clean power being harnessed in the electrification of end uses in transport (such as the shift to electric vehicles), industry and buildings. For more, see BNEF's *New Energy Outlook 2024* (behind a paywall: web | terminal).

The cumulative installed base for renewable energy reaches 11.6 terawatts (TW) by 2030 in the Net Zero Scenario, roughly triple 2022 levels (Figure 3). Of that, 7.2TW is from solar (62%), while 2.7TW comes from wind (23%). The remaining 1.5TW is a mixture of other renewable resources, including hydro, geothermal and biomass.

Figure 3: Global installed renewable energy capacity versus BNEF's 2030 forecast and Net Zero Scenario, and tripling renewables target



Source: BloombergNEF. Note: 'Other renewables' includes bioenergy, geothermal, solar thermal and marine. 'Tripled capacity' is compared with 2022.

The buildout of this capacity will require not only a scale-up in jobs, skilled labor and supply chains around clean power, but will also hinge on huge capital flows being unleashed. The Net Zero Scenario requires $12.7 trillion of investment from 2024 to 2030 across renewables, battery storage, pumped hydro and power grids, including asset replacement, system reinforcement and new connections. This translates to annual investment nearly doubling relative to today's levels.

The tripling renewables target amounts to 11TW by 2030, but can be higher depending on the technology mix achieved and units of measurement

How much is tripling, anyway?

The tripling renewables target set during COP28 was relative to 2022 levels. At the end of that year, there was nearly 3.6TW of renewables installed globally, meaning roughly 11TW of capacity must be reached by 2030 to achieve a threefold increase.

However, the generation output of the renewables base matters most for determining whether tripling aligns with net zero, not necessarily capacity. Renewables will have different annual generation profiles, depending on the type of technology deployed, location, how much similar technology is already deployed in a market and the presence of demand-side flexibility or battery storage.

In BNEF's Net Zero Scenario, a greater reliance on solar – which has lower capacity factor than wind – results in 11.6TW of renewable installations by 2030, which is technically 3.3 times larger than the 2022 base. But the International Energy Agency's Net Zero scenario sees 11TW in 2030, of which 6.1TW is solar and 2.7TW wind.

Part of this difference can also be explained by units: BNEF measures solar capacity in direct current (DC) capacity, which is the capacity of the module. However, some official bodies report capacity in alternating current (AC), which is that of the inverter and grid connection. This value is usually 75-85% of the module capacity. For more, see Appendix A.4.

Progress has been made but the pace is still too slow

The past year has brought several milestones for renewable energy. Some 561 gigawatts of wind and solar was added globally, representing nearly 91% of net new power capacity additions in 2023 (Figure 4). The surge in deployment also led to record levels of electricity generation, with the two technologies representing 14% of on-grid power generation last year. Together with hydro, nuclear and other renewables like biomass and geothermal, the share of global electricity generation from zero-carbon sources hit a record-high 41% (Figure 5).

Figure 4: Global new power generation capacity, by technology

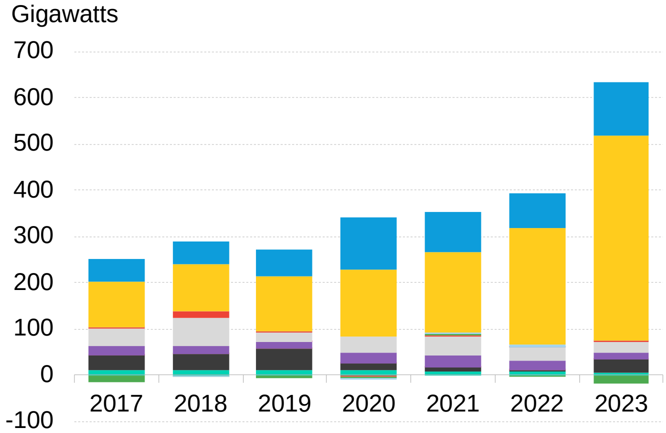
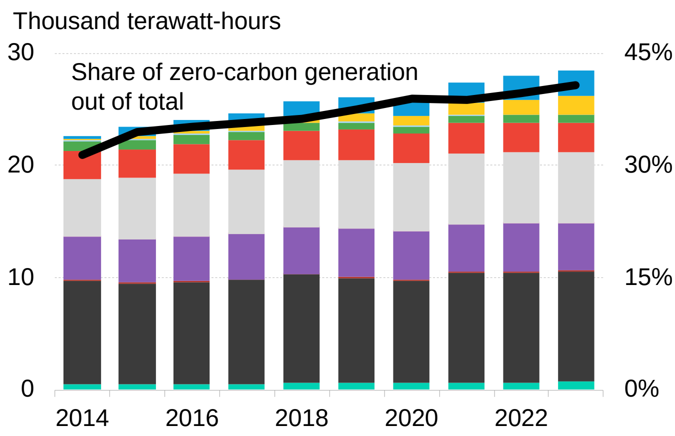


Figure 5: Global power generation, by technology



Biomass and waste, Coal, Geothermal, Hydro, Natural gas, Nuclear, Oil and diesel, Other - fossil, Solar, Wind

Source: BloombergNEF

Source: BloombergNEF

None of this is fast enough to triple global renewable energy capacity. If the world continues to add 578GW a year, the total installed renewables base would only reach 8.2TW by 2030 – far short of the COP28 goal (Figure 6).

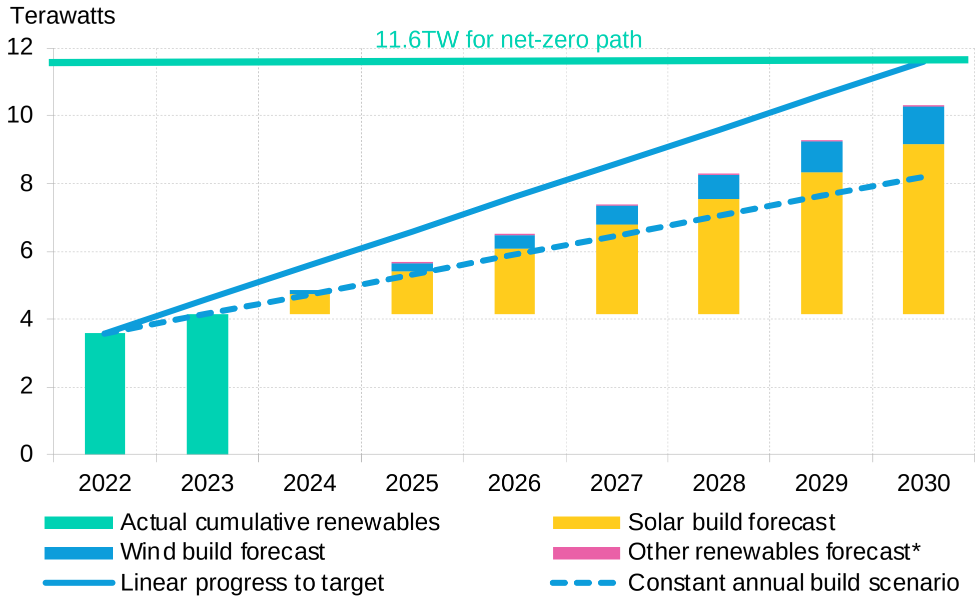
BNEF expects 6.7TW of solar to be installed by the end of the decade, 8% shy of the Net Zero Scenario but 16% higher than forecast in November 2023, when the tripling target was agreed

BNEF does forecast the rate of annual additions will rise over the years ahead, with annual solar build nearly doubling by 2030, while annual wind installations rise by over 70%. These forecasts for wind and solar (photovoltaics) are adjusted regularly based on BNEF's country-level analysis of policies, project pipelines, asset financing, economics, local targets, renewable energy demand, past adoption and other locally relevant information (behind a paywall: web). Forecasts for other renewables, including hydro, biomass and geothermal, have been taken from the baseline Economic Transition Scenario of BNEF's *New Energy Outlook*, which is primarily driven by the cost competitiveness of technologies and may understate the deployment that can be driven by supportive policy.

BNEF expects 6.7TW of solar to installed by the end of the decade on this basis, which is 8% shy of the Net Zero Scenario but 16% higher than was forecast in November 2023, when the tripling target was agreed. Stronger demand and lower module prices have largely driven BNEF's projection up.

Meanwhile, wind is expected to reach 2.1TW by 2030, some 30% below the Net Zero Scenario. This is only 9% higher than what the forecast set in November when COP28 was held, suggesting little progress has been made to unstick the industry to date.

Figure 6: Pathways to reach tripling-renewables target at constant compound annual growth rate, and forecasts



Source: BloombergNEF. Note: 'Constant annual build' shows the result of annual additions holding constant at 2022-23 levels. The 11.6TW line shows the 2030 capacity under BNEF's Net Zero Scenario. BNEF's forecasts for wind and solar are based on detailed country-level analysis of project pipelines, asset financing, renewable energy demand, economics and enabling policies. The forecast for 'other renewables' is based on project pipelines only and is aligned with BNEF's Economic Transition Scenario.

The slow pace of wind relative to solar is also challenging the efficacy of the tripling target. This is because it is ultimately terawatt-hours, not terawatts, that matter to decarbonization.

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BNEF's Net Zero Scenario, published in May 2024, sees 23,000 terawatt-hours (TWh) of renewable electricity generation globally in 2030, compared to 8,4000TWh in 2022. This abates 50% of emissions relative to a no-transition pathway. The volume of generation is relatively unchanged from the Net Zero Scenario in the 2022 edition of BNEF's *New Energy Outlook*, which envisaged 22,000TWh of renewable electricity generation globally in 2030.

However, the amount of capacity required to achieve this level of generation has grown by 1.1TW due to a greater reliance on solar relative to wind. This reflects the fact that solar deployment continues to skyrocket, while the wind industry has been shaken by high-profile contract cancellations and declining investment in assets at a global scale. Rising interest rates and higher costs of debt have also added to financing burdens, while lagging grid buildout has lengthened development timelines, particularly for wind, putting 2030 clean energy ambitions at risk.

Solar has a lower capacity factor and high seasonality compared to wind, leading to less generation per terawatt installed. A rapidly decarbonizing world that is overly reliant on solar while tripling renewables capacity does not see the same impact on electricity generation, nor emissions reductions, as one with a more diverse fleet of renewables.

A world overly reliant on solar while tripling renewables capacity does not see the same impact on electricity generation or emissions reductions as one with a more diverse fleet of renewables

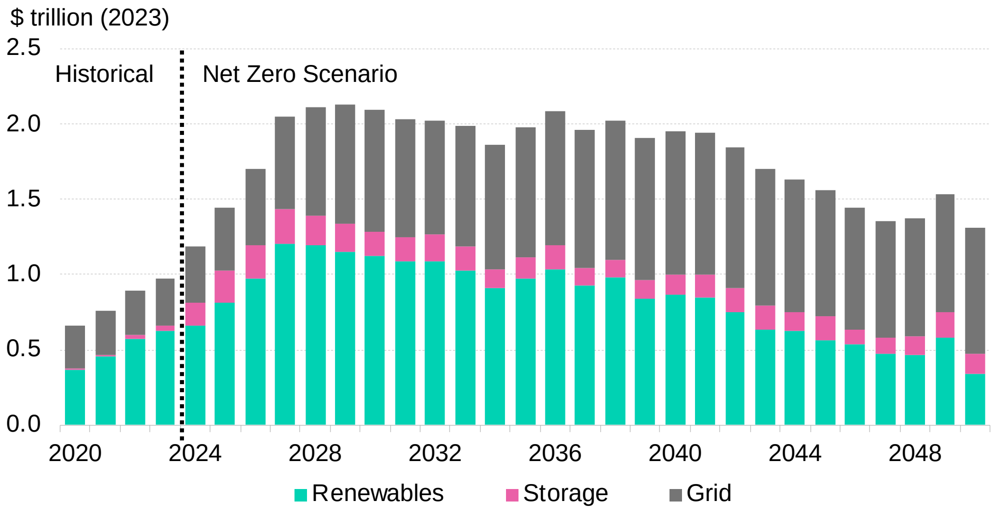
There is even some danger that high solar generation in the daytime and in summer could cannibalize the returns of other clean power plants such as wind farms, preventing build and driving more fossil-fuel use at night and in the winter. Addressing emissions requires a balanced deployment of clean power technologies and considerations to the time of day and year when different sources are likely to be available – not merely tripling the capacity deployed.

Investment

The Net Zero Scenario requires an average of $1 trillion (in 2023 dollars) to be invested in renewable energy every year between 2024 and 2030, plus an average of $193 billion per year in battery storage and $607 billion in the grid. This is an increase on current investment volumes but not a dramatic step change given the recent growth seen.

BNEF analysis shows that $623 billion was invested in renewables worldwide in 2023, plus $36 billion in energy storage and $310 billion in grid (Figure 7). In addition, $634 billion was directed toward electrified transport, which will generally support the energy transition but is not explicitly included in the investment volumes required. Together, this energy transition investment far exceeds the $1,098 billion the International Energy Agency estimates was invested in fossil fuels in 2023. For more, see *Energy Transition Investment Trends 2024*.

Figure 7: Outlook for energy investment in BNEF's Net Zero Scenario



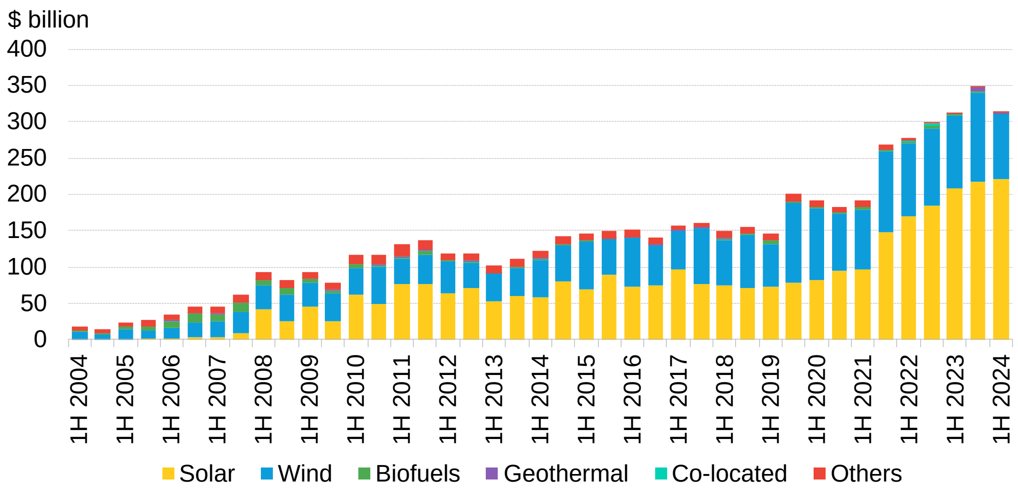
Source: BloombergNEF

Solar is driving investment volumes despite – or perhaps because of – a drop in module prices

Early indicators for 2024 are not bad: investment in renewable energy projects hit its second-highest level ever in the first half of this year (Figure 8). At $313 billion for renewable energy, this was an 11% dip from the record set in the second half of 2023 but was roughly in line with the first half of 2023.

Solar once again drove investment volumes, despite – or perhaps because of – a drop in the price of modules, which pushed down per-megawatt spending. Wind investment fell 26% from a year earlier and 26% from the second half of 2023, to land at $90.7 billion. Offshore wind investment was down 56% year-on-year, as the sector tends to be driven by the timing of large projects from government auction calendars. On the other hand, onshore wind was up 13%.

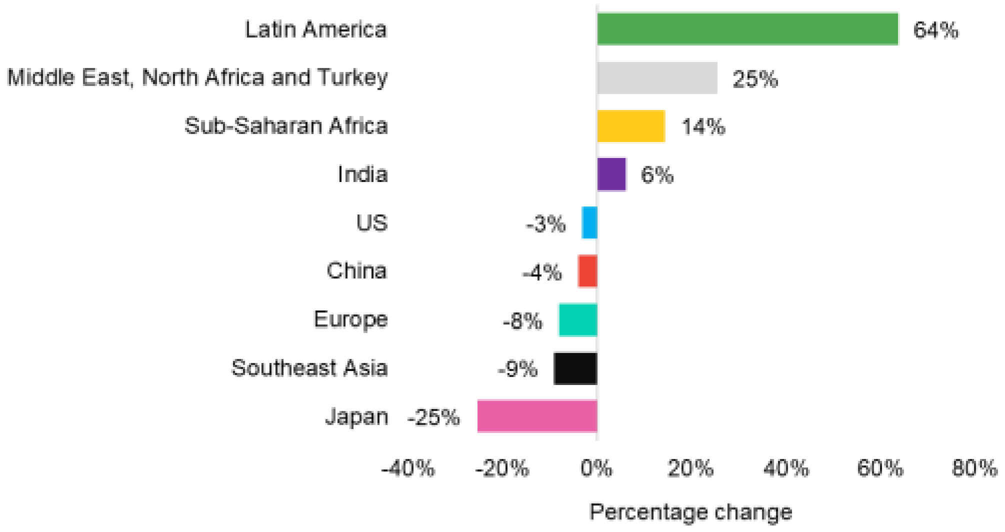
Figure 8: Global investment in renewable energy, by half year



Source: BloombergNEF. Note: 'Others' includes biomass and waste, small hydro and marine.

However, the story varies by region. Small-scale solar investment, driven partly by low prices for modules, spurred massive rises in renewable energy investment in the first half of 2024 compared with the same period in 2023 (Figure 9).

Figure 9: Change in investment flows for renewable energy, 1H 2024 vs 1H 2023



Source: BloombergNEF. Note: 'Europe' is the European Union plus UK, Switzerland and Norway.

Brazil's net metering scheme for solar projects under 5 megawatts (MW) was a major contributor to the rise in investment in Latin America, though other countries in the region also have growing small-scale solar markets and several large wind farms, like Casa dos Ventos de Sao Rafael, closed finance in 2024. Investment in the Middle East, North Africa and Turkey region rose 25% due to increases in small-scale solar deployment, despite lower prices.

Investment in sub-Saharan Africa rose drastically over this period off the back of a few big deals in South Africa, notably $515 million for the 330MW Perpetua Impofu wind portfolio and $214 million for phase one of the Seriti Mpumalanga wind farm. The government of Mali also closed collaborations with developers to build 400MW of solar parks.

India increased investment volumes year-on-year in the first half of 2024. Investment in other regions dropped, largely thanks to stagnant volumes and lower solar prices. Japan is expected to have its lowest year of solar build since 2012, with wind flat on 2023 levels.

Enabling investment flows

Solar and wind are the cheapest source of electricity in most countries, so what is holding back investment is generally not bulk economics

Solar and wind are the cheapest source of electricity in most countries, so what is holding back investment is generally not bulk economics. Five key challenges hinder renewable energy financing and deployment:

- **Barriers to access** such as licensing requirements and uncertainty around land ownership make it difficult for developers to build pipelines, while continued government subsidies for fossil fuels reduce the ability of renewable generation to compete on cost. Both can hinder the establishment of a financeable project pipeline, reducing capital mobility, particularly to emerging markets and developing economies.
- **Auctions and offtakes** for clean power must also be improved and expanded. Offtake agreements for power at fixed or predictable prices, and auctions to allocate these contracts,

can be powerful tools for helping developers to get projects built. However, they must also be designed for the long-term good of the power system, and to ensure sustainable prices by allowing strong competition between developers.

- **Grid infrastructure** is not currently keeping pace with the deployment of clean power. Many markets are underinvesting in their grids, leading to curtailment of power from built projects, and long connection queues and high costs to connect further projects.
- **Permitting** delays are also adding significantly to project development timelines and construction uncertainty. Prolonged and unpredictable appeals processes, a lack of staff to process permits at the municipal level, repetitive work for environmental impact studies and a lack of centralized geospatial and biodiversity data amplify the challenges faced by developers. The Energy Transitions Commission estimates solar and wind project development in Europe takes four to 12 years due to permitting and grid connection challenges.
- **Power market design** is critical to ensuring a low-carbon power system. Competitive price signaling for generation and demand enables a more diverse supply mix, efficient use of dispatchable resources including storage and flexible demand, and more corporate power purchase agreements. Competitive and standardized ancillary service markets are also important for managing the grid and ensuring renewables integration.

Overcoming these is key to achieving a tripling of renewables capacity and requires coordinated and increased ambition from governments. The main efforts needed to increase investment also differ by market (Table 1). More on the potential solutions can be found in Section 3.

Table 1: Key challenges for scaling investment in renewables, by market

Region	Market	Key challenges for scaling investment				
		Increased access (Cut fossil-fuel subsidies, ease generation licensing, encourage market participation)	**Auctions and offtakes** (Trustworthy offtakes, de-risking projects, diverse technologies)	**Grids and infrastructure** (Expanding grid capacity, regional interconnectors, managing grid queues)	**Permitting and land** (Clarifying appeals, data sharing, staffing of municipal offices)	**Power market design** (Long-term targets, competitive price signals for capacity and dispatch)
Americas	Brazil	Gray	Yellow	Red	Yellow	Red
	US	Gray	Gray	Red	Red	Gray
Europe, Middle East and Africa	Europe	Gray	Yellow	Red	Red	Yellow
	Middle East, North Africa and Turkey	Red	Red	Yellow	Yellow	Gray
	Sub-Saharan Africa	Red	Red	Yellow	Red	Yellow
Asia Pacific	India	Gray	Yellow	Gray	Red	Red
	Indonesia	Red	Red	Gray	Gray	Red
	Japan	Gray	Yellow	Red	Red	Yellow
	China	Gray	Gray	Yellow	Gray	Yellow

Source: BloombergNEF. Note: Qualitative assessment undertaken by BNEF. Red shading indicates issues of most importance to that region. Yellow indicates the region has some challenges of this sort. Gray indicates these are issues that are not what is currently deterring investment in the region.

Section 2. Regional pathways

To meet the tripling-renewables target in a way that effectively contributes to climate goals, different regions need to build very different amounts of capacity. China and Brazil are broadly on track, whereas Europe, the US and India have strong policy support for the energy transition but need to accelerate. Japan, Indonesia, the Middle East, North Africa and Turkey region, and sub-Saharan Africa are lagging well behind in both volume of deployment and investment (Table 2).

Table 2: Regional assessment of global renewables tripling goal

On track for 2030 contribution?	Region	Renewables capacity in 2023 (gigawatts)	BNEF Take
On track Forecasts for these regions are in line with net zero and a global tripling of renewables.	China	1,558	China is expected to more than triple its renewables capacity by 2030 and be on course for net zero. The country must continue to build out its grid and energy storage to allow a greater deployment of wind.
	Brazil	203	Brazil is not set to triple its renewables by 2030. However, given that 85% of its generation mix is already low-carbon thanks to a large hydro base, a better goal here might be to focus on reducing carbon emissions outside the power sector, such as in industry, transport and agriculture.
Slightly behind These regions are making progress and have policy support, but they are insufficient to meet a global tripling of renewables or net-zero pathways.	Europe	750	Europe can do less than triple its renewable capacity by 2030 and still align with net zero. A by 2.4 times increase would be adequate. However, it is set to miss this, and in particular is not expected to build enough wind. Individual countries are attempting to address the permitting and grid bottlenecks holding back deployment. In some markets with high renewables penetration, electrification needs to speed up to support revenues for project developers, and time-of-day power tariffs implemented.
	US	430	The US is behind on renewables capacity deployment relative to its net-zero goals and tripling capacity, and will struggle to meet a net-zero path unless it can improve bottlenecks around permitting and grids.
	India	195	India needs to quadruple renewables capacity by 2030 to align with BNEF's Net Zero Scenario. The country is actively building, but we expect it to miss the target by 27%.
Not on track These regions are not on track and are making little progress.	Japan	127	Japan does not need to triple its renewable capacity by 2030 to align with net zero, but even so is set to miss the net-zero pathway by 40%.
	Sub-Saharan Africa	59	BNEF sees sub-Saharan Africa's renewables base increasing by 2.5 times by 2030, largely driven by solar. However, this is from a small base. More will need to be done to align with net zero, especially given governments' plans to add more fossil-fuel power to meet rising electricity demand and make use of domestic resources.
	Middle East, North Africa and Turkey (MENAT)	113	BNEF sees the MENAT region nearly tripling its renewables base by 2030, mostly with solar. However, the existing base is small and this will be insufficient to align with net zero.
	Indonesia	14	Indonesia is not on track for BNEF's Net Zero Scenario, which sees the renewable energy fleet growing more than sixfold by 2030, compared to an expected doubling in our forecasts.

Source: BloombergNEF. Note: The Net Zero Scenario referenced is from BNEF's 2024 New Energy Outlook (behind a paywall: web | terminal).

China

China added about 260GW of solar panels and 76GW of wind turbines in 2023, with investment of $367 billion broadly in line with the levels needed to reach net zero by 2050. It also met a 2030 target of 1.2TW(AC) of solar and wind, set in 2020, six years early. In 2023, solar and wind produced a combined 16% of China's electricity.

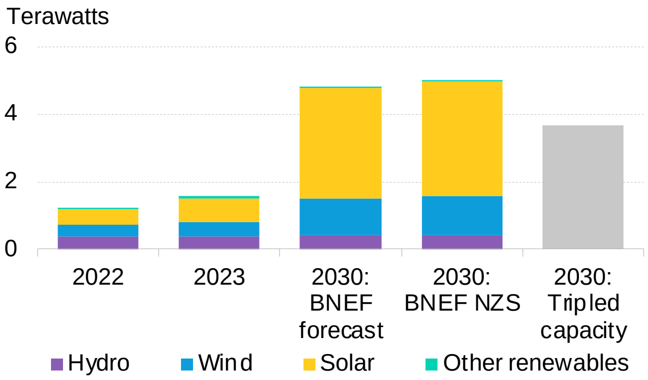
Figure 10: Market overview of China

Status	Key challenges to scaling investment
On track	 **Grids and infrastructure** (Expanding grid capacity, regional interconnectors, managing grid queues)

Source: BloombergNEF

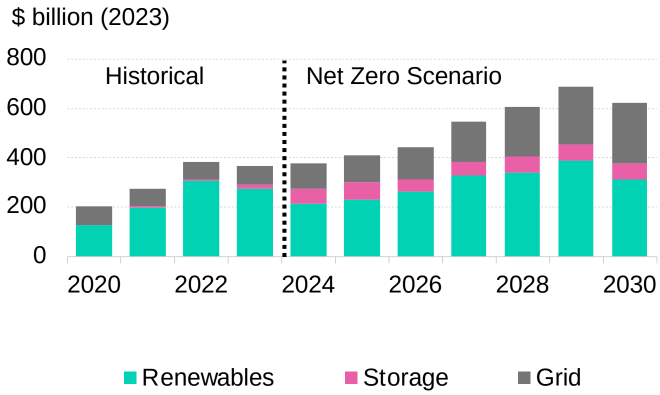
Large wind and solar projects are built by state-owned developers in 'megabases' organized by the national government in China's deserts and barren land – for more, see *China's Unprecedented 455GW Energy Megabase Plan* (behind a paywall: web | terminal). Rooftop solar has boomed in key provinces due to local guaranteed power export prices and an approach of awarding whole areas to certain developers, allowing small systems to be deployed in bulk. As of mid-2024, China has huge overcapacity to manufacture solar polysilicon, wafers, cells and modules, and firms are consequently scrambling to make use of them domestically.

Figure 11: China's renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 12: China's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF Note: The distribution of investment between 2024 and 2030 is determined by nuances of the long-term model, such as decommissioning of existing capacity.

There are some risks to the continued smooth scale-up of China's renewables industry, mainly because investment in grid and storage is needed to effectively integrate larger volumes of solar and wind. Although China has the world's largest network of ultra-high voltage transmission lines, which transferred power equivalent to 6.5% of national electricity demand in 2022 and link the vast northern and northwest provinces with the highly populated southern and eastern provinces, many of these power lines have low utilization factors. The low utilization is a concern to the market and may slow plans to build further megabases.

Investment in distribution grids and local storage is also required, as congestion on the local grid has become a problem in provinces such as Henan and Shandong, where rooftop solar has boomed. Henan, for example, has proposed a policy mandating new commercial and industrial solar projects consume all power generation onsite, which is likely to encourage storage. Although there is a lack of investment from national grid operators like State Grid, which favors long-range transmission expansion, the central government has released an Implementation Plan for High-Quality Development of Distribution Networks (2024-2027) setting aims for provincial grids.

China also has the usual practical problems. For example, the offshore wind industry is running out of near-shore sites, and will need to move to deeper waters, which are much more expensive and challenging to develop. Floating wind turbine technology, which would reduce this challenge, is reaching maturity more slowly than expected. The government is also pushing through long-term reforms to liberalize the electricity market and increase the amount of power traded on exchanges rather than sold under inflexible contracts. In the long run, this will make China's dispatch and use of power more efficient. But in the short term, measures to spur solar and wind projects to sell their power at variable merchant rates rather than guaranteed prices is negative for investment outlook.

Brazil

Brazil does not need to triple its renewable energy capacity by 2030 to be on track for net zero. The country's vast hydro generation resources and growing fleet of wind and solar plants meant around 90% of its electricity came from renewables in 2023. Brazil was the world's third-largest market for both wind and solar additions last year, with 21GW of new projects coming online. This took the country's cumulative renewable energy capacity to 203GW, keeping growth in line with the trajectory of BNEF's Net Zero Scenario for carbon neutrality by 2050.

Figure 13: Market overview of Brazil

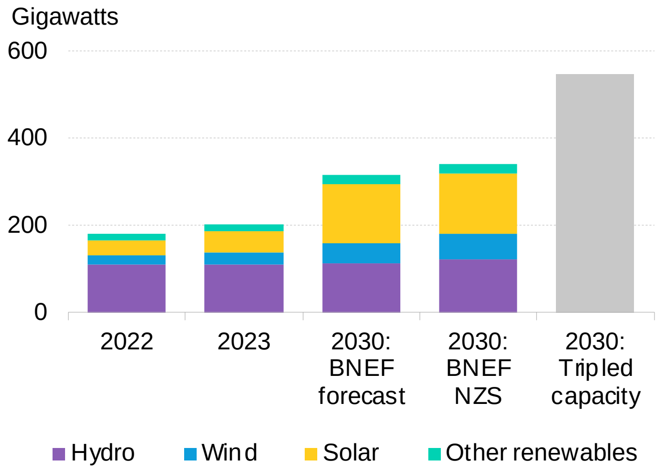
Status	Key challenges to scaling investment	
On track	**Grids and infrastructure** (Expanding grid capacity, regional interconnectors, managing grid queues)	**Power market design** (Long-term targets, competitive price signals for capacity and dispatch)

Source: BloombergNEF

While the strong growth in solar installations looks set to continue this decade, largely thanks to the booming rooftop sector, BNEF expects Brazil's wind installations to fall from 2024 through 2027. The wind industry faces headwinds tied to the oversupply of energy across the country's vast hydroelectric fleet, as well as the solar boom. This has reduced market appetite for pricier wind power purchase agreements, cutting permitting and financing activity since last year.

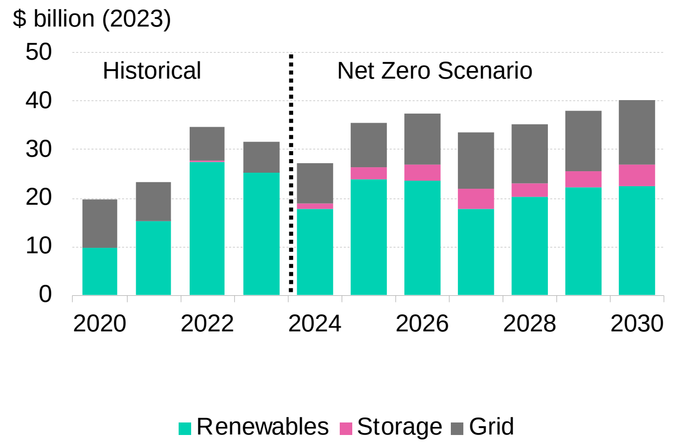
Brazil financed $4.5 billion of wind projects in 2023, down 39% from a year earlier. Worsening transmission bottlenecks are also constraining grid access for new projects in the northeast, the region with the highest capacity factors. This leads wind capacity in BNEF's 2030 forecast to fall 13GW short of the total in the Net Zero Scenario.

Figure 14: Brazil's renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 15: Brazil's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF Note: the distribution of investment between 2024 and 2030 is determined by nuances of the long-term model such as decommissioning of existing capacity.

Renewable energy investment in Brazil was $27.6 billion in 2022 and $25.4 billion in 2023, higher than the $21 billion required every year for the rest of the decade in the Net Zero Scenario. But there needs to be a significant increase in grid and energy storage spending. Successful transmission auctions over 2023-24 should increase investment and ease the grid constraints from 2028 onwards, facilitating a wind industry comeback.

The energy storage market has yet to take off in Brazil. The country is considering allowing batteries to bid into capacity auctions and provide ancillary services. Brazil also has many isolated systems in the Amazon region and batteries could play an important role in off-grid solutions to displace diesel generators.

Europe

EU member states, along with Norway, Switzerland and the UK, added a net 80GW of renewables in 2023, reaching an installed base of 757GW. BNEF forecasts renewable capacity in the region will rise to nearly 1.4TW by 2030, although this will fall around 15% short of a net-zero pathway. BNEF's wind forecast, in particular, is around 100GW below the volume envisaged in the Net Zero Scenario.

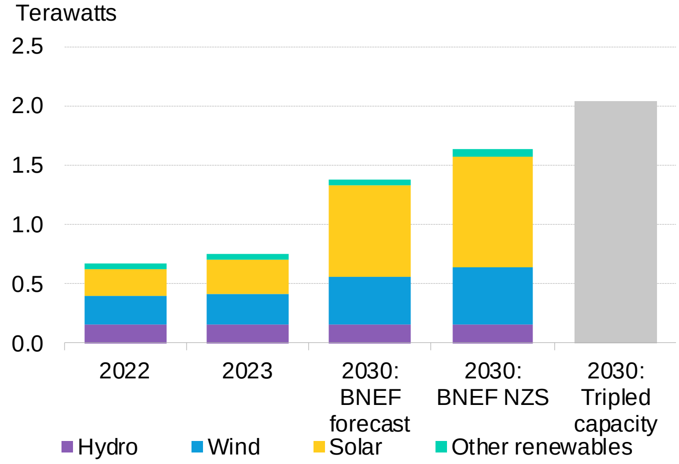
Figure 16: Market overview of Europe

Status	Key challenges to scaling investment		
Almost on track	**Grids and infrastructure** (Expanding grid capacity, regional interconnectors, managing grid queues)	**Permitting and land** (Clarifying appeals, data sharing, staffing of municipal offices)	**Power market design** (Long-term targets, competitive price signals for capacity and dispatch)

Source: BloombergNEF

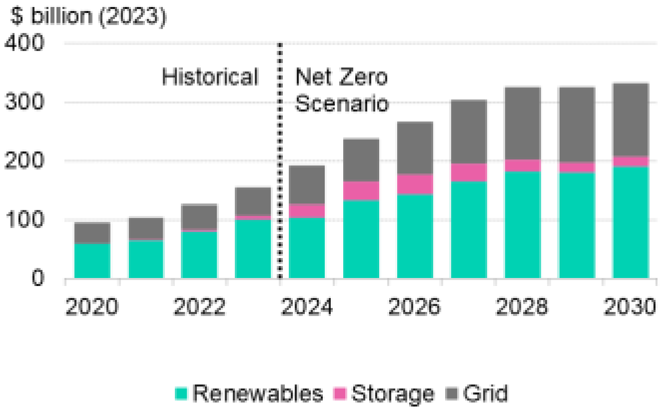
Investment flows into the region across renewables, the grid and storage rose 23% between 2022-23. Investment needs to keep growing at its current pace through 2028 to align with the tripling renewables goal, while also shifting more toward wind capacity. Grids and battery storage require more funding, with average annual capital expenditure on grids needing to double and storage triple this decade.

Figure 17: Europe's renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: Europe is the European Union, UK, Norway and Switzerland. NZS is Net Zero Scenario.

Figure 18: Europe's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF. Note: Europe is the European Union, UK, Norway and Switzerland. Distribution of investment between 2024 and 2030 is determined by nuances of the long-term model, such as decommissioning of existing capacity.

Grids and permitting are one of the primary challenges facing renewables deployment in Europe. It can take four to 12 years to develop a solar or onshore wind project in Europe, according to a 2023 report by industry think tank the Energy Transitions Commission, and over 12 years for offshore wind. This leads to major development uncertainty, financing challenges and cost overruns.

Governments across Europe are working to address this. The EU allows projects to receive 'overriding public interest' status, enabling automated or fast-tracked environmental approvals.

The bloc also published an action plan in 2023, with concrete recommendations to member states for unlocking growth in the region's grids. Grid investment is rising in many markets. BNEF's *2024 Power Grid Investment Market Outlook* (behind a paywall: web | terminal) sees spending plans for 2024-26 increasing by 28% from 2023 levels in Germany, Great Britain, France, Italy and Spain. Challenges around affordability for end users, regulated equity returns and availability of government funding still pose risks to the buildout.

Another area of focus is revenue certainty. Longer development timelines due to permitting and grid challenges, and rising interest rates are putting pressure on the expected returns for renewable energy investment. This is exacerbated by elevated equipment costs for wind – see BNEF's *1H 2024 Wind Turbine Price Index: Another Hike* (behind a paywall: web | terminal) – as well as increased negative power prices and zero-priced hours as renewable energy levels rise, especially during daytime hours for solar. New market designs to enable the adoption of battery storage, the electrification of industry, buildings and transport to boost clean power demand, and greater demand-side flexibility, will all be essential to supporting renewables expansion in Europe.

On the market design side, dedicated storage auctions are already bolstering adoption and improving revenue certainty for battery storage by offering long-term fixed-price contracts for difference. The first two rounds were held in Greece in September 2023 and awarded developers contracts with an average bid of €49,748 ($53,904) per megawatt per year, roughly half what project operators could have earned from market revenues alone in 2023, according to BNEF analysis (behind a paywall: web | terminal).

The European Commission also plans to support battery manufacturing and has approved two battery factory support packages totaling €6.1 billion since 2019, intended to trigger more than €13.8 billion of private investment. A total of 59 companies in 12 EU member states are involved in the project.

On offshore wind, some governments, like in Germany and the Netherlands, have moved away from providing revenue support. Instead, companies bid to pay the government to win site exclusivity, development rights and often access to a grid connection. This means developers must find an alternative route to market, usually through corporate PPAs. Reducing such revenue risks through two-way contracts for difference, supporting permitting and accelerated auction schedules could boost project deployment in offshore wind.

India

India built 13.5GW of solar and only 2.8GW of wind in 2023. This was a slowdown in capacity deployment from 2022, largely due to a 28% fall in solar build driven by import restrictions on modules, which made projects more expensive and led to delays. The $22.6 billion invested in 2023 is only a third of the average annual investment needed for the Net Zero Scenario between 2024 and 2030.

BNEF does expect a considerable acceleration. According to the Ministry of New and Renewable Energy, India added 13.9GW(AC) of solar – about 18GW of modules – in the first seven months of this year.

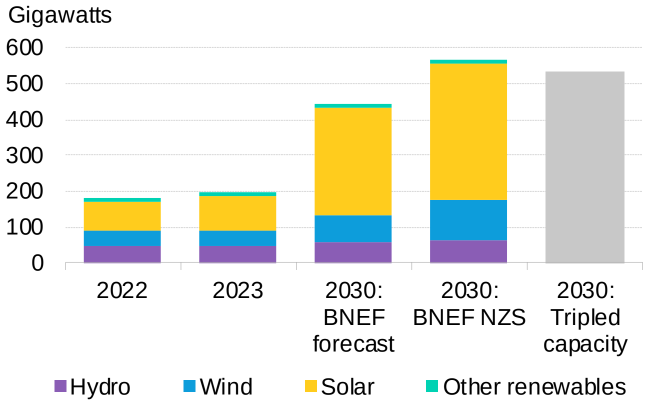
Figure 19: Market overview of India

Status	Key challenges to scaling investment	
Not on track	**Permitting and land** (Clarifying appeals, data sharing, staffing of municipal offices)	**Power market design** (Long-term targets, competitive price signals for capacity and dispatch)

Source: BloombergNEF

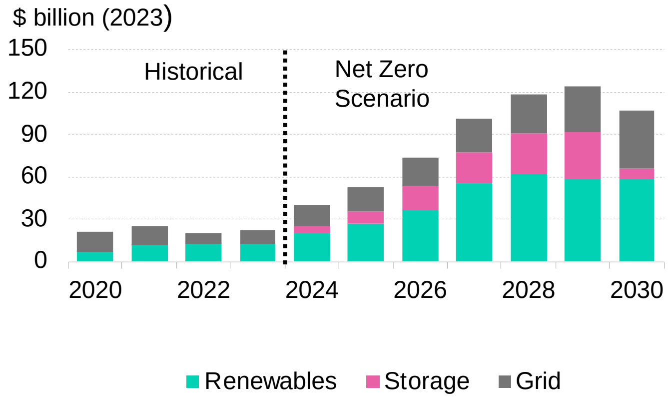
Although the country still has both import tariffs on solar modules, and a non-tariff barrier called the Approved List of Models and Manufacturers (ALMM), domestic manufacturers are ramping up production and importers have brought in plenty of supply. The landed cost of renewables is cheaper than the grid tariff in most Indian states, and the Indian government regularly auctions wind, solar and 'complex' projects (those requiring multiple technologies). See *India's Complex Renewable Auctions: Strategies and Winners* (behind a paywall: web | terminal) for more. Inda also has a waiver on transmission charges for projects connecting to the federal grid and priority dispatch for renewables.

Figure 20: India renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 21: India's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF. Note: The distribution of investment between 2024 and 2030 is determined by nuances of the long-term model, such as decommissioning of existing capacity.

Although investment in both grid and storage needs to ramp up for a net-zero transition, several grid expansion plans are being implemented for the transport of renewable power, including those where transmission projects have been auctioned to private developers. The addition of grid-scale storage in India is slower than some other markets because of the relatively high cost of storage and low share of intermittent renewables in the generation mix. However, several recently auctioned projects mandate an energy storage component and the country has also carried out auctions for grid-connected standalone storage. There are over 66GW of early-stage pumped hydro projects in the pipeline and the government is offering a capital subsidy for 4 gigawatt-hours of batteries – see *India's Billion Dollars in Subsidies to Spur Battery Build* (behind a paywall: web | terminal) for more.

Land acquisition remains a slow process, which if streamlined could speed up capacity additions. Some local governments have successfully identified very large parcels of barren land for renewables. The financial clean-up of power distribution companies and tariff rationalization for end users could create further demand for new renewables and lead to a proactive buildout of grid and storage by these entities.

United States

The US added 37GW of solar and 7GW of wind in 2023, taking its cumulative renewable energy capacity to 430GW. While wind and solar installations are set to grow, benefitting from the generous subsidies in the Inflation Reduction Act (IRA) passed in 2022, the country needs to ramp up capacity much faster to get on track for net zero.

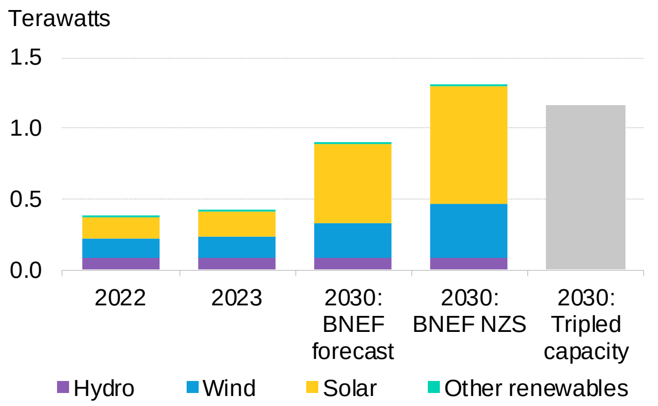
Figure 22: Market overview of the US

Status	Key challenges to scaling investment	
Not on track	**Grids and infrastructure** (Expanding grid capacity, regional interconnectors, managing grid queues)	**Permitting and land** (Clarifying appeals, data sharing, staffing of municipal offices)

Source: BloombergNEF

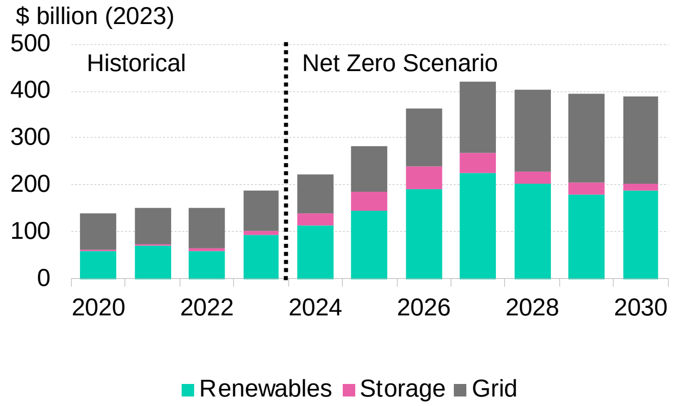
While the tax credits in the IRA boost project economics for developers of wind, solar and other technologies, other factors are holding back faster renewable energy growth. A shortage of transformers – which convert AC power from low to high voltage (and vice versa) for transportation – and other electrical equipment is hampering US wind and solar build. Meanwhile, trade restrictions aimed at equipment imports from China and Southeast Asia make solar more expensive in the US than anywhere else globally. That said, module prices have decreased by 37% in the last 12 months and utility-scale solar is currently buoyed by optimism and strong demand, although there is some policy uncertainty.

Figure 23: US renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 24: US clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF Note: The distribution of investment between 2024 and 2030 is determined by nuances of the long-term model, such as decommissioning of existing capacity.

Permitting and grid connection constraints are longstanding challenges that are delaying projects. Strong historical build in the windiest regions has caused grid congestion and negative power prices during periods of high generation. Local pushback and permitting challenges are also making it difficult for US wind developers to construct projects in regions with large populations and high load. Meanwhile, solar still has room to grow in markets with lower penetration.

US clean energy investment increased by 26% in 2023 compared with 2022. Investment must continue to rise at a compound annual growth rate of 22% from 2024-27 and remain at almost $400 billion per year for the rest of the decade if the US is to stay on track for net zero. Solar and wind investment reached $38.5 billion in the first half of 2024, in line with the first six months of last year, meaning activity will have to pick up in the rest of 2024. There is no shortage of investors looking to spend on new US renewable energy projects. Project supply could improve if reforms to permitting, both for transmission projects and wind farms themselves, and grid interconnection queue processes are effective.

Japan

Japan added a modest 5.8GW of renewable energy capacity in 2023, a year-on-year growth rate of 5%. This falls well below the country's needs for a net-zero trajectory. Under BNEF's Net Zero Scenario, Japan reaches a cumulative 300GW of renewables by 2030. Of this, 221GW is solar, making it the single-largest source of power capacity for Japan by the end of the decade. Offshore wind also hits 13GW in the Net Zero Scenario, from up from just 156MW of operational capacity at the end of 2023.

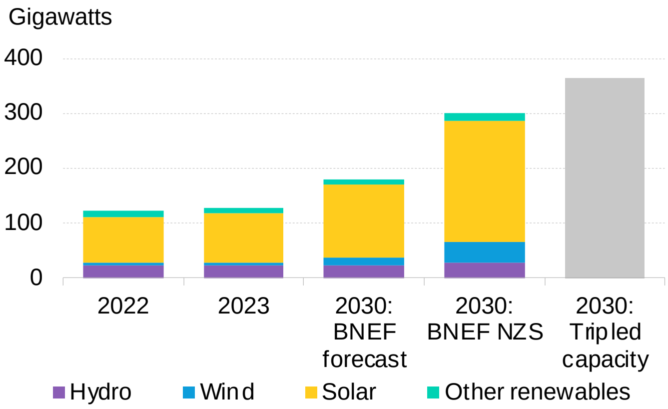
Figure 25: Market overview of Japan

Status	Key challenges to scaling investment	
Not on track	**Grids and infrastructure** (Expanding grid capacity, regional interconnectors, managing grid queues)	**Permitting and land** (Clarifying appeals, data sharing, staffing of municipal offices)

Source: BloombergNEF

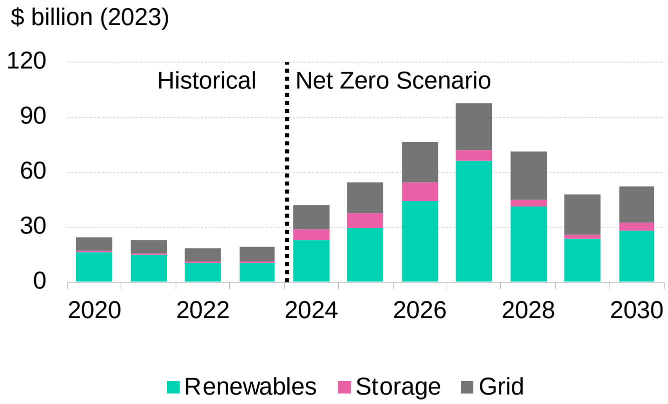
To get on track for this pathway, Japan's average annual investment in renewables, battery storage and the grid must more than triple from 2023 levels. But rather than rising, investment has waned in recent years, driven by a drop in large-scale solar deployment. Solar investment fell from a peak of $35 billion in 2014 to $10.5 billion in 2020 and a decadal low of $6.2 billion in 2023.

Figure 26: Japan's renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 27: Japan's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF Note: The distribution of investment between 2024 and 2030 is determined by the nuances of the long-term model, such as decommissioning of existing capacity.

The drop in solar investment is due to declining support in the form of lower subsidies for larger projects and reduced auction volumes. Land constraints also factor in: Japan has ample land, but much of it is mountainous terrain that drives up the capital expenditure required, to the point that projects do not make economic sense at the current levels of government support. Higher capex subsidies could make a difference here. In the interim, developers are largely targeting flatter terrain, where they often face competing end-use claims like agriculture. A new law to increase the use of acreage with no clear owner – estimated at 4.1 million hectares, or 10% of Japan's total land mass – has also seen low uptake, indicating a potential information and skills gap among local municipalities.

Japan's lengthy permitting and community outreach process for wind projects makes adding more capacity this decade a challenge. BNEF expects capacity awarded in onshore wind auctions to come online only at the end of this decade. While permitting processes in Japan are also difficult for solar, there are many more suitable sites, so this is not a major constraint on growth.

Offshore wind investment also needs to kick into overdrive to hit Japan's 2030 requirements for a net-zero pathway. This necessitates ramping up auction capacity and including support within the auction design for permitting and grid infrastructure, both of which developers currently undertake themselves, adding to project risk. Expanding into exclusive economic zone waters will unlock greater capacity and higher wind speed sites, although it is unlikely those auctions and the related projects could be commissioned before 2030.

Beyond specific measures for wind and solar, Japan's own targets are below the levels needed for a net-zero trajectory: it is aiming for 135-153GW of module capacity, compared to the 180GW under BNEF's Net Zero Scenario. Similarly, the government wants to auction 10GW and have a total of 5.7GW of offshore wind built by 2030, well below BNEF's Net Zero Scenario. Renewed government enthusiasm for nuclear reactor restarts is further clouding the investment picture for renewables, distracting from these assets as a near-term opportunity for investment and emissions reduction.

Sub-Saharan Africa

Sub-Saharan Africa is still in the early stages of its energy transition, which is critical for its 1.2 billion people and the world. Renewable energy capacity rose 12% in 2023 and investment amounted to $7.5 billion, far less than the $31 billion a year average for renewables needed to 2030 for a net-zero transition.

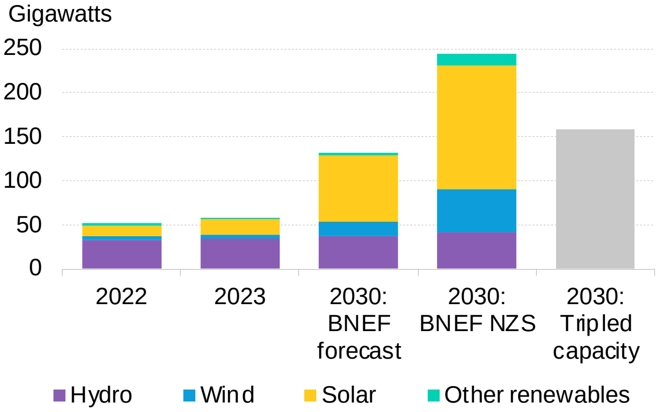
Figure 28: Market overview of sub-Saharan Africa

Status	Key challenges to scaling investment		
Not on track	**Increased access** (Cut fossil-fuel subsidies, ease generation licensing, encourage market participation)	**Auctions and offtakes** (Trustworthy offtakes, de-risking projects, diverse technologies)	**Permitting and land** (Clarifying appeals, data sharing, staffing of municipal offices)

Source: BloombergNEF

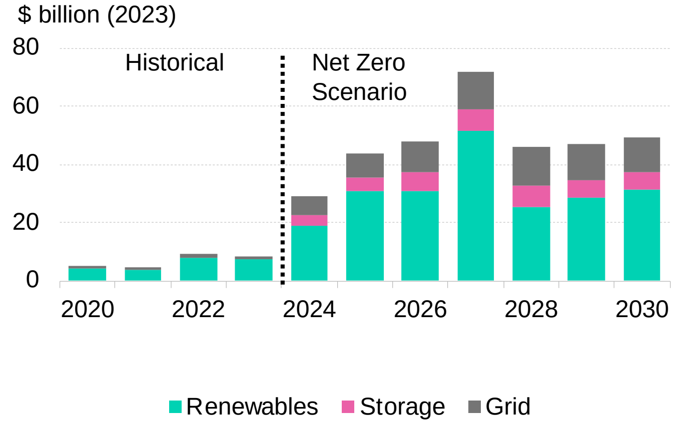
BloombergNEF's 2030 forecast of renewables capacity in the region has also decreased since last year. This is largely because of a downturn in South Africa, a key market, in 2024 compared with 2023. About 2.6GW of rooftop solar was added in the country without subsidy last year as households and businesses sought alternatives to unreliable grid power. However, in 2024 the grid situation has improved and blackouts behave become came less frequent. State utility Eskom's System Adequacy Reports estimate just 587MW of rooftop solar was added in the first 30 weeks of this year, and local media MyBroadband reports local installers have seen their sales halve. Although large installations are scheduled to come online in the next few years and the rooftop market is not dead, we have reduced our forecast for South Africa.

Figure 29: Sub-Saharan Africa's renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 30: Sub-Saharan Africa's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF Note: Distribution of investment between 2024 and 2030 is determined by long-term modeling pathway nuances.

Financing large renewable energy projects in low-income countries is always a challenge. The International Finance Corporation's Scaling Solar program, which aims to use World Bank development finance to unlock private capital for solar plants in emerging markets, continues to proceed very slowly.

One bright spot is likely to be continued adoption of small-scale renewables with no or limited subsidy. Although information availability on this is poor, export data indicates $1.5 billion of solar products were shipped from China to sub-Saharan Africa in 2023 (about 6.3GW of modules at a typical 2023 price of $0.24 per watt) and $488 million in the first half of 2024 (about 4.4GW of modules at a typical 2024 price of $0.11 per watt). The biggest markets were South Africa and Nigeria, which removed subsidies for gasoline briefly in 2023, causing private generators to buy solar panels. Although the subsidies were reinstated in 2024, gasoline prices remain high and Nigeria continues to import large volumes of solar panels from China. Other top importers were Senegal, Namibia and Kenya. These five markets are not those with large, recorded projects.

For large solar and wind projects, governments in Africa can do more to support a greater flow of capital toward local renewable energy projects by encouraging consistent clean power procurement – for instance, through clear and reliable auctions and tenders that are open to independent power producers. They can also aid grid buildout through clear development plans and enable domestic financiers to thrive with monetary reforms. For more, see *Scaling-Up Renewable Energy in Africa: A NetZero Pathfinders Report*.

Middle East, North Africa and Turkey

The Middle East, North Africa and Turkey (MENAT) installed 15GW of renewable energy projects in 2023, adding to the 106GW of cumulative capacity at the end of 2022. While BNEF expects the region's renewables capacity to almost triple by 2030, with a greater contribution from solar than wind, this still puts it well behind the path required to reach net-zero emissions. MENAT needs to more than triple capacity to contribute its share to the global target due to the comparatively small starting point for renewables in the region.

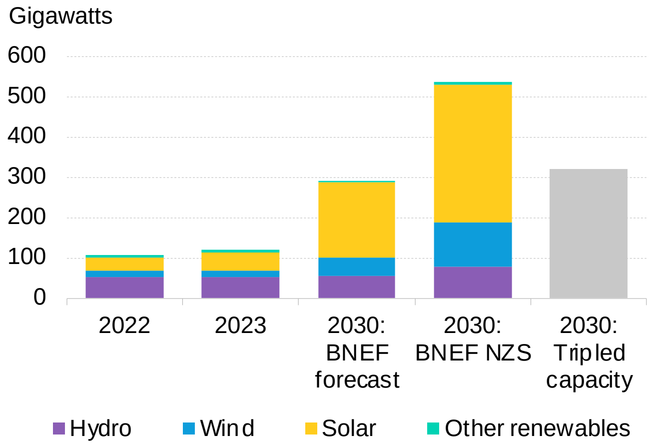
Figure 31: Market overview of Middle East, North Africa and Turkey

Status	Key challenges to scaling investment	
Not on track	**Increased access** (Cut fossil-fuel subsidies, ease generation licensing, encourage market participation)	**Auctions and offtakes** (Trustworthy offtakes, de-risking projects, diverse technologies)

Source: BloombergNEF

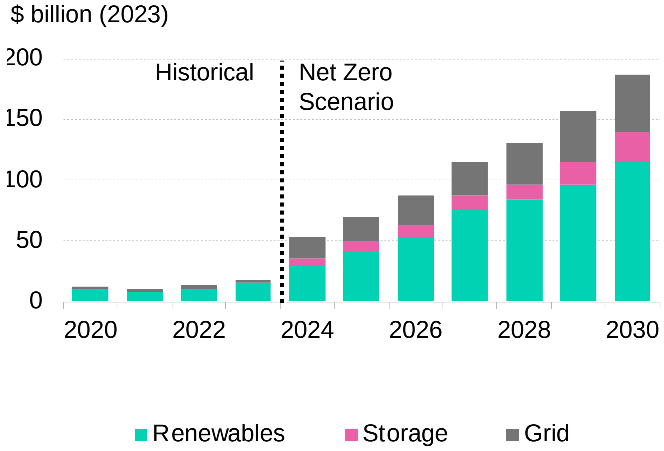
This also necessitates a rapid scale-up of investment flows to the region. Investment in renewables, energy storage and the grid reached $18 billion in 2023, up 39% from 2022, largely due to a few large-scale deals like Saudi Arabian developer ACWA Power's 1.8GW (DC) solar portfolio covering two sites: Ar Rass VIII and the NEOM PV plant, dedicated for hydrogen production. However, investment needs to rise more than sixfold over 2024 to 2030 to align with net zero.

Figure 32: Middle East, North Africa and Turkey's renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 33: Middle East, North Africa and Turkey's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF. Note: Distribution of investment between 2024 and 2030 is determined by nuances of the long-term model, such as decommissioning of existing capacity.

Competitiveness with fossil fuels is a key theme in the region. A mere 5% of generation and 11% of installed capacity in the Middle East came from renewable energy including hydro in 2023, lower than any other region in the world. An outsized share of local fundraising for energy activities is also oil-related: the United Arab Emirates accounted for over a fifth of fossil-fuel fundraising in emerging markets in 2022, at 44 billion dirham ($12 billion) according to BNEF's December 2023 report *Mobilizing Capital in and to Emerging Markets*.

Going forward, investment in the Middle East and North Africa is likely to be defined by large, one-off auctions and dedicated capacity to power electrolyzers for green hydrogen and ammonia. This makes investment opportunities uncertain, both because the auction calendar is patchy and because the ultimate demand for green hydrogen and ammonia is uncertain.[1]

To scale renewables investment, the region needs to foster more stable and certain demand. This can be done through increased auction capacity, feed-in tariffs and other incentives to boost revenue. A prime example of this is Turkey. In December, Turkey's Energy Markets Regulatory Authority handed out 25.6GW of pre-licenses for energy storage assets to be co-located with wind or solar farms of the same capacity. Over half the capacity went to projects that will be linked to new wind farms. These projects will be able to apply for Turkey's new feed-in tariff – called Yekdem – also introduced last year.

While Turkey is building large volumes of renewables, the government is not primarily concerned with phasing out coal, which provided 36% of its electricity in 2023. Instead, it seeks to make its energy sector less dependent on imports, particularly gas, by building renewables and nuclear (link). Overall, this aim is probably compatible with a low-carbon pathway, although a more targeted approach to reduce coal use would have benefits.

Greater commercial and industrial demand has recently boosted solar adoption in the region. MENAT is on track to install nearly 15GW of solar this year, almost tripling installations from 2021. Turkey, in particular, has been growing, with solar installations doubling year-on-year in 2023 to 5.5GW, thanks to strong commercial adoption. In December, the Tunisian government published the implementing decrees allowing commercial entities to connect their solar systems to the medium- and high-voltage network, and to sell part of their surplus solar generation to local utility STEG (Tunisian Electricity and Gas Company) – leading to record levels of uptake so far in 2024.

Currency risk is another focus for auctions and offtake arrangements in MENAT, as many players will buy equipment in US dollars but could be earning revenue in local currency. Governments can support this by offering dollar-indexation in their revenue calculations. For instance, Turkey's Yekdem contracts pay out in Turkish lira but with prices adjusted according to the consumer price index, a producer price index and dollar and euro exchange rates with the lira.

Indonesia

Indonesia has less than 14GW of renewables, and installed 1GW in 2023. Just $5 billion was invested in clean energy and the grid last year, compared with an average of $32 billion needed each year to 2030.

[1] Green hydrogen and ammonia is still a nascent sector with uncertain demand. It is also unclear how competitive the Middle East's hydrogen and ammonia output will be with production in other regions, particularly the US, given the potential for generous tax credits.

Figure 34: Market overview of Indonesia

Status	Key challenges to scaling investment		
Not on track	**Increased access** (Cut fossil-fuel subsidies, ease generation licensing, encourage market participation)	**Auctions and offtakes** (Trustworthy offtakes, de-risking projects, diverse technologies)	**Power market design** (Long-term targets, competitive price signals for capacity and dispatch)

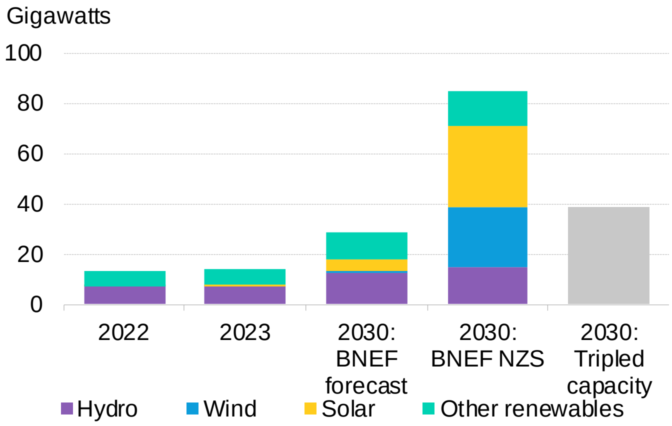
Source: BloombergNEF

Indonesia is the fourth-largest country in the world by population. It increased power generation by 10% in 2023 and sourced 62% of its electricity from coal. This makes it hugely important to the energy transition, and it is one of the regions that needs to more than triple renewable energy capacity for the world to meet its COP28 goals.

Indonesia has one state-owned power utility, Perusahaan Listrik Negara (known as PLN), which is a vertically integrated monopoly. Independent power producers can only sell power to PLN and customers can only buy power from PLN, except in specific areas like industrial zones. Offsite PPAs are not allowed. Onsite PPAs are also technically not allowed, though there is a legal loophole that enables this. There are local content requirements for solar panels, which drive prices up.

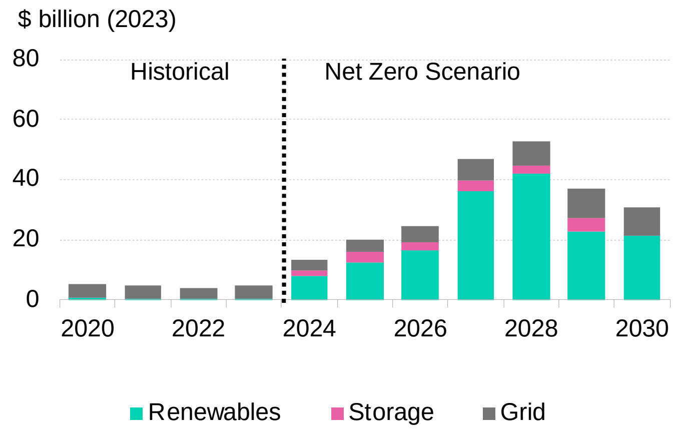
There are also supply-side incentives for coal. Coal miners are obligated to sell 25% of their output domestically, and coal sold for power generation cannot be more expensive than $70 per metric ton, making coal power artificially cheap in Indonesia. New coal plants have been banned since 2022, but there are big loopholes. Those already included in PLN's current power development plan (which runs from 2021-2030) are exempt, as are those intended to provide captive power for industries that add value to extracted natural resources or contribute significantly to job creation and economic growth. In practice, these are usually nickel refining facilities.

Figure 35: Indonesia's renewables capacity – 2022-23 versus BNEF's 2030 forecast and New Energy Outlook Net Zero Scenario



Source: BloombergNEF. Note: NZS is Net Zero Scenario.

Figure 36: Indonesia's clean energy and grid investment – historical and Net Zero Scenario



Source: BloombergNEF Note: The distribution of investment between 2024 and 2030 is determined by nuances of the long-term model, such as decommissioning of existing capacity.

Renewable energy project developers need to get onto PLN's whitelist before they can participate in competitive auctions, and private developers are often obliged to enter into joint ventures with one of PLN's subsidiaries when they win in an auction. In some cases, PLN insists its subsidiary should have a majority equity stake. Developers have also complained that risk sharing is not proportionate to equity sharing.

Further information can be found in 2023 Comprehensive Investment and Policy Plan for Indonesia's Just Energy Transition Partnership. Progress on the energy transition in Indonesia requires addressing some of these issues.

Section 3. Solutions

This section further explores how governments can address the barriers to meeting their contributions to a global tripling of renewables capacity, beyond simply relying on subsidies. We focus on five key areas where intervention could have the most impact.

Barriers to access

Tripling renewables by 2030 entails some basic work to make sure clean power developers can build projects. This includes ensuring renewables compete on an equal footing with fossil-fuel-based generation by ending subsidies for coal and gas, removing licensing and regulatory barriers to private sector participation in power plant ownership and development, and clarifying the ownership of land on which projects are to be constructed.

1. **Remove subsidies for fossil fuels.** Many markets still offer subsidies for fossil-fuel-based power generation, with the G-20 governments and state-owned enterprises providing $583 billion in support in 2021, based on BNEF analysis. For instance, Indonesia subsidizes coal use in its power sector, while many African countries such as Senegal and Angola still subsidize gasoline – which is then used instead of solar and storage for on-site backup power generation to ensure supply resiliency. Nigeria briefly removed gasoline subsidies in 2023, but these were reinstated after protests; the International Monetary Fund expects the country to spend the equivalent of 48% of its oil revenue on subsidies in 2024 (link). This can make it difficult for renewable energy to compete economically, resulting in potentially wasteful use and production of fossil fuels, and investment in long-lived, emission-intensive equipment and infrastructure. Even though many of these subsidies intend to help low-income households and other vulnerable consumers, they tend to disproportionately benefit the wealthy. Such support can lead to double subsidization and an inefficient allocation of government revenue if renewable energy support schemes are then introduced.
2. **Smooth the path to generation licensing.** Many markets require would-be renewable energy and storage project developers to acquire complicated and unnecessary licenses to build and connect projects. This can range from a double licensing standard for battery storage assets – which may have to apply for both generation and consumption licenses, or may not have a defined role in government regulations – to rules that require owners of grid-connected power plants to qualify as a utility, often bringing particularly onerous rules and regulations that fall beyond the remit of power generation.
3. **Clarify land ownership.** A lack of clear land ownership rights can hold back renewable energy projects. This can be especially difficult in emerging markets and developing economies, leading to lengthy development cycles or shallower project pipelines. While often discussed alongside other permitting challenges, an inability to acquire and prove rights to land represents a fundamental barrier to clean power development.
4. **Easing supply chains.** Supply chains – particularly around equipment like wind turbines and transformers – have recently posed a challenge to renewable energy development. In addition, import tariffs, restrictions on products allowed to enter a country, and complex local supply requirements can impede deployment. India and the US are coupling these policies with incentives to boost local manufacturing, which could encourage domestic firms to meet demand. In industries with demand uncertainty, like offshore wind and grids, governments

may also be able to play a role in guaranteeing offtake to support new manufacturing capacity.

Case study: South Africa's generation license removal experiment

South Africa has been in a power crisis since 2007. The coal plants belonging to state utility Eskom are old and have not been adequately maintained. Planned rolling blackouts, known as 'load shedding', are a regular experience for homes and businesses.

The government took a wide range of measures to increase generation, including lifting the threshold size for a private generator to connect to the grid without a generation license to 100MW in 2021, and removing the threshold entirely in January 2023. This meant that a major barrier to consumers supplying their own power was removed.

April and May 2023 saw some of the worst blackouts ever in South Africa, driving residential and commercial power consumers to buy 1GW of solar panels in these two months alone, according to Eskom's system status reports. That is more than a third of the 2.6GW of solar installed in the entire year. At the same time, Eskom increased maintenance at its coal plant fleet and reduced outages.

Together with other measures, this allowed the country to celebrate a full month without power cuts in April 2024 and 150 days without any planned power outages in August 2024. As of 2024, the market for new solar panels for homes and small businesses has slowed down in response, but there are still plans to add larger facilities to mines and factories to reduce costs.

Auctions and offtakes

Long-term offtake contracts for clean power are an important way to accelerate clean energy deployment, by shifting power price risk from project owners to utilities and state power firms. These contracts may act as a form of hedging for the buyer as well – for example, during the 2022 energy crisis, when the price of natural gas rose and drove up power prices around the world, leaving buyers in long-term renewables contracts much better off.

Due to the falling costs of solar and wind over the last decade, long-term contracts can often be agreed at prices comparable with fossil-fuel-generated power and acceptable to the buyer and the developer. The certainty around revenue allows developers to arrange debt financing at lower interest rates than if the project were exposed to power price risk, bringing down the levelized cost of energy of the project as well.

Offtake contracts are often awarded in auctions, where project developers submit bids on various criteria, usually primarily price. Competition between developers ideally means the offtakes are awarded in a cost-effective manner, if the auction is well designed.

There are several concrete steps governments can take to ensure auctions and offtakes are sufficient to incentivize renewables deployment:

1. **Design auctions to de-risk projects.** In most renewable energy auctions, developers have to find their own sites and grid connection when they bid for the power contracts offered. This means developers do a lot of work for no guaranteed reward. While this is part of a developer's job, it is inefficient and can result in auctions being undersubscribed. Taking over pre-bid work – as India has done in some solar auctions and Germany and the Netherlands for some offshore wind tenders – or guaranteeing winners a grid connection, would accelerate renewables deployment this decade. In markets where developers buy equipment

in US dollars but earn revenue in local currency, auctions designed to manage currency or inflation risk can also speed up build, as was effectively done in Vietnam.

Providing visibility on future auctions is also essential for developers looking to participate in new markets, such as sub-Saharan Africa, and to give supply chains a sufficient signal to build out capacity, particularly in newer areas like offshore wind. Sticking to an auction calendar – for example, by avoiding last-minute changes and cancellations – is also important for building investor certainty.

2. **Include diversification criteria.** If auctions only awarded power contracts on a price-per-megawatt-hour basis, solar would win almost all the capacity on offer. This would not be good for a diverse energy mix. Well-designed auctions should include criteria that enable higher-cost solutions to compete. These can include carve-outs for specific technologies, a multiple for power produced at the most useful times, or complex availability and capacity factor requirements like India's "24/7 auctions," which encourage a mixture of solar, wind, batteries and even fossil-fuel power for emergencies.
3. **Allow and encourage corporations to sign power purchase agreements.** This enables firms to meet their net-zero targets and voluntary renewable energy procurement commitments, while incentivizing additionality (ie ensuring they are only getting credit for projects that would not otherwise have been built). It is also an effective way for buyers and sellers to hedge commodity price risk. A trustworthy green certificate market can empower small- and medium-sized enterprises to participate both as buyers and sellers.
4. **Mitigate offtaker risk.** The offtake counterparty needs to be credible and able to meet its obligations, so that banks will be willing to finance the project with low-cost debt. In some places, the existing government structures do not meet these criteria, and reinforcement is useful. The Solar Energy Company of India (SECI) was set up in 2011, in part to be the auction counterparty and reduce the risk of projects relying on Indian distribution companies for payment. Sovereign risk guarantees, where the government backstops the offtaker's liability to pay, can be used but are only as robust as the issuing government. Development banks also often provide debt of first recourse to reduce the risk that underpayment will hurt the returns of commercial banks, encouraging them to participate in deals.

Case study: India's complex clean power auctions

India is leveraging its successes with wind and solar bids to unlock the next phase of renewables growth. It is pioneering 'complex' auctions – where projects need to combine multiple technologies – to reduce the intermittency of output, increase capacity factors and move closer to firm, dispatchable clean power. The country had held 31 complex auctions up until March 2024.

These auctions fall into four main categories. Hybrid auctions allow bids from a mixture of wind and solar, with a minimum combined annual capacity factor of 30% and at least 33% of capacity from both. Peak power, round-the-clock and load-matching auctions all include wind, solar and energy storage, with no restrictions on the sizing of the wind and solar.

Peak power auctions specify energy dispatch and availability for four to six peak hours daily. Round-the-clock auctions specify minimum availability and capacity factors, either monthly or annual. Load-matching auction projects may be called upon to meet a representative hourly demand profile for 25 years. Projects are allowed to sell excess generation either to a third party or to the wholesale market.

Auctions of complex clean power projects in India rose to 9.7GW(AC) in the first quarter of 2024, more than the total capacity awarded in 2022 and 2023. The top winners of complex auctions are all experienced domestic independent power producers, led by ReNew and Adani Green. Government-owned companies may increase participation in a few years, as they have done in solar bids. Competitive pressure means that prices are usually contested between several firms.

These auctions provide a powerful incentive for renewable energy capacity in India to be built in a manner that fully utilizes the existing grid and matches well with the timing of power demand.

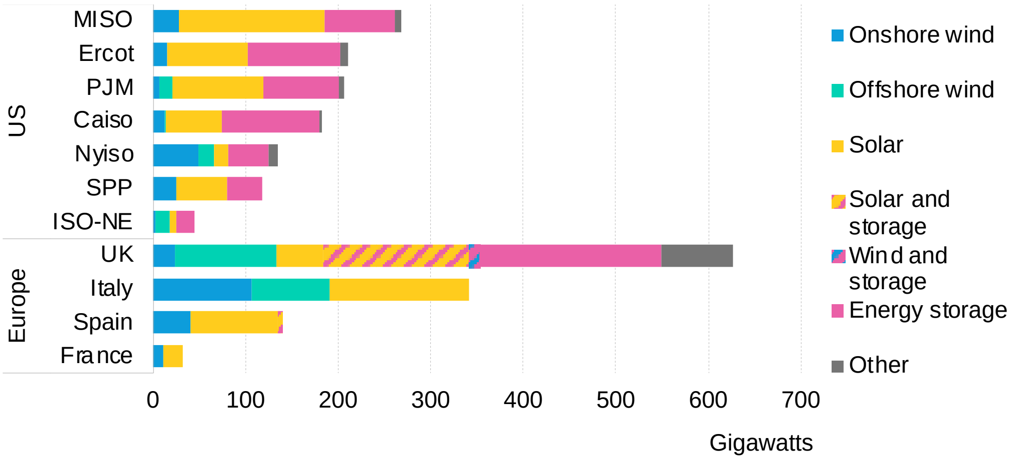
For more, see *India's Complex Renewable Auctions: Strategies and Winners* (behind a paywall: web | terminal).

Grids and infrastructure

BNEF estimates that, on average, $607 billion needs to be invested in the grid each year through 2030 to align with a net-zero pathway – nearly double 2023 investment levels. This is essential to enable additional renewable energy connections, new demand and the resiliency of power provision globally.

However, the world is currently not on track for this investment. Power grid development plans analyzed by BNEF indicate there will be a 13% year-on-year rise in capital expenditure in 2024. These plans account for approximately half of global power grid spend. Total global grid investment is also on track to grows by 13% in 2024 when including markets with grid investment modeled by BNEF – see *2024 Power Grid Investment Outlook* (behind a paywall: web | terminal) for more. Rising energy costs since 2022 have also squeezed consumers financially, making many regulators reluctant to allow large increases to consumers' grid rates.

Figure 37: Capacity of power projects in grid connection queues in selected markets in the US and Europe



Source: BloombergNEF, California ISO (Caiso), Electric Reliability Council of Texas (Ercot), Pennsylvania-New Jersey-Maryland Interconnection (PJM), New York ISO (Nyiso), Midcontinent ISO (MISO), Southwest Power Pool (SPP), ISO New England (ISO-NE), Lawrence Berkeley National Laboratory (LBNL), RTE (France), REE (Spain), Terna (Italy), National Grid ESO (UK).

With grid investment lagging, interconnection queues for renewable energy have skyrocketed (Figure 37). BNEF now estimates nearly 2.2 terawatts of wind, solar and battery storage capacity is stuck in queues across four European markets – France, Spain, Italy and the UK – and the service areas of seven independent system operators in the US.

The financing strategies for grid investment vary by market. Throughout the 1900s, most power grids in the West were state- or municipality-owned, but the 1990s started a trend of privatization of grid companies. Today, many grid operators in Europe and the US are privately owned and not under direct government control, although the state retains partial or full ownership of grids in, for example, Spain and France.

India and Brazil are also increasingly reliant on private capital to expand their grids, mainly through independent transmission projects tendered to private developers. China's grid expansion remains dominated by state-owned State Grid Corp of China (State Grid), but the company depends on capital markets for debt capital. European state-owned grid firms, such as German and Dutch transmission system operator TenneT, also rely on private debt capital.

There are several steps governments can take to accelerate the expansion of grids and ease this bottleneck to renewables build:

1. **Create central plans for grid expansion, including interconnectors.** Grid plans can be designed to match the amount of renewables capacity targeted by 2030. These plans can preselect corridors for new grid development, providing greater certainty for renewables site selection. They can also lay out the role of new hardware deployment and non-wire solutions, like digitalization and flexibility, in achieving greater grid capacity. A 10-year plan prepared by a body that has the authority to sanction projects would be ideal, coupled with a 2050 grid vision that guides the development of that overall grid architecture.

   Interregional networks can be a vital part of this, both in island nations like the UK, Indonesia and Japan, or regions with vast land masses like the US and China. Interconnected systems are more resilient to extreme events and supply energy more affordably to end users. But they are difficult to build without the support of deliberate, coordinated interregional planning, coupled with centralized permitting capabilities.

2. **Enable anticipatory grid investment.** Most markets take a risk-averse approach to grid investment. Operators can create plans, but new capacity must often be needs-tested by a regulator, who will not allow those projects to be funded from regulated revenues if there is uncertainty. This can be particularly detrimental to markets where the regulator does not believe renewable energy targets will be met or where electrification of new end uses in transport, buildings and industry is hard to predict. Allowing projects to meet differentiated needs-testing thresholds can help them progress in the face of uncertainty, assuming environmental and construction permitting requirements are fulfilled.

3. **Encourage private sector participation.** This is essential for modernizing infrastructure, introducing innovation and moving more quickly. It offers a solution to public sector budget constraints, especially in developing economies, by attracting funds and expertise. This includes merchant and independent transmission lines developed by non-incumbent participants. For such models to be successful, a balance of revenue certainty for investors and robust oversight is necessary, alongside clear cost allocation. In developing markets, private sector participation is focused on attracting investment due to capital constraints, while in more liberalized markets like the UK, private sector participation can also create a competitive environment where innovation is encouraged.

4. **Manage grid queues effectively.** There are several ways to improve queues for projects applying to connect to the grid. Requiring projects to hit defined milestones to remain in a queue can reduce speculative bids that are likely to fail even if they do get a grid connection, which would be a waste of time to assess. Transparent processes and timeframes, better

coordination between transmission and distribution operators, and streamlining data flows across departments can also help reduce connection timelines, while connect-and-manage programs can allow projects to access the grid while major upgrades to transformers and substations are still underway.

Case study: Great Britain's transmission grid buildout

Great Britain's National Grid Energy System Operator (ESO)* is planning a transmission grid buildout in line with the market's ambitious offshore wind targets. The Holistic Network Design (HND), which sets out a plan to connect 23GW of new offshore wind by 2030, was released in 2022.

The ESO's subsequent Beyond 2030 plan, published in March 2024, integrates the offshore and onshore grid planning processes, improving coordination between grid and energy generation projects.

Transmission grid companies must balance building the grid either proactively or reactively. Until recently, British grids were typically strengthened only after the existing infrastructure became frequently overloaded. The HND shows a shift towards proactive grid buildout, to prepare for anticipated and targeted growth of renewable energy generation. This supports Britain's target of a 100% carbon-free electricity sector by 2035.

To enable proactive grid investment, energy regulator Ofgem, has revised the regulation concerning cost recovery and risk management for offshore grid projects, allowing them to build before offshore wind projects are ready to connect. The connection of offshore wind requires significant strengthening of the onshore grid, with new transmission lines from the shores to large centers of power demand.

The ESO recommends grid investment double this decade from the last decade. In 2022, the system operator proposed a total of £53 billion ($70 billion) in investment by 2030. With inflation, this has risen to almost £60 billion. In April 2024, a further £58 billion of investment over 2031-38 was recommended in the Beyond 2030 plan.

Permitting

Permitting can add years to renewable project development timelines. In Europe, permitting can take 10 or more years for offshore wind, four to nine years for onshore wind and one to four years for solar (which tends to have a lower impact on its surrounding environment). Designating projects as having an 'overriding public interest', as introduced by the EU in 2022, or allowing for automatic approval or exemption if applications are not reviewed or rejected within a certain period of time, is one way to speed up the process.

Permitting processes play an important role, filtering out projects that are significantly detrimental to the local environment or communities. Some sites should never be built on for social or ecological reasons. However, every effort should be made to clarify and improve existing processes to identify suitable sites. These can include:

1. **Streamlined permitting processes**. Establishing one-stop-shops for permitting applications, enabling information-sharing between departments through digitalization and reducing the number of duplicated processes (such as having to submit information with only slight differences to multiple departments), can go a long way to improving the speed of renewable project permitting. For instance, in 2020, Denmark established a one-stop-shop for offshore wind permitting, borrowed from past measures used to support North Sea oil production.

2. **Staffing local government departments**. Many departments involved in the permitting for power plants were set up to manage a handful of large thermal power plant applications, not hundreds or thousands of distributed renewable energy projects each year. Staffing levels must increase to reflect this new paradigm. The need for sufficient employment extends to courts and judges, to ensure permitting appeals and legal challenges can be heard in a timely manner.
3. **Clarifying appeals and stakeholder engagement**. To ensure renewable energy scales, it is essential that local communities and stakeholders are identified and involved. The opacity of the process often means appeals and legal challenges appear either late in the development cycle or with an unclear timeline toward resolution. Measures to ensure legal cases are heard by judges within a certain number of months (as was done in France), to specify the number of appeals that can be made, or to specify the time period in which legal challenges can be submitted, can all help the development process.
4. **Improved data and site designations**. Governments, non-profits and non-governmental organizations can help establish central databases with essential geospatial data, including information on biodiversity, landscape, easements and land use from nearby populations. This data can be hard to find and efforts to collect it may be duplicated by multiple players in the selection of sites and completion of environmental impact assessments. If the data is in a central place, governments could also use it to conduct initial environmental surveys for developers, to predesignate energy development zones in regions that are likely to have a limited impact on wildlife and local communities. Governments can also set more appropriate easement requirements, which dictate siting distances for wind farms from specific types of sites or buildings, and are often set conservatively.

Case study: Germany's wind permitting overhaul

Securing consent for building an onshore wind farm in Europe takes longer than the building process itself. Lawsuits, land-use conflicts and bureaucratic burdens have all slowed permitting rates, holding back Europe's onshore wind growth.

In response, the EU has been implementing measures to shorten permitting procedures to two years, from five years or longer in some member states. In late 2022, the bloc adopted a temporary 18-month regulation to streamline the permitting process by limiting lawsuits against wind farms or fast-tracking certain permitting stages. Some of the provisions have been extended until mid-2025.

Germany is one of the early adopters of some of the measures, which helped the country cut its permitting pipeline from 11GW to 3GW from 2019 to 2023. Permitting activity has increased, with over 7.5GW of projects approved in 2023, up 80% from 2022. Almost 3GW of onshore wind projects were permitted in the first quarter of 2024. To limit the basis for lawsuits, Germany has designated renewable energy as “of overriding public interest”, meaning legal rulings can favor renewable energy projects over other matters such as species protection or landscape impacts.

Securing an environmental permit is one of the most time-consuming stages of permitting. Germany temporarily exempted projects from this stage, provided they are located in pre-identified dedicated areas that have already been assessed or that pose low ecological risks.

In 2022, Germany eased permitting rules around species protection for onshore wind repowers, meaning developers do not have to restart the laborious consenting process when replacing old turbines in a project. The country has one of the oldest wind fleets in Europe, with over 26GW set to have reached their design life of 20 years by 2030. Developers commissioned 1.1GW of repowers in 2023, the highest since 2014. For more, see *Europe's Wind Permit Overhaul Is Working* (behind a paywall: web | terminal).

Market design

Effective market design is critical to both ensure renewable energy can compete with existing fossil-fuel fleets and be built on a cost-effective basis. It is also essential to make sure the power system can handle increased renewables penetration or achieve 24/7 production of low-carbon generation.

1. **Competitive price signals.** Renewables are currently the cheapest source of new generation in markets equivalent to 59% of global electricity generation, according to BNEF (see *2H 2023 Levelized Cost of Electricity Update*, behind a paywall: web | terminal). Since early 2023, falling prices for fossil fuels saw coal and gas regain the title of cheapest bulk electricity source from renewables in the US and Japan, but solar and wind are still widely competitive. However, many markets, especially those with powerful state-owned vertically integrated regional monopolies or high levels of regulation, do not take economics fully into consideration when building out their generation portfolios. Those markets that do bring in competitive price signals for both capacity development and dispatch tend to see a greater deployment of solar and wind.
2. **Renewables integration.** Power market design is also critical to the ability to handle increased penetration of wind and solar. In addition to a competitive dispatch signal, markets need to ensure that flexible low-carbon loads are encouraged through either scarcity pricing in a wholesale market, dynamic tariffs to encourage power users to load shift, or capacity payments that consider carbon intensity. Ancillary service markets, which competitively tender key grid services as the share of non-spinning generation rises, should also be initiated and standardized to encourage the scale-up of energy storage system deployment.
3. **Long-term targets, emissions pricing and regulation.** A carbon price sets an immediate premium for renewable power over the local price of fossil fuels. However, to drive decarbonization, carbon prices need to be high enough and credible for the long term, while concessions to participants (such as free permits) should not be too generous. A coal power ban is another way for governments to promote clean electricity, while a net-zero target signals to investors that renewable s are likely to be favored over fossil-fuel plants by future policy. These are two major ways for governments to encourage investment in renewable energy, in addition to auctions and corporate power purchase agreements.

Case study: Argentina’s radical new energy law

In July 2024, a new law was passed in Argentina aimed at taming the country’s snowballing deficit and promoting pro-business reforms, which could mean major changes for the energy industry. With an array of incentives designed to attract sorely needed private investment in clean energy, power transmission, oil and gas, and mining, the law could roll out the red carpet for new power projects and oil and gas drilling – although it may also drive up power prices for consumers.

The “Ley de Bases”, as the legislation is known, gives recently elected President Javier Milei sweeping emergency powers over administrative, economic, financial and energy-related matters. The 200-plus articles in the new law include privatization goals, labor-law and income-tax modifications, and incentives for private investment. The Large Investment Incentive

Regime (RIGI) offers additional benefits for projects with investment above $1 billion, of which mining and the oil and gas sectors will likely be the main beneficiaries.

RIGI could well attract long-term foreign investment for clean energy and transmission projects, as it may mitigate some investors' concerns around capital controls. The revamp in transmission infrastructure will be key to allow more renewables build. However, it is very unlikely Argentina will hold renewable auctions during Milei's term. The corporate PPA market will likely be the exclusive route for new renewables plants to find offtakers for their electricity. That said, potential investors may prefer to wait until macroeconomic conditions in Argentina improve, especially as recent delays in power payments from the government to energy generators could leave them with cold feet.

The Ley de Bases could also promote radical changes in Argentina's energy market. The law promises to essentially liberalize the sector, ensuring maximum competition in the power market by allowing consumers to elect their power suppliers. BNEF expects the government to slash power subsidies and stop the country's market administrator, CAMMESA, from acting as a middle agent between power generators and distributors in new power purchase agreements.

To date, price controls and a lack of infrastructure have been major impediments to resource exploration in Argentina. This new law will benefit fossil-fuel exploration, as well as clean power. Under the Ley de Bases, the government will not be allowed to intervene in commercial prices of hydrocarbons for the domestic market, and oil and gas producers will be able to deploy the infrastructure needed for hydrocarbon transportation. This could enable the vast Vaca Muerta shale deposits, the fourth-largest shale oil reserve in the world, to be developed.

Appendices

Appendix A. Methodology

A.1. Technology coverage

The analysis in this report defines renewable energy as solar, wind, hydropower, geothermal, bioenergy and marine. This is similar to the technology coverage of the International Energy Agency, which we compare in Table 3.

Table 3: Comparison of renewable technology coverage

Category	BNEF	IEA
Solar	• Small-scale solar (residential and commercial plants below 1 megawatt or primarily for onsite consumption) and large-scale solar (plants above 1MW or mainly feeding into the grid)	• Distributed and utility-scale solar
Wind	• Onshore wind, offshore wind	• Onshore wind, offshore wind
Hydropower	• Large hydro, small hydro	• Reservoir, run-of-river
Other renewables	• Geothermal, bioenergy, solar thermal, marine	• Geothermal, bioenergy, solar thermal, marine (tidal and wave)

Source: BloombergNEF, International Energy Agency.

A.2. Data sources

The renewables capacity data in this report comes from three sources:

- **Historical data (2000-2023)** is derived from BNEF's *Power Transition Trends 2024* (behind a paywall: web | terminal). This annual report examines trends in global generation, capacity and emissions. It is based on data collected by BNEF analysts on six continents from primary sources in 140 markets, along with aggregated data from the rest of the world.
- **Investment data** is from BNEF's *Energy Transition Investment Trends 2024* and *Renewable Energy Investment Tracker 2024* (behind a paywall: web).
- **Net Zero Scenario (2024-2030)** is a model result drawn from BNEF's *New Energy Outlook 2024* (behind a paywall: web | terminal). The Net Zero Scenario describes an economics-led evolution of the energy economy to achieve net-zero emissions in 2050. It limits global warming to well below 2C with no overshoot or major reliance on carbon removal technologies after 2050.
- **Forecast data (2023-2030)** reflects BNEF's latest renewables installation outlook by 2030. The current wind and solar forecasts can be viewed here (behind a paywall), and this analysis used the forecasts as of August 2024. For technologies that we do not produce regular forecasts for (geothermal, hydropower, marine and bioenergy), we rely on the baseline Economic Transition Scenario of our New Energy Outlook. As this scenario is driven primarily by the cost competitiveness of technologies and assumes no new policy changes, this approach may understate the build that can be driven by policy.

A.3. Regional groupings

Table 4 shows how countries are categorized by region.

Table 4: Country coverage by region

Region	Countries			
Europe	• Austria • Belgium • Bulgaria • Croatia • Cyprus • Czech Republic • Denmark • Estonia	• Finland • France • Germany • Greece • Hungary • Ireland • Italy • Latvia	• Lithuania • Luxembourg • Malta • Netherlands • Norway • Poland • Portugal • Romania	• Slovakia • Slovenia • Spain • Sweden • Switzerland • UK
Middle East, North Africa and Turkey	• Algeria • Bahrain • Egypt • Iran • Iraq	• Israel • Jordan • Kuwait • Lebanon • Libya	• Morocco • Oman • Qatar • Saudi Arabia • Syria	• Tunisia • Turkey • United Arab Emirates • Yemen
Sub-Saharan Africa	• Angola • Benin • Botswana • Burkina Faso • Burundi • Cameroon • Cape Verde • Central African Republic • Chad • Cormoros • Democratic Republic of the Congo	• Djibouti • Equatorial Guinea • Eswatini • Ethiopia • Gabon • Gambia • Ghana • Guinea-Bissau • Ivory Coast • Kenya • Lesotho • Liberia • Madagascar	• Malawi • Mali • Mauritania • Mauritius • Mozambique • Namibia • Niger • Nigeria • Republic of the Congo • Rwanda • Sao Tome and Principe • Senegal	• Seychelles • Sierra Leone • Somalia • South Africa • South Sudan • Sudan • Swaziland • Tanzania • Togo • Uganda • Zambia • Zimbabwe

Source: BloombergNEF

A.4. Solar capacity

BNEF tracks solar in MW(DC), also known as MWp – in other words, the capacity of the solar modules rather than the capacity of the inverter or grid connection, which is in MW(AC). It is much easier to estimate plant capex, land use and output from the DC capacity, and it is the historical standard in Europe and China. Some grid operators, however, collect data in AC capacity and this is then reported by research organizations. In 2024, the DC capacity is usually 1.2 to 1.3 times the AC capacity, depending on the plant design and market. AC stands for alternating current; DC for direct current.

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