TRIPLING RENEWABLE POWER BY 2030

THE ROLE OF THE G7 IN TURNING TARGETS INTO ACTION

International Renewable Energy Agency

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

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FOREWORD

The historic call at COP28 in the United Arab Emirates to triple renewable power generation capacity and double the rate of energy efficiency improvement by 2030, has set the stage for a rapid scaling up of renewables in the remainder of this decade.

A record 473 gigawatts of renewable power capacity was added in 2023 worldwide; yet the trajectory to 2030 still remains short of that required to meet the tripling goal and reach 11 terawatts of renewable power in 2030 - particularly in terms of new additions of onshore and offshore wind, hydropower, geothermal and bioenergy for power.

The goal, however, remains within reach; thanks to the success achieved in accelerating solar PV deployment, the world has time to accelerate growth in these renewable power options to ensure the 2030 target is met.

This requires urgent action, including strengthening existing policies that have a proven track record and introducing new support policies where needed. Most importantly, it is essential that key enablers for the tripling of renewable power capacity are scaled up - notably in the context of grids and storage.

The G7 has a vital role to play in delivering on the global tripling goal - both directly through renewable power capacity expansion, and indirectly by leading action to address deployment and integration barriers, and in supporting emerging market and developing economies in ramping up their own renewable capacities.

IRENA is grateful to the Italian G7 Presidency for its collaboration and support, and remains committed to assisting its members in delivering on the pledge to triple renewable power capacity by 2030 to keep the world on a 1.5°C pathway. We know what is needed; it is now time to act with the sense of urgency that the climate crisis demands.

Francesco La Camera

Director-General

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ABBREVIATIONS

°C	degrees Celsius
CO_2	carbon dioxide
EMDEs	emerging market and developing economies
EU	European Union
GW	gigawatt
GWh	gigawatt hour
MW	megawatt
NDC	Nationally Determined Contribution
PV	photovoltaic
TSO	transmission system operator
TW	terawatt
TWh	terawatt hour
UAE	United Arab Emirates
USD	United States dollar
WACC	weighted-average cost of capital

EXECUTIVE SUMMARY

Key findings

Achieving the goals of the Paris Agreement to avoid the dangerous and costly implications of climate change is an urgent global priority. The tripling of renewable power capacity by 2030 is one of the key metrics of this endeavour.

IRENA has extensive experience tracking the progress of the global energy transition and the key performance indicators required for success in its World Energy Transitions Outlook. Building on the Agency's 1.5°C Scenario, which formed the intellectual and analytical basis for the tripling pledge at COP28 in the United Arab Emirates (COP28 Presidency *et al.*, 2023), IRENA continues to track progress toward the 2030 target, assisting its Members and the international community in delivering on the goals of the Paris Agreement.

The World Energy Transitions Outlook demonstrates that the tripling goal is challenging but achievable. It does not imply every country will need to triple renewable power capacity, however; individual countries face different starting points and national circumstances, resulting in different contributions that may amount to more or less than a tripling.

2023 witnessed a historic acceleration in new global renewable capacity additions, which reached 473 GW - a jump of 54% over 2022. New solar PV capacity additions are soaring, as costs continue to fall, and their contribution between 2023 and 2025 will keep the world on track to meet the tripling goal. Capacity additions of global wind power also reached a new record in 2023.

New capacity additions globally in 2023 of onshore and offshore wind, hydropower, geothermal and bioenergy for power did not increase at the pace required for a 1.5°C pathway. However, the welcome acceleration in solar PV means there is still time to accelerate growth in the other renewable power options to ensure the 2030 target is met.

Enabling policies with a proven track record of success are available to countries to accelerate new renewable power capacity additions. This will not only keep the transition to renewable energy on track, but also realise significant co-benefits in terms of increased energy security, economic prosperity, local jobs and value creation, and lower climate and health costs of fossil fuel use.

The G7 will play an important role in delivering on the global tripling goal, both directly through the expansion of renewable power capacity, and indirectly, by leading on action to address deployment and integration barriers, and in supporting emerging and developing economies (EMDEs) in delivering their contributions to the global tripling goal.

Key challenges

Overall, new renewable power capacity additions in 2024 and 2025 are likely to grow sufficiently over 2023 levels; and, based on current deployment expectations, the world looks set to meet the required level of solar PV capacity in 2030 for the tripling goal.

The G7 target for solar PV could also be achieved by 2030; however, additional policy efforts are required, given that current trends for deployment imply a shortfall to the collective G7 target of around 13%.

Of greater concern is that current trends suggest new capacity additions of onshore and offshore wind, hydropower, geothermal, bioenergy and concentrating solar power (CSP) to 2030 will all fall short of those required to meet the tripling goal – both among the G7 and globally.

The gap is expected to open up in 2026 and grow each year to 2030, as current growth in installed capacity for all technologies except solar PV is expected to be linear - not exponential, as required. Therefore, without further action today, the shortfall in 2030 could be as much as 2.3 TW (or 20%).

With onshore and offshore wind, bioenergy for power, geothermal and CSP contributing less than anticipated, the implicit renewable power generation target will be missed by an even wider margin (25%) – this is due to the higher capacity factors of these technologies compared to solar PV.[1]

There is still time to act to ensure that the tripling goal is met, given that the gap in new capacity additions will begin to be felt in 2026. Urgent action is therefore required, as adjusting existing policy settings or implementing new support packages takes considerable time. Expanding already successful policy programmes, addressing more rapidly a number of key barriers to renewable power capacity deployment and assisting EMDEs in scaling-up deployment can close the potential gap.

[1] Capacity factor describes the ratio of 1) actual generation per GW of capacity over a year, to 2) what is theoretically possible if generation was at maximum output 24-hours per day, 365 days per year. As these technologies have higher capacity factors (on average, globally) than solar PV, the subsequent deficit in capacity is magnified when considering generation output.

The rapid growth in renewable capacity additions must be accompanied by accelerated deployment of crucial enabling infrastructure, such as: investment and progress in modernising, digitising and expanding electricity grids; and increased adoption of grid flexibility options including energy storage and demand side management. In 2023, investments in electricity grids and flexibility sources to integrate higher shares of solar and wind power were USD 368 billion - around half of the USD 720 billion on average required each and every year between 2024 and 2030 (inclusive) (IRENA, 2024c).

The increase in inflation and base rates for borrowing as supply chains became strained during and after the COVID-19 pandemic, as well as since the conflict in Ukraine, has resulted in significant increases in the cost of capital for power generation projects since 2021. In the G7, this has not fundamentally affected the competitiveness of renewable projects, given recent high fossil fuel prices. However, the high cost of capital poses a real and immediate barrier to renewable power deployment in many EMDEs, as they have seen disproportionate increases in the cost of capital for renewable power projects.

Left unaddressed, the current slow progress in delivering these key enablers for the tripling goal could begin to limit the deployment rate of new renewable power capacity in some countries to levels below what is needed.


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Key recommendations to the G7

The G7 should increase dialogue around delivering its collective targets for solar PV and offshore wind. Current expectations are that deployment will fall short of the collective G7 goal for solar PV, but only by 13%. This gap can be closed with enhancements to existing policy. The situation is more concerning for the G7's collective target for offshore wind, where current expectations of a shortfall of 46 gigawatts (GW) – just under a third - exist today.

Given rapidly falling solar PV costs, the G7 should consider raising its collective target of "at least 1 terawatt (TW) of solar PV in 2030" to "at least 1.3 TW of solar PV in 2030", which would align the G7 with a 1.5°C pathway consistent with the global tripling goal.

Similarly, the G7 should consider setting a collective goal for onshore wind power of 775 GW of total installed capacity by 2030. This should be accompanied by policies and measures to address permitting and grid connection delays, supply chain resilience and the growth of the skilled workforce required.

Permitting processes that are cumbersome and not aligned with the urgency of the tripling goal, as well as the slower than needed modernisation and expansion of electricity grids, risk becoming major contraints to achieving the tripling goal. G7 governments should therefore consider the following actions:

- Work more closely with national regulatory and planning authorities, and transmission system operators (TSOs) to ensure that, at a minimum, TSO plans for the expansion of electricity transmission and distribution systems are aligned with country targets, expected market growth and the G7's collective target for renewable power (whichever is higher).
- Urgently review progress in modernising, digitising and expanding electricity grids, as progress in investment and metrics for grid congestion are lagging in many markets.
- Accelerate the implementation of measures that increase the flexibility of electricity systems, and expand transmission and distribution system capabilities that, together, can help to relieve grid constraints to new renewable power connections and generation. This can include, but is not limited to, energy storage (including hybrid projects), demand-side management and other clean flexibility options.
- Share best practices on, and work to ensure, the implementation of innovative business models for providers of flexibility services, as well as creating 'fit for purpose', streamlined renewable power project permitting systems and grid connection rules to achieve the tripling goal.

In order to maximise the generation from the renewable power capacity added, the G7 should consider an electricity storage target that would bring forward storage capacity investments. Based on IRENA analysis, this could take the form of:

- A collective, G7 commitment to adding at least 1–2 megawatts (MW) of electricity storage capacity for every 10 MW of renewable power capacity added (depending on national circumstances).[2]

A skilled workforce available at the right time and with the right skills will be crucial in achieving the tripling goal, the G7 should consider:

- Undertaking a rapid assessment of potential misalignments in skills and work force availability across the entire ecosystem required to deliver on the tripling goal.
- Introducing or expanding programmes to align education and vocational training programmes, while expanding existing plans and programmes to manage potential misalignments in the availability of skilled workforces for the tripling goal by location and skillset.

The G7 can support emerging and developing economies in delivering on the tripling goal

The G7 has an opportunity to contribute not only to meeting the global tripling goal, but potentially exceeding it by supporting emerging market and developing economies (EMDEs) in delivering their contribution. The G7 should consider assisting, or increasing assistance to, EMDEs in the following areas:

- Efforts to increase the ability of local renewable power project developers to develop large, high-quality project proposal pipelines in order to ensure an adequate supply of projects.
- Continuing to support capacity building, system operations, and development of support policies and regulatory frameworks in EMDEs that facilitate renewable power deployment.
- Increasing the volume of public funds available for financing renewable power generation and the required infrastructure, while using them strategically to reduce finance costs for projects and to quickly crowd in greater private sector financing by:

[2] *This will depend on national circumstances and the balance of renewable capacity deployment. The "duration" of the electricity storage needs to increase over time and will need to average at least five hours for each MW of electricity storage capacity added to 2030 in the G7, necessitating an increase in long-duration electricity storage.*

  - Working with stakeholders (*e.g.* project developers, policy makers and energy planners, development finance institutions, multi-lateral development banks, *etc.*) to develop standardised – and easy to access and process – financing products that address the three main cost drivers of the high weighted-average cost of capital (WACC) in EMDEs: country risk, exchange rate risk and offtake risk.
  - Prioritising "high-impact" public financing that can leverage greater renewable capacity roll-out in grid expansion, TSO management and assessment capabilities, storage solutions, *etc*.
  - Linking additional financing needs to deliver greater ambition in countries' Nationally Determined Contributions (NDCs) to ensure that the global South can access low-cost financing that matches its ambition.
- Supporting EMDEs' domestic abilities to develop ambitious energy sector NDCs, which today are too often narrowly focused on a subset of energy technologies/uses or rely on outdated data, due to a number of constraints that these countries face. Fully aligning NDCs with the outcomes of target setting that reflects the tripling goal would create new momentum. Crucially, efforts to include greater ambition in NDCs should come with support to allow the scale-up of up the enabling measures necessary to deliver on the tripling goal (*e.g.* market and regulatory reform, grid expansion, system operation, storage technologies and other clean electricity system resources, demand-pull, electrification, *etc.*).
- Support EMDEs in accelerating the deployment of wind power technology, particularly onshore wind, as this provides the second largest source of new capacity in the tripling target. The current trend in new capacity additions for wind power is insufficient to meet the tripling goal. Activities could focus on:
  - Implementing best practices in permitting and environmental regulation, noting the importance of ensuring sufficient, low-cost financing is available, as outlined above.
  - The opportunity for the G7 to work with the global South to build more resilient and diversified supply chains. Regional co-ordination of targets could send clear market size information to investors, when backed by secured off-takers for new projects. Recent difficulties in the sector are in part due to supply chain issues and broader international collaboration, based on fair trade principles; co-ordination on supply chains would result in lower costs, higher energy security and healthier supply chains ready to support further growth in EMDEs and the G7.

IRENA, with its near universal membership and deep collaboration with Members, has acquired a comprehensive understanding how EMDEs' diverse priorities need to be factored into tailored national energy transitions. Drawing on IRENA's extensive knowledge base, well-tested capacity building methods, incisive analysis and proven convening power, the Agency can support the G7's efforts to work with EMDEs in the areas of highest impact for both groups. As a trusted, independent source of advice, IRENA can play a crucial role in delivering a global tripling in renewable power capacity in a manner that meets the goals of the G7 and EMDEs.

1. TRIPLING RENEWABLE POWER BY 2030: THE CRUCIAL ROLE OF THE G7

1.1 Introduction

The economic and environmental benefits of renewable power are now overwhelming. In 2022, renewable power generation reduced the fuel costs of the electricity system by over USD 500 billion (IRENA, 2023a), insulating the world from what was probably the greatest fossil fuel price shock since the Second World War. The acceleration of renewable power capacity deployment in 2023 reflects the growing realisation that the key selling point of renewable power today is its economic benefits. However, the growth in new renewable power capacity additions needs to be accelerated if the tripling goal is to be met.

With each passing day that the world falls behind the progress in renewable power capacity deployment required to deliver a pathway consistent with achieving a sustainable energy system by 2050 – which also requires a doubling in the rate of energy efficiency improvement – the challenge and the cost of avoiding dangerous climate change grows. The welcome acceleration in renewable power deployment in 2023 shows there is still time to act.

The international community is ramping up efforts to combat dangerous and costly climate change. On 20 May 2023, in the G7 leaders' communiqué from Hiroshima under the Japanese presidency, G7 members agreed to a goal of "expanding renewable energy globally and bringing down costs" (G7, 2023) by aiming to increase their solar PV capacity to at least 1 terawatt (TW) by 2030 and adding 150 gigawatts (GW) of new offshore wind capacity, raising the total G7 country offshore wind capacity to at least 173 GW in 2030.

That momentum was maintained when, on 9 September 2023, the G20 leaders' communiqué under the Indian presidency stated that the G20 would "pursue and encourage efforts to triple renewable energy capacity globally through existing targets and policies" by 2030 (G20, 2023).

Finally, the COP28 negotiations in the United Arab Emirates (UAE) yielded, on 13 December 2023, the first Global Stocktake text of the United Nations Framework Convention on Climate Change (UNFCCC, 2023). This called on all Parties to contribute to the tripling of renewable power generation capacity by 2030, and to doubling the rate of energy efficiency improvement. In addition, more than 130 countries signed the Global Renewables and Energy Efficiency Pledge, declaring their "intent to work collaboratively and expeditiously to pursue" those goals (COP28 Presidency, 2023).[3]

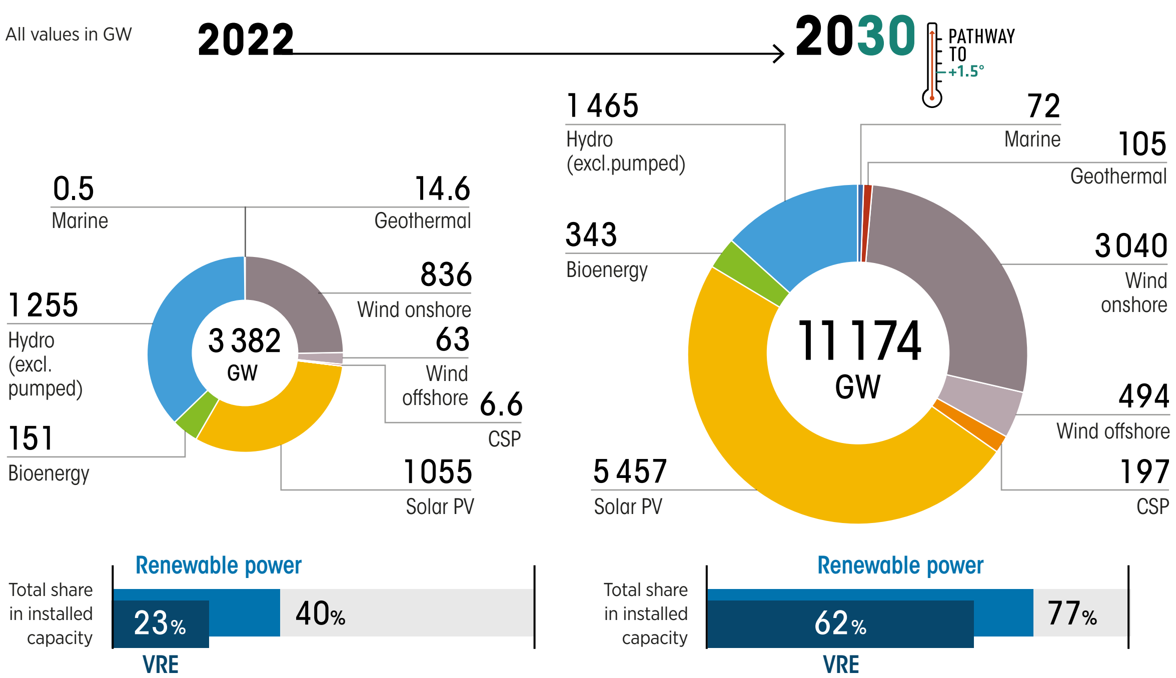
[3] *Throughout this report, the tripling goal contained within the Global Stocktake text, the Global Renewables and Energy Efficiency Pledge and the UAE Consensus is referred to as the "tripling goal" or "tripling pledge". Where necessary for clarity, the text points to the specific instrument that is being referred to, to avoid confusion.*

The goals in the UAE Consensus, which include an unprecedented reference to transitioning away from all fossil fuels in energy systems, in addition to the tripling pledge, represent a significant leap in ambition.

Crucially, the UAE Consensus goals, including the tripling goal, are ambitious but achievable. The world has the technologies available today to deliver on the goal of tripling renewable power capacity by 2030 and doubling the rate of energy efficiency improvement. The tripling goal entails that, by 2030, the world would need to increase renewable power generation capacity from around 3.4 TW in 2022 to around 11.2 TW in 2030, an increase of around 7.8 TW in eight years (Figure 1). With the welcome acceleration in renewable power capacity additions over the last two years, this goal can be achieved, with the right policies.

However, current estimates are that the world risks being below the trajectory needed on growth in renewable power generation capacity to 2030, despite the acceleration seen in 2023. Thus, a range of barriers remain that need to be addressed to reach the goal. If the world fails to deliver on the tripling goal, it will not be due to any gaps in the technologies available to us, a lack of financial resources, or cost challenges, but because of a failure to co-ordinate and collaborate to deliver the enabling frameworks and infrastructure that will allow the goals to be met. The year 2023 has given us a timely reminder that when the policy environment and economic incentives support the flow of public and private sector capital to where it is needed, renewable power capacity additions can grow rapidly.

Figure 1 Global renewable power capacity in the tripling pledge, 2022 and 2030



Source: (COP28 Presidency, IRENA and GRA, 2023).

Note: CSP = concentrated solar power; GW = gigawatt; PV = photovoltaic; VRE= variable renewable energy; bioenergy includes biogas, biomass waste and biomass solid

It cannot be overstated how important it is to *urgently* accelerate the energy transition. Limiting global temperature increase to 1.5 degrees Celsius (°C) above pre-industrial levels by the end of this century, in line with the Paris Agreement, requires rapid, sustained and concerted action. The biggest challenge that the G7 and the world faces is time.

Balcony-mounted solar PV can be added in days or weeks, rooftop solar PV in weeks or months, but gigawatt-scale offshore wind projects need five to seven years to come onstream, whereas grid infrastructure can sometimes take even longer.

With a little over six years to deliver on the global tripling goal by 2030, the urgency of the challenge that the G7 and the world faces demands decisiveness combined with a focus on effective solutions. Without a day to waste, collaboration, co-ordination and peer-to-peer knowledge sharing become great assets in unlocking accelerated deployment and in de-bottlenecking the challenges to accelerated renewable power deployment and grid integration. In learning from each other, it is possible to shorten discovery processes to determine what works and what does not, avoiding costly mistakes and delays.

Success in achieving the goal of tripling renewable power generation capacity to *at least*[4] 11.2 TW by 2030 and doubling the rate of energy efficiency will be determined as much by how successfully the G7 collaborates together and supports emerging market and developing economies (EMDEs), as by the individual actions of each G7 country.

It also needs to be re-stated: the goals of the UAE Consensus are not "nice to have"; they are essential targets. Renewable power and energy efficiency represent the only two levers left[5] to the world that can scale rapidly enough and in sufficient volumes achieve a pathway by 2030 that is consistent with the Paris Agreement goals. If the world fails in delivering the UAE Consensus, it will fail in delivering the Paris Agreement goals.

The UAE Consensus and the goal of tripling renewable power capacity by 2030 represent delivering not only on the G7s international commitments, but unlocking increased energy security, economic prosperity, local jobs and value creation, lower balance-of-payment costs, and lower climate and health costs. It is an opportunity for the G7 to lead on international collaboration and leverage its expertise, financing and capacity building to help the world achieve its collective target for 2030.

[4] *The analysis in IRENA's* World Energy Transitions Outlook*, on which the tripling goal is based, is dependent on accelerated decarbonisation of the end-use sectors, where there also remains a risk of under-delivery to 2030. This would necessitate that the power sector "over delivers" to 2030 to compensate.*

[5] *In combination with increased electrification of end-use sectors.*

To aid the G7 in this process, this report covers the following crucial areas:

1. The implications of the goal of tripling renewable power generation capacity by 2030 for individual G7 countries, and the risks in terms of delivery.
2. A discussion of a number of the key enablers essential to delivering the 2030 goals, including grids, financing and electricity storage.
3. The potential role of international collaboration in achieving a global pledge that has to be delivered by countries without individual targets. This includes a special emphasis on how the G7 can leverage its existing activities, expertise, knowledge and programmes to support EMDEs in delivering on their contribution to the pledge.

1.2 Tripling renewable power capacity by 2030: Implications for the G7

The world is at a crossroads. IRENA's *World Energy Transitions Outlook 2023* has identified that global energy-related carbon dioxide (CO_2) emissions need to fall to 23 gigatonnes of CO_2 ($GtCO_2$) by 2030 (IRENA, 2023a). Yet those emissions rose to a record high of 37.4 $GtCO_2$ in 2023 (IEA, 2024). Despite progress in the growth of renewable energy deployment, the world therefore remains off track, and urgently needs to shift focus to accelerating today's commercially available, scalable solutions.

The stakes have never been higher. Not delivering the tripling of renewable power capacity by 2030 and the doubling of the rate of energy efficiency improvement, when combined with transitioning away from fossil fuels, will result in failure to achieve the Paris Agreement goals.

The Global Renewables and Energy Efficiency Pledge (COP28 Presidency, n.d.) and the text in the First Global Stocktake communication from the United Nations Climate Change Conference in Dubai (COP28) (UNFCCC, 2023), are timely reminders that the world has the solutions it needs today. The two texts identify the core elements of what is needed to get on track. They are a call to action and a reminder that there is a technically and economically feasible pathway to 2030 that will ensure that we avoid the worst of dangerous climate change and keep the Paris Agreement goals in play.

Urgency is required, as tripling renewable power capacity by 2030 and doubling the rate of improvement in energy efficiency represent, whilst transitioning away from fossil fuels, the only realistic options for achieving the scale of CO_2 reductions that are necessary by 2030. Renewable power generation technology, in particular, has proven its ability to rapidly accelerate deployment rates, when grid access is facilitated, the right price signals are seen by consumers and investors, and when the policy and regulatory framework is conducive to their growth.

The tripling goal for 2030 represents an average new capacity addition requirement of 974 GW for each and every year between 2022 and 2030. The world therefore needs to rapidly ramp up capacity additions from the 308 GW added in 2022 (Figure 2) and in the investments in grids and storage, which go hand-in-hand with renewable capacity deployment growth.

The year 2023 represents a historic acceleration in new renewable capacity additions and offers compelling evidence that the tripling goal is achievable. The fossil fuel price crisis of 2022 demonstrated that individuals and businesses will rapidly respond when the incentives to accelerate renewable power deployment are in place and when governments have done the hard work to establish the right policy, regulatory and market frameworks.

Total new renewable power capacity additions globally grew 54% year-on-year, from 308 GW[6] added in 2022 to 473 GW added in 2023, a new record by a long margin. Around 346 GW of solar PV was added in 2023, 74% more than the previous record of 199 GW added in 2022. The other major contributors in 2023 were onshore wind power, which added around 105 GW globally, in addition to offshore wind (11 GW), hydropower (7 GW) and bioenergy for power (4 GW).

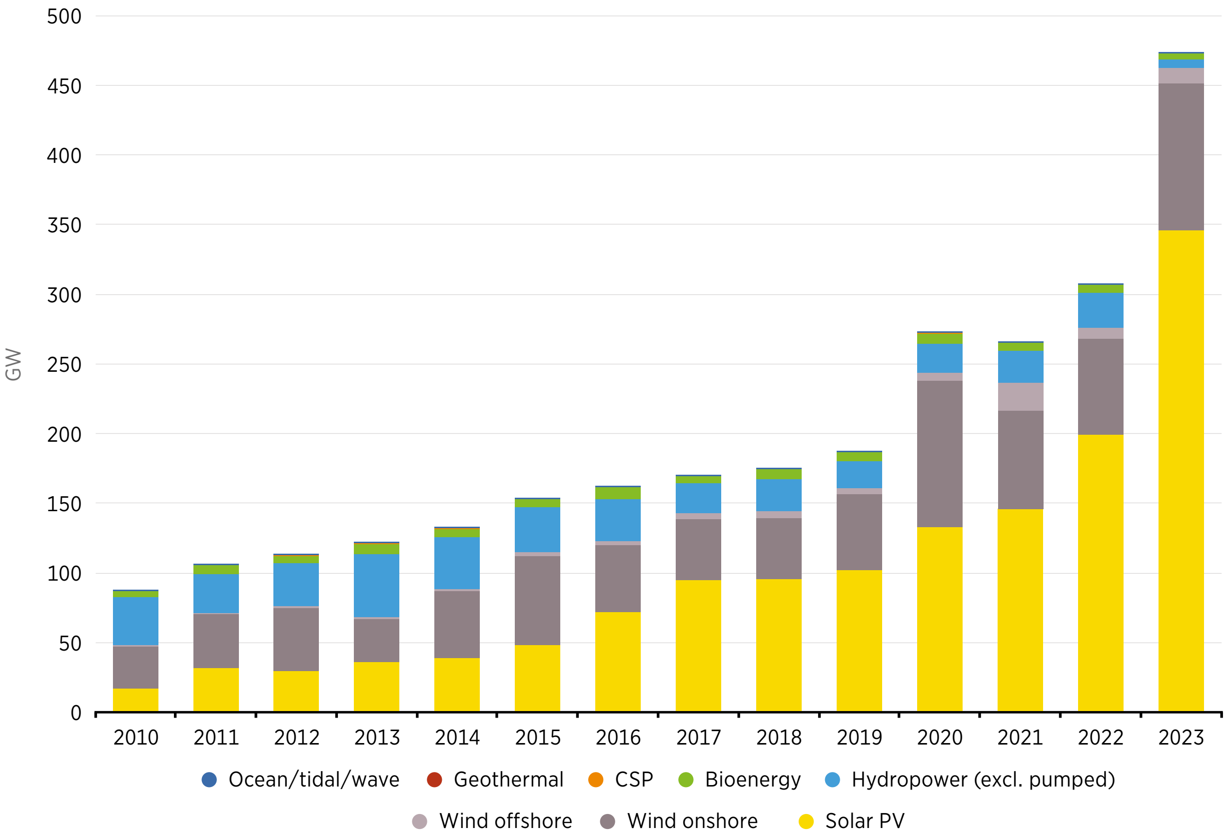
In this context, 2023 represents a remarkable acceleration driven by falling renewable power costs (especially for solar PV), the fossil fuel price crisis of 2022 that lingered well into 2023 and, in some markets, reinvigorated industrial policy. To put 2023 in context, just the *increase* in new capacity additions between the 308 GW added in 2022 and the 473 GW added in 2023 (an increase of 166 GW year-on-year) would have represented a new record of *total* new renewable power capacity additions any year before 2017.

The solar PV capacity additions in 2023 of 346 GW (74% higher than in 2022) accounted for almost three-quarters (73%) of all new capacity additions. Excluding 2022, *just the increase* in new PV additions in 2023 of 146 GW (from 199 GW in 2022 to 346 GW) would have been a new annual capacity record for solar PV. Put another way, the new capacity additions in 2023 were almost equal to all new solar PV capacity additions in the eight years from 2010 to 2017, inclusive. Onshore wind also saw a significant increase in new capacity additions during 2023, to more than 105 GW, matching its previous record in 2020, but this time on a much more durable basis.

The slow and steady growth in new capacity additions between 2010 and 2019 represented a continuous underperformance compared to what is needed to avoid dangerous climate change. Particularly in 2015-2019, this growth had clearly not been aligned with the goals that the countries of the world adopted in Paris or the global goal to ensure access to affordable, reliable, sustainable and modern energy for all under the UN 2030 Agenda for Sustainable Development.

[6] *All data cited for renewable power generation capacity in this report are in alternating current (AC) terms, unless expressly noted.*

Figure 2 Global annual new capacity additions of renewable power, 2010-2023



Source: (IRENA, 2024a).

Four key points can be taken from the record growth in new capacity additions in 2023:

1. *Aligning economic incentives for new renewable power deployment can drive the accelerated deployment required to meet the tripling goal.*

   During the fossil fuel price crisis in 2022 and 2023, individuals, businesses, utilities and industries were given a compelling reminder of just how competitive renewable power has become, as well as its ability to insulate electricity users from volatile fossil fuel prices. They responded by investing heavily in new renewable power generation capacity.

2. *The energy security benefits of renewable power are clear, and policy makers should also consider the macroeconomic costs of fossil fuel price shocks.*

   The year 2022 was the year that the energy security benefits of renewable power were "rediscovered". Renewable power helped reduce the fossil fuel bill of the global electricity system by USD 521 billion (IRENA, 2023b) in 2022. Policy makers would be wise to find ways to value these benefits, as well as the role that renewables play in reducing the macroeconomic and social costs that stem from fossil fuel price shocks (IRENA, 2024b).

3. *Lacklustre support for accelerating the growth in renewable power deployment between 2012 and 2019 made the 2022 fossil fuel price shock worse than it needed to be, as did the lack of reform of electricity markets.*

   A lack of urgency in accelerating solar and wind power between 2012 and 2019 as costs fell dramatically meant that economies were more vulnerable to the fossil fuel price shock of 2022, exacerbating the costs. Similarly, the slow pace of electricity market reforms meant that consumers typically did not benefit from the fact that cash costs for existing renewable power did not increase materially in 2022 (IRENA, 2023b).

4. *The ability of solar and wind power technologies to rapidly accelerate deployment in response to market and policy signals is second to none, with solar PV a clear leader.*

   In 2023, the 54% increase in new renewable power capacity additions, smashed the record of 2022, with a surge in solar PV deployment that saw it account for a record 73% of new renewable capacity additions (IRENA, 2024a). This is a testament to the competitiveness of solar and wind power, and their ability to scale rapidly. This is crucial to why the tripling goal is at once ambitious, but eminently achievable.

The tripling goal is challenging, however, as an average of 974 GW of new renewable capacity is needed each and every year between 2022 and 2030 to achieve the tripling goal, new capacity addition records need to be broken by a significant margin each year to 2030. The moment the rate of increase in new capacity additions slows, the more challenging the goal becomes. This implies policy makers need to anticipate challenges, not react to them if the goal is to be met.

Overview of existing G7 country targets, regional and global targets, and trends to 2030

The goal for tripling renewable power capacity by 2030 is global, it does not include individual country targets. Depending on national circumstances, countries will need to expand renewable power by more or less than a tripling if the world is to achieve the tripling goal. Indeed, countries and regions starting from a low base may need to more than triple, while others will increase by less than a tripling if they are already starting from high shares of renewable power generation.

All G7 countries have some renewable energy targets or commitments, either national and/or as a result of their membership in different regional or global forums. These targets or commitments may vary in nature: at a country level they may be "light" or "implicit" as implied in official energy scenarios, or they may be legally binding due to their direct or indirect inclusion in legislation. Thus, although there are no specific targets in the pledge, it is possible to glean some information about what targets individual G7 countries (or the fora they belong to) have set, and how these compare to a 1.5°C pathway that is consistent with the tripling goal.

This tapestry of nested commitments needs to be understood in order to make sense of the role that national commitments play in the delivery of these high-level targets, as well as identify to what extent existing targets might, or might not, be compatible with successful delivery of the tripling goal.

Figure 3 provides an overview of these targets for 2030. The combined explicit and implicit targets[7] for cumulative renewable power generation capacity in 2030 of each individual G7 country totals around 2 TW for 2030, with the United States accounting for 47% of that. These are a mix of explicit (announced as government policy) and implicit (embedded in government energy or climate scenarios) goals.

In addition, each G7 country is part of a joint commitment "*to expanding renewable energy globally and bringing down costs*" by aiming to increase solar PV capacity to at least 1 TW by 2030 and to add 150 GW of new offshore wind capacity, raising the total G7 country capacity to at least 173 GW in 2030. This is the legacy of the G7 leaders' communique (COP28 Presidency, n.d.; COP28 Presidency, IRENA and GRA, 2023; Ember, 2023; European Commission, 2023; G7, 2023) from Hiroshima under the Japanese presidency of 2023.

The absence of a collective G7 target for onshore wind and other renewable power technologies means that this target cannot be easily compared to individual country targets, or to the European Union (EU), G20 or tripling pledge.

Germany, France and Italy are also impacted by the EU goals, which have recently increased in ambition; the target under the REPowerEU initiative totals 1 234 GW. The EU is targeting a cumulative installed capacity of solar PV of around 590 GW by 2030, along with nearly 400 GW of onshore wind and 111 GW of offshore wind, with other renewable power technologies contributing 134 GW.

Also relevant is the G20 target agreed under the Indian Presidency, to *"pursue and encourage efforts to triple renewable energy capacity globally through existing targets and policies*". IRENA's analysis and briefing of G20 members – which would require them to, collectively, reach 9 355 GW of renewable power capacity by 2030 – was instrumental in building the confidence in the target. It demonstrated the coherence of this target within the overall framework of efforts by G20 members to keep the Paris Agreement goals alive.

Finally, the joint report *Tripling Renewable Power and Doubling Energy Efficiency by 2030: Crucial Steps Towards 1.5°C* (published in 2023 by IRENA, the Global Renewables Alliance and the COP28 Presidency), as well as IRENAs efforts to inform stakeholders via briefings and events, the tireless political engagement of many IRENA Member States (including in the G7), and civil society efforts – were crucial in seeing around 130 countries sign on to the Global Renewables and Energy Efficiency Pledge. It also contributed to the knowledge base that allowed negotiators to ensure that the First Global Stocktake included the following text:

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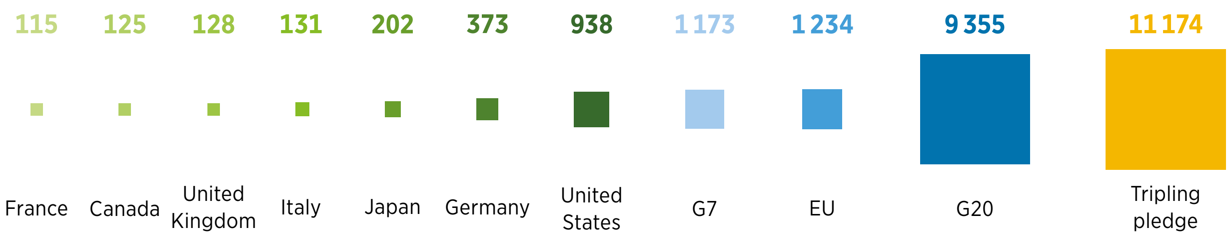
[7] Not all countries have explicit targets for renewable power generation capacity in 2030. For instance, for Canada and the United States, no explicit targets at a national level have been set. The targets presented here for these two countries are from official government scenarios for 2030. The source for all country data in this section, unless explicitly mentioned is from Ember (2023).

> *Further recognises* the need for deep, rapid and sustained reductions in greenhouse gas emissions in line with 1.5°C pathways and *calls on* Parties to contribute to the following global efforts, in a nationally determined manner, taking into account the Paris Agreement and their different national circumstances, pathways and approaches:
> - Tripling renewable energy capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030.

This goal sets a target for cumulative renewable power generation capacity in 2030 of 11.2 TW. Notably, the difference between the G20 goal and the global goal in the tripling pledge is only 1.8 TW. With individual G20 countries accounting for around 62%[8] of the world's population, there is a significant upside to this renewable power capacity value in 2030 if the rest of the world is empowered to deliver an accelerated energy transition that also addresses sustainable development goals, which includes elements in addition to renewable power capacity.

Figure 3 Individual country, regional and global renewable power targets in GW, 2030



Sources: (COP28 Presidency, IRENA and GRA, 2023; Ember, 2023; European Commission, 2023; G7, 2023).

Notes: The data for individual countries, the EU, G20, the tripling goal and the targets are for all renewable power technologies. The G7 target is only for solar PV and offshore wind. For Canada and the United States, no explicit targets at a national level have been set. The targets presented here for these two countries are from official government scenarios for 2030. The source for all country data is Ember (2023).

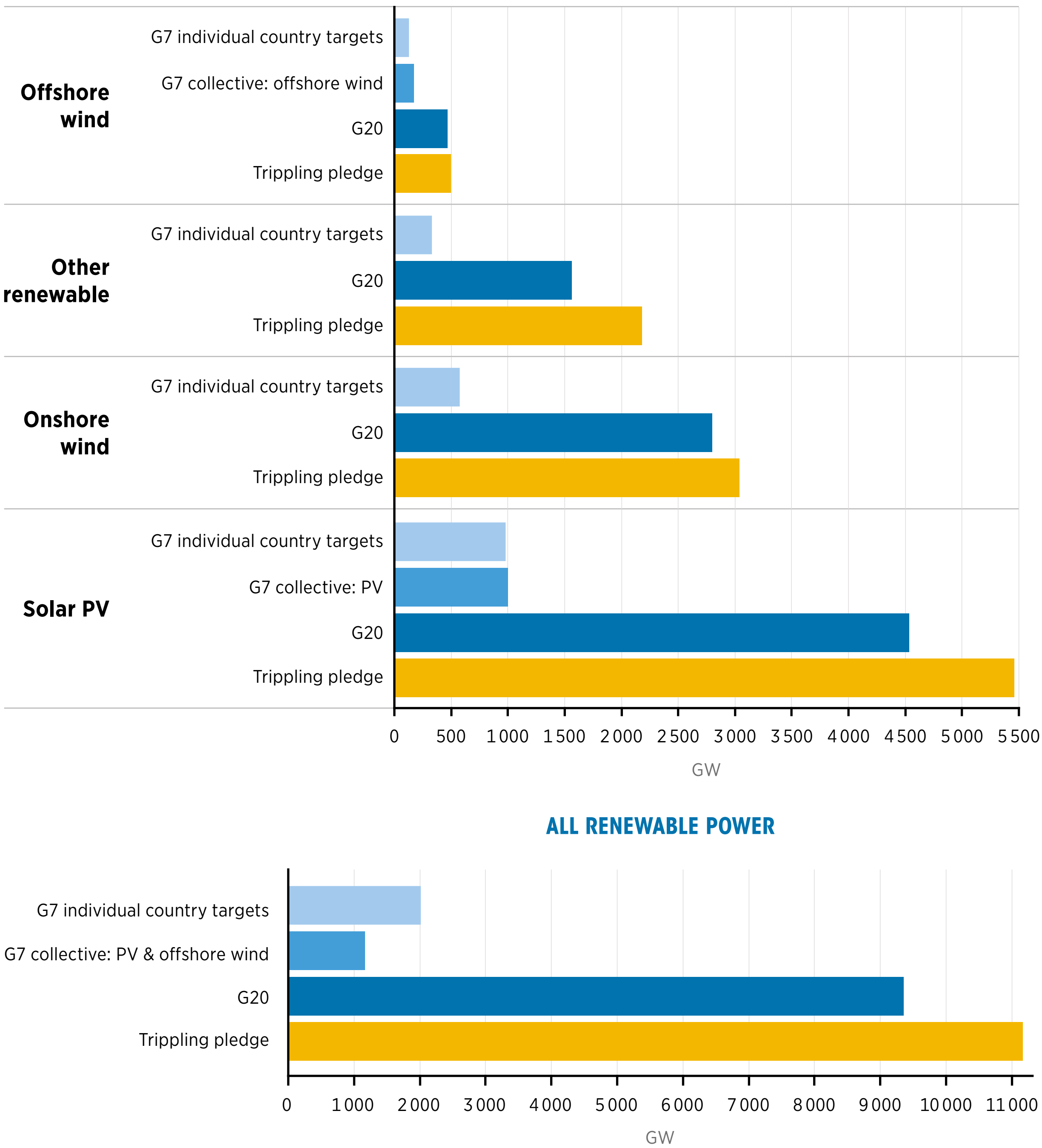
Figure 4 presents the targets by country and bloc, and by technology. For onshore and offshore wind, the global tripling goal's targets[9] are 9% and 6% higher, respectively, than the G20 value. However, this is not the case for solar PV and "other renewables", where new capacity additions are expected to be more widely distributed. The global tripling pledge value for solar PV is 20% higher than the G20 value, and for "other renewables" it is 40% higher. The difference is largest for "other renewables" due mainly to hydropower, where the unrealised economic potential is higher outside of G20 countries.

[8] *Excluding the "other EU" Member States.*

[9] *There are no explicit targets for individual technologies in the global tripling pledge. When 'targets' or 'values' for 2030 are referenced in the text, they simply refer to the advice provided by the COP28 Presidency, IRENA and the Global Renewables Alliance in the joint report,* Tripling Renewable Power and Doubling Energy Efficiency by 2030: Crucial Steps Towards 1.5°C.

For solar PV and offshore wind, where the G7 countries have individual goals, whether explicit or implicit, and the G7 itself has an overall goal, we can see that there remains a significant ambition gap. Individual G7 countries' targets for offshore wind total around 127 GW, which is around 46 GW (27%) less than the requirement for the G7 goal of adding an additional 150 GW by 2030. For solar PV, individual G7 country targets, at 980 GW, are more or less in alignment with the target of a minimum of 1 TW of cumulative capacity set by the G7 in 2023.

Figure 4 Individual country, regional and global renewable power targets by technology, 2030



Source: (COP28 Presidency, IRENA and GRA, 2023; Ember, 2023; European Commission, 2023; G7, 2023).

Current G7 country targets, expectations for deployment and a 1.5°C pathway for the G7

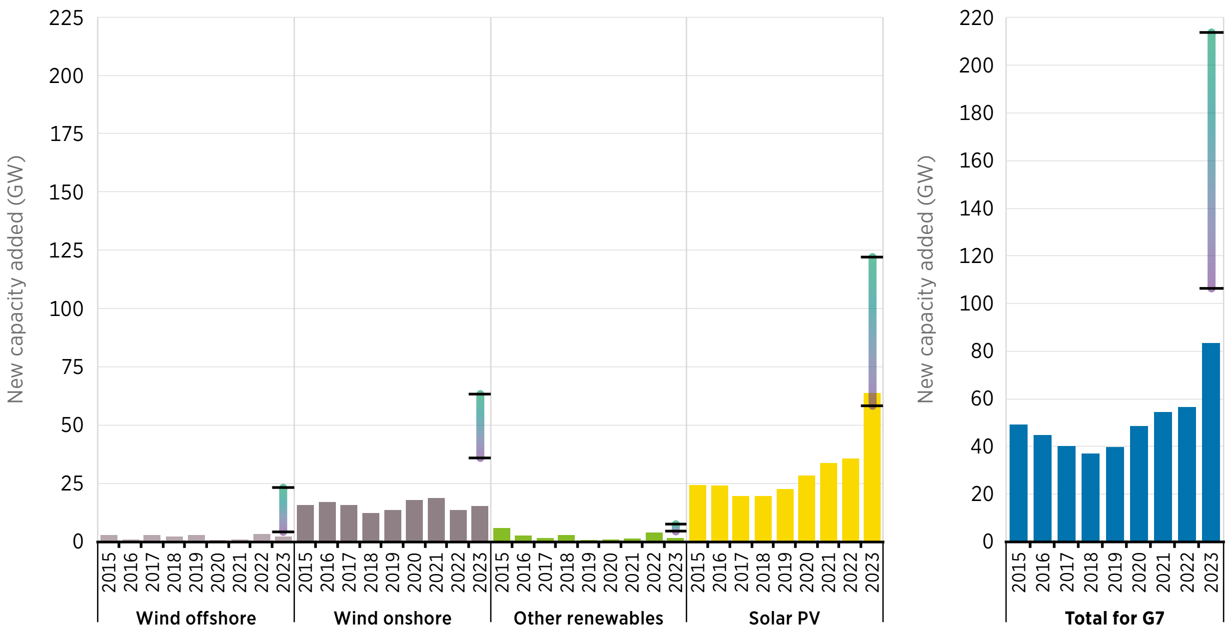
Each G7 country's specific national circumstances, resource endowment and energy system structure ensures that the future will look very different for each country in the G7, as they navigate a pathway to reaching their domestic, regional and global commitments.

With the G7 looking to show leadership with earlier decarbonisation of the electricity sector than in many emerging market and developing economies (EMDEs), the G7 needs to lead the way in terms of accelerating new renewable power capacity additions. However, the rapid acceleration in new deployment capacity in the G7 and the world in 2023 was largely the result of the record additions of solar PV.

This is visible in Figure 5, where the 64 GW of new solar PV capacity added in 2023 by the G7 was 2.7 times higher than seven years previously (in 2016) and falls within the range of what could be expected for a pathway consistent with the tripling goal. New offshore wind capacity additions are below what is needed for the tripling goal but are expected to accelerate towards 2030, given that there is greater visibility on offshore wind given its longer lead times.

The major concern, as has been the case for a number of years, is the relatively modest new capacity additions of onshore wind, which were actually lower in 2022 than in 2016 and less than half what is consistent with a tripling pathway for the G7.

Figure 5 New capacity additions of renewable power in the G7 compared to what is required for the tripling goal in 2023, 2015 -2023



Analysis based on: (IRENA, 2023c, 2024a).

Welcome progress in the accelerated deployment of renewable power generation in every G7 country, however, masks the fact that, collectively, the rate of progress is currently expected to be too slow from 2026 to 2030 in the G7 and globally for the tripling goal. The acceleration of solar PV deployment, however, means that this gap from 2026 can be addressed if urgent action by policy makers is taken to enhance existing support policies and address the other key enabling areas (*e.g.* with respect to grid expansion, financing, storage rollout, *etc.*) before the goal is put in jeopardy.

How large is the emerging gap between current expectations for deployment by 2030 and what is needed for the collective G7 target and what would be consistent with a 1.5°C pathway for the G7 by 2030?

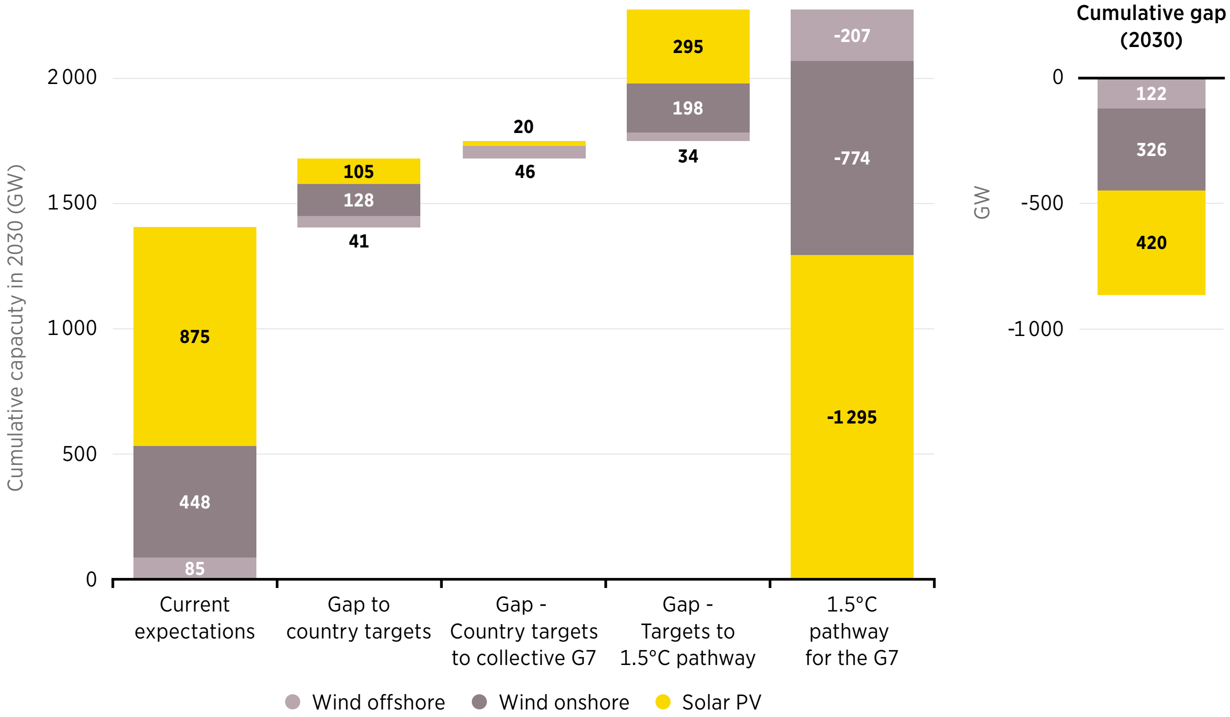
Looking specifically at the G7 countries and their current trajectory relative to these goals, three points are clear:

1. Current expectations are that deployment of solar PV and of onshore and offshore wind under current policies will fall short of individual G7 country targets for these technologies by around 275 GW in 2030.
2. The country targets are close to the collective G7 target for 2030 for solar PV, with only a 20 GW deficit. However, for offshore wind the gap is 46 GW. Thus, for offshore wind, the G7 needs to consider how to co-ordinate efforts to close that gap in order to be able to deliver on the collective target.
3. Finally, there is a gap, of a further 527 GW, between the collective targets of the G7 for offshore wind and solar PV and the individual country targets for onshore wind, and what is needed for the G7 as a group to hit a 1.5°C pathway.

Today's expectations for new capacity additions of solar PV and of onshore and offshore wind to 2030 show that, collectively, G7 countries are expected to reach a cumulative installed capacity of around 1 410 GW by 2030 (Figure 6). This is around 868 GW (38%) lower than a 1.5°C pathway for G7 countries that would be in alignment with the global tripling pledge for the G7.

This gap represents an undershoot (based on today's policies and macroeconomic environment) relative to the tripling goal that is significant and is sufficiently large to place the success of the global goal in jeopardy. However, as noted, policy makers have time to adjust course and meet the G7's share of the tripling goal, if urgent action is taken now.

Figure 6 How Individual G7 country, regional and 1.5°C pathway power targets for the G7 compared to current expectations for cumulative capacity in 2030



Source: Analysis based on (Ember, 2023; IRENA, 2023d; SolarPower Europe, 2023; WindEurope, 2024; Wood Mackenzie, 2024).

Examining Figure 6 in more detail shows that, of the missing 275 GW needed to close the gap from current expectations of cumulative capacity in 2030 to meet individual country targets, policies need to unlock an additional 105 GW of solar PV, 128 GW of onshore wind and 41 GW of offshore wind.

That would still mean that the individual country targets in the G7 for solar PV and offshore wind would be 66 GW below 2023's agreed collective target. For offshore wind, individual country targets total around 126 GW in 2030, 27% (46 GW) lower than the implied collective G7 target of 173 GW agreed in 2023.

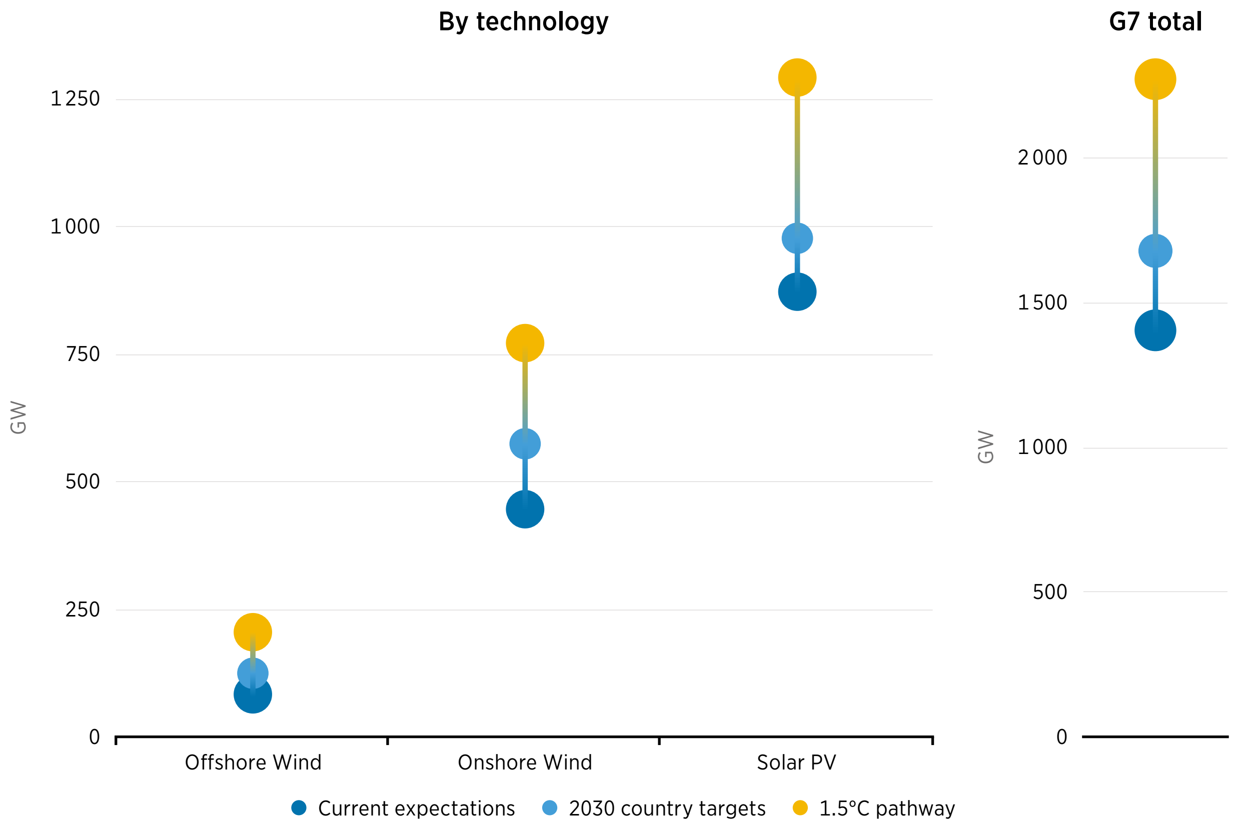
Finally, there remains a gap between the collective G7 target for offshore wind and the country-level onshore wind targets compared to a G7 pathway consistent with a 1.5°C pathway. The collective goal for the G7 for solar PV in 2030 is, however, less than what is consistent with a 1.5°C pathway. This remaining gap of 527 GW is mainly driven by solar PV (295 GW) and onshore wind (200 GW), with just 43 GW attributable to offshore wind.

Overall, when looking at the gap between current trends in deployment – based on existing policies and macroeconomic conditions – the expected cumulative total installed capacity of solar PV and of onshore and offshore wind in 2030 is 868 GW lower than what is needed for a 1.5°C pathway in 2030. Policies need to unlock an additional 420 GW of new solar PV capacity additions relative to today's projections, as well as 326 GW of onshore wind and 122 GW of offshore wind, to 2030.

If this does not occur, the G7 as a whole will significantly undershoot a pathway for renewable power capacity additions that would be consistent with the global tripling pledge. This "missing" capacity for 2030 (868 GW) in the G7, collectively, places the tripling goal in jeopardy.

Looking at just current deployment expectations, country targets and what would be needed for a 1.5°C pathway form a technology perspective (Figure 7), it can be seen that most G7 countries are expected to deploy significantly less than what might be needed for the G7 as a whole to meet their individual country targets, which, as noted, are already lower than what would be required for a 1.5°C pathway for the G7 in 2030.

Figure 7 Current expectations of cumulative renewable power capacity in the G7 in 2030 compared to country targets and a 1.5°C pathway consistent with the tripling goal by technology, 2030



Source: Analysis based on (BNEF, 2023a, 2024a; IRENA, 2023c; SolarPower Europe, 2023; WindEurope, 2024).

Note: This chart excludes the collective G7 targets for offshore wind and solar PV in order to be able to make a direct comparison relative to total solar and wind power deployment.

With the recent challenges experienced by the offshore wind industry, the G7 may miss current country targets by 41 GW in 2030; but even these are 46 GW below the collective G7 target, which is in turn around 34 GW below a level that approaches the required amount for the tripling goal.

Current expectations are that solar PV deployment to 2030 will fall below the collective target, even as the world appears to be on track to meet the solar PV capacity highlighted in the report by the COP28 Presidency, IRENA and the Global Renewables Alliance that details the intellectual basis for the tripling pledge (COP28 Presidency, IRENA and GRA 2023). Thus, despite the recent acceleration in solar PV deployment, more work is needed to unlock continued growth in new capacity additions to 2030 in the G7.

The majority of the projected gap, across all technologies, emerges as a significant delivery challenge after 2026 for the G7. Policy makers in the G7 therefore should act urgently to enhance policy settings, address non-market barriers and introduce new support policies as needed.

The situation for wind power is concerning, especially in the case of offshore wind. Given offshore wind projects take four to seven years to commission after a procurement process, this implies that the window for addressing this gap will close as early as in the next year or so. At the very least, it will be challenging for the industry to bridge this gap if certainty is not provided this year (in 2024) around the required commissioning timelines and volumes.

Global trends in renewable power capacity growth and the tripling goal

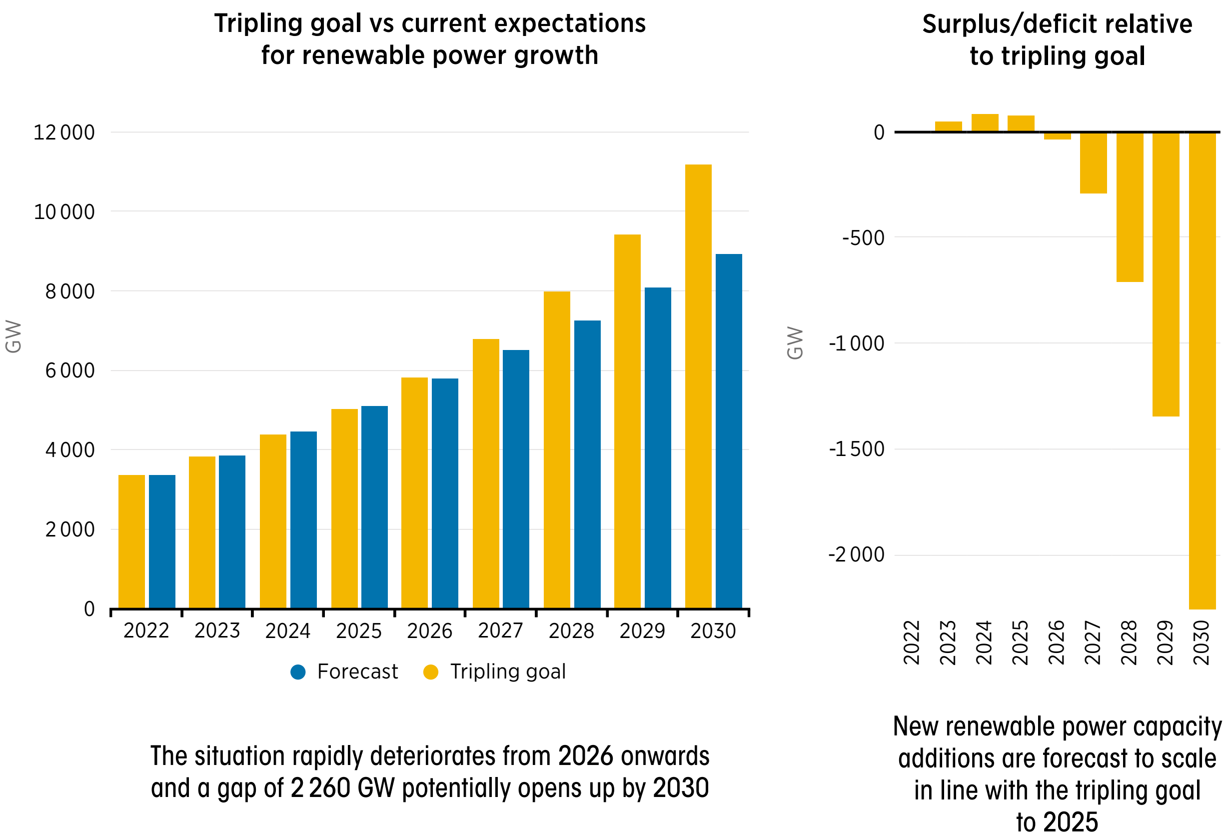
The acceleration in new renewable power capacity additions that occurred in 2023 is not expected to be replicated to the same extent in 2024 and beyond.[10] However, the rate of growth appears to be sufficient to ensure that the world remains on track to achieve the tripling goal in terms of renewable power generation capacity in 2024 and 2025.

[10] *For instance, in its central estimate, BloombergNEF expects that new solar PV capacity additions in 2024 will increase by around 30% compared to 2023, dropping to a 9% increase in 2025 over 2024 (BNEF, 2024a).*

Trends in global renewable power capacity growth globally compared to the tripling pledge

Despite the progress in 2023, current expectations are that the *growth* in new renewable power capacity additions from 2026 will slow. This trend indicates that, with current policy settings, the world is not on track to meet the tripling goal for 2030 (Figure 8), unless policy adjustments are made, and, as noted, made very soon. Figure 8 shows that current forecasts for renewable power deployment start to fall materially below the tripling goal pathway after 2026, and that in the space of just four years, a gap of around 2.3 TW could open up if urgent action is not taken.

Figure 8 Current expectations of global cumulative renewable power capacity to 2030 compared to the tripling goal, 2022-2030



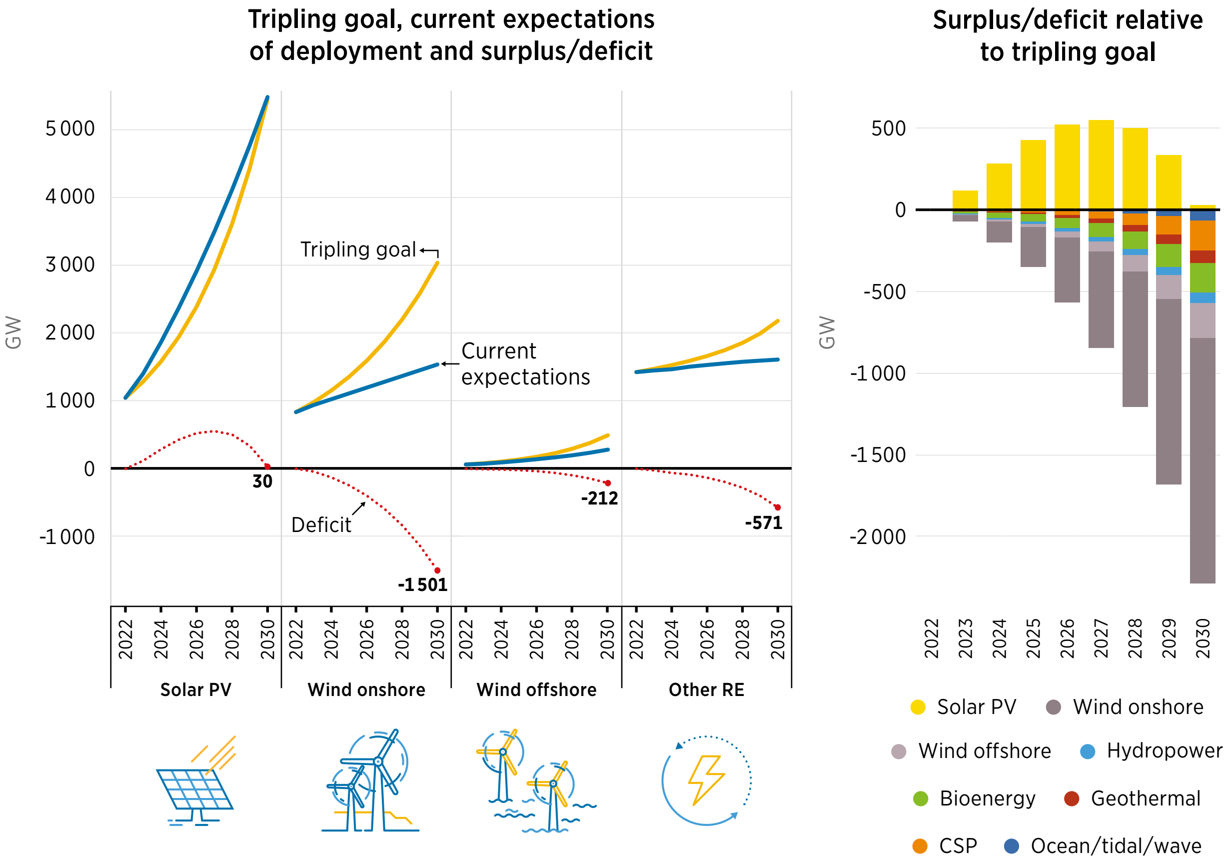
Analysis based on: (IRENA, 2023d; SolarPower Europe, 2023; WindEurope, 2024; Wood Mackenzie, 2024).

When looking at the trends by technology, it becomes clear that the challenge faced in delivering the tripling goal is not evenly distributed (Figure 9). The unprecedented acceleration in solar PV capacity additions in 2023, and the expected continued increase in 2024, mean that current expectations are that solar PV is likely to hit the level needed under the tripling goal by 2030 of around 5.5 TW.

However, this cannot be said for any of the other renewable power technologies.

Both onshore and offshore wind capacity additions look set to fall well short of what is needed globally by 2030 to hit the tripling goal. The same is true for all other renewable power technologies (*e.g.* bioenergy for power, concentrating solar power, geothermal, hydropower and marine/ocean power).

Figure 9 Current expectations of global cumulative renewable power capacity to 2030 compared to the tripling goal by technology, 2022-2030



Based on: (BNEF, 2023a, 2024a; IRENA, 2023d; SolarPower Europe, 2023; WindEurope, 2024; Wood Mackenzie, 2024).

Note: The tripling pathway is based on a fixed, simple compound average growth rate needed to increase the capacity of each technology from its base in 2022 to the 2030 tripling goal value. It is therefore only indicative of one possible pathway.

A number of points of interest can be taken from these trends:

- The rapid acceleration of solar PV deployment in 2023 is potentially putting solar PV above the curve required for the tripling goal over the next few years.
- This demonstrates solar PV's ability to rapidly expand supply chains, up to and potentially beyond the needs of the tripling goal,[11] when growth expectations are clear to industry.

[11] *This holds at least in the short term, given that the ongoing profitability of the supply chain remains a critical question mark that will only be resolved in the coming years. Historically, the PV supply chain has innovated itself into what it hoped was a more profitable business environment, by continuously expanding scale of production, manufacturing improvements and more advanced cell architectures with higher efficiency. It remains to be seen whether this is still tenable given the massive recent expansion in supply chain capacity. Much will depend on demand growth over the next 2-3 years.*

- The slowing in the growth in annual new solar PV capacity additions, however, results in the earlier "surplus" rapidly eroding by 2030.
- The fact that solar PV is the only major technology with rapidly accelerating deployment masks the fact that, for the moment, all of the other technologies are not seeing the right policy settings to scale quickly enough.

Indeed, in every year between 2022 and 2030, none of the non-solar PV renewable power generation technologies are expected to deliver on the needed increase in new annual capacity additions. The growth in total installed capacity for these technologies remains linear, not exponential. The deficit between the needed pathway to 2030 and actual deployment therefore grows inexorably every year. This is particularly true for onshore wind, where current expectations are that policies will likely deliver just 32% of the necessary new capacity additions over 2022 levels required, leaving onshore wind in 2030 at just half of the needed total cumulative installed capacity for the tripling goal.

For offshore wind, current expectations are that cumulative installed capacity will grow to 282 GW by 2030, from 63 GW at the end of 2022. This impressive, 4.5-fold increase in cumulative installed capacity by 2030, however, hides an only slightly less serious situation for offshore wind, given its lower starting point. These expectations suggest that only half of the needed new capacity will be added by 2030 relative to what is required for the tripling goal, leaving global cumulative capacity at only 57% of what is needed.

Although "other renewable" power capacity addition needs are lower in capacity terms than for solar and wind power in the tripling goal, the generally higher capacity factors of these technologies mean that they are vital to delivering the necessary electricity required under the tripling goal. Here, again, expectations are that deployment will not accelerate quickly enough to meet the requirement under the tripling goal by 2030, with a deficit of around 571 GW opening up by 2030.

One goal: Two major delivery risks

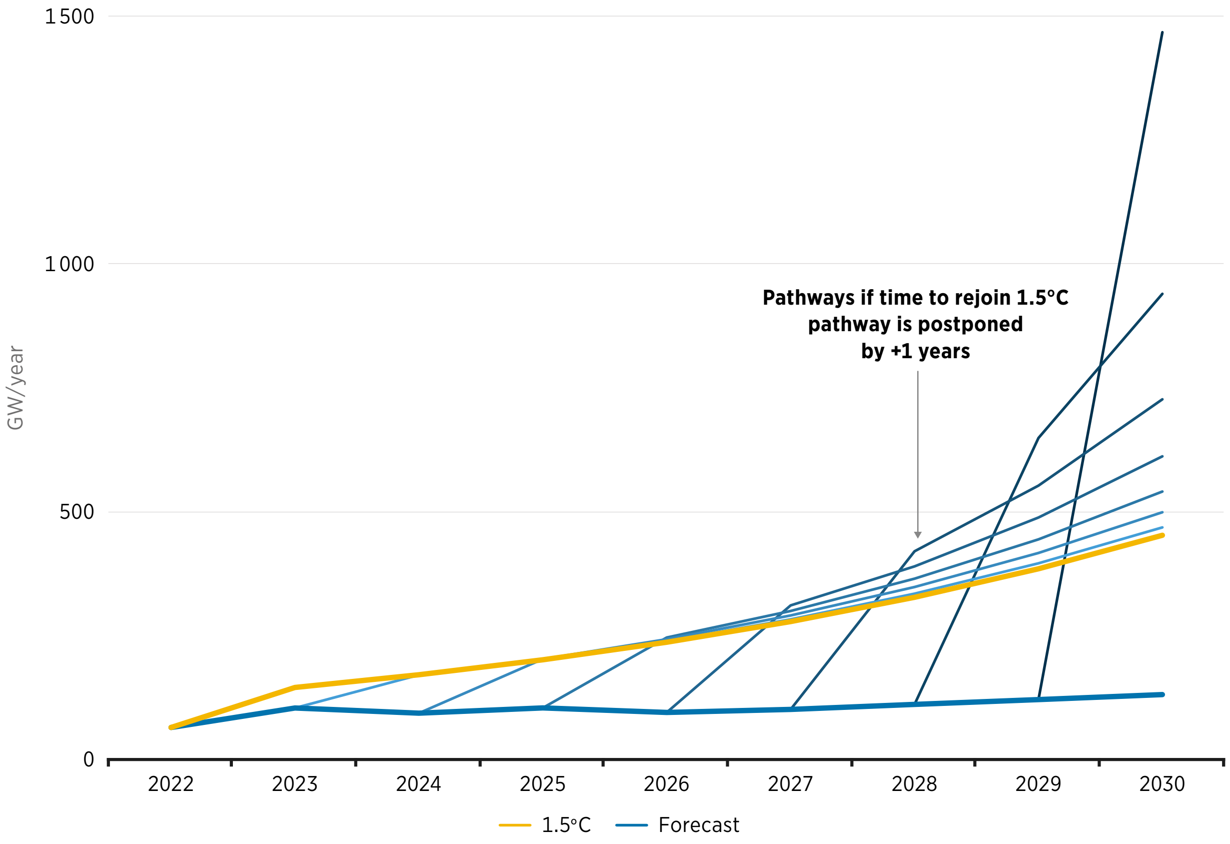
Figure 9 highlights two key issues that pose major delivery risks to achieving the tripling goal by 2030. The first challenge is that current policies are not anticipated to drive sufficient acceleration of the new capacity additions of renewable power to 2030. By 2030, current expectations are that we will remain 2 260 GW below the target.

But the concern is not just missing the GW target for the tripling goal; it is also the imbalance in projected growth. Over the period 2022 to 2030, the 1.5°C pathway calls for around 57% of all new added capacity to come from solar PV, while in 2023 it was 74%. This imbalance in today's new capacity addition trends is the second challenge.

The first challenge is, in and of itself, significant. The gap of 2 250 GW to the tripling goal expected today for 2030 means missing the goal by one-fifth, as only 71% of the needed new capacity additions are expected to be delivered by 2030. It is not too late to correct course and to adapt existing policies and introduce new ones to ensure that the target is still reached, but time is not on our side.

To illustrate this, it is worth examining the dynamic that responding only slowly to correct for the expected low deployment growth to 2030, relative to a tripling pledge pathway, has on the world's ability to deliver on the tripling goal by 2030. Figure 10 presents a generic technology pathway to illustrate the challenge. In this scenario, new annual capacity additions from current policy settings are expected to remain systematically below a tripling pathway based on an average compound growth rate. The additional lines on the chart indicate the change in average annual capacity additions that would have to occur with every year's delay in accelerating deployment above current expectations.

Figure 10 Generic pathways to align annual new capacity additions with the tripling pledge pathway



As can be seen in this generic example, the impact is not dramatic if a rapid adjustment is made. After one year's delay, the annual new capacity additions needed in 2030 are only 4% above the tripling pledge pathway – which is already well above expectations – but this increases to 10% above after two years delay, 19% after three, 35% after four, 60% after five, *etc*. The longer the delay, the more pressure there is on every actor in the ecosystem required to deliver on the goal, and the less time to correct errors or policies that do not deliver as expected. This would likely lead to rapidly mounting delivery pressure and possibly to an exponential increase in the risk of missing the targets. It can therefore be seen that acting early to adjust upward the rate of new capacity additions will make achieving the tripling pledge much more likely.

Given that the tripling goal is derived from the 1.5°C pathway in the *World Energy Transitions Outlook* (IRENA, 2023a), there are two challenges. Firstly, if the world is short of the goal in gigawatt-terms, the goal will clearly be missed in terms of the capacity *and* electricity generation that needs to be satisfied from renewables in 2030 to maintain that pathway. However, the second problem is more subtle. We can achieve the tripling goal in terms of power capacity, but still fail in getting onto a 1.5°C pathway if solar delivers more than anticipated and other renewable power technologies deliver less than in the 1.5°C pathway.

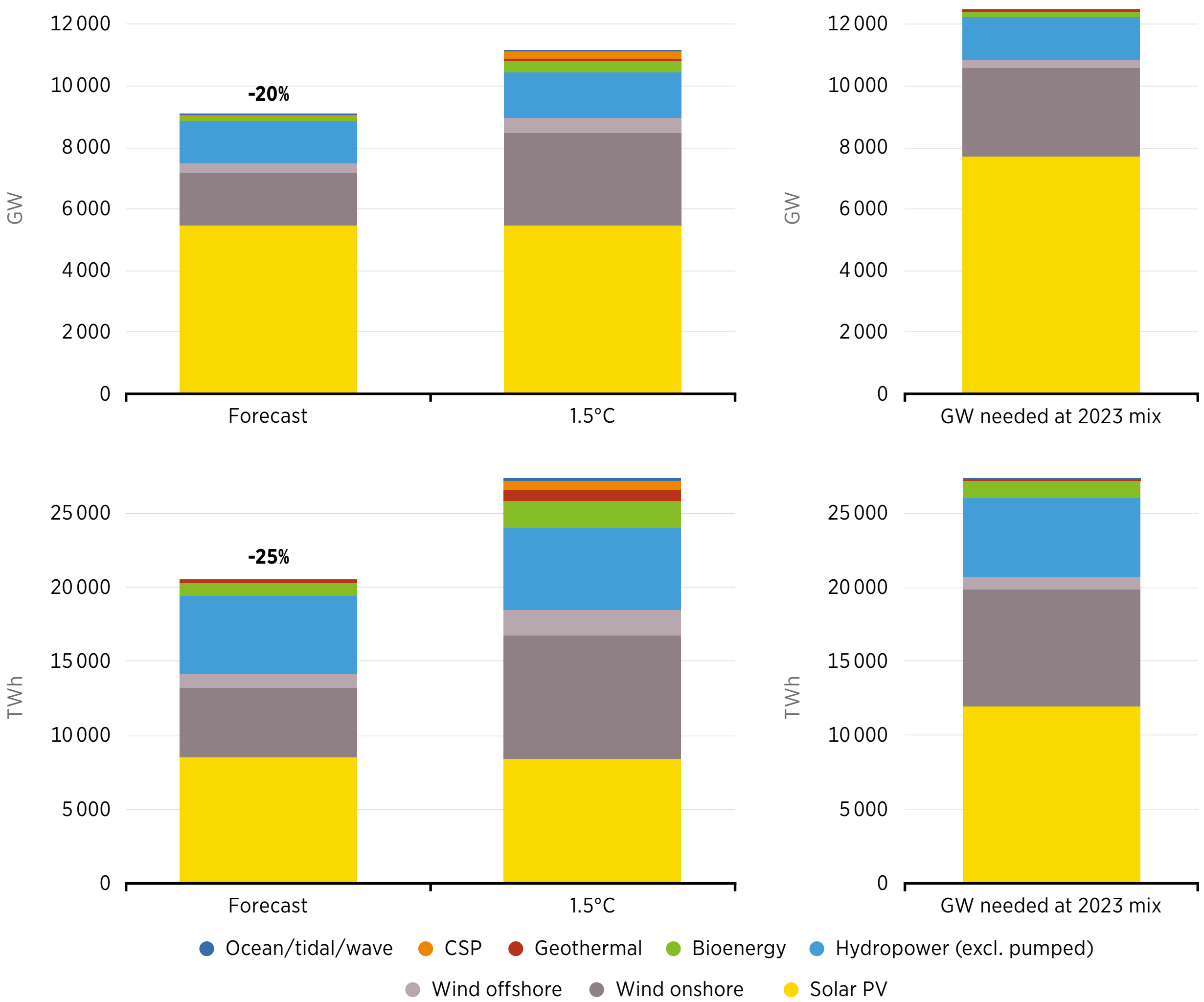
This is because solar PV has a lower capacity factor the other renewable technologies. If the world relies more on solar PV to hit the goal, the tripling goal can easily become a quadrupling goal to deliver the same amount of electricity generated by the mix in Figure 1. For instance, to hit the terawatt hour (TWh) goal for 2030 implicit in the tripling pledge, every "missed" GW of onshore wind requires at least 1.8 GW of solar PV, every missed GW of offshore wind requires 2.4 GW of solar PV, and every missed GW of bioenergy requires 3.4 GW of solar PV.[12]

Figure 11 presents this dual challenge facing delivery of the tripling pledge by 2030. Current expectations for the deployment of renewable power capacity by 2030 suggest that the world will not add the 7.8 TW necessary to reach the tripling goal of just over 11 TW; rather, it will add only around 71% (5.5 TW) of the new capacity needed, falling short of the goal by around about 2.2 TW. Given that other technologies have higher capacity factors than solar PV, the mix of capacity will only add 59% (10 319 TWh) of the needed generation increase over 2022 of 17 575 TWh by 2030, with total renewable generation reaching around 20 100 TWh in 2030. This is a quarter below the implied value required of 27 358 TWh global generation from all renewable sources in 2030.

Around 70% of the "missing" TWh is due to the lower capacity deployment than required, with 30% stemming from the lower weighted-average capacity factor of the capacity expected to be deployed by 2030, given that only solar PV is currently expected to hit its target.

[12] *This analysis is based on the scenario results in the* World Energy Transitions Outlook *(IRENA, 2023b).*

Figure 11 Global electricity generation under the tripling goal compared to current expectations, 2030



Based on: (BNEF, 2023a, 2024a; IRENA, 2023c; SolarPower Europe, 2023; WindEurope, 2024; Wood Mackenzie, 2024).

Figure 11 also includes on the right-hand side an example of where the underlying electricity generation goal of the tripling pledge is met, with new capacity added to 2030 matching the shares seen in 2023 for new capacity additions. In this scenario, the goal is met by adding not 7.8 TW between 2022 and 2030 as in the tripling pledge's original formulation, but 9.1 TW (1.3 TW more). In this scenario, onshore wind capacity additions are 2 TW, just 0.2 TW below what was expected in the tripling pledge.

However, all other technologies, except solar PV, are well below their anticipated new capacity additions. New capacity additions between 2022 and 2023 for offshore wind are half of what was envisaged in the tripling pledge. The gap is closed by proportionately more GW of solar PV, with new capacity additions between 2022 and 2030 increasing from 4.4 TW in the original tripling pledge formulation, to 6.7 TW (a cumulative total of 7.7 TW installed at the end of 2030) and a total cumulative installed capacity reaching 12.5 TW, 12% higher than was envisaged.

This would transform the tripling goal from a 3.3-fold increase in renewable power generation capacity between 2022 and 2030, into a 3.7-fold increase. Solar PV would now provide 31% more electricity generation than was planned in the tripling pledge, while other renewables and wind power would provide less than anticipated. The generation from solar PV in 2030 in this example would reach 43% of the total, compared to 31% in the 1.5°C pathway consistent with the tripling goal presented in Figure 1. In this case, cumulative installed solar PV would reach 7.7 TW in 2030, 2.2 TW higher than the 5.5 TW in the 1.5°C pathway presented in Figure 1. This alternative pathway is not inherently 'sub-optimal', as many pathways to the tripling goal are possible, when considering the capacity target and the implied generation that supports a 1.5°C pathway. However, it might present significantly different challenges for the electricity system in some countries.

The previous example assumes stakeholders adjust policy settings to ensure that all technologies exceed current expectations for deployment to 2030, albeit falling short of what is presented in Figure 1 for the tripling goal, with the exception of solar PV. Meeting the tripling target with current expectations for deployment of all renewable technologies, except solar PV, would require even more solar PV to be deployed.

In either case, this would require additional policy efforts to account for the higher share of solar PV In generation. It would probably necessitate additional efforts to accelerate the ability of the electricity system to manage higher shares of variable renewables. This is because the lower contribution of concentrating solar power, bioenergy for power, geothermal, hydropower would mean less clean flexibility options on the grid; while the complementarity of wind power and solar PV in many countries helps to reduce the needed grid expansion and flexibility needs. For onshore and offshore wind, the complementarity with solar PV over days, weeks, months and seasons helps to reduce variability, while the firm, dispatchable renewables help reduce additional flexibility needs significantly.

A pathway to the tripling goal that relies more heavily on solar PV would therefore likely necessitate bringing forward investments in grids, electricity storage, demand-side management and other supply-side flexibility options.

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2. DELIVERING ON THE TRIPLING PLEDGE: KEY ENABLERS

2.1 Introduction

The tripling pledge is ambitious, but also technically and economically feasible, and would provide a range of co-benefits and improved outcomes for the environment, electricity access, energy security and the economy. The world has the tools available to deliver on the energy transition, in terms of both technologies and policy levers.

However, it is an ambitious goal for a reason: the world is not currently on track to deliver an energy transition that aligns with the Paris Agreement goals. The twin goals of tripling renewable power generation capacity by 2030 and doubling the rate of energy efficiency improvement can change that. This will, however, require efforts by all stakeholders to get the key enabling frameworks right, given that today's policy settings are not set to deliver the required growth in deployment.

What is clear is that greater ambition and stronger collective action are urgently required to accelerate progress and to ensure that the world quickly pivots onto a pathway that will meet the tripling pledge. The example of 2023, and in particular the acceleration in solar PV deployment, shows what can be achieved in the right circumstances.

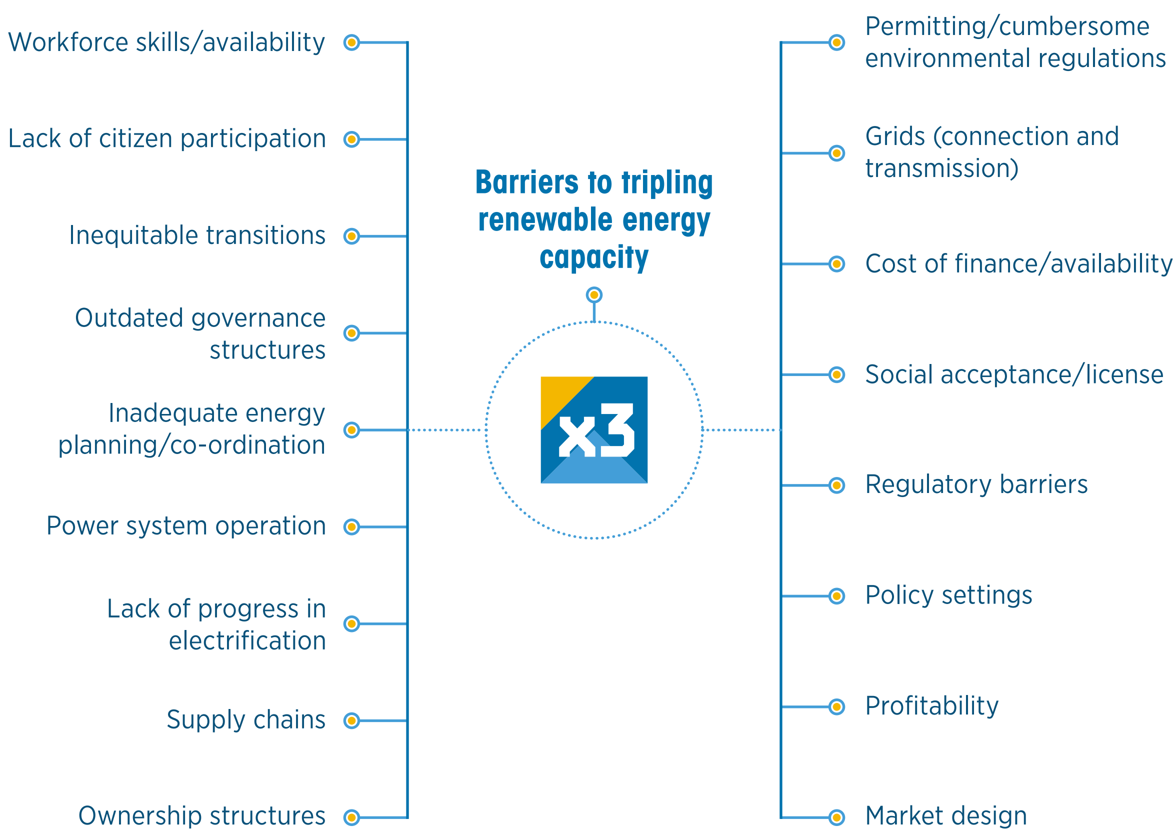
Policy makers and all stakeholders now need to work together to urgently ensure that policies, regulations, market structures, infrastructure, support instruments and financing are all rapidly aligned with delivering on the tripling target.

The key action areas discussed in the report *Tripling renewable power and doubling energy efficiency by 2030: Crucial steps to 1.5°C* (COP28 Presidency, IRENA and GRA, 2023), include:

- Modernising and expanding physical energy infrastructure.
- Improving power system operations and ensuring that flexibility grows with the penetration of solar and wind power.
- Adapting or expanding existing policies and regulatory frameworks to facilitate the rapid growth in renewable power that is needed.
- Allocating sufficient funds and ensuring policies align to generate a significant increase in public and private financing flows, at reasonable cost, into the power sector, especially in the global South.
- Building resilient supply chains, scaling up the necessary workforces and ensuring that they have the skills required.

This is not an exhaustive list and a wide range of barriers exist that may impede the rapid growth in new renewable capacity additions required to meet the tripling goal. Figure 12 highlights many of these other additional factors. Although outside the scope of this report, the range of barriers presented in Figure 12 all need to be addressed to a greater or lesser extent, depending on national circumstances in order to deliver on the tripling goal and many represent areas where IRENA has long established programmes of work.

Figure 12 Key areas where enabling frameworks are needed to address the barriers to achieving the tripling of renewable power capacity by 2030



Finally, for the tripling pledge to be successful, it will need to be a just and inclusive pathway, given that if EMDEs are left behind, they will not deliver the gigawatts needed for the goal. In this context, international collaboration and the leadership that the G7 can play in this area will be vital.

Given the challenges identified in the previous chapter, the present chapter focuses on four key areas that urgently need to be addressed to deliver on the tripling target: grid expansion and flexibility needs, financing, energy storage and workforce development and skills.

2.2 Grid expansion and increasing flexibility needs

With the acceleration in the deployment of renewable power needed to meet the tripling pledge, wind and solar power will begin to dominate an increasing number of electricity systems. This will require enhancements to – and expansion of – current power grid systems (both transmission and distribution networks), and the modernisation and upgrading of power system operations.

As has been documented for a number of years, investments in the electricity grid have lagged in comparison to investments in renewable power capacity. In 2023, investments in electricity grids and flexibility sources to integrate higher shares of solar and wind power were USD 368 billion, around half of the USD 720 billion on average required each and every year between 2024 and 2030 (inclusive) (IRENA, 2024c).

This is not just a concern about how much new capacity the grid can effectively distribute. Uncertainty around grid access and around the level of local grid constraints that can lead to the curtailment of a power project's generation increases the project risk, raises the cost of capital and may also lead to developers postponing investment decisions for renewable power projects.

Grid modernisation, digitalisation and expansion must speed up

In a number of markets, this lagging investment in grid infrastructure is already slowing the deployment of renewable power projects, or may soon do so. For instance, in the United States, the surge in project development plans for solar and wind power meant that more than 1200 GW of solar and wind had entered interconnection queues by the end of 2022; however, the time span between entering the interconnection queue and starting commercial operation increased to five years, compared to three years in 2015 and under two years in 2008 (Rand *et al.*, 2023). By the end of 2023, the total had risen to 1432 GW of standalone wind and solar in the queue (Rand *et al.*, 2024). A significant amount of this capacity won't be built, but the growing trend suggests that an increasing amount will be completed over time.

In the United Kingdom, the volume of grid connection applications has grown ten-fold in just five years, consisting almost entirely of renewable power and storage requests (Department for Energy Security & Net Zero and Ofgem, 2023). Currently, only 14% of projects receive the grid connection date agreed with the transmission system operator, with the rest receiving a delay of, on average, five years.

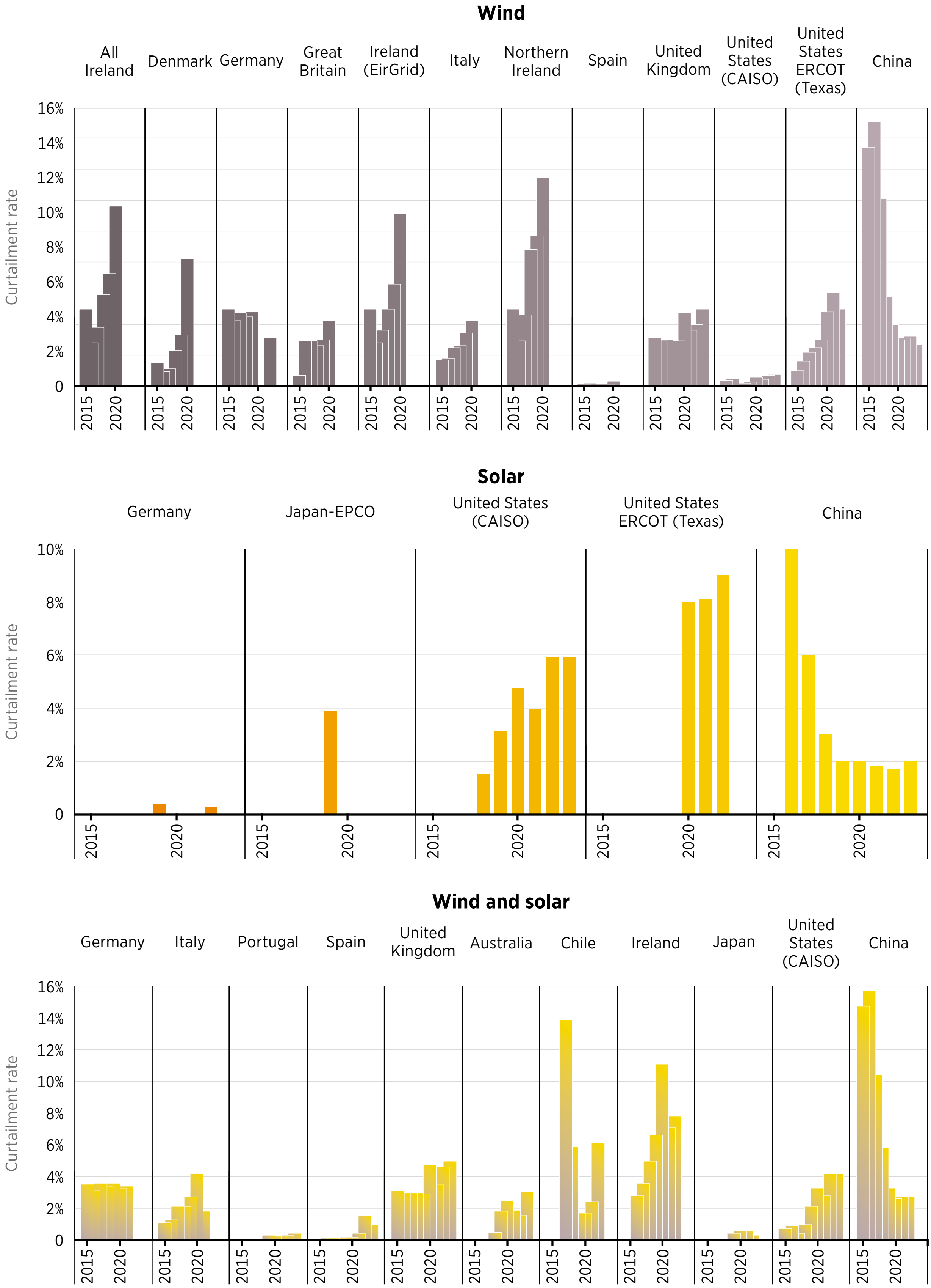
Other signs of the chronic underinvestment in grids are also appearing, as curtailment of existing renewable power projects is starting to rise in a range of markets (Figure 13). It is important to note that, not all curtailment should be considered bad – there can be economic reasons for why solar and wind projects self-curtail, including negative wholesale power prices if they are exposed to them. However, curtailment due to grid congestion is increasingly the result of a combination of poor spatial planning, grid expansion delays, and market or regulatory failures to allow for a future electricity system dominated by low-cost solar and wind power. These issues need to be addressed urgently.

For instance, in Germany, in 2014, around 1.2% of renewable electricity was curtailed (Figure 13), but by 2019, this had risen to 2.8% and in 2022 to 3.3% (Bundesnetzagentur, 2016, 2019, 2023). Much of this is attributable to onshore wind in the north of the country that is waiting for new transmission lines to connect to southern demand centres.

Spain and Portugal provide contrasting examples, given that both countries have similar mechanisms for dealing with grid constraints. In Portugal, curtailment has risen from a low of around 0.2% in 2021 to 0.4% in 2023, while in Spain it rose around 0.3% in 2021, to represent 1% of total solar and wind generation.

In the United Kingdom, where virtually all curtailment is for wind power, the curtailment rate rose from 3% in 2015 to 6% in 2020, and was 5% in 2023 (Staffell *et al.*, 2021, 2024). This is because grid expansion that would allow much of this wind power to be transmitted from Scotland to the south is not yet in place, even as new capacity is being added in Scotland.

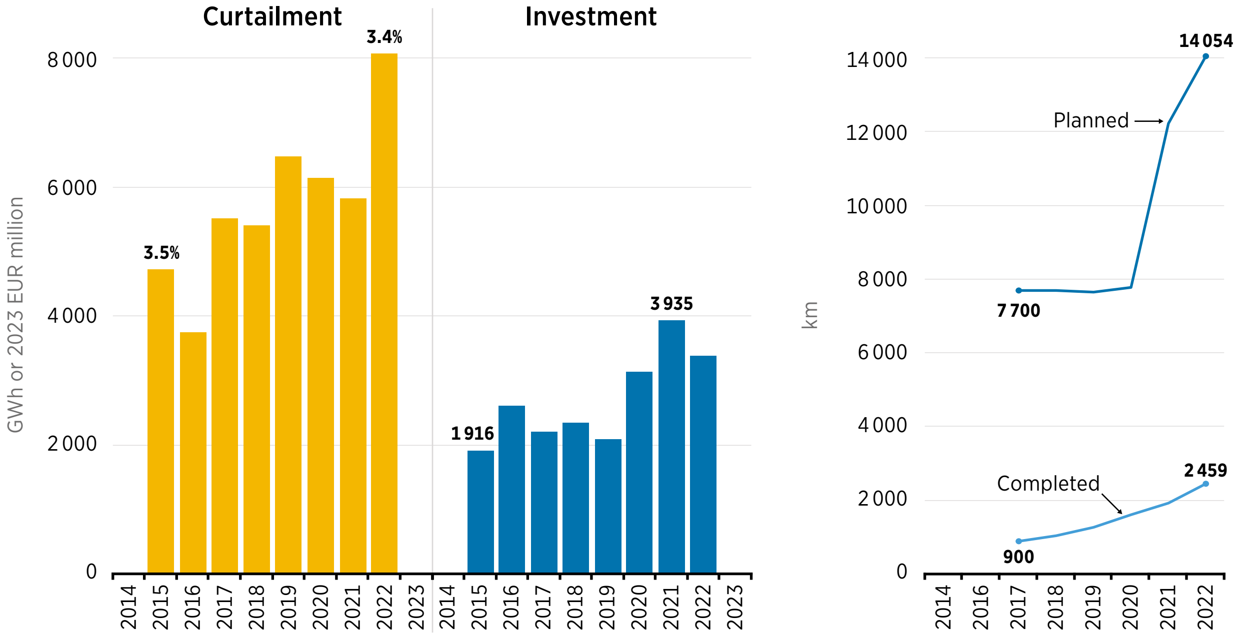
Figure 13 Curtailment rates for solar, wind and variable renewable electricity by country, 2015-2023



Sources: (Bundesnetzagentur, 2016, 2019, 2023; Staffell *et al.*, 2021, 2024; Yasuda *et al.*, 2022; IEA, 2023a; Castro, 2024).

Figure 14 shows the trends in Germany for grid investment by the commercially owned transmission system operators, the line transmission line length added, renewable power generation and percentage curtailment. Although investment has increased in recent years, it has not yet borne fruit in terms of avoiding an increase in GWh curtailed, albeit the curtailment rate has stayed broadly the same. Progress on the expansion of new transmission line length construction has been disappointing, particularly for the portion that is being directed by the state, which is now seven years behind schedule (Bundesrechnungshof, 2024). Crucially, it is proving difficult to expand the grid at the rate envisaged to meet the targets for solar and wind that pre-dated the significant increase in ambition since the onset of the crisis in Ukraine.

Figure 14 Grid curtailment of solar and wind, transmission network investment and planned and completed line length for Germany, 2015-2022



Source: (Bundesnetzagentur, 2016, 2019, 2023).

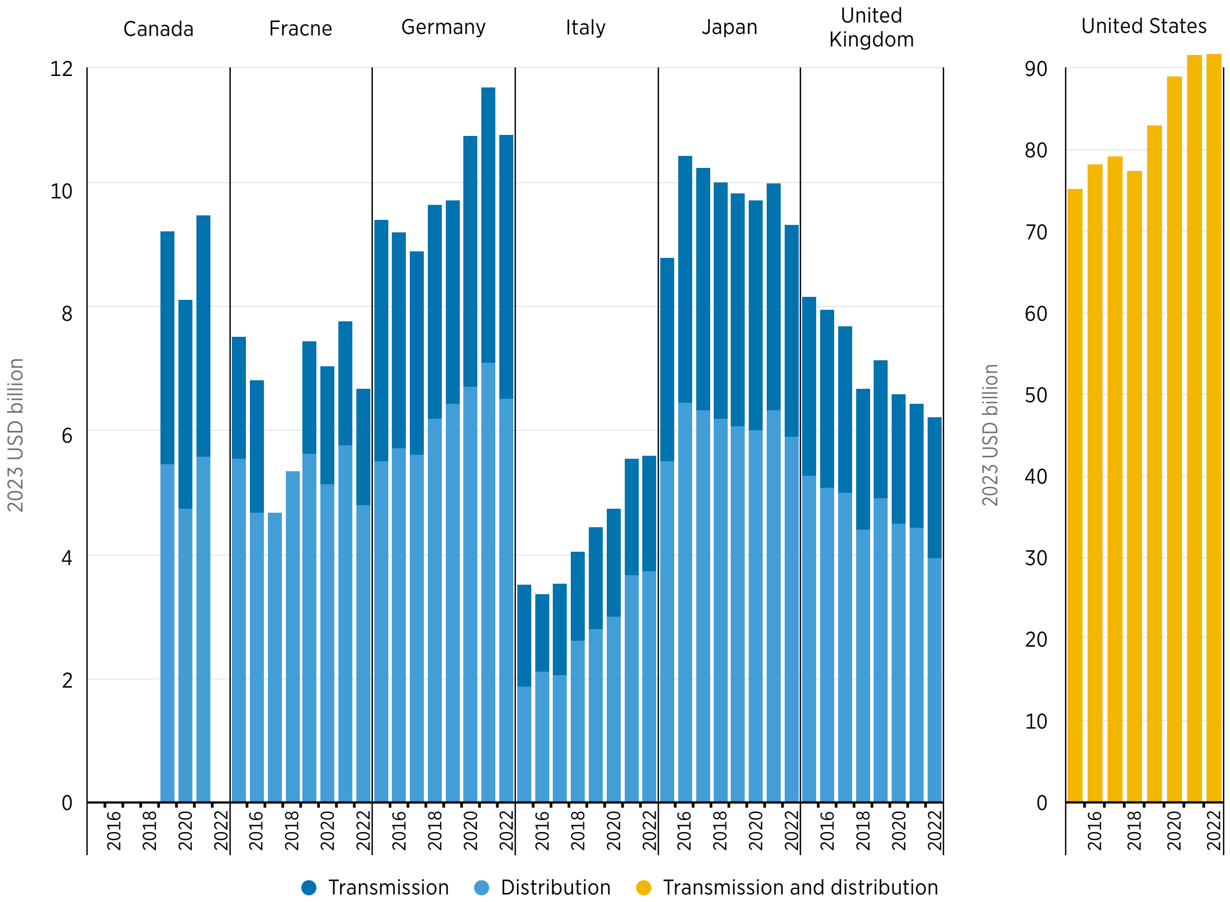
As can be seen in Figure 14, an important dynamic is that as solar and wind generation grows, even if curtailment rates still stay the same, the volume and potential value of lost electricity grows. In some cases, this makes investment in additional grid capacity extremely economic. For instance, in the United Kingdom, the additional investment cost of doubling the planned increase in the North-South transmission capacity additions to 2030 from Scotland to England might be paid back in just two years, given the value of curtailments at that time (Sani, 2023).

In terms of investment in grids, the trends across the G7 countries are mixed (Figure 15). In Germany, Italy and the United States, investment grew in real terms between 2015 and 2022 by 15%, 59% and 22% respectively. The United Kingdom has seen its annual investments fall in real terms, by 24% between 2015 and 2022, and France by 11%. Japan's investment in 2022 was 6% higher than in 2015, but 11% lower than in 2016. The data for Canada cover only three years, so do not allow an analysis over the same period as the other countries.

Overall, the total investment in grids has increased. However, with incomplete data by year and country, it is difficult to be categorical about the overall trend in investments in the G7. It appears likely that these have grown between 2015 and 2022, perhaps in the order of around 15%. Yet, as previously discussed, this appears to have been insufficient to match the growth in renewable power, with indicators for curtailment and grid connection wait times all suggesting that serious underfunding issues remain.

Although significant time lags often occur between annual investment expenditures and new transmission (or, to a lesser extent, distribution) capacities coming online, which cloud the analysis, it appears that investment is well below what is needed. Annual average investment in the G7 in transmission and distribution grids needs to ensure that the tripling goal is met. Globally, annual investments in grids need to double, on average, over the period 2022-2030. To what extent this holds true for the G7 will largely depend on growth in other areas of the transition, notably in relation to investments in electricity system flexibility, and national circumstances. Slower progress in these areas would require even higher investments in grids.

Figure 15 Investment by G7 countries in transmission and distribution grids, 2015-2022



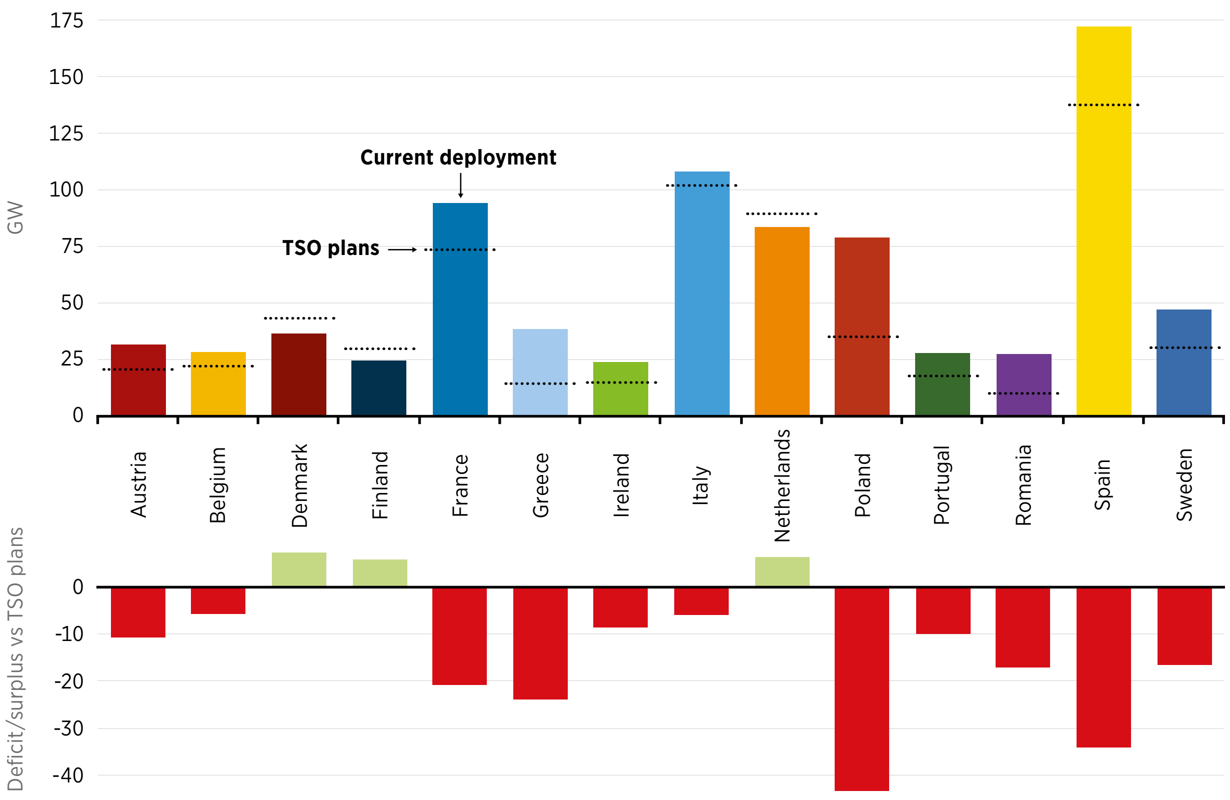
Source: (Bundesnetzagentur, 2016, 2019, 2023; Enedis, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023; RTE, 2021; Électricité Canada, 2022; IEA, 2023b).

The lag in the development of grid infrastructure as renewable power deployment has accelerated over the last two years, not to mention the increased plans and market outlook for renewable power since the onset of the crisis in Ukraine, represents a warning sign about countries' ability to absorb the required capacity for the tripling pledge. Recent analysis suggests that in Europe, there is a compounding problem. In addition to today's slow roll-out of new transmission capacity relative to planned needs, those planned needs by transmission system operators now look to be too low.

The analysis in Figure 16 suggests that, for many European markets at least, current market expectations for combined solar and wind capacity in 2030 now exceed TSO plans by a significant margin (Cremona and Rosslowe, 2024). Of the 26 countries analysed, 11 of those had TSO plans based on outdated targets (Cremona *et al.*, 2024). But the situation is more worrisome than this, given the increase in expected solar and wind deployment resulting from the fossil fuel price crisis of 2022.

Of the countries shown in Figure 14, only Denmark, Finland and the Netherlands have TSO plans that do not currently underestimate the solar and wind capacity that is likely to be connected to their networks in 2030. Overall, across all 26 European countries analysed, grid plans for 2030 are designed with more than 200 GW less than current expectations. Combined with the slow-paced grid expansion and increasing delays, this situation will likely either lead to a growth in curtailment beyond what is economically optimal, or result in unacceptable delays to grid connection windows for projects.

Figure 16 Anticipated solar and wind capacity in transmission system operators' expansion plans compared to current expectations of actual deployment in 2030



Source: (Cremona and Rosslowe, 2024).

Good planning for the energy transition is therefore essential. Countries need an expansion plan for the grid that not only matches current market expectations for solar and wind growth, but also has options in place to meet the tripling goal. Crucially, this has to be delivered "on time" or in advance of the renewable power growth.

Uncertainty around grid capacity and connection availability is not just an issue for the delivery of renewable electricity when it is needed. If the current situation is not promptly addressed, it will result in higher project costs and financing costs, reducing the benefits of the energy transition to consumers.

Notably, the world does not have good indicators to track grid modernisation, expansion and operation. The metrics that are available are relatively crude and most commonly cover the overall investment value in transmission and distribution networks and the line length added. These metrics are not sufficient, in and of themselves, to understand if they are meaningfully expanding the ability of the grid to handle higher volumes of wind and solar generation. The complexity of the interaction between physical grid infrastructure, grid operation and electricity system flexibility all play a role in that ability. It is therefore clear that it is challenging to identify a robust set of metrics, but more needs to be done.

Curtailment trends are a lagging indicator of the adequacy of the grid capability to handle higher shares of solar and wind. But lagging indicators are not ideal and curtailment data may not separate out economic curtailment from that resulting from grid constraints. Moreover, given the urgency of the tripling goal, countries need to correct course before problems arise. In that respect, lagging indicators may hinder delivering the tripling goal. This means that the quality and comprehensiveness of transmission and distribution operators' plans for the future are crucial, and they need to take into account a holistic approach to the energy transition. They also need to align – not just with stated goals, but with market expectations for growth in renewable power.

Recommendations for the G7 countries and others to address these issues include:

- Countries need to closely integrate their power planning and grid expansion, modernisation and enhancement programmes, in order to ensure alignment and that grid capacity is matched to planned capacity growth. Crucially, this needs to also align with market expectations for deployment, when they exceed country, which is increasingly the norm.
- Introduce an integrated approach to grid planning that looks at the combined benefits of solar, wind and storage, as well as demand-side resources (see below for more details).
- Measures should be taken to consult all relevant stakeholders to identify opportunities to address interconnection backlogs (projects awaiting connection to the grid) where they exit and identify what is required to accelerate grid connection for these projects and the role of each stakeholder in delivering on this plan.

- Permitting and approval processes need to be streamlined for new grid capacity and inter-connections between countries, while the co-location of storage at existing grid interconnections could help boost existing inter-connection capabilities.
- Grid operation and management needs to continuously evolve to adapt to higher shares of solar and wind power. This must encompass technical operation, market rules or design, and regulatory bottlenecks to greater flexibility that can unlock higher penetration of solar and wind power.
- Support the investment of EMDEs in grid infrastructure, with financing and capacity building.

However, more radical action is required, given the slow progress in a number of G7 countries on delivering the grid modernisation and expansion to support targets that are still below the tripling pledge pathway. G7 member states should continue to work to achieve the targets that their transmission and distribution operators have already set. But they must also act urgently to plug the likely gap in the grid capability to absorb and transmit to end users the renewable capacity and generation required to meet the tripling goal. This can be achieved, but it will require a focus on a range of grid-enhancing technologies that can be deployed faster than line extensions, as well as tapping into greater demand-side flexibility and energy storage than was previously anticipated for 2030.

These additional investments in grid-enhancing technologies, demand-side flexibility and energy storage are not "instead of" total grid and flexibility measures planned in the 1.5°C pathway. But they will contribute to securing these investments in time to solve the almost certain problem that grid modernisation and expansion will fall short of not just existing targets, but the additional efforts required to reach the tripling goal in 2030 based on today's trends.

G7 countries should therefore consider implementing policies and support programmes designed to urgently scale up these technologies and the regulatory and market changes required to ensure that they have viable business models. Specifically, the G7 should target:

- Polices and measures to incentivise an accelerated deployment of grid-scale electricity storage to 2030. This will be discussed in more detail later in this report.
- Rapidly increasing the contribution of demand-side flexibility to help manage solar and wind generation peaks and troughs. The growing share of end users that are becoming energy producers as well as consumers, when combined with the increased penetration of storage (thermal, stationary battery storage and electric vehicles) and electrification (*e.g.* heat pumps), as well as the low cost of networked digital controls, means opportunities to tap significant levels of flexibilityare increasingly being missed are increasingly being missed.

- A rapid scale-up of so-called grid-enhancing technologies – which are a mix of advanced controls, sensors and advanced optimisation tools – allows for greater electricity flows across the grid than without their implementation.[13] These have often been seen as a cheaper alternative to grid expansion, but with the likelihood of grid expansion plans falling short of needs by 2030 in the tripling pathway, they could be crucial to ensuring that the tripling goal can be met during the period grids are expanded.

As the G7 faces the challenge of meeting the tripling goal, it is important to acknowledge the potential barriers to delivering on the goal. In the case of grids, this means that the second dimension of a solution's suitability – its timeline and ease of implementation – starts to become of paramount importance.

2.3 Financing investment in renewable power and electricity infrastructure

The world has sufficient capital available to finance the energy transition many times over. However, lending institutions and businesses will only lend to or invest in projects where the risk-reward profile meets certain minima. The challenge is therefore multi-faceted, as it is about both the volume of bankable projects and the finance that is available to them at an affordable rate.

Successful policies to support the financing needs of the tripling pledge will therefore need to address three key metrics: 1) the demand (bankable project volumes), 2) the supply or availability of sufficient funds in different markets for different technologies and 3) the cost of finance.

Lack of progress, to a greater or lesser extent by market and technology, on these three core issues at least partially explains why current expectations are that renewable power deployment will not accelerate rapidly enough to meet the tripling target by 2030. This is especially true in many EMDEs. For instance, around 85% of global renewable energy investment in 2022 benefited less than 50% of the world's population, and Sub-Saharan Africa received less than 1% of the global total in the past two years (IRENA and CPI, 2023). As a result, renewable power capacity additions in Africa were just 2% of the new capacity added in 2022 (IRENA, 2023e).

In 2023, total investments in renewable power generation were estimated to have increased 28% from 2022 levels, to reach USD 570 billion. However, even allowing for the falling costs of renewable power, this still falls well short of the required USD 1 550 billion annual investment needed each and every year on average to 2030 (IRENA, 2024c). Just as crucially, current annual average investment in grids and flexibility, at around USD 368 billion in 2023, remains around half of what is needed each and every year to 2030.

[13] See IRENA (2019, 2020, 2022) and US DOE (2022) for more details on grid-enhancing technologies, their characteristics and their applications.

Low-cost finance for the energy transition is on hold

Inflation started to tick upwards as the world emerged from the first year of the COVID-19 pandemic in 2021, due to the unleashing of supply chain issues and pent-up demand as the world returned to more "normal" times. The crisis in Ukraine, however, sent energy and commodity costs soaring, driving a spike in consumer price inflation of an annualised value of 9% in the United States in June 2022 and of 10.9% in the EU in September 2022. Compared to target values for inflation that typically platform at annualised rates of around 2% in most advanced economies, central banks reacted more or less rapidly to raise lending rates and try to reduce inflation.

This has raised the cost of capital for all economic actors, including renewable power project developers. The yields on United States 10-year Treasury Bonds, often used as a benchmark for the "risk-free" rate of capital, more than doubled in 2022 to 2.95%, from an average of 1.44% in 2021 (OECD, 2024). With inflation still running high, the situation in 2023 saw continued increases with yields on US 10-year bonds continuing to rise in 2023, peaking at 4.8% in October 2023, before finally starting to ease towards the end of 2023. However, overall, they averaged another 1% higher than in 2022 at around 4%. Thus, the risk-free rate of capital benchmark increased by a factor of 2.7 overall. The situation was exacerbated by the macroeconomic damage of high energy prices and consumer inflation, which led to an increase in country risk premiums in many markets, especially EMDEs, as their fiscal and macroeconomic situations deteriorated.

This uptick in financing base rates has a significant impact on the cost of the energy transition. The cost of capital is a very important driver of the total electricity cost, given that, apart from bioenergy for power, renewable power technologies have no fuel costs. For instance, for a representative solar PV project or onshore wind project, the total levelised cost of electricity (LCOE) increases by around 80% if the cost of capital is 10% rather than 2%. Given the paramount importance of access to low-cost finance in achieving the required mobilisation of capital to support the energy transition, understanding the current cost of capital and its drivers is very important for policy makers, energy researchers and energy modellers.

Figure 17 represents the weighted-average cost of capital (WACC) for solar PV in 100 countries based on the survey results of IRENA, ETH Zurich and IEA Wind (IRENA, 2023e) and the updated benchmark model calibrated from the survey results where data gaps exist.[14] The increase in the WACC for utility-scale solar PV between 2022 and 2024 can clearly be seen. In advanced economies, this increase has been relatively uniform; however, many EMDEs have seen disproportionate increases as the lingering COVID-19 supply chain issues, highly inflationary environment, and deteriorating macroeconomic and fiscal conditions have contributed to increases in the WACC of more than 7% in some countries in the space of two years.

[14] *The WACC benchmark model is updated annually based on changes in country risk premium and risk-free interest rates, as well as additional survey data, when available.*

The impact for projects commissioned in 2023 was significant, with an increase of around 1.0 to 1.2 percentage points in Europe and 1.0 to 1.6 percentage points in Africa. However, the real impact of the recent increases in the cost of finance will be felt in 2024, with a further increase in the WACC in Europe of between 0.8 and as much as 3.3 percentage points, although for most markets it will be in the range 0.8 to 1.2 percentage points. In Africa, the situation is much more serious: the WACC of projects commissioned in 2024 could be as much as 6.5 percentage points higher than in 2022, although in countries with more stable macroeconomic and fiscal outlooks, the increase is restricted to as little as 1.5 percentage points over 2023.

Figure 17 Nominal, post-tax weighted-average cost of capital for utility-scale solar PV projects by country, 2022-2024

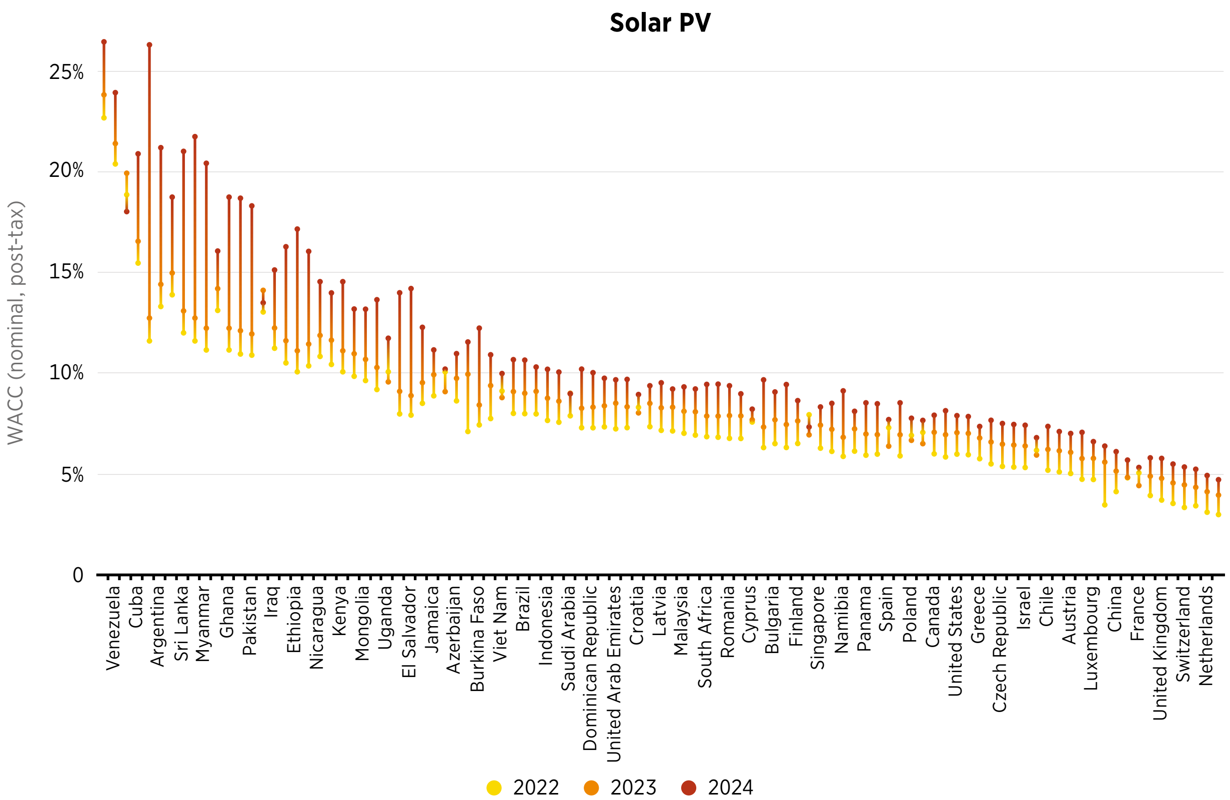
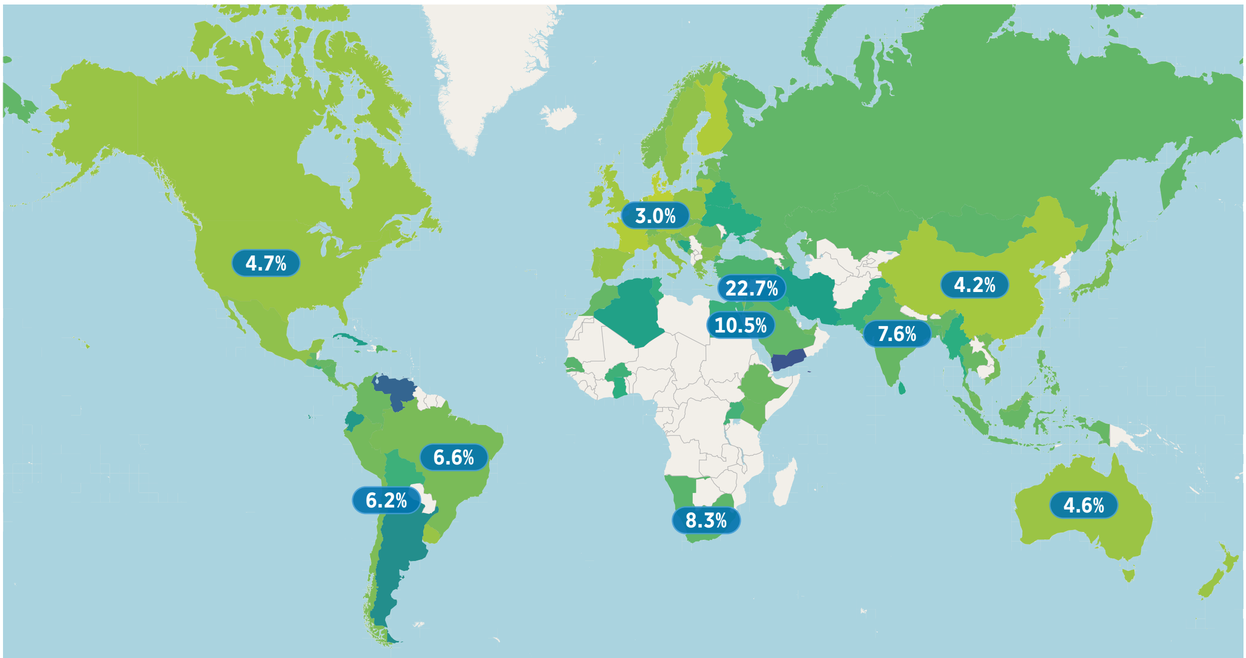


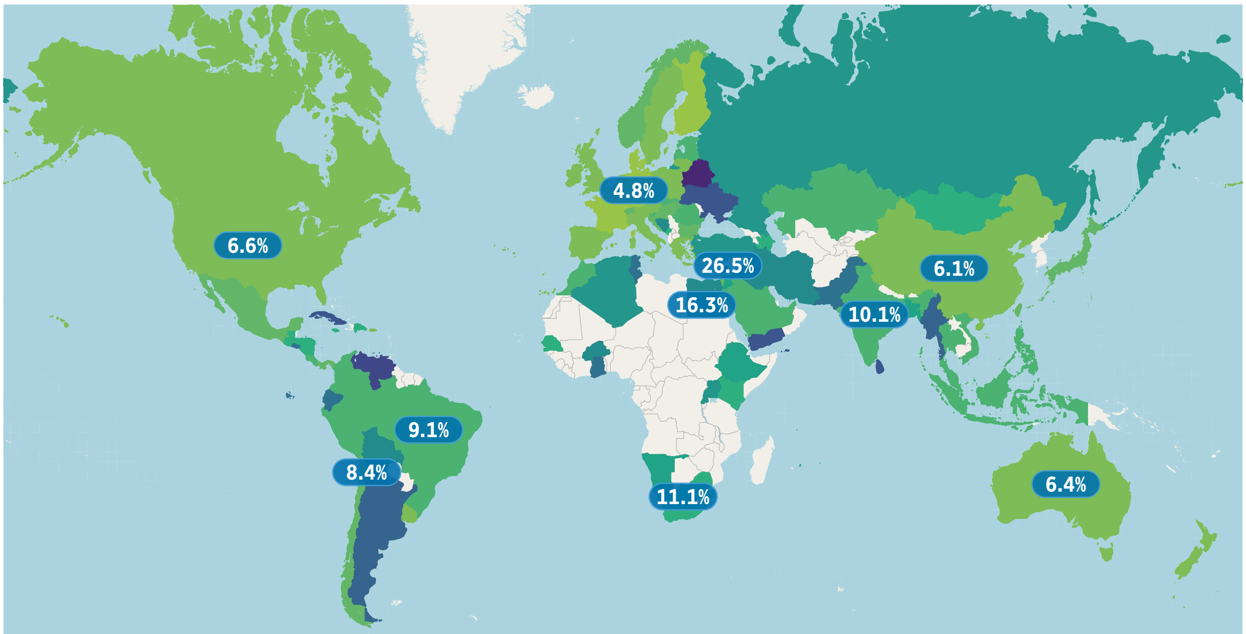
Figure 18 shows the change in the nominal, post-tax WACC for onshore wind between 2022 and 2024. In many markets, solar PV technology risk premiums are lower than for onshore wind, although this does vary by market depending on the level of maturity of the local market for each technology. For instance, there is virtually no difference in the cost of capital for solar PV and onshore wind in Germany, but in Finland onshore wind can attract a much lower cost of capital than solar PV. The trend in the increase in the cost of capital is, however, clear over the two years across all markets.

Figure 18 Nominal, post-tax weighted-average cost of capital for onshore wind projects by country, 2022 and 2024

Onshore wind for 2022



Onshore wind for 2024



WACC (nominal, post-tax)

0% 30%

Disclaimer: These maps are provided for illustration purposes only. Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.

Overall, based on the share of deployment, the global WACC is estimated to have fallen significantly for projects commissioned between 2010 and 2022, but increased in 2023 and is set to increase again in 2024 (Table 1). What emerges from the changes in both the cost of capital by country and the relative changes in deployment is that, for the global average at least, the impact of higher financing costs is muted. However, given the increase in the cost of capital across the board in 2022 and 2023, the continued increase in the global WACC by technology – depending on new capacity addition shares by country in 2024 – will continue.

Table 1 Global weighted-average cost of capital for solar PV, concentrating solar power, and onshore and offshore wind power by year of commissioning, 2010 to 2023

Year	Onshore wind	Solar PV	Offshore wind	Solar thermal
2010	7.8%	7.5%	7.5%	7.5%
2011	7.4%	7.3%	7.1%	7.1%
2012	7.0%	6.8%	6.6%	7.0%
2013	6.6%	6.4%	6.1%	7.7%
2014	6.3%	6.2%	5.9%	7.0%
2015	5.7%	5.7%	5.4%	7.4%
2016	5.3%	5.5%	5.4%	7.8%
2017	5.1%	5.0%	4.8%	7.2%
2018	4.5%	5.0%	4.0%	6.6%
2019	4.1%	5.0%	4.1%	5.6%
2020	3.4%	3.9%	4.6%	5.0%
2021	3.3%	3.7%	4.5%	5.0%
2022	2.9%	3.6%	4.1%	5.0%
2023	3.5%	3.8%	5.2%	n.a.

Note: This is the weighted-average cost of capital by technology based on the year of commissioning, assuming a one-year lag for full pass-through of changes in the WACC to account for the time between financial investment decision (FID) and commissioning. However, this is likely to be a poor indicator for offshore wind, and IRENA is currently undertaking analysis to identify if it is feasible to assign project-specific WACC assumptions based on data on the FID in order to improve the accuracy of this metric.

In order to scale up the finance flows to renewable power projects at the lowest cost of capital, it is necessary to properly identify for individual countries and technologies the specific risk drivers that are adding significant premiums. When this mapping is done, the most significant drivers for cost premium can be targeted with appropriate policies to mitigate these risks, reduce the cost of capital and crowd-in greater shares of private finance. By doing so, projects can achieve viable economics, allowing them to meet debt service obligations and the expectations of equity investors, while charging a lower price for power.

Table 2 provides a summary of the range of risks that impact the cost of finance for renewable power generation projects, as well as some of the potential tools available to mitigate these risks to the greatest extent possible to drive down the cost of capital. Addressing these risks in EMDEs will be key to unlocking the larger volumes required for the tripling goal, at the least cost.

Table 2 Key investment risks and mitigation tools to address them

Risk	Definition	Risk-mitigation tools
Country risk premium	Primarily driven by fiscal policy, indebtedness, perceived and real corruption, fiscal policy management performance, political risk/instability (*e.g.* war, civil disturbance, currency inconvertibility, breach of contract, expropriation, non-honouring of sovereignty obligations).	International guarantees, political risk insurance, partial risk/credit guarantees, export credit guarantees.
Currency risk	Risks associated with changing or volatile foreign exchange rates that adversely affect the value of investments. Risks arise when there is a mismatch between assets (revenues) and liabilities (debt financing).	Government guarantees, currency risk hedging (swap, forward), loans in local currency or covered in the power purchase agreement, partial credit guarantees.
Policy or regulatory risk	Risks associated with changes in legal or regulatory policies that have significant, adverse impacts on project development or implementation (*e.g.* incentive programmes, taxes, interconnection regulations, permitting processes).	Government guarantees, potentially backed by partial risk/credit guarantees, export credit guarantees and political risk insurance.
Counterparty risk (power off-taker risk)	Credit and default risk by a counterparty in a financial transaction. For renewable energy investments, this category is related to the risk of default or non-payment by the power off-taker, typically the electric utility.	Government guarantees, political risk insurance, partial risk/credit guarantees, export credit guarantees, liquidity facility, options and termination clauses in power purchase agreements.
Grid and transmission risk	Risks associated with limitations in interconnection, grid management and transmission infrastructure (including curtailment risk).	Government guarantees, liquidity guarantees, natural disaster insurance.
Permitting risks	Risk that permits required by the project, for example environmental authorisation, building permits, generation licences, are not provided at all or in a timely manner.	Government or the off-taker can take on some of the permitting responsibilities and risks if the site is provided or the country is using specific corridors or zones.
Resource risk	Risks associated with uncertainties around the availability, future price and/or supply of the renewable energy resource (*e.g.* resource risks related to geothermal projects).	Government guarantees and grants, convertible grants, geothermal exploration insurance.
Technology risk	Risks associated with use of nascent technology or unexperienced labour deploying it.	Specialised insurance products.
Re-financing risk	Risk that a borrower is unable to re-finance the outstanding loan during the life of the project owing to inadequate loan terms (high cost of borrowing, mismatch between loan maturity and lifetime of the asset).	Larger supply of capital market instruments for re-financing (*e.g.* green bonds/funds), partial credit guarantees.

Natural disasters	Risk that a natural disaster will affect the ability of a counterparty to fulfil its obligations (*e.g.* produce power, make payments).	Property, casualty and specialty insurance.
Site provision and preparation risk	Risk that land ownership of the project site is unclear, or that private land ownership is not allowed (*e.g.* in Ethiopia). It also refers to the risk that a government-provided site is poorly prepared and/or selected.	Government can provide sites, although with some limitations.
Social and environmental risks	Risks that there are social and/or environmental factors associated with the particular project site that can delay the project, increase costs and/or stop implementation.	Government can require project sites to be prepared in line with international social and environmental performance standards.
Supply chain risks	Risk that projects will face delays in receiving equipment or that costs will increase during development stage.	Policies to localise value chains and indexation to inflation and increasing costs.

Source: (IRENA, 2016 and IRENA and AfDB, 2022).

Understanding risk and the impact on capital availability and cost

The role of public funds will, however, remain essential in many EMDCs given the breadth and depth of the challenges they face in attracting private finance. Development finance institutions, in particular, have an important role to play in supporting renewable power investments in EMDEs by offering liquidity support, partial risk guarantees in lieu of sovereign guarantees and security packages, hard currency denomination of power purchase agreements or exchange rate hedges, among other solutions. Targeted support like this is critical for the bankability of projects in EMDEs, which may otherwise be faced with myriad sizeable risks, ranging from selling to financially challenged power off-takers to challenges with grid access. All this means that in many cases, for investors – and in particular lenders – to be comfortable with the risks involved, additional credit enhancement and risk-mitigation cover is required for the most challenging markets.

The three risks that have the greatest impact on the cost of capital for renewable power generation projects in EMDEs are the country risk, the currency risk (for projects that do not receive hard currency denominated offtake contracts) and the off-taker risk. Providing a one-stop-shop for addressing these elements would go a long way to unlocking funds to renewable projects at a lower cost than today.

Overall, a range of solutions will be required to drive greater financing at low cost to support the tripling goal in EMDEs. Notably, EMDEs are made up of very diverse set of countries with very different drivers of overall risk. Many already have well-established and liquid financing markets for renewable power projects because of a range of policy and regulatory settings adapted to their individual circumstances. In other countries, especially the least developed ones, the role of public financing and international assistance is pre-eminent, and almost no infrastructure, in the energy sector or elsewhere in the economy, relies solely on private financing.

Therefore, it is key to unbundle EMDEs into different contexts, to understand how their unique characteristics and circumstances shape different types of risks, the resultant cost of financing and the actions needed to support renewable energy deployment. This can help identify whether tailored solutions can help mobilise affordable financing, or whether there is a need for a higher degree of public intervention including public finance.

Addressing many of the risk factors in Table 2 will require more than just best practice in terms of policy, regulation, energy planning and target setting. It will be crucial to increase the volume of public funds available to support growth in renewable power deployment in EMDEs. These funds will always be in short supply, so it is crucial to ensure that they are targeted, increasingly smartly, towards the de-risking of the major risk drivers of investments, through policies and instruments that make these projects bankable to private investors. Where this is not always possible, the increased use of blended finance can be considered, which encourages the sharing of risks and know-how among transacting parties through the pooling of public and private capital.

Policies that ensure that financing institutions and investors assess renewable power projects and energy storage projects (whether standalone or in a hybrid configuration) with a comprehensive definition of investment risk – which includes the environmental and social externalities of fossil fuel use (including the macroeconomic costs of periodic fossil fuel price shocks) – would go a long way to helping align financial decision making with broader public and social goals.

Increased public funding is possible, despite tight fiscal situations. With significant public capital flows still going to fossil fuels – including through direct investments, subsidies, export credit guarantees, and concessional financing – these flows can be redirected to renewable energy and supportive infrastructure. New investments in grids and transmission modernisation projects will also be needed, because investment in these areas is lagging as well (as discussed in the next section).

The G7, and other advanced economies, should actively engage in climate finance initiatives that help deliver a more equitable distribution of investments into renewable power and supporting infrastructure.

Finally, policy and regulatory certainty is essential to helping reduce a range of risk factors for renewable energy projects. This needs to be complemented by clear targets that give investors the confidence to invest not just in individual projects, but the supply chains and skilled workforces that are needed to deliver cost-competitive projects.

2.4 Electricity storage to 2030: Growing importance and required grid upgrades

For decades, electricity storage has been an important tool to minimise overall electricity system costs – mainly using pumped hydropower storage systems – by providing ancillary services to the electricity market and energy arbitrage (*e.g.* storing electricity at times of relative surplus, for instance overnight, for release when wholesale prices or generating costs are higher). With the electricity system transitioning from one where large baseload thermal power plants provided the least-cost volume of electricity to one where solar and wind now fulfil that role, the need to upgrade and modernise grids and the role of electricity storage are increasing in importance.

As with other parts of the energy transition, electricity storage – and energy storage in general – is undergoing rapid technological innovation, industrialisation of new technologies and cost reductions. Today, an increasing number of energy storage solutions are available, including electro-chemical storage (notably lithium-ion batteries, but also flow batteries and other chemistries), thermal energy storage (which employs rocks, bricks or molten salts to store heat), mechanical technologies (employing compressed air, liquid air or gravitational potential) and chemical storage (storing energy in chemical bonds such as hydrogen or its derivatives). These are being added to the mainstay of electricity storage today, pumped hydropower, at a rapid pace.

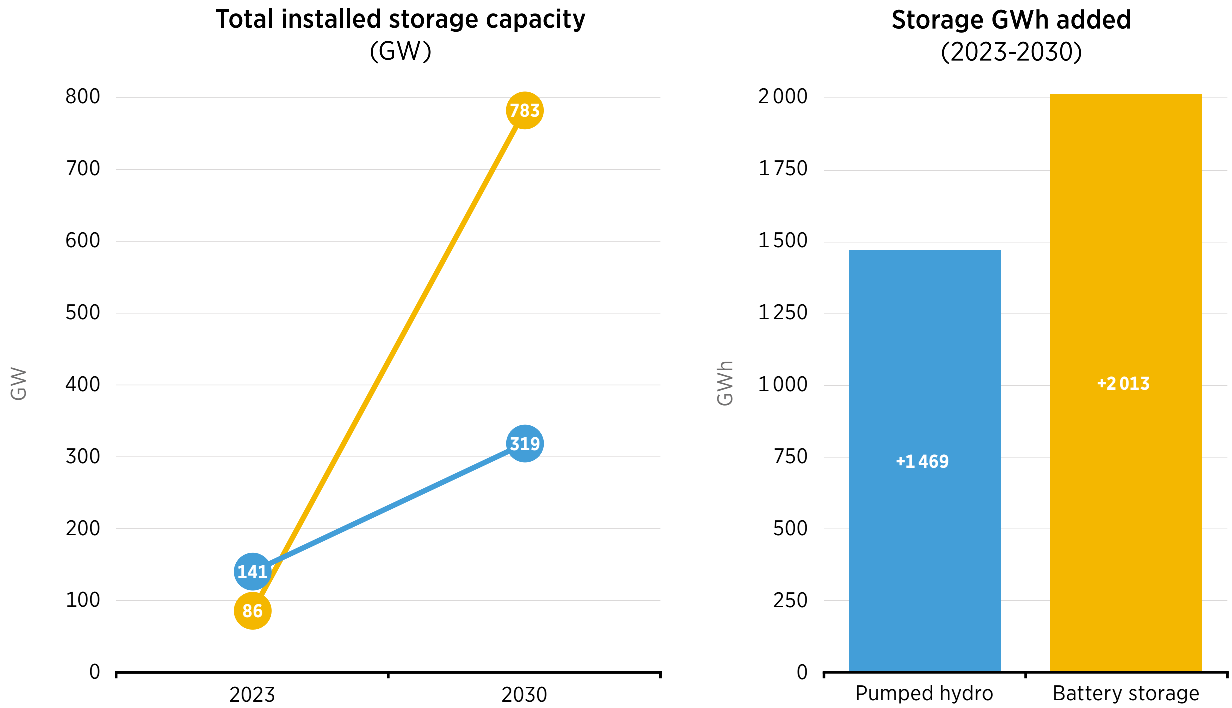
Each of these technologies potentially has a role to play in providing flexibility, security of supply and economic services – either at the level of an individual household, a commercial entity or at the utility scale. These storage technologies can be coupled directly, increasingly, with solar PV[15] or wind (as with hybrid generation assets) or as a standalone asset, or in optimising the use of distribution or transmission assets and systems.

Currently, pumped hydropower dominates the electricity storage landscape, with around 140 GW of capacity and 9 TWh of electricity storage (IHA, n.d.; IRENA, 2023d). However, stationary battery storage capacity is expected to grow rapidly to 2030, globally. Installed capacity could grow from around 86 GW (192 GWh) to 782 GW (2 013 GWh) in 2030 (BNEF, 2024b).

Battery storage is increasingly being used to accelerate solar and wind deployment in the face of challenges related to the slow processing of grid connection requests, the uncertainty around future curtailment or grid congestion regimes, and to manage grid congestion as grid modernisation, renewal and expansion gathers pace. For instance, 98% of the proposed solar PV projects in the interconnection queue in the US state of California are now hybrid solar-storage projects (Rand *et al.*, 2023), while so-called grid-booster storage projects are starting to be trialled or commercially deployed in Brazil, Germany, Latvia, Lithuania and the United States (Murray, 2024).

[15] 45% of the projects, by capacity, in the interconnection queue in the United States are solar-storage hybrids, where the storage technology is almost always a battery system (Rand et al., 2023).

Figure 19 Projected battery storage growth and required pumped hydropower capacity growth to 2030



Source: (BNEF, 2024b; Global Data, 2023; IRENA, 2023c, 2024a).

Battery storage growth is therefore accelerating. Figure 19 shows the projected increase in pumped hydropower storage consistent with the tripling goal, as well as current expectations of battery storage capacity growth between 2023 and 2030. The total installed power capacity of battery storage is projected to increase 9-fold from 86 GW in 2023 to 782 GW in 2030, while pumped hydro storage needs to grow 2.3-fold from around 141 GW in 2023 to 319 GW in 2030.

The relationship between pumped hydropower capacity and storage duration is, in theory, not fixed, but was in the past designed around a maximum of 12 hours[16] for daily cycling to make the most of excess thermal or nuclear production overnight, as well as to provide ancillary grid services. There are exceptions to this, where small pumped hydro facilities have been added to very large reservoirs, and storage can run into the hundreds or even thousands of hours.[17]

Lithium-ion battery storage is currently limited to around four hours maximum duration, but other long-duration storage technologies are emerging, such as flow batteries. However, by 2030 lithium-ion batteries will dominate. As a result, although battery storage power capacity grows by 564 GW to 2030, it adds just 1.7 TWh of storage, while the needed increase in pumped hydropower of 178 GW would add in the order of 1.5 TWh.

[16] *These systems were designed for daily cycling, so storage duration was typically 12 hours or less. Of systems with less than 24 hours of storage, the simple average of existing facilities is around 8 hours (IHA, 2024).*

[17] *The current data suggest that 23 facilities globally have in excess of 100 hours of storage representing 5.3 GW of capacity and 4.9 TWh of storage; those with more than 1 000 hours of storage represent only 263 MW of power (IHA, 2024).*

Increasingly, though, as the energy transition accelerates to 2030 the system will need long-duration energy storage, as well as a combination of other flexibility measures (bioenergy for power, geothermal, reservoir storage hydropower, demand-side management, interconnectors, *etc*.). For instance, analysis for the United Kingdom suggests that by 2035, periods of oversupply of renewables will last up to 96 hours or more, while shortfalls tail off rapidly after around 48 hours, but small shortfalls can persist for up to 96 hours. The optimal solution therefore requires careful modelling, given that small shortfalls of several days might still be manageable with the projected large quantities of battery storage coming online – if efficiently co-ordinated and incentivised. However, it is increasingly clear that significant flexibility or long-duration energy storage will be needed to meet security-of-supply requirements if this is to be provided cleanly.

Notably, in terms of the economic incentives to deploy long-duration energy storage, interconnectors and demand-side flexibility periods of oversupply represent much larger volumes and durations across all durations, but especially for periods above 48 hours.

Given the solar PV deployment is accelerating, the implication this has for grid operation, as well as the increasing likelihood that grid investments are going to lag behind the rate needed for the tripling pledge is that more storage will be needed sooner compared to current plans. It is recommended that G7 countries:

- Undertake flexibility studies – in consultation with all key stakeholders – to identify the role of electricity storage in 2030 in integrating the solar and wind power of the tripling pledge and minimising system costs. These studies should take into account the tripling goal needs, as well the current evolution of renewable deployment and the likely actual rate of grid modernisation, expansion and refurbishment to identify any gaps.
- Identify policies, market and regulatory changes to support a variety of business models, and to close any necessary financial gaps (especially where electricity system benefits are not flowing to project owners) to drive diverse storage solutions to market, including:
  - Stand-alone grid-connected electricity storage projects for grid congestion relief and energy arbitrage.
  - Electricity storage projects as “virtual” transmission capacity to displace in time solar and wind generation to periods where the lines are not constrained.[18]
  - The increased contribution of existing and new behind-the-meter small-scale electricity storage systems to grid flexibility, in terms of energy arbitrage and absorbing solar and wind electricity when grid locations are constrained. This will often require new business models that incentivise the aggregation of large numbers of small assets and reward their participation appropriately, as well as adjustments to market rules and grid regulations to facilitate their participation at the least cost possible.

[18] *There are still relatively few such projects, but plans are growing. For instance, TenneT and TransnetBW are both planning “Netzbooster” storage facilities at vulnerable locations on their grids (Murray, 2022).*

- Identify electricity storage targets for 2030, with a carve-out for long-duration energy storage given the ambitious nature of the tripling goal. This identification of targets should take into account national circumstances, the likely grid expansion, evolution in peak demand, existing and planned alternative flexibility sources, and interconnectors. The G7 could consider a proportional storage target:
  - The G7 collectively commits to adding at least 1 to 2 megawatt (MW), depending on national circumstances, of electricity storage capacity for every 10 MW of renewable power capacity added.
- Integrate the storage targets into existing support programmes and/or develop storage-specific support packages, regulatory and market rule changes to facilitate the delivery of the target and the full utilisation of the storage assets once built.
- Track progress towards the storage targets on an annual basis, consulting with all key stakeholders around upcoming bottlenecks through to 2030 in order to anticipate and course-correct before targets are put in jeopardy due to changing economic, technology, market or policy challenges.

A skilled workforce to support the tripling of renewable power

Delivering on the tripling goal by 2030 also depends on ensuring the scaling of the skilled workforce required. This spans the whole supply chain, from the labour force in the manufacturing of key equipment (*e.g.* PV modules, wind turbine nacelles, battery cells, *etc.*) through the myriad of products and services in the supply chain required to complete renewable power, electricity transmission and electricity storage projects, not to forget the O&M workforce required to maintain these systems. This requires:

- putting in place educational and skill-building programmes from the vocational level to university courses;
- devising strategies to reskill and upskill people (including those who currently work in fossil fuels but have applicable and transferable expertise), offering assistance to workers who need new and sometimes costly re-certifications;
- facilitating access to STEM training as well as to viable career paths for women in many traditionally male-centric industries;
- co-ordinating between the evolving needs of the renewable energy industry and the offerings of educational and training sector (which requires anticipating and modelling future skills needs); and
- ensuring that occupational safety and health in the workplace are integral considerations (which also requires adequate labour rights such as collective bargaining processes, as well as labour policies to ensure decent jobs).

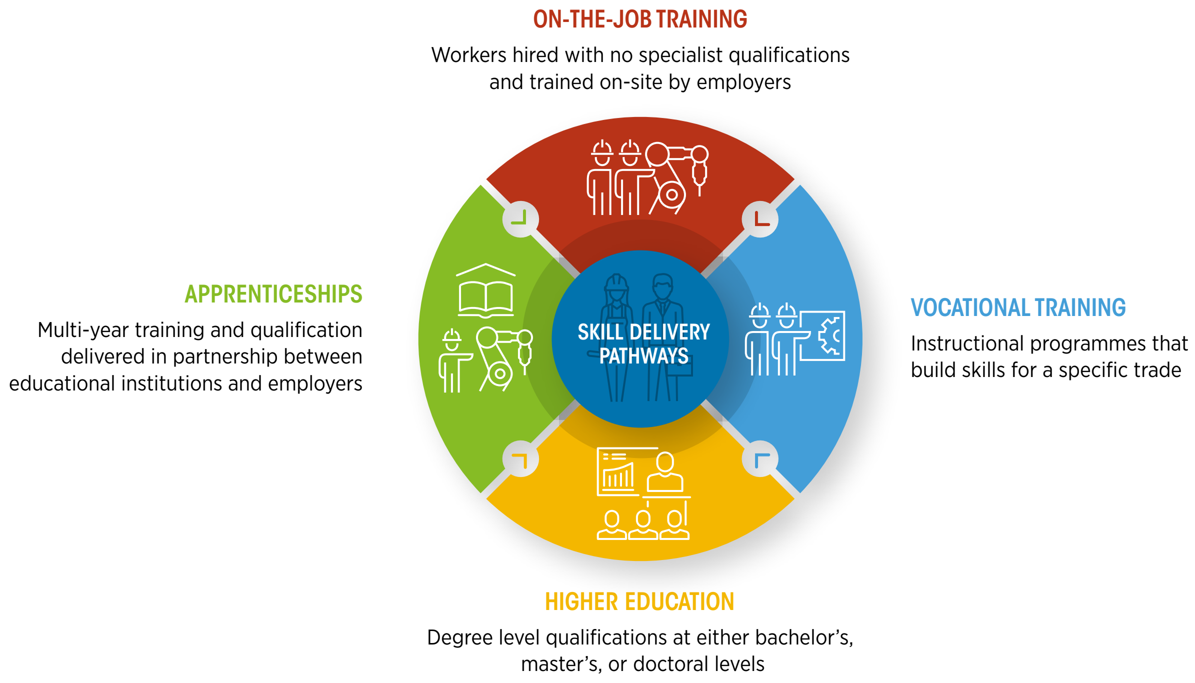
Another important point is that educational programmes and skill training, labour market measures, social protection and regional economic development efforts are essential to overcome potential misalignments between job losses in fossil fuels and gains in renewables during the energy transition.

These misalignments could be of a **temporal** nature (occurring when job losses precede job gains on a large scale). They could be **spatial** (where new jobs emerge in communities, regions, or countries other than those that experience job loss). There may also be **educational** misalignments when the skill levels or occupational patterns are not transferable between old and new energy jobs. Finally, **sectoral** misalignments can occur where value chains shift from one set of required inputs to another.

Action in a number of key policy areas can ensure adequate levels of skill training and education, including efforts to keep up with emerging skill requirements; implementation of national skill standards; labour market interventions to facilitate skills transitioning; and investing in transition training funds.

Skills delivery can and must take place in a variety of ways. Figure 20 highlights some of the key pathways, including on-the-job training (workers can be hired with no specialist qualifications and trained on-site by employers); vocational training (this includes both vocational courses and specialised short courses); university degrees (that is, bachelor's, master's and doctoral level degrees) and apprenticeships (qualifications delivered in partnership between education institutions and employers). Some roles also require a government-regulated professional licensure, for example, in the case of professional engineers and skilled trades persons.

Figure 20 Projected skill-delivery pathways



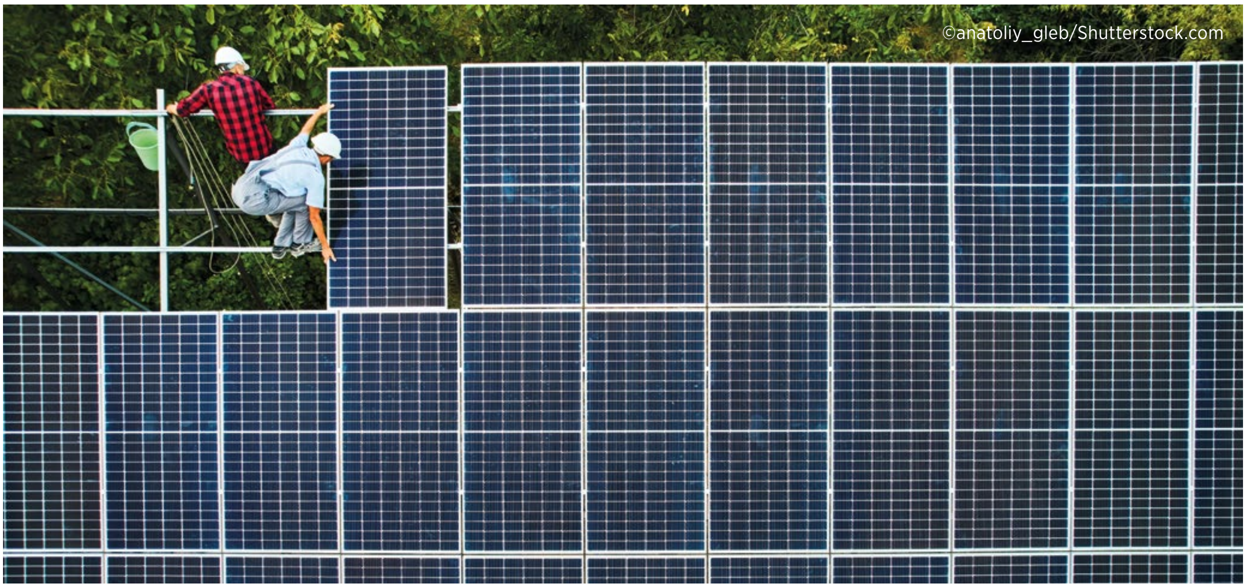
Source: (IRENA *et al.*, 2021).

An analysis of the skill delivery pathways for 35 key occupations in the solar PV sector, for example, shows that only 16 of these jobs require a university degree with the remainder of skills built through either on-the-job training, vocational training and/or apprenticeships (IRENA and ILO, 2021).

Labour market interventions can facilitate the transition of workers from the fossil fuel power sector to renewables. These include adequate employment services (matching jobs with qualified applicants; facilitating on- and off-job training; and implementing job safety nets), along with measures to facilitate labour mobility. In addition to the identification of transferable skills, governments will also need to dedicate funds to the reorientation and reskilling of the workforce. The costs of securing formal recognition and credentialing of existing relevant skills can be steep and are often borne by workers who may not be able to afford them.

The rapid innovation taking place within the energy sector brings with it an evolving set of skills requirements. Efforts to avoid skills shortages are of vital importance. The tripling goal makes this an imperative and the G7 should consider committing to:

- Undertaking a rapid assessment of potential misalignments in skills and work force availability across the entire ecosystem required to deliver on the tripling goal.
- Introducing or expanding programmes to align education and vocational training programmes to deliver the skilled workforce required for the tripling goal.
- Introducing or expanding existing plans and programmes designed to manage the potential misalignment in the availability of skilled workforces for the tripling goal by location, skillset and in time.
- Working to co-ordinate skills-related efforts of universities and vocational schools, employers, and labour representatives, and reconciling the objectives of these stakeholders as much as possible.



3 THE VITAL ROLE OF INTERNATIONAL COLLABORATION: HOW THE G7 CAN HAVE A GLOBAL IMPACT

The preceding chapters have highlighted both the challenges and opportunities around delivering on the tripling goal for the G7 as a group, and for the world as a whole. While the goal is eminently achievable, it is challenging. The current expectation is that, from 2026, the trends in new capacity addition growth are likely to fall short of what is needed to deliver – if policies or the current economic outlook does not change.

The G7 plays a crucial role in providing leadership and demonstrating that it is moving quickly to deliver its share of the tripling goal. However, many emerging market and developing economies (EMDEs) will not be able to deliver their share of the goal without international support and that of international organisations. This includes organisations that deliver financing and capacity building, facilitate peer-to-peer learning, and provide knowledge and insights on everything from renewable power procurement to policy design, market structures and regulatory regimes.

Based on the preceding chapters, the G7 countries should consider the following recommendations on how to leverage their existing international collaboration programmes, as well as where to target new initiatives in order to support the global delivery of the tripling goal. These are not exhaustive but focus on the key points raised in this report, and further areas of focus are certainly not excluded. The key recommendations are:

1. Assist countries in developing target-setting processes that align with the tripling goal, given national circumstances and starting points. Assist countries in identifying their own key progress metrics and in developing the capability to collect and report on progress on an annual basis.
2. Work with countries to help them identify opportunities for a step-change in renewable power capacity growth, by mapping the key bottlenecks to rapid growth. In many countries, this could be supporting "high-impact" projects in grids, system operation, market, policy and regulatory reform.
3. Support inclusive and co-ordinated regional grid planning, interconnector projects and grid expansion/modernisation plans to unlock greater scope for renewable power capacity deployment.
4. Support EMDEs in identifying near-term opportunities for renewable electricity demand-pull, both directly (*e.g.* in encouraging corporate/industry procurement of renewable power) and indirectly via increased electrification, or in the energy transition in hard-to-abate sectors, from green steel or chemical production to sustainable aviation fuels.

5. Support EMDEs with the process of taking stock of successful support policies for renewable energy deployment and sharing peer-to-peer knowledge on what has been successful in what context. Just as importantly, share knowledge on how and why support policies have failed in different contexts.

6. Fully integrate targets, energy planning and grid planning with support policies for renewable power deployment to provide greater certainty to industry on the volume of capacity by technology needed and when. This will reduce project risks and hence the cost of capital, support investment in skills and workforces, and strengthen the local and regional supply chains necessary for low-cost projects.

7. Support efforts to increase the ability of domestic renewable power project promoters to develop large, high-quality bankable project proposal pipelines in order to ensure an adequate supply of projects in EMDEs that can deliver capacity when the rest of the policy, regulatory and financing landscape is ready to deliver.

8. Increase the volume of public funds available for financing renewable power generation projects and use them strategically to reduce finance costs for projects, crowd-in greater private sector financing and in reduced time frames, by:

    a. Working with stakeholders to develop standardised financing products that are easy to access and process and that address the three main cost drivers of the high weighted-average cost of capital in EMDEs: country risk, exchange rate risk and offtake risk.

    b. Prioritise "high-impact" public financing that can leverage greater renewable capacity roll-out, whether that is in grid expansion, transmission system operator management and assessment capabilities, storage solutions, *etc*.

9. Support EMDEs with best practices in grid expansion and modernisation planning, as well as in grid operation with high shares of variable renewables.

10. Support grid flexibility assessments and projected flexibility needs for 2030, identifying bottlenecks and potential technology, market operation or regulatory solutions. Special attention should be paid to the opportunity to introduce greater demand-side flexibility and the role of energy storage, including long duration energy storage.

11. Support the development of EMDEs' Nationally Determined Contributions (NDCs), which today are often narrowly focused or rely on outdated data, due a number of constraints that these countries face. Fully aligning NDCs with the outcomes of target setting (see point 1 above) would create new momentum. Crucially, it should support countries' ability to broaden the focus of NDCs beyond renewable power to take into account the enabling measures necessary to deliver on the tripling goal (*e.g.* market and regulatory reform, grid expansion, system operation, demand-pull, electrification).

12. Support EMDEs in accelerating the deployment of wind power technology, in particular onshore wind. The current trend in deployment is not enough to achieve the tripling goal. Activities could focus on:

- Implementing best practices in permitting and environmental regulation, noting the importance of aligning this with the activities in point 3 above.
- The G7 should consider working with the global South to build more resilient and diversified supply chains – helping to create multilateral markets with secured off-takers for new producers of technologies based on fair trade agreements. Recent difficulties in the sector are in part due to supply chain issues, and broader international collaboration and co-ordination on supply chains would result in lower costs, higher energy security and healthier supply chains ready to support further growth.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