COP30 BRASIL AMAZÔNIA BELÉM 2025

UAE CONSENSUS | COP28 UAE

Global Renewables Alliance

IRENA International Renewable Energy Agency

Delivering on the UAE Consensus

TRACKING PROGRESS TOWARD TRIPLING RENEWABLE ENERGY CAPACITY AND DOUBLING ENERGY EFFICIENCY BY 2030

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THE UAE CONSENSUS

COP28 delivered the historic UAE Consensus, an ambitious negotiated response to the First Global Stocktake charting progress against the Paris Agreement. It includes unprecedented language around transitioning away from fossil fuels in a just, orderly and equitable manner. The negotiated text – agreed by 198 Parties in Dubai – also includes a number of global goals, such as calls for tripling renewable energy, halting deforestation and doubling energy efficiency by 2030.

In early 2024, IRENA was designated the Custodian Agency for tracking and reporting on two of these goals; this report is the second edition of a resultant annual series of reports charting global progress toward them:

II. A. 28. *Further recognizes* 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:

(a) Tripling renewable energy capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030;

UNFCCC, Outcome of the First Global Stocktake, 2023.

Simon Stiell

Executive Secretary

United Nations Framework Convention on Climate Change

IRENA's new data show the 2030 target of tripling renewables and doubling energy efficiency, agreed at the COP28 UN Climate Conference, remains within reach. But it's now time to pick up the pace. COP30 in the Amazon is the moment for nations to reinforce global climate co-operation, and to accelerate climate action, because it's in every nations' interest – to protect every economy from worsening climate disasters, and to spread the massive benefits of renewables, efficiency and climate resilience to billions more people: more jobs, stronger economies, better health, more secure and affordable energy for all.

UAE CONSENSUS | COP28 UAE

United Nations Climate Change

The **International Renewable Energy Agency** (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future. The Agency serves as the principal platform for international co-operation, 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**

Hosted by Brazil in 2025, **COP30** is the 30th session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC). The conference will bring together governments, businesses, civil society and international organisations to address the urgent challenges of climate change, build on past commitments and drive ambitious action towards a resilient future. The COP30 Presidency has three strategic objectives: to strengthen multilateralism and the credibility of the UNFCCC; to connect the climate agenda with people's daily realities; and to accelerate the implementation of the Paris Agreement.

The **Global Renewables Alliance** (GRA) was established by the Global Wind Energy Council, Global Solar Council, International Hydropower Association, Green Hydrogen Organisation, Long-Duration Energy Storage Council and the International Geothermal Association to unify these global bodies. Collectively we strengthen the private sector's voice on accelerating the energy transition, working to triple global renewable energy capacity by 2030 to at least 11 000 GW. **www.globalrenewablesalliance.org**

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DISCLAIMER AND ACKNOWLEDGEMENTS

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NDC PARTNERSHIP

REN21 RENEWABLES NOW

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Francesco La Camera
Director-General, International Renewable Energy Agency

The Outcome of the First Global Stocktake in 2023 called for universal efforts to triple renewable energy capacity and double the average annual rate of energy efficiency improvements by 2030 to keep the world on track to achieve the objectives of the Paris Agreement.

IRENA, in its capacity as the custodian agency for monitoring these key aspects of the UAE Consensus, reports annually on global progress made toward these goals. The findings and recommendations presented herein are also intended as key inputs to the development of the COP 30 Action Agenda, and particularly Axis I (focussing on the transition of energy, industry and transport), in which IRENA participates as part of its role as Energy Focal Point for the Marrakech Partnership for Global Climate Action.

This year's report shows that the pace of global renewable power deployment continues to improve, with 582 GW of additional capacity installed in 2024. While this 15.1% increase still falls short of the rate required to meet the tripling goal, it marks a new global deployment record for a third consecutive year. At this pace, the projected shortfall in capacity falls to 0.9 TW by 2030, from the 1.49 TW reported last year, providing much-needed hope that the tripling target can still be met.

IRENA's 1.5°C Scenario, from its *World energy transition outlook* workstream, shows that solar PV capacity additions are on track to reach, and even exceed, the required capacity by 2030. Nonetheless, the deployment of other technologies continues to lag behind.

Energy efficiency improvements have been negligible, at around 1% – well below the 4% required each year between 2022 and 2030 to achieve the doubling goal. Significantly more progress must be made to address this gap, particularly in end-use sectors such as transport, heat, buildings and industry.

As of 1 October 2025, 60 of the 195 Parties to the Paris Agreement had submitted new Nationally Determined Contributions. This third round of submissions (NDC 3.0) is intended to be informed by the Outcome of the First Global Stocktake, and has so far raised collective ambitions for renewable power from 5.4 TW to 5.8 TW by 2030. However, announcements made at the UN Climate Summit in September 2025 could ultimately result in a collective ambition of more than 6.9 TW by 2030, and 8 TW by 2035.

The equitable deployment and distribution of this renewable power will depend on the international community's ability to unlock additional financing for renewables, particularly in emerging markets and developing economies. To this end, a decision at COP30 on the *Baku to Belém Roadmap to 1.3T* will be an important driver for scaling up climate finance to benefit more people in those parts of the world that face the highest barriers to development.

The progress and commitments made so far show that it is still possible to bridge the gap and achieve the UAE Consensus goals, keeping the world on a 1.5°C compatible pathway. This will require, *inter alia*, infrastructure modernisation and expansion; robust regulatory frameworks and market design that support the transition; resilient supply chains; and sufficient human resource capabilities to reliably deliver a new renewable era that is just, equitable and leaves no-one behind.

IRENA
International Renewable Energy Agency

Amb. André Corrêa do Lago
President-Designate, COP 30

We have made a lot of progress since the UAE Consensus agreed upon during COP 28, which called on all Parties to the UNFCCC to contribute to efforts to triple renewable energy capacity globally and double the global average annual rate of energy efficiency improvements by 2030. To keep momentum, the COP 30 Presidency will continue to champion this important outcome of the First Global Stocktake.

Increasing renewable energy capacity and diversifying energy sources is an essential part of the energy transition and a condition to keep the 1.5°C temperature goal within reach. It is also indispensable in achieving universal access to electricity and improving energy security. Additionally, it allows for reducing countries' dependence on fossil fuel, and its health, environmental, financial and fiscal consequences.

Bringing attention to successful cases helps us understand the main challenges, the benefits derived from the shift to renewable energy and the bottlenecks that are preventing progress. In the last years, we have seen rapid advances in technology, cost reduction and record-high investments that have made renewables mainstream. Recent IRENA data reveals that 91% of new renewable projects are now cheaper than fossil fuel alternatives, which is a remarkable development that can completely change the future of energy systems, especially in developing countries – not least by tackling energy poverty, advancing clean cooking and bringing Mission 300 in Africa closer within reach.

Yet investments remain uneven. Europe, Asia and North America account for most of the installed renewable power capacity. In other regions, countries struggle to access climate finance, attract investments and lower the cost of capital. We urgently need to diversify the geographic deployment of renewables to address the investment gap. It is important to call upon financing institutions and countries, especially those that have historically contributed to climate change, to make efforts to catalyse and scale up investment from all financial sources and channels, especially for developing countries.

The fact that leaders – including the Brazilian President and IRENA's Director-General, in the joint letter "All hands on deck for the just and equitable energy transition", released last September – reiterated their commitment to advancing renewable energy and energy efficiency globally demonstrates that this goal will continue to be at the top of the political and financial agendas.

To achieve net-zero goals, it is also necessary to exponentially scale up production and use of bioenergy for power and sustainable fuels such as biofuels, biogases, hydrogen and hydrogen-based fuels to replace fossil fuels. These energy sources allow for a sharp decrease of emissions from hard-to-abate sectors such as industry and aviation, maritime and road transport.

This report is essential to keep stakeholders mobilised and highlight areas where there is room to boost collaboration. We should also use this important document to inform discussions and demonstrate progress made towards tripling renewables, particularly in the current global landscape, pushing all relevant actors to follow these concrete recommendations in support of this global effort to accelerate implementation of the GST commitments.

COP30
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BELÉM 2025

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Ben Backwell
Chair, Global Renewables Alliance

The energy transition is in full swing and is here to stay, with the 3xRenewables goal gaining momentum, although progress remains too slow.

Millions of dedicated renewable energy sector employees, and the continued commitment of the private sector, drove a record 582 GW of new renewable power additions in 2024 – 91% of all new capacity. This record growth is matched by over twenty years of rising investment in renewables, hitting over USD 600 billion in 2024.

The reason is simple: economics. In 2024, more than 90% of new renewable energy generation was cheaper than new fossil fuel alternatives. Countries that have invested in future-proof renewable energy are now realising substantial economic and strategic advantages: renewable energy already employs nearly 16 million people worldwide, with millions more projected. By shielding economies from fossil fuel price swings, renewables also drive stability and long-term economic growth.

Over 75% of NDCs submitted up to September 2025 referenced renewable energy. At the same time, a gap remains between ambition and what is needed to align with 1.5°C.

Despite commitments and record additions, we remain off track to meet the 3xRenewables goal by 2030 set at COP28. In 2024 alone, the renewables industry installed an incredible 582 GW across the globe, yet this was 462 GW short of the average annual additions called for in the previous edition of this report. This means the challenge gets bigger; renewable capacity must now grow at an even faster pace. Missing this target means missing the tripling goal, and with it, exposing societies to more costly and dangerous climate impacts.

Governments need to deliver action. This means championing renewable technology and celebrating its benefits; it means calling out disinformation; and it means providing a stable investment environment for the public sector.

The Global Renewables Alliance urges leaders and governments to act on three priorities: first, set ambitious national renewable targets aligned with the tripling goal; second, remove barriers by streamlining permitting, activating off-takers and prioritising the development of grids and storage; third, close the financing gap by de-risking investments and lowering the cost of capital in emerging markets and developing economies, so that every region can benefit.

COP30 is the moment for world leaders to show *mutirão* – collective effort – that demonstrates multilateralism is delivering and accelerating the energy transition. Now is the time to collaborate and to move from commitment to implementation. This is more than an energy transition – it is a global transformation that will create jobs, growth and security for all.

Global Renewables Alliance

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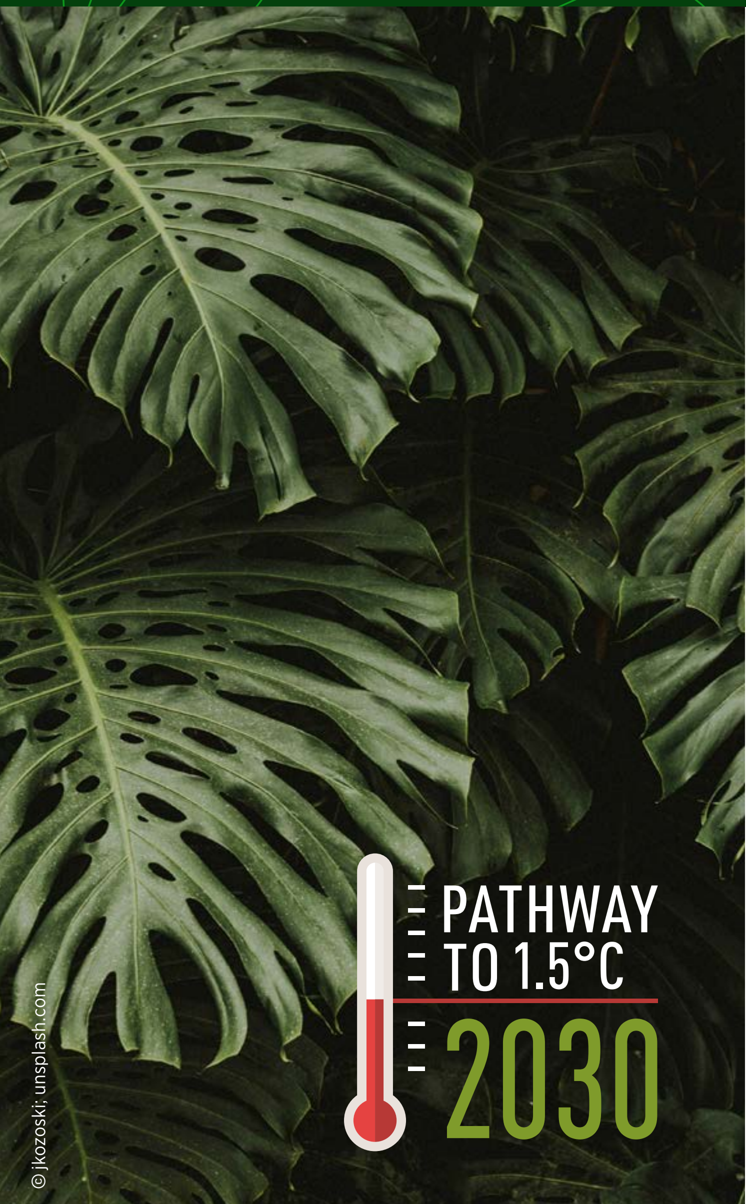

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KEY FINDINGS

3X TRIPLING BY 2030 REQUIRES: **+1 122 GW/yr** 2025-2030

+16.6% annual growth

2024

+581.9 GW

+15.1% growth 2024

(0.7 percentage points more than in 2023)

Solar PV

+452.1 GW added in 2024 (27% higher than in 2023); averaged 139 MW per project

Wind energy

+114.3 GW added in 2024 (105.7 GW onshore)

Hydropower

+9.3 GW (excluding pumped hydro) to reach 1 277 GW

Bioenergy

+5.1 GW added in 2024 to reach 151 GW

Geothermal, CSP and Marine

+1 GW combined added in 2024 to reach 23 GW

Investment in Solar PV manufacturing in 2024: **-72%**

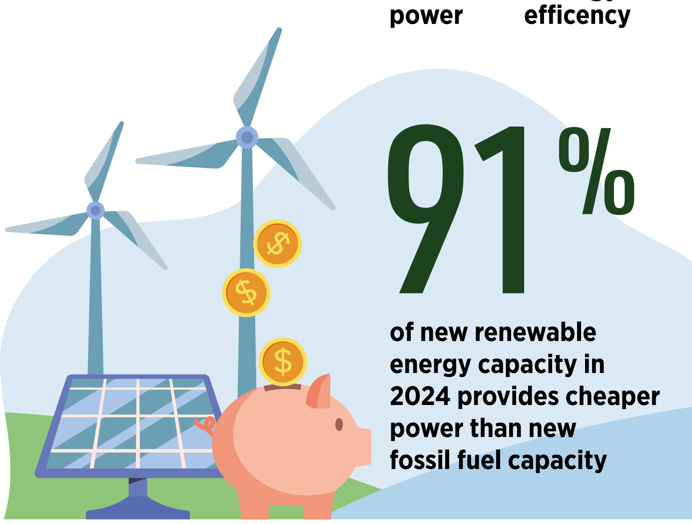
INVESTMENTS IN 2024

624 USD billion — **Renewable power**

348 USD billion — **Energy efficency**

102 USD billion investment in solar, battery, wind and electrolyser manufacturing in 2024

Investment in battery manufacturing almost doubled in 2024 **2x**



91% **of new renewable energy capacity in 2024 provides cheaper power than new fossil fuel capacity**

STORAGE IN 2024

Battery storage:

+74 GW (around 180 GWh) of battery storage in 2024

China	United States	EU+UK	Rest of world
39 GW	12 GW	11.5	11.5

Pumped hydro storage capacity:

+8.3 GW added in 2024 - total installed 150 GW

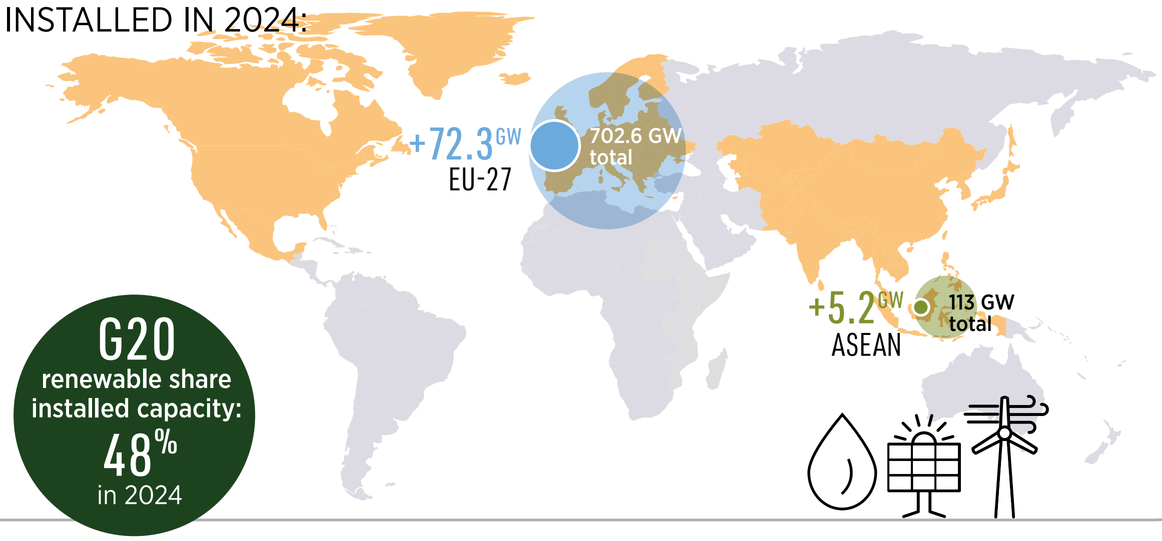
Notes: ASEAN = Association of Southeast Asian Nations; CSP = conentrated solar power; EU = European Union; EVs = electric vehicles; G20 = Group of twenty; GW = gigawatts; GWh = gigawatt hour; MW = megawatt; NDCs = nationally determined contributions; PV = photovoltaic; RE = renewable energy; yr = year.

INSTALLED RENEWABLE POWER IS **GEOGRAPHICALLY UNEVEN:**

Asia, Europe and North America **85.4%**

14.6% Rest of the world

INSTALLED IN 2024:



G20
renewable share installed capacity:
48%
in 2024

NDC 3.0 FACTS

60
parties submitted
NDC 3.0
(1 October 2025)

60 updated NDCs increase their RE commitments to
244 GW
by 2035

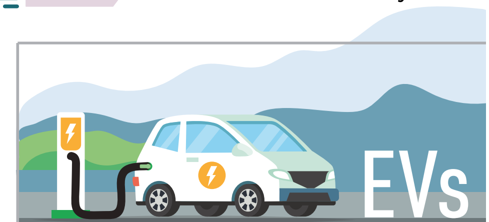
+112 GW

132 GW

Least developed countries' NDCs 2030 renewables target:

113 GW

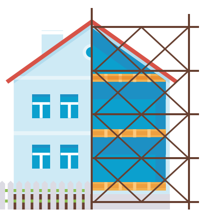
88% of NDC 3.0s mention energy efficiency



EVs

21% of global new car sales, 2024

14.4 million residential heat pumps sold in 2024 (+6%)



A
B
C
D
E

Global building renovation rate: **1%**
(of building stock in 2024)

+3 GW
electrolyser capacity in 2024

1% energy intensity improvement in 2023-2024

URGENT ACTIONS FOR POLICY MAKERS

KEY RECOMMENDATIONS

SUPPLY CHAINS

- Ensure socially responsible procurement of renewables by encouraging uptake of sustainable supply chain assurance schemes.
- Incentivise public–private partnerships and investment in circularity.
- Ensure fair and transparent trade practices for critical renewable energy technologies and pursue international co-operation to safeguard trade corridors for key materials and components.
- Integrate trade measures within local industrial development strategies, underpinned by assessments of the sectors and technologies in which developing countries can specialise.
- Implement fiscal incentives (*e.g.* tax credits, subsidies, grants, loan guarantees for manufacturing); public funding for research and development; affordable access to electricity and land; and investments in infrastructure upgrades.

KEY RECOMMENDATIONS

POLICY, REGULATION AND NDCS

- Include specific, measurable renewable energy capacity targets within NDCs and integrated energy plans that align with the UAE Consensus energy goals, and issue NDC investment strategies that promote quantified, bankable mitigation projects supported by robust investment mechanisms.
- Develop robust and transparent methodologies and standards for authorities issuing carbon and renewable energy certificates.
- Establish tariff-based support mechanisms to provide revenue certainty (*e.g.* CfDs, PPAs, *etc.*) and reduce perceived risks of renewable energy projects.
- Tailor auctions to local contexts and objectives, and balance these between low prices, project realisation and broader development and macroeconomic objectives.
- Address social equity concerns associated with projects – including distribution of system costs – to avoid disproportionately impacting low-income or vulnerable consumers; and undertake early community engagement and meaningful consultation.
- Streamline renewable energy and grid deployment, identifying zones that avoid nature-sensitive and culturally significant areas; incentivise deployment of renewable energy projects on degraded and desert land to reduce impacts; and expedite processes for developers repowering assets on existing sites.

WORKFORCE SKILLS AND DIVERSITY

- Adopt long-term, multi-level workforce strategies in close co-ordination with industry, government, labour representatives, and educational and training institutions; these should empower women and marginalised groups.
- Invest in dedicated transition training funds to expand vocational and university programmes, apprenticeships and reskilling opportunities, especially in technical trades.
- Integrate renewable energy into national curricula – from primary to tertiary – and promote lifelong learning opportunities to adapt to evolving technologies and the increase of digitalisation and AI in energy systems.
- Close the gender gap in leadership and technical roles by issuing measurable targets for women's representation in STEM, and expanding access to mentorship and networking.
- Address cultural and organisational barriers by introducing policies that guarantee the inclusion of women and minorities, and protect workplace cultures without reinforcing structural inequities.

KEY RECOMMENDATIONS

INFRASTRUCTURE AND SYSTEM OPERATION

- Simplify and fast-track permitting, digitalise grids and prioritise storage; governments and stakeholders can achieve rapid scale-up by focusing on near-term measures in the next five years.
- Accelerate the permitting and deployment of critical energy infrastructure, including power grids, bioenergy conversion plants, hydrogen networks, and fuel terminals in ports and airports.
- Develop the power system infrastructure necessary to guarantee access, reliability and cost efficiency.
- Systemic planning for grid and flexibility infrastructure should balance investment and operational costs and enhance energy security.
- Near-term grid enhancement and flexibility solutions, including demand management and sector coupling, are needed immediately, ahead of more comprehensive infrastructure expansion.

QUICKFACT

POWER SYSTEM FLEXIBILITY NEEDS BY 2030 COMPARED TO 2019:

3x daily flexibility

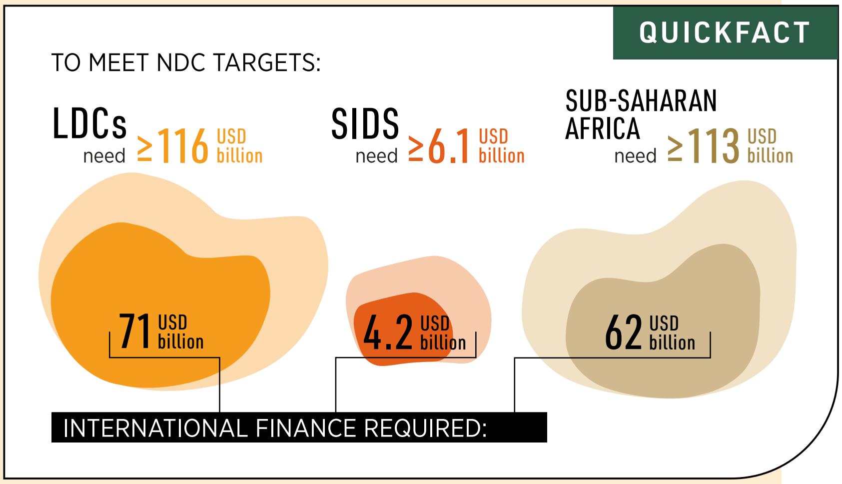
2.5x weekly flexibility

2x seasonal flexibility

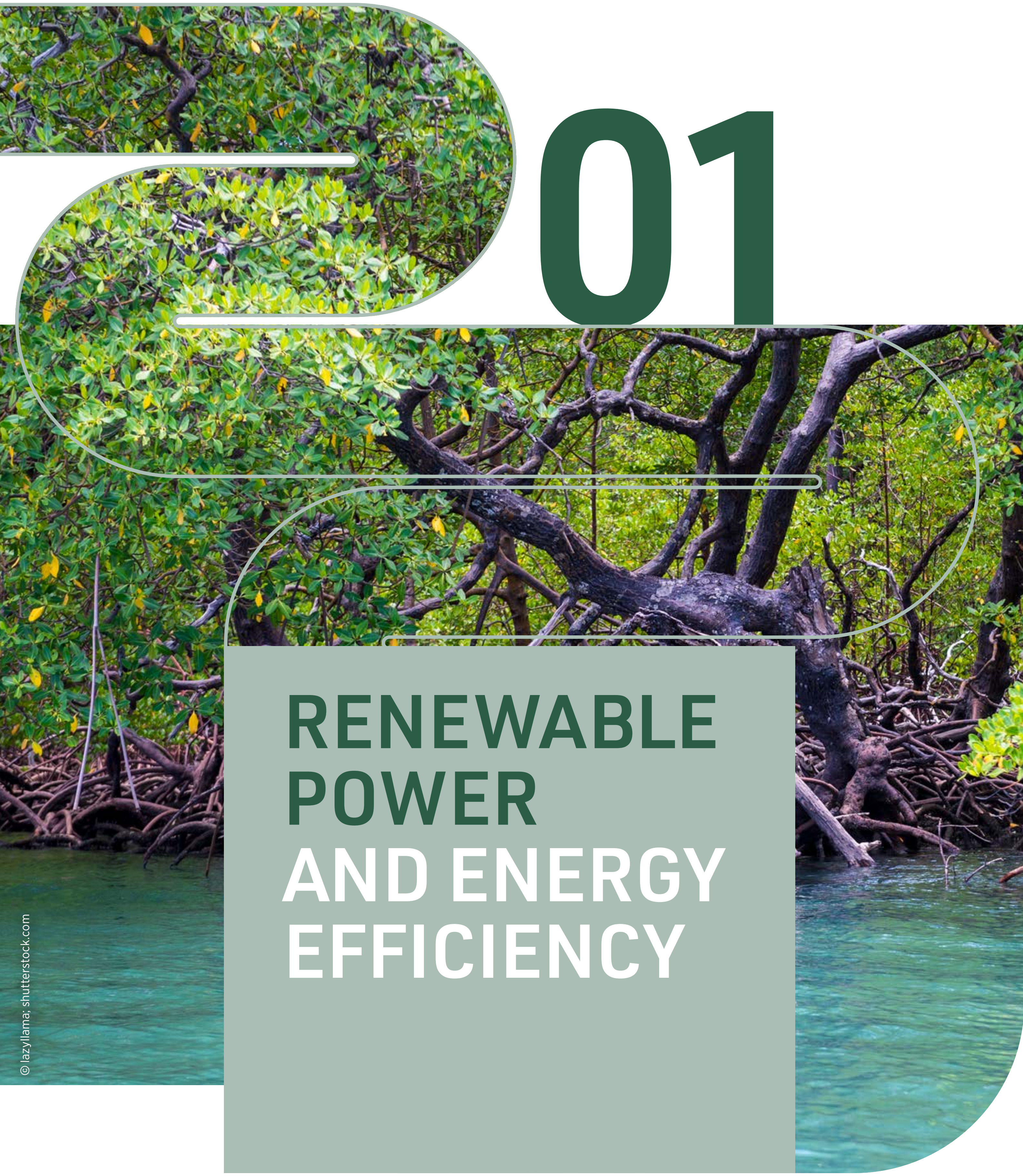
KEY RECOMMENDATIONS

INTERNATIONAL COLLABORATION: ENERGY TRANSITION FINANCE

- Deliver the USD 300 billion annual commitment in the New Collective Quantified Goal (NCQG) and progressively scale up towards the aspirational USD 1.3 trillion target.



- Direct a greater share of financial flows to least-developed countries (LDCs), landlocked developing countries (LLDCs) and small island developing states (SIDS), ensuring more inclusive, regionally-balanced progress.
- Increase the use of grants, concessional loans, equity and enhanced risk-mitigation tools to better match countries' needs, moving beyond debt-heavy approaches.
- Unlock capital for high-impact, development-oriented projects with socio-economic co-benefits such as enhanced energy access, local job creation, affordability and strengthened domestic industrial capacity, even where such projects fall outside traditional bankability criteria.
- Strengthen project pipelines and de-risking mechanisms, expand project preparation support, improve investment planning processes, and deploy fit-for-purpose de-risking tools to attract private capital at scale and speed, particularly in markets currently lacking affordable financing.
- Embed energy transition priorities into global financial frameworks, strengthen donor co-ordination, and channel more public capital to absorb risk in underserved markets, building on the outcomes of the 4th International Conference on Financing for Development (FfD4), such as new debt relief mechanisms, blended finance platforms, and risk-mitigation tools under the Sevilla Platform for Action.



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01

RENEWABLE POWER AND ENERGY EFFICIENCY

The tripling of installed renewable power generation capacity by 2030 is a key pillar of the UAE Consensus and a critical milestone for keeping the 1.5°C goal within reach (COP28, 2023). IRENA's 1.5°C Scenario from the *World energy transition outlook* workstream provided the analytical basis for the goal, as documented in a joint report with the COP28 Presidency and the Global Renewables Alliance released before the Conference in 2023 (COP28 Presidency *et al.*, 2023). This resulted in 133 countries pledging to triple global installed renewable power capacity by 2030 compared to 2022 levels, and the subsequent call in the Outcome of the First Global Stocktake (part of the 'UAE Consensus') for all Parties to the Paris Agreement, adopted under the United Nations Framework Convention on Climate Change (UNFCCC), to *contribute to efforts to triple renewable energy capacity globally and double the global average annual rate of energy efficiency improvements by 2030* (UNFCCC, 2023).

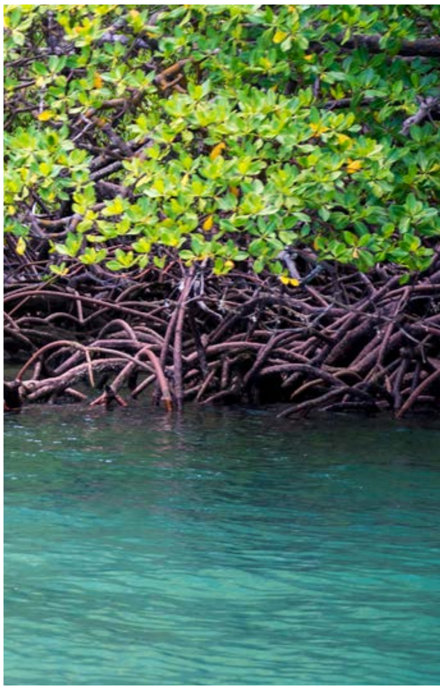
IRENA's 1.5°C Scenario identifies a pathway for the energy transition that aligns with the Paris Agreement goal of limiting the global average temperature increase to 1.5°C above pre-industrial levels by the end of this century (IRENA, 2023a). It emphasises the use of readily available technological solutions, particularly low-cost renewables combined with energy efficiency measures, that – when scaled up rapidly – can help achieve the 1.5°C target. The Scenario also outlines a sharp and continuous decline in carbon dioxide (CO_2) emissions, with the goal to reach net zero by 2050.

Achieving the tripling goal can also result in additional benefits, if supported by enabling global economic structures and policy frameworks. Renewable power – and energy efficiency – can: reduce the health impacts of fossil fuel use; improve energy security; insulate economies from the macroeconomic shocks of fossil fuel price spikes; support local value creation (even when equipment is imported); provide more stable and predictable energy costs; support local jobs; and assist in addressing social inequities, such as in energy access.

Recent policy signals are adding momentum to global climate action. China's newly announced targets, revealed at the United Nations General Assembly in September 2025 – including deeper emissions cuts, a higher share of non-fossil energy, and a massive expansion of wind and solar by 2035 – demonstrate growing ambition from the world's largest emitter. Together with commitments from other major economies (covered in detail in Section 3 of this report), this marks a clear shift in the energy transition. The goals to triple renewable power capacity and double energy efficiency improvement by 2030 remain within reach, but must be supported by strong political will and accelerating technological progress.

1.5°C WETO
World Energy Transition Outlook

3X



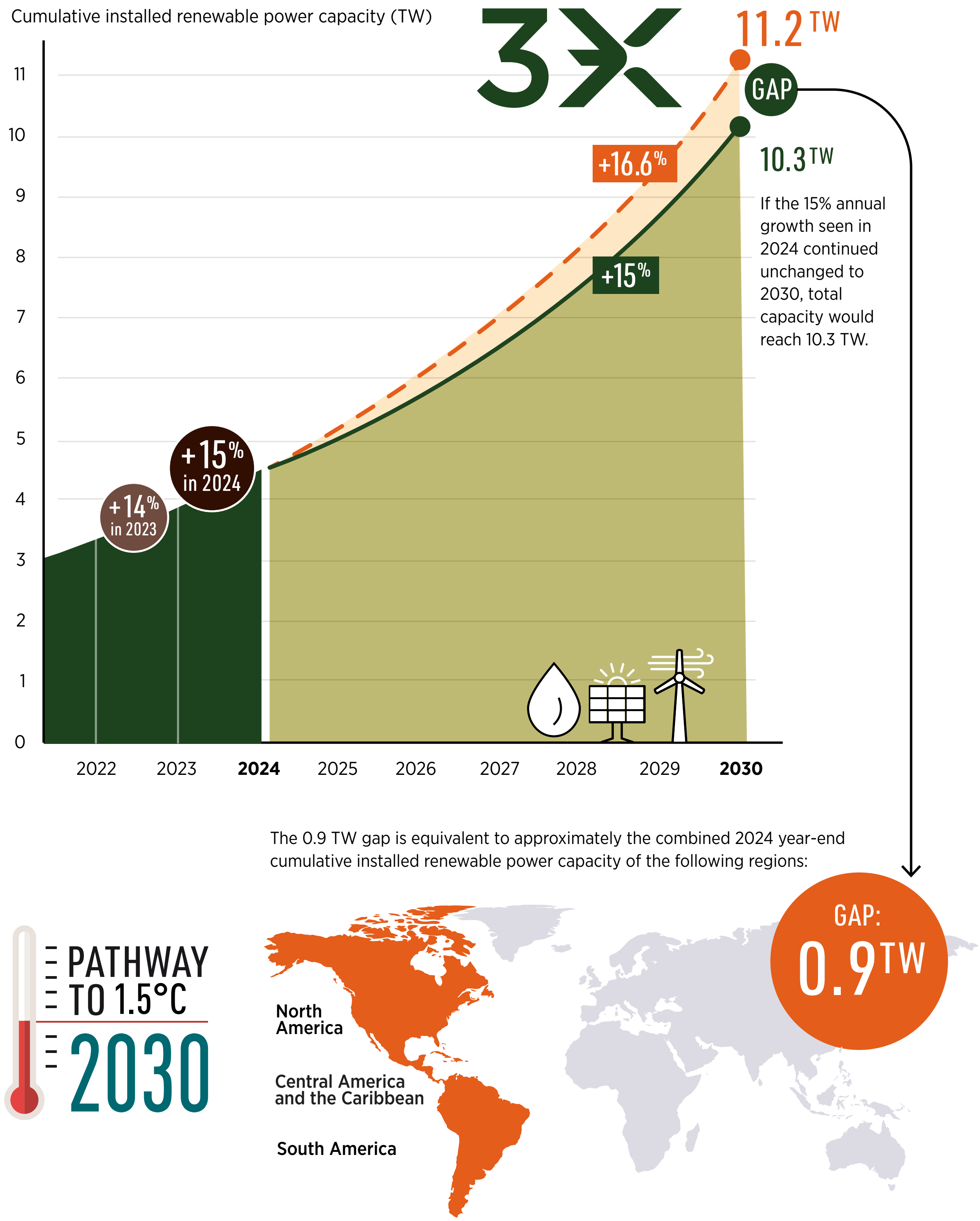
3X RENEWABLE POWER

The tripling of renewable power capacity to reach 11.2 terawatts (TW) in 2030 requires average additions of 1 122 gigawatts (GW) each year between 2025 and 2030, representing a 16.6% compound annual growth rate, up from the 16.1% growth required each year when the trajectory was originally presented in the first edition of this report.

In 2024, 581.9 GW of new renewable power capacity was added, representing a 15.1% annual growth rate – an increase of 0.7 percentage points compared to the 14.4% growth reported in 2023. Despite this progress, capacity growth still falls short of the trajectory required to achieve the tripling target by 2030, as illustrated in Figure 1. Although the trend is positive year on year, if the growth rate seen in 2024 continued for the remaining years of the decade, only 10.3 TW of renewable power capacity would be installed by 2030, falling 0.9 TW (7.7%) short of the target. To place this shortfall in context, it is more than the total installed renewable energy capacity at end-2024 of North, Central and South America, and the Caribbean, combined (see Figure 1). Nonetheless, this represents an improvement over the shortfall of 1.49 TW calculated in 2024 (IRENA COP28 *et al.*, 2024)

Since capacity additions in both 2023 and 2024 fell short of the required 16.1% growth rate, renewable capacity must now expand even faster (by 16.6% annually) in the remaining six years of the decade to deliver 6.7 TW of installed renewable power capacity. This equates to an average annual addition of 1 122 GW of renewable power capacity in 2025 and each year onwards to 2030. Delivering this capacity would result in variable renewable technologies overtaking total fossil fuel capacity by 2030, accounting for 61% (solar photovoltaic [PV] 41% and wind 20%) of total installed capacity, up from 31% in 2024.

FIGURE 1 Closing the gap



Note: TW = terawatts.

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Solar energy accounted for most of the new capacity additions in 2024. More than three quarters of this new added capacity was in the form of solar PV, with 452.1 GW added in 2024 (27% higher than in 2023, and the highest annual addition of any renewable power technology in a single year); this was followed by wind energy, with an addition of 114.3 GW – of which 105.7 GW was in the form of onshore wind. Hydropower (excluding pumped hydro) capacity increased by 9.3 GW, while bioenergy, geothermal, concentrated solar power (CSP) and marine energy, combined, rose by 6.1 GW worldwide, with bioenergy accounting for 83% of this.

This exponential growth in solar PV in recent years has been driven by rapid cost reductions, short project development timelines, large-scale deployments – averaging 139 MW per project for solar PV in 2024 – fossil fuel price shocks, supportive policies and mature supply chains. Global solar PV capacity tripled between 2019 and 2024. At the current pace, the 2030 solar PV target of 6.15 TW appears achievable, requiring a rise in average annual additions to 716 GW of capacity each year between 2025 and 2030, inclusive.[1]

Aside from solar PV, capacity additions for all renewable energy technologies remain well below the level required to meet the tripling target. From a 2024 baseline, the world needs to scale up capacity additions of wind power by almost three times; hydropower by three times; and bioenergy by five times; while CSP and geothermal will need to scale up by a staggering 27 and 25 times, respectively.

Global wind power capacity additions in 2024 were 114.3 GW, having experienced a modest drop compared to the previous year. Whilst onshore wind capacity deployment continued to expand steadily (from 103.7 GW added in 2023 to 105.7 GW added in 2024), the growth in offshore wind capacity deployment slowed from 11.6 GW in 2023 to just 8.6 GW in 2024 (a 26% decline). Global cumulative installed capacity for the wind sector reached 1 133 GW by the end of 2024; now less than six years remain to install the 1.9 TW of wind capacity required to meet the tripling target, requiring slightly less than a tripling in annual capacity additions to around 320 GW each year to 2030 under IRENA's 1.5°C Scenario.

1 IRENA's *Regional energy transition outlooks* reflect the evolving dynamics of the transition at the regional level, not only refining the global 1.5°C Scenario analysis but also highlighting the pace and scale of the energy transition across different regions. Notably, the 2030 target for solar PV technology has been revised upward (from 5.5 TW to 6.15 TW) in light of rapid advancements, widespread ongoing adoption, favourable investment schemes, and policies such as net metering and tax incentives. The targets for most of the other renewable energy technologies have subsequently been adjusted downward, considering country-level progress and policy updates, the pace of technological development and other relevant factors affecting their scalability by 2030.

FIGURE 2

TRACKING COP28 OUTCOMES: TRIPLING RENEWABLE POWER BY 2030

RENEWABLES	2024	PATHWAY TO 1.5°C 2030
Total installed renewable capacity (GW)	4 443	11 174
Renewable energy share in installed capacity (%)	A 46%	B 74%
Renewable energy share in generation (%)	30% (2023)	64%

3X

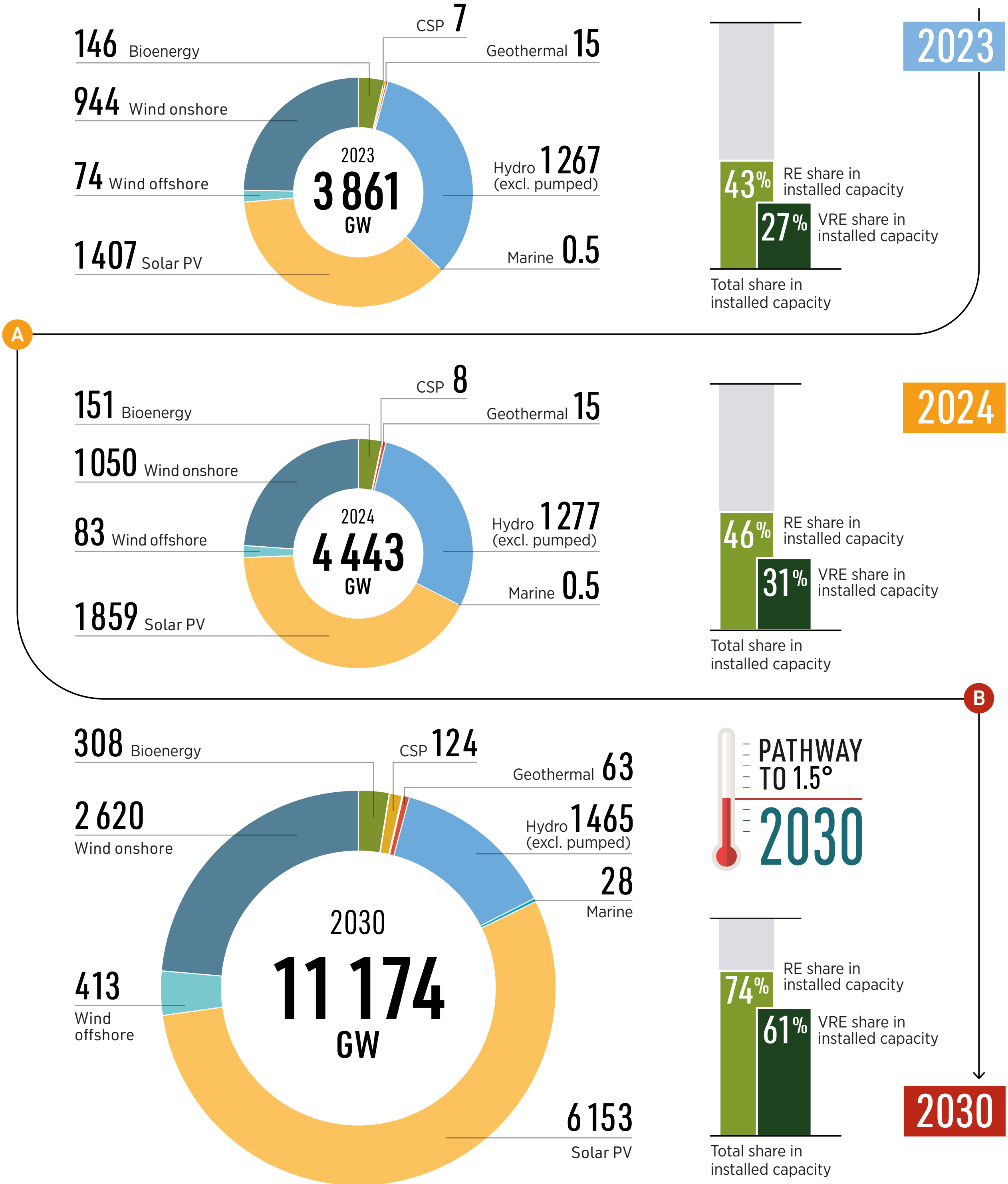
RENEWABLE CAPACITY ADDITIONS	2024	Average annual additions 2025 – 2030
Annual additions (GW/yr):		
Renewable power capacity	581.9	1 122
Solar PV	452.1	716
Wind energy	114.3	317
Wind offshore	8.6	55
Wind onshore	105.7	262
Hydropower	9.3	31
Bioenergy	5.1	26
Geothermal	0.3	8
CSP	0.717	19
Marine energy	0.002	5

PATHWAY TO 1.5°C 2030

Source: (IRENA, 2025a).

Notes: CSP = concentrated solar power; GW = gigawatt; PV = photovoltaic; yr = year; wind data includes onshore and offshore; hydropower data excludes pumped hydro.

FIGURE 3 Global installed renewable power capacity in the 1.5°C Scenario, 2023, 2024 and 2030



Source: (IRENA, 2025a).

Notes: CSP = concentrated solar power; GW = gigawatt; PV = photovoltaic; VRE = variable renewable energy; bioenergy includes biogas, biomass waste and biomass solid; hydropower data excludes pumped hydro; tripling target for the global installed capacity by 2030 is compared to 2022 status.

Whilst solar PV additions are on track to meet – or even exceed – their share in the tripling of renewable capacity under the 1.5°C Scenario, they are not sufficiently rapid to fully compensate for the lack of growth achieved by other renewable technologies. Current wind capacity additions are inadequate to meet the 3 TW target of overall wind capacity. Average annual onshore wind capacity additions need to more than double and offshore wind must scale up by a factor of six in the period 2025–2030. Although the growth in global onshore and offshore wind capacity to approximately 2 620 GW and 415 GW, respectively, by 2030 in the 1.5°C Scenario is ambitious, this highlights the need for urgent actions on policy support, infrastructure and supply chains to address the key challenges and implement solutions that will pave the way for achieving the scale required to meet the tripling goal.

Global, cumulative installed hydropower capacity (excluding pumped hydro) grew by 0.7% in 2024, with 9.3 GW added during the course of the year to reach 1 277 GW. The capacity added in 2024 remains below the five-year rolling annual average of 17 GW. To meet the trajectory required by the 1.5°C Scenario, an average of 31 GW of additional hydropower capacity is required each year to 2030 – three times the capacity added in 2024. Realising this target will require co-ordinated efforts to streamline permitting and approval process, increase investment – both for new capacity and refurbishments – and expand the sector's skilled workforce.

In 2024, around 5.1 GW of bioenergy capacity was added, bringing the cumulative installed capacity to 151 GW. Tripling renewable capacity under the 1.5°C Scenario would require bioenergy to double by 2030 to nearly 310 GW. To achieve this, average installations around the world would need to rise to 26 GW per year, representing a fivefold increase over the 2024 level.

Geothermal, CSP and marine energy, combined, accounted for 1 GW of new power capacity added in 2024, resulting in a cumulative total of 23 GW. These technologies remain significantly underutilised and require a major scale-up to meet their potential. Accelerated progress in the deployment of these technologies is essential to diversify the renewable energy mix and strengthen system resilience on the path to net zero. Capacity shortfalls must otherwise be addressed by even greater increases in solar PV. Yet, it is crucial to note that solar PV – which will likely comprise the vast majority of new capacity additions to 2030 – has one of the lowest capacity factors of all renewable power generation technologies;[2] hence the urgency of efforts to scale up other complementary renewable technologies.

2 Capacity factor describes the ratio of actual production of electricity to nameplate capacity. In 2024, the global weighted average capacity factor for new utility-scale solar PV plants was 17.4% (IRENA, 2025b).

The geographic deployment of renewables remains highly uneven, with Asia, Europe and North America accounting for 85.4% of installed renewable power capacity at end-2024. The remaining 14.6% was shared by Africa, Central America and the Caribbean, Eurasia, the Middle East, Oceania and South America. Asia accounted for the majority of renewable power additions in 2024 (71.0%), increasing its total by 413.2 GW to reach 2 374 GW, or 53.4% of global installed capacity. Europe's capacity expanded by 71.9 GW (9.2% growth year-on-year) to reach 19.1% of global capacity. North America and South America continued their upward trends, adding 45.5 GW (8.7% growth) and 22.5 GW (7.7% growth) in 2024. Meanwhile, Oceania's installed capacity increased by 8.7 GW (14.1% growth), and the Middle East added 4.0 GW of renewable power capacity (a 10.8% increase). Africa continued to grow steadily, with an increase of 4.7 GW in newly commissioned capacity in 2024, to reach 70 GW.

The Group of 20 (G20) nations[3] account for around 87% of the globe's installed renewable capacity in 2030 under the 1.5°C Scenario, requiring G20 renewable capacity to scale up by 2.4 times to reach 9.7 TW[4] by 2030, compared to 4.0 TW in 2024. This equates to average capacity additions of around 957 GW each remaining year until the end of the decade, compared to the 563.2 GW added in 2024. The renewable energy share in installed capacity for G20 countries would rise to 77% by 2030, from the 48% observed in 2024.

The Group of 7 (G7) must lead with collective ambition. G7 leadership on the 2030 goal requires renewable power capacity to reach 2.3 TW in 2030 (from 1.05 TW in 2024), accounting for 21% of global capacity. Realising this ambition will entail boosting annual renewable energy capacity additions to an average of 214 GW per year to 2030 (from 84.9 GW in 2024) to account for 75% of total installed capacity, compared to the 42% observed in 2024.

While the European Union (EU) is making strong progress in renewable power expansion, it also remains off track. The EU-27 added 72.3 GW of new renewable power capacity in 2024, bringing the total installed to 702.6 GW – an increase of just over 11% compared to 2023. Under the 1.5°C Scenario, renewable capacity must reach 1 247 GW by 2030 – an almost 80% increase from current levels (IRENA, 2025c). This would raise the share of renewables in total installed capacity to 79%, up from around 60% in 2024, and would be driven by solar and wind, which together are expected to contribute 57% of total electricity generation by 2030. Overall, renewables are projected to supply 71% of the EU's electricity by the end of the decade in the 1.5°C Scenario.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3 Includes South Africa but excludes other African Union countries.

4 This number reflects the updated analysis to IRENA's 1.5°C Scenario, based on the recent trends across all renewable energy technologies within G20 nations, as of September 2025.

The ASEAN region added 5.2 GW of new renewable energy capacity in 2024, bringing its cumulative installed capacity to 113 GW. Capacity additions grew by 5% year-on-year from 2023 to 2024. Despite this encouraging growth, the current pace of capacity additions in ASEAN countries is not sufficient; acceleration is needed, particularly in solar and wind. Under IRENA's 1.5°C Scenario, the region must triple its renewable power capacity by 2030 (370 GW) compared to 2024 (IRENA, 2022a). This would require net average capacity additions of 43 GW each year to 2030, up from the 5.2 GW added in 2024. The region is expected to see a substantial shift towards renewable energy; with wind and solar leading the transition and supplying up to 20% of total electricity generation by 2030. Under the 1.5°C Scenario, the renewable share in ASEAN's installed capacity would rise to 57% by 2030, from 32% in 2024.

The Middle East region saw a modest increase in total installed renewable power capacity in 2024, adding 4 GW – an increase of 10.8% – during the year to account for just under 1% of global installed capacity. The region's share of renewable energy in total electricity capacity also rose, from 10.2% in 2023 to 11.0% at end-2024. The Middle East has a key role to play in achieving the tripling target; with abundant solar resources, growing energy demand and rising policy ambition, countries such as the United Arab Emirates, Saudi Arabia and Oman are scaling up investments in solar PV, wind and green hydrogen. Building on its financial capacity, infrastructure and strategic location, the region can emerge as a hub for renewable generation and export, while also enhancing energy security.

Africa, meanwhile, added only 4.7 GW of renewable power capacity in 2024, and urgently requires more renewables to meet rising electricity demand and provide broader energy access. Africa has abundant technical potential for renewable energy and expanding renewable energy capacity in the region is crucial for addressing its energy challenges. Currently, Africa has only 70 GW of installed renewable power capacity – representing 1.6% of the global total. Under the 1.5°C Scenario, the unlocking of sustainable renewable energy resources to meet the 2030 target would require a quadrupling of capacity to around 300 GW by 2030 (IRENA, Forthcoming [a]), in line with the 2023 Nairobi Declaration (African Union, 2023). Reaching this level would require sustained additions of 38 GW each year to 2030, by which time renewables would account for 60% of total installed capacity, up from 26% in 2024.

Latin America is already a global leader in renewable energy capacity compared to other regions, yet further growth is needed to accelerate decarbonisation. By 2030, renewable capacity must reach 74% in Central America (driven mainly by hydropower, solar and wind) and 77% in South America (led by solar PV and wind). In 2024, Central American countries accounted for around 14 GW of installed renewable capacity, while South America reached 313 GW, corresponding to 67% and 73% of total power supply capacity, respectively. In terms of electricity generation, renewables accounted for 66% in Central America and 77% in South America in 2023, marking these sub-regions as the cleanest electricity matrices worldwide and illustrating their considerable potential for further decarbonisation in the power sector.

Under IRENA's 1.5°C Scenario, Central America would need to expand its renewable power capacity by 1.6 times the 2024 level to reach 22 GW by 2030. On average, 1 GW of renewable capacity addition is required each year until 2030 compared to 0.12 GW added in 2024. Under the Scenario, renewables would supply 74% of Central America's power capacity by 2030 – mostly in the form of hydropower (32%), with solar PV and wind together making up nearly a third (31%) of the total (IRENA, 2022b).[5]

5 Report published in 2022, using 2018 as base year and countries' public information complemented with documents shared by stakeholders up to 2021.

FIGURE 4 Renewable power capacity by region in 2024

NORTH AMERICA
Global share: 12.9%

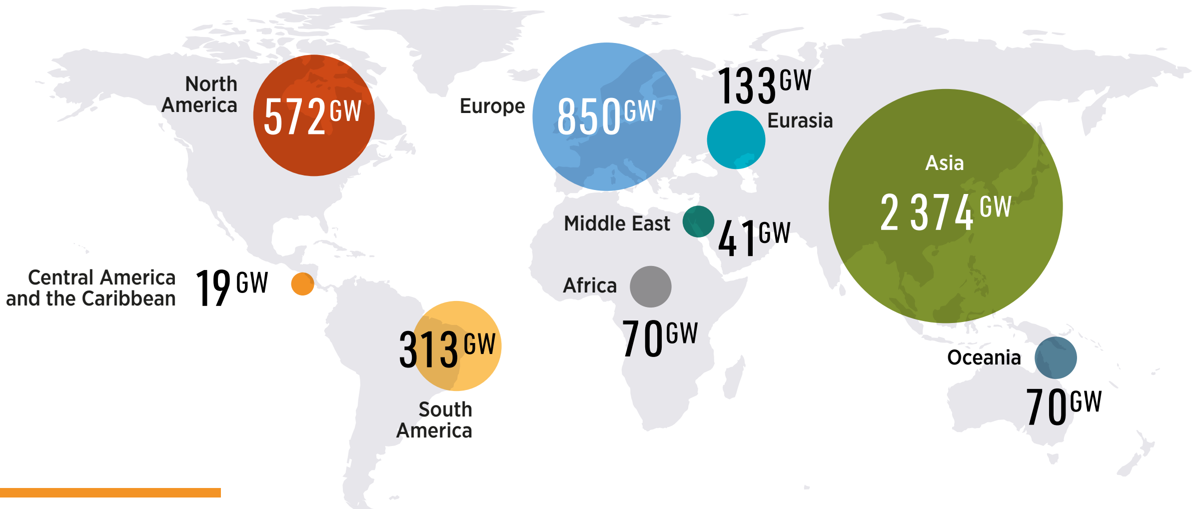
Change 2023-2024	Growth
+45.5 GW	+8.7%

EUROPE
Global share: 19.1%

Change 2023-2024	Growth
+71.9 GW	+9.2%

ASIA
Global share: 53.4%

Change 2023-2024	Growth
+413.2 GW	+21.1%



CENTRAL AMERICA AND THE CARIBBEAN
Global share: 0.4%

Change 2023-2024	Growth
+0.4 GW	+2.1%

MIDDLE EAST
Global share: 0.9%

Change 2023-2024	Growth
+4.0 GW	+10.8%

EURASIA*
Global share: 3.0%

Change 2023-2024	Growth
+10.9 GW	+8.9%

SOUTH AMERICA
Global share: 7.0%

Change 2023-2024	Growth
+22.5 GW	+7.7%

AFRICA
Global share: 1.6%

Change 2023-2024	Growth
+4.7 GW	+7.2%

OCEANIA
Global share: 1.6%

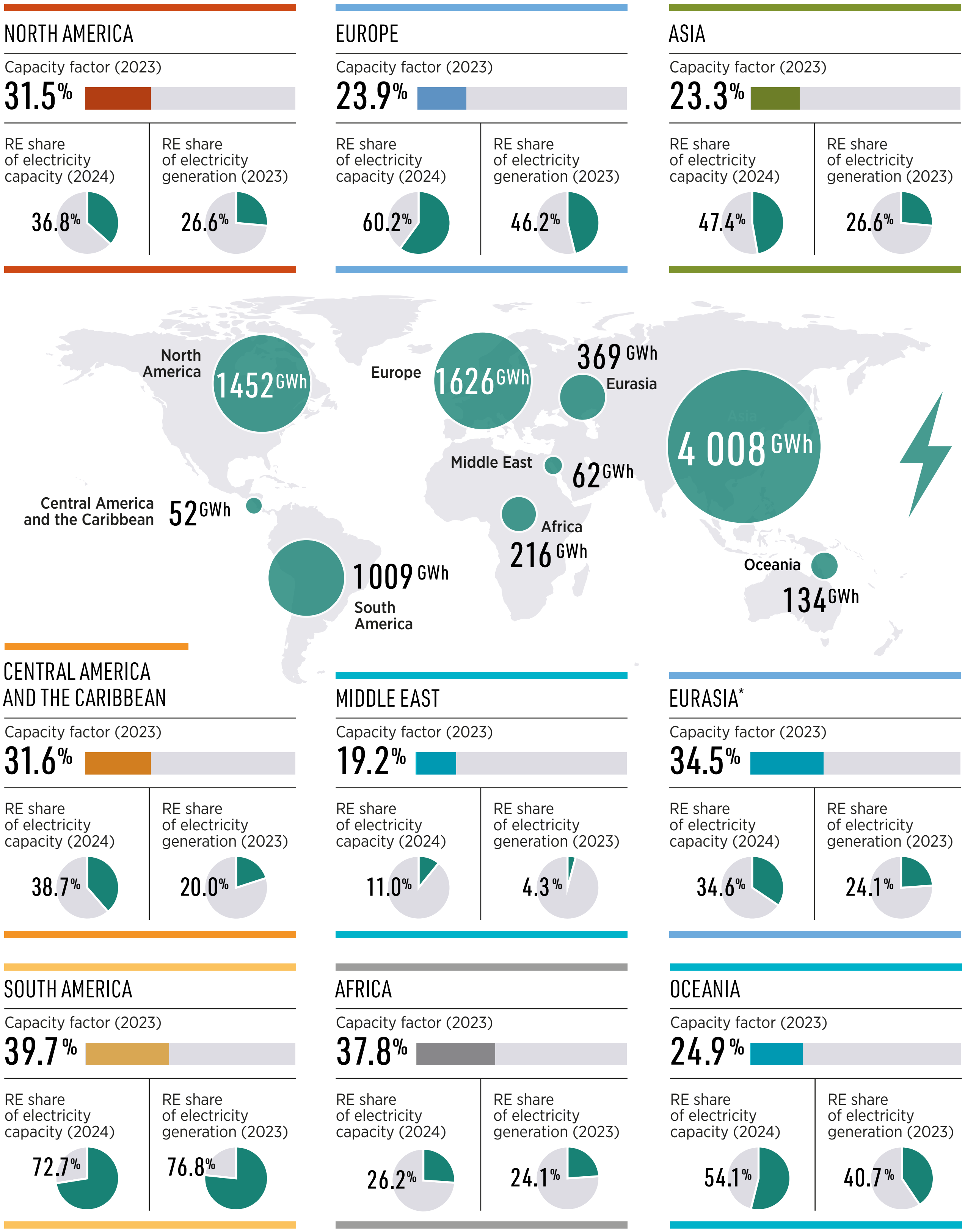
Change 2023-2024	Growth
+8.7 GW	+14.1%

Source: (IRENA, 2025a).

Notes: *Comprising Armenia, Azerbaijan, Georgia, Russian Federation and Türkiye; GW = gigawatt; GWh = gigawatt hour; RE = renewable energy.

Disclaimer: These maps are provided for illustration purposes only. Boundaries and names shown on these maps do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

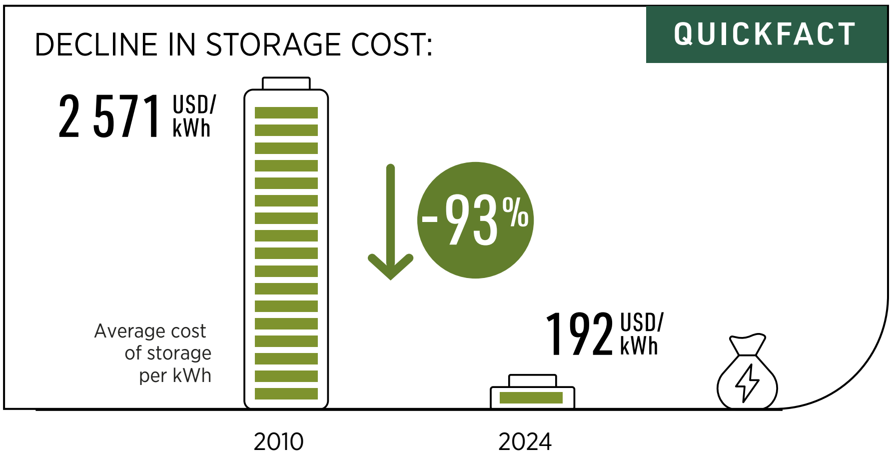
FIGURE 5 Renewable energy capacity factor, share of capacity, and total generation



By 2030, South America's installed renewable capacity will need to expand by 1.4 times to reach c. 430 GW, up from 313 GW in 2024. Renewables would comprise 77% of the 560 GW total installed capacity in 2030, of which solar PV and wind combined represent 38% (IRENA, Forthcoming[b]). Maintaining the 1.5°C transition pathway, South America requires average additions of 19 GW each year between 2025 and 2030, inclusive. Accelerated policy action, infrastructure investment and international support will be critical in achieving the regional 1.5°C pathway.

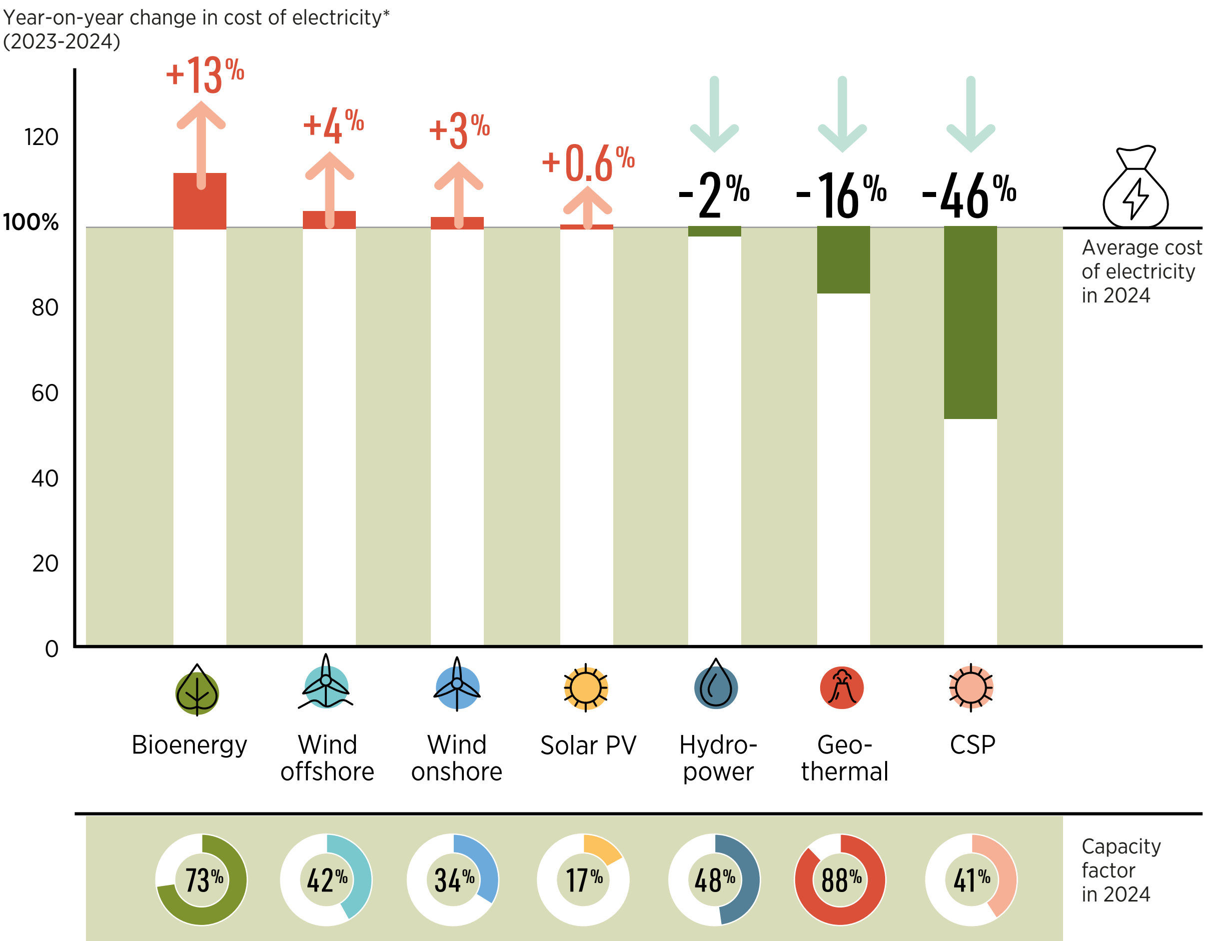
Renewables remained the most cost-competitive option for new electricity generation in 2024, with 91% of newly commissioned utility-scale capacity delivering power at a lower cost than the cheapest, newly installed fossil fuel-based alternative.[6] In 2024, new utility-scale onshore wind projects remained the cheapest source of renewable electricity, with a global weighted average levelised cost of electricity (LCOE) of USD 0.034/kilowatt hour (kWh), followed by new solar PV (USD 0.043/kWh) and new hydro power (USD 0.054/kWh). Between 2010 and 2024, total installed costs (TIC) declined sharply across major renewable technologies (IRENA, 2025b). By 2024, TIC fell to USD 691/kilowatt (kW) for solar PV, USD 1 041/kW for onshore wind, and USD 2 852/kW for offshore wind.

The costs of a fully installed and commissioned battery storage project fell by almost 30% between 2023 and 2024, contributing to a decline of 93% between 2010 and 2024, from USD 2 571/kWh to USD 192/kWh (BNEF, 2024a). In recent years, this cost reduction has been driven by technological developments that have improved materials efficiency and manufacturing processes, leading to economies of scale. In 2024, abundant supply capacity and competition are the main drivers of cost declines in energy storage systems (BNEF, 2024b).



6 On a levelised cost of electricity (LCOE) basis.

FIGURE 6 Global average cost of electricity from newly commissioned utility-scale renewable power



Source: (IRENA, 2025b).

Notes: PV = photovoltaic; CSP = concentrated solar power.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Long-term cost reductions are expected from continued technological learning and supply chain maturity; yet, emerging geopolitical risks – notably trade tariffs on renewable components and materials, and Chinese manufacturing sector dynamics – could raise costs in the short term.

Energy storage technologies will become essential for balancing electricity demand and supply and providing ancillary services. Under IRENA's 1.5°C Scenario, the tripling of renewable power must be underpinned by a two- to fivefold increase in battery storage capacity by 2030, from a total of 164 GW in 2024 (BNEF, 2025a) to between 360 GW and 900 GW by 2030. Meanwhile global installed pumped hydro storage capacity would need to increase by almost 170 GW, reaching a cumulative capacity of 320 GW by 2030, providing much needed short-term reserves and long-term system flexibility. This would require an average build rate of 28 GW each year to 2030 – 3.4 times the capacity added in 2024. Other forms of storage, such as flow batteries and thermal storage, are now being deployed at scale and will also be needed to complement batteries and pumped hydro storage.

In 2024, 8.3 GW of pumped hydro storage capacity was added, bringing the cumulative installed capacity to c. 150 GW (IRENA, 2025a). Pumped hydro storage plays an instrumental role in improving grid stability, maintaining energy security, and enabling smooth integration of renewable energy into the global power system.

In 2024, 74 GW (around 180 GWh) of battery storage was added, a continued surge in capacity fuelled by falling prices, marking almost double the capacity additions observed in 2023 (BNEF, 2025a). The growing need for grid reliability, combined with the declining costs of technology (IRENA, 2025b), is driving a rapid transformation of the battery energy storage landscape. Capacity growth in 2024 was driven by China, the United States and Europe, collectively accounting for nearly 85%. China, the leading energy storage market, alone commissioned 39 GW (77% more than in 2023), followed by the United States with around 12 GW, and Europe with approximately 11.5 GW in 2024 (BNEF, 2025a). Some major economies are promoting the deployment of battery storage through financial incentives, subsidies, targets and funds for research and development. The rapid growth in China is driven by Chinese provincial mandates to integrate utility-scale variable renewable energy projects with energy storage. Similarly, in Europe, the deployment was boosted by targeted auctions and EU-approved support schemes.

With an estimated addition of more than 3 GW of electrolyser capacity in 2024, global cumulative capacity has exceeded 6 GW, marking a major milestone in the long-term success of the energy transition (BNEF, 2025b; Collins, 2025). Electrolysers, which use clean electricity to produce low-emission hydrogen, are central to decarbonising hard-to-abate sectors and therefore directly linked to the tripling renewables target: without a rapid scale-up of renewable power, the production of green hydrogen cannot reach the levels needed. IRENA's 1.5°C Scenario anticipates that low-emission hydrogen demand would need to significantly increase from negligible levels today to almost 15 exajoules (EJ) – or 125 million tonnes (Mt) – by 2030, concentrated largely in the industry sector (14 EJ) for green steel production, and as feedstock in the chemicals and petrochemicals industries.[7]

Today, most electrolyser stack factories are underutilised – with a utilisation factor of between 3% and 22% in 2024 – due to slower progress on green hydrogen projects than manufacturers had expected (BNEF, 2025b). China, Europe and the United States dominate electrolyser demand and supply markets, with the former accounting for the majority of global installed capacity and manufacturing capacity (BNEF, 2025b).

Growing demand for green hydrogen across various end-use sectors will drive the expansion of electrolysers, which are envisaged to contribute around 40% of total low-emission hydrogen using renewable electricity by 2030. The electricity needed for global green hydrogen production would amount to around 6% of power generation in 2030; this indicates the cumulative installed electrolyser capacity would need to grow from around 6 GW in 2024 (BNEF, 2025b; Collins, 2025) to some 470 GW by 2030. Reaching this goal requires average annual additions of around 77 GW to 2030 – more than 20 times the 2024 addition.

7 IRENA's hydrogen analysis is being updated as part of the world energy transition outlook workstream and these figures will most likely be revised downwards.

2X ENERGY EFFICIENCY

Doubling energy efficiency by 2030 is a crucial complement to the tripling of renewable power capacity. Achieving the energy transition requires adopting more energy-efficient technologies, securing structural and behavioural changes, and accelerating energy efficiency measures across all end-use sectors (see Figure 8).

The improvement in energy intensity achieved in the period 2023–2024 is around 1% – well below the 4% needed each year between 2022 and 2030 to achieve the global energy efficiency target.[8] This shortfall in progress means that an annual improvement in energy intensity of at least 5% is now required between 2025 and 2030. This requires cross-sector policies and co-ordination among a broad range of stakeholders (government, private sector actors in supply chains, civil society, research institutions, regulation and standards institutions, and financial institutions) to implement policies, minimum standards and labelling, and funding. The Global Energy Efficiency Alliance (GEEA), launched at COP29 in 2024 under the UAE's leadership, provides a platform to support progress toward delivering the UAE Consensus goal to double global energy efficiency improvement by 2030, advancing international co-operation, finance mobilisation and technology deployment to this end.

Global building renovation rates remain at very low levels – at around 1% of building stock per year – well below those needed to meet climate goals (UNEP and GlobalABC, 2025). Renovating existing building stock is key to realising significant energy savings, as buildings account for a large share of global energy consumption. Whilst momentum is growing in retrofitting buildings with energy-efficient technologies, there must be a significant acceleration to achieve the necessary reductions in energy use by 2030.

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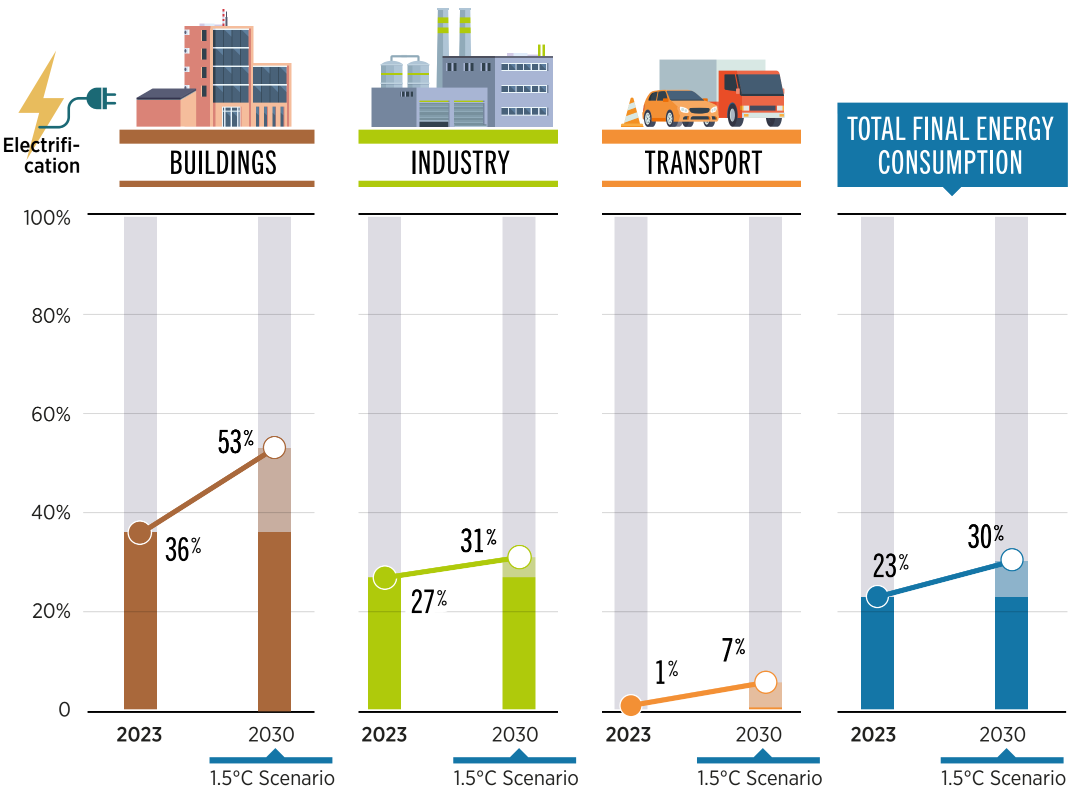
8 Over the past two years, annual energy demand has increased by an estimated 2% (IEA, 2024a), while global economic growth has been around 3% per year (IMF, 2025).

The electrification rate of end-use sectors must increase from 23% in 2023 to 30% by 2030 to stay on the 1.5°C pathway. The increase required in transport is from 1% to 7%, from 36% to 52% in buildings, and from 27% to 31% in industry (IRENA, 2024a) (see Figure 7). Accelerated electrification, as a key efficiency improvement measure, is based on the adoption of more energy-efficient technologies (including electric heat pumps, which are typically 300–400% more efficient than traditional boilers, and electric vehicles [EVs], which are around 60–80% more efficient than internal combustion engines [ICEs]), while also reducing emissions through the use of renewable power generation. This dual benefit of energy savings and emission reductions underscores the critical role of electrification in achieving both efficiency and sustainability goals. The deployment of electric heat pumps and EVs will play a key role in reaching the targets.

FIGURE 7 Global electrification in end-use sectors and TFEC, 2023 and 2030



Source: 2030 values from: (IRENA, 2024a).

Note: TFEC = total final energy consumption.

Global residential heat pump sales increased by more than 6% to 14.4 million units in 2024 from 13.5 million units in 2023. This growth was primarily driven by the Asia Pacific region, which accounted for 16% of the annual increase in global sales for 2024 (BNEF, 2025c). Japan led the world in annual heat pump sales, reaching 4.5 million units, an impressive 21% rise from 2023. This surge is the result of decades of government support, especially for high-efficiency hot water systems tailored to traditional household needs (EU-Japan Centre for Industrial Cooperation, 2025). Meanwhile, China's heat pump market grew by 9%, despite the reduction of coal-to-electricity subsidies and increased competition from gas. In North America, heat pump sales rebounded, with the United States recording a 14% year-on-year increase in shipments for 2024, totalling 4.1 million units. This marked the second-best sales year on record, following a dip between 2022 and 2023, and was championed by a recovery in the housing market (AHRI, 2025). In contrast, Europe experienced a significant downturn, with sales dropping approximately 27% in 2024 compared to the previous year, falling from 2.9 million to 2.1 million units. This decline was largely due to reduced subsidies and lower natural gas prices (EHPA, 2025).

Electric vehicles accounted for a record 21% of global new car sales in 2024, marking their highest share to date, driven by increased competition, policy support and technological advancements. Sales of electric heavy-duty vehicles (HDVs) also increased, albeit more slowly, but accelerated take-up and expanded charging infrastructure is needed to further push electrification across more vehicle modes. EV market shares are growing rapidly, especially in the passenger car segment (26% of new sales) and the two- and three-wheeler segment (45%). Electric buses also show strong adoption at 42%, while electric vans and trucks still lag behind, each accounting for less than 8% of new vehicle sales globally, and need to be deployed far more quickly to meet net-zero ambitions (BNEF, 2025d).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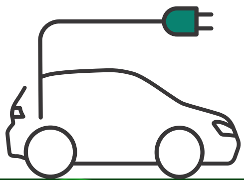
The progress achieved in transport electrification in 2024 was significant but remains insufficient. Under IRENA's 1.5°C Scenario, electrification of transport sector total final energy consumption[9] worldwide would need to reach nearly 7% by 2030, with road transport offering the greatest potential. To achieve this, the combined battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) light passenger vehicle stock will still need to increase from around 57 million in 2024 (BNEF, 2025d) to 360 million by 2030 – requiring a trajectory far above current growth rates. This more than six-fold increase would result in EVs accounting for 20% of the global vehicle stock and contributing a comparable share to total transport activity by 2030. However, achieving these reductions would depend on demand-side and modal-shift policies, including reducing overall transport energy demand through behaviour change and shifting travel patterns from private car use to public transport and active modes (walking and cycling). This shift must be supported by key policy approaches that include integration of smart charging infrastructure (5.2 million public charging connectors were available in 2024 [BNEF, 2025d]) to manage grid demand, incentivising shared mobility solutions and promoting transit-oriented urban planning to reduce travel distances and car dependency (IRENA, 2025d).



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9 Including all road, rail, shipping and aviation transport.

FIGURE 8 Global energy efficiency and electrification of end-use consumption

ENERGY EFFICIENCY	RECENT YEARS	PATHWAY TO 1.5°C 2030
Energy intensity improvement rate (%)	1%[1]	5%[2]
Building renovation rate (% stock/year)	1%[3]	2%

ELECTRIFICATION OF END-USE CONSUMPTION	RECENT YEARS	2030
Electrification rate in TFEC (%)	23%[4]	30%
Electric and plug-in hybrid light passenger vehicles stock (million)	57M[5]	360M
Heat pumps in buildings (GW)	1 376GW[6]	8 937GW
Heat pumps in industry and in DH systems (GW)	no data/negligible[7]	434GW

Notes: DH = district heating; GW = gigawatt; M = million; TFEC = total final energy consumption.

[1] Energy intensity improvement achieved in 2024

[2] Annual improvement rate between 2025 and 2030

[3] Estimated percentage of renovated buildings in the global stock in 2022

[4] 2023 value, IEA World Energy Statistics & Balances

[5] 2024 value, BNEF Electric Vehicle Outlook 2025

[6] 2023 value estimated from IEA Clean Energy Market Monitor 2024, IEA Net Zero by 2050: A Roadmap for the Global Energy Sector 2021 and IEA Global Energy Review 2025

[7] No database of industrial heat pumps exists today (Schlosser *et al.*, 2020). They are assumed to have negligible share of the total final energy consumption in industrial process heat supply (Agora Energiewende, Fraunhofer IEG, 2023).

BOX 1 The post-2030 global energy transition

1.5°C WETO
World Energy Transition Outlook

Aligning renewable capacity additions with the Paris Agreement goal to limit global average temperature increase to 1.5°C above pre-industrial levels by the end of this century, requires sustained annual efforts post-2030. Under IRENA's *World energy transition outlook* 1.5°C Scenario, the power sector will need to undergo deep decarbonisation, with expansion of renewable electricity facilitating the transition away from fossil fuels. Total installed renewable generation capacity will need to increase more than seven times by 2050, over the 2024 level. This growth in capacity corresponds to reaching a renewable power generation capacity share of 94% by 2050, compared to the 2024 share of 46%. Solar PV and wind technology dominate the renewable mix, accounting for 81% of total installed capacity. Other renewable technologies such as bioenergy, geothermal, CSP and ocean technologies will help diversify and enhance the resilience of the energy system. Fossil fuels would see a sharp decline from a dominant share of 47% in global installed power capacity to approximately 5% by the middle of the century and comprise only natural gas. This remaining natural gas capacity will be necessary to support system flexibility. Nuclear energy remains stable throughout the Outlook period, with no major expansion beyond existing national plans.

PATHWAY TO 1.5°C 2030

Due to widespread electrification across end-use sectors, electricity generation would need to grow substantially by 2050, expanding by three times compared to 2023, with renewables providing around 91% of total electricity supply. Achieving the long-term goal to reach climate neutrality by 2050 would also require systemic energy market reforms. Post 2030, the deep decarbonisation of the power sector requires overcoming significant challenges related to integration of variable renewable energy, significant grid infrastructure expansion and modernisation, integration of long duration storage solutions and phase out of fossil fuel-based generation.

02

ENERGY TRANSITION INVESTMENTS

INVESTMENTS IN RENEWABLE POWER AND ENERGY EFFICIENCY

Meeting the UAE Consensus renewable energy and energy efficiency goals will require USD 29-30 trillion in cumulative investment in renewables, grids, flexibility measures, energy efficiency and conservation in the years 2025–2030, averaging approximately USD 5 trillion in annual terms. Annual average investments in renewable power capacity between 2025 and 2030 must increase by 2.3 times to around USD 1.44 trillion per year compared to USD 0.6 trillion in 2024. While the technological maturity of renewables and supportive policies have positioned the industry at the heart of climate and energy strategies, there is still a substantial investment and financing gap; first, in the volumes needed for the tripling goal globally; and second, in the share of investment going to emerging markets and developing economies (EMDEs). The same is true for energy efficiency policies and electrification.

Total global investment in renewable power generation capacity reached USD 624 billion in 2024,[10] up by 7% from the previous year. However, this growth rate is well below the 28% growth observed in 2023. In 2024, global solar PV investment soared to USD 436 billion, outpacing all other renewable power generation technologies combined. Investments in hydropower and bioenergy technology each increased by approximately 45% compared to 2023 levels, attracting around USD 31 billion and 19 billion, respectively. Meanwhile, investment in CSP totalled USD 2.4 billion, representing 18% year-on-year growth, significantly lower than the 127% growth recorded in 2023. In contrast, 2024 saw a pronounced decline of 28% in offshore wind investment (USD 22 billion) and a slight decline of 6% in onshore wind investment (USD 112 billion) over the same period. In 2024, around 77% of investments went to China, the European Union and the United States.

10 Annual investment in renewable energy capacity is calculated based on the annual capacity additions per technology deployed in a given year multiplied by the global weighted average total installed cost of each technology. Other organisations may report financial commitments in a specific year (financial investment decisions), so comparisons may reveal a temporal separation in values.

The tripling of renewable power capacity by 2030 will require an additional USD 8.6 trillion in investment in the period 2025–2030. Clear investment messages are required to expand project pipelines and speed up construction timelines. While annual investment in solar PV is on track to meet the tripling goal, other technologies remain under-funded on an annual basis (see Figure 9). Annual investment in wind and hydropower technologies must increase by four times each the current levels, and bioenergy by six times, and significant investment is also needed to refine dispatchable geothermal, CSP and marine technologies.

Of the USD 8.6 trillion required in additional investments, almost a third will be needed as equity, and the rest as debt, to finance the remaining 6.7 TW of renewable capacity that needs to be added between 2025 and 2030 (inclusive) (GRA, Forthcoming). Project developers face different financing conditions for each renewable technology by country due to different policy, regulatory and market settings, as well as risk perception, access to finance, macroeconomic conditions, and both the size and maturity of the domestic financial sector. Providers of debt and equity do not have the same requirements for considering investments and project developers must meet different criteria to unlock debt and equity financing, even if many of the broad factors affecting bankability are similar. Understanding these dynamics can allow policy makers to craft custom solutions to unlock greater finance volumes at lower cost.

Emerging markets and developing economies (EMDEs) are largely being left behind. Excluding China, investment flows in 2023 were only 15% of what was required on average to 2030, improving to only one-fifth of that needed in 2024. EMDE's excluding China need to invest one-quarter more than advanced economies in 2025–2030 and will require around USD 2 trillion in debt and USD 1 trillion in equity to meet the tripling goal. Key challenges for EMDEs include unlocking 'first-loss' capital[11] for early-stage projects and innovative ways of accessing concessional finance, given the challenges they face in accessing capital at reasonable costs. Addressing the dual challenge of finance availability and cost (finance rates can be two to five times higher in EMDEs than in the OECD) will be critical to meeting the tripling goal.

EMDE's excluding China face a triple challenge. They are in most need of scaled-up financing flows, but their poor sovereign risk ratings mean finance availability is low and – where available – is more costly. The poorer sovereign risk ratings of EMDEs lead to higher costs for finance, two to five times higher than for similar projects in advanced economies, as well as limiting the access to finance. This impact, reinforced by lower debt ratios for projects without public finance to de-risk projects, raises the cost of capital.

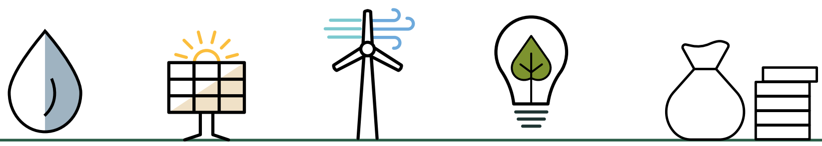
11 'First-loss' capital refers to an arrangement in which one party accepts to bear the first part of any loss up to a pre-defined amount, before additional parties become liable to share further losses.

Grid infrastructure investment has shown modest growth of 9% compared to 2023 (IEA, 2025c). Strategic investment in modernising and expanding electricity grids networks is the essential foundation for integrating new capacity and enhancing energy security. Electricity grids will require substantial funding to adjust to the new power generation mix.

Average investment[12] of USD 791–912 billion each year is required in grids and flexibility between 2025 and 2030, inclusive, up from current investment of USD 433 billion (BNEF, 2025e; IEA, 2025c). Around USD 671 billion of the annual investment required between 2025 and 2030 must be assigned to strengthening electricity grids, while the remainder is required for rapidly scaling energy storage solutions, supporting the integration of renewables and ensuring grid stability. A renewable-based market, complemented by enhanced grids and flexibility measures, will help to ensure price stability and affordability; any delay in clean energy transition technology investment will lead to higher long-term electricity wholesale prices.

Investment in battery storage grew by 33% year-on-year in 2024, reaching USD 54 billion and marking a new record high (BNEF, 2025e; IRENA and CPI, Forthcoming). China – the world's largest battery manufacturer, accounting for 62% of new battery storage capacity in 2024 – represented 40% of global investment, driven by co-location mandates and provincial subsidies. In the United States, incentives under the Inflation Reduction Act positioned it as the second largest destination, making up 29% of investments. Germany is the third-largest destination for energy storage investments, making up 11%. Investments in other developing economies such as Chile, South Africa, the Philippines and India, are also growing (nearly doubling between 2023 and 2024), but made up just 3% of the total in 2024.

Investments in energy efficiency will need to increase by more than seven times the USD 348 billion invested in 2024. Doubling energy efficiency will require, on average, USD 2.6 trillion of investments in buildings, transport and industry each year between 2025 and 2030. Investments in 2024 saw an increase of almost 9% from the previous year (IEA, 2025c), mainly driven by developments in EMDEs and China, while advanced economies, including in the EU, experienced a period of stagnation compared to the previous year (IEA, 2025c).



12 The average annual investment requirement range reflects the corresponding lower and upper bound estimates for battery energy storage capacity (360–900 GW).

FIGURE 9 Investments required to triple renewable power capacity and double energy efficiency by 2030 compared with 2024 progress

PATHWAY TO 1.5°C 2030

All numbers in 2024 USD billion[1]

	Investment in 2024[2]	Average annual investments required 2025-2030
RENEWABLE POWER GENERATION CAPACITY[3]		
Marine	0.0	29
Geothermal	1.3	39
CSP	2.4	78
Bioenergy	19.2	106
Hydro (excl. pumped)	31.1	127
Wind offshore	22.0	184
Wind onshore	112.2	365
Solar PV	435.7	511
Total	624	1 438 USD billion/yr
ENERGY EFFICIENCY[4]		
Buildings	276	1 210
Industry	26	1 217
Transport	46	182
ENERGY CONSERVATION[5]	12	35
Total	360	2 644 USD billion/yr
GRIDS AND FLEXIBILITY[6]	433	791 – 912[7]
TOTAL	1 417	4 874 – 4 994 USD billion/yr
		2025 – 2030: 29 – 30 USD trillion

Notes: CSP = concentrated solar power; PV = photovoltaic; yr = year

[1] All figures have been adjusted for inflation and are represented in real terms; *i.e.* 2024 US dollars.

[2] (IRENA, 2025a; BNEF, 2025e; IEA, 2025c).

[3] Renewable power generation capacity: Investment in deployment of renewable technologies for power generation.

[4] Energy efficiency in industry: Improving process efficiency, demand-side management solutions, highly efficient energy and motor systems and improved waste processes. Energy efficiency in transport: All passenger and freight transport modes, notably road, rail, aviation and shipping. Vehicle stock investments are excluded. Energy efficiency in buildings: Improving building thermal envelopes (insulation, windows, doors, *etc.*).

[5] Energy conservation: Investments in energy conservation includes those in bio-based plastics and organic materials, chemical and mechanical recycling and energy recovery.

[6] Grids and flexibility: Investment in transmission and distribution networks (excluding public EV charging stations investments), smart meters, pumped hydropower and battery storage among other energy storage technologies.

[7] The average annual investment requirement range reflects the corresponding lower and upper bound estimates of battery energy storage capacity (360 GW to 900 GW) due to uncertainties in other flexibility measures such as grid and sector coupling.

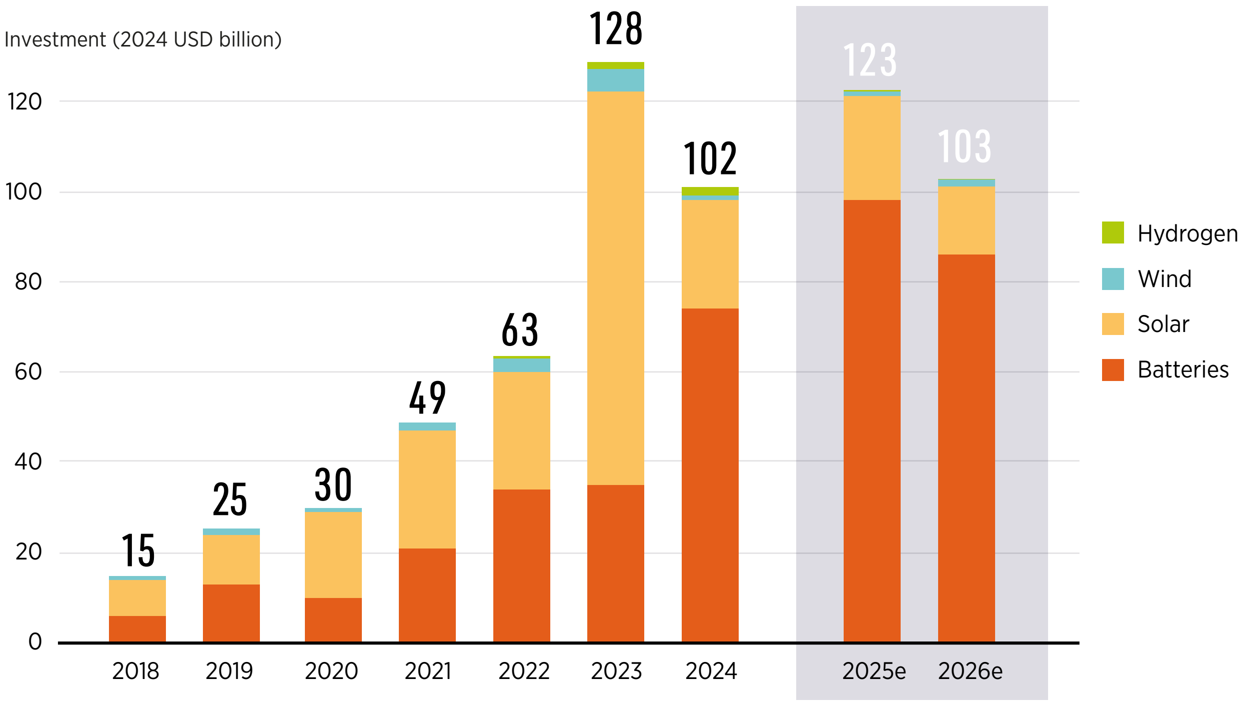
INVESTMENTS IN ENERGY TRANSITION SUPPLY CHAINS[13]

Investments in factories for manufacturing solar, wind, battery and hydrogen technologies dropped by 21% to USD 102 billion in 2024, after reaching a peak of USD 128 billion in 2023 (BNEF, 2025e). This is the net impact of a 72% decline in investments in solar PV factories, after a record-high reported in last year's report for 2023, and record-high investments in battery manufacturing. This is largely because overcapacity has depressed module prices, while battery factory investments have more than doubled (see Figure 10) (BNEF, 2025e).

Cumulatively, at least USD 411 billion had been invested in manufacturing facilities for solar, wind, battery and hydrogen technologies by the end of 2024, translating to more than 1.5 TW/year of solar PV module manufacturing capacity (Wood Mackenzie, 2025a) and more than 3 terawatt hours (TWh) of battery manufacturing capacity (IEA, 2025d). China accounted for more than 80% of global investments between 2018 and 2024, as the country holds more than three-fifths of the world's manufacturing capacity for clean energy technologies such as solar PV, wind systems and batteries (IEA, 2023). Europe and the United States attracted 7% and 5% of global investments, respectively, while the remainder was shared between Southeast Asian economies (2.6%), India (1%) and the rest of the world (3.6%).

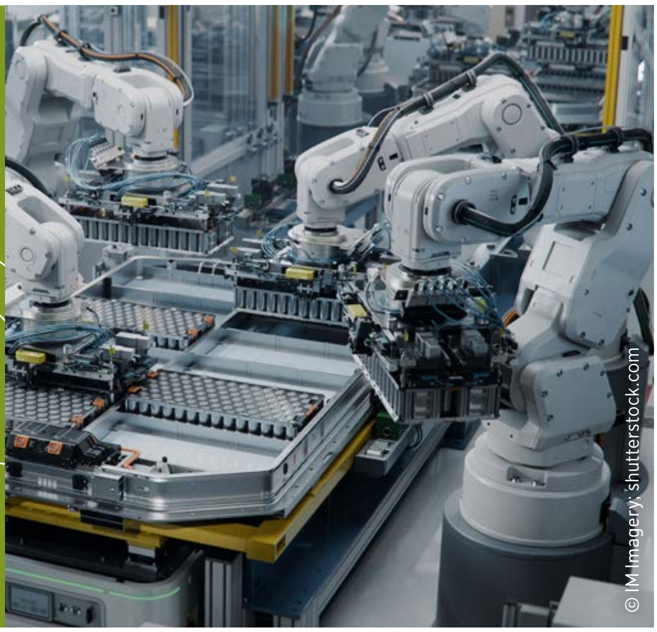
13 This section draws on IRENA's upcoming flagship report, *Global landscape of energy transition finance* (IRENA and CPI, Forthcoming).

FIGURE 10 Investments in solar, wind, battery and hydrogen technology manufacturing, 2018–2026



Source: (BNEF, 2025e).

Note: This includes factory investments across the manufacture of solar (polysilicon, wafers, cells and modules), batteries (separators, electrolytes, cathodes, anodes and cells), wind turbines (nacelles only), and hydrogen electrolyser manufacturing (stack assembly only); 2025e and 2026e are estimates. While BNEF data is missing some parts of the supply chain, new data launched by the Net Zero Industrial Policy Lab in September 2025 captures a broader set of clean-tech manufacturing technologies for Chinese investments overseas (including for EVs, electric buses, and charging stations). This data suggests that overall investments in manufacturing may be far greater than stated above. The data also confirms the decline in solar PV investments (Xue and Larsen, 2025).



US investment in solar factories increased by 78% between 2023 and 2024 to reach USD 4.5 billion, and battery factories increased by six times, reaching USD 5 billion. This was mainly due to the incentives offered by the Inflation Reduction Act, as well as tariffs that made domestic PV production more profitable.

Recent cuts to federal incentives, and the One Big Beautiful Bill Act, are undercutting the United States' earlier efforts to boost local energy transition technology manufacturing. While the country was expected to double its share of battery investments from 5% in 2023–2024, to 10% in 2025–2026 (BNEF, 2025e), these cuts will significantly affect both domestic and global progress (as in the case of China and India discussed below). The United States saw cancellations of USD 22 billion worth of new factories and energy transition related projects between January and May 2025, foregoing the creation of 16 500 new jobs (E2, 2025).

In 2024, global investment in solar PV factories fell by 72%, driven primarily by an oversupply of manufacturing capacity worldwide. The PV market is currently oversupplied, this has seen module prices fall while trade barriers have increased; as a result, major manufacturers – particularly in China – saw profit margins more than halve in 2024 (BNEF, 2025f).[14] In 2024, additional tariffs were imposed by the United States, while the European parliament is also considering enacting tariffs on Chinese solar PV imports. Today, 98% of Europe's solar panels and parts are imported from China (Abnett, 2024). Similar to the United States, countries such as Brazil, India and South Africa had previously enacted a combination of restrictive import policies and supportive industrial policies and subsidies to boost domestic production (Jowett, 2024; Wood Mackenzie, 2024a).

14 Some of the decline is likely a result of an expected correction from peak investment in 2023.

Investments in Southeast Asia declined by 62% in 2024. The region is the largest solar PV manufacturer after China,[15] accounting for 6.5% of solar module, cell and wafer manufacturing in 2024 (Wood Mackenzie, 2025a). Southeast Asia primarily exports to the United States, but the lifting of a two-year exemption on tariffs on solar PV imports in June 2024 (for Malaysia, Cambodia, Thailand and Viet Nam) (Ford, 2024), and additional levies announced in late 2024 have led major manufacturers in the region to cut back production and halt expansion plans for new manufacturing facilities (Saeed, 2025).

Solar PV manufacturing investments in 2025-2026 are expected to decline significantly to just one-third of the level seen in 2023–2024 (BNEF, 2025e). However, a higher portion of 'new' factory investment and construction is expected to occur outside China and Southeast Asia, as other countries look to diversify their supply chains. For example, India is emerging as a major solar PV manufacturing and exporting hub, with domestic solar module manufacturing capacity growing from less than 5 GW in 2018 to more than 68 GW in 2024 (Wood Mackenzie, 2025a). Going forward, India's share of global investment is expected to more than triple from 2.5% in 2023–2024 to almost 8% in 2025–2026, underpinned by the Production Linked Incentive (PLI) scheme.

However, export-oriented manufacturers in India are facing significant hurdles, with the United States – a major trading partner that accounts for 97% of the Indian solar PV module export market in 2024 – imposing a 25% tariff on Indian goods in August 2025. Prior to this, solar PV exports from India to the United States increased by 23 times between 2022 and 2024. Margins on overall exports were 40-60% higher than domestic sales in 2024 (Institute for Energy Economics and Financial Analysis, 2024). The latest tariffs may curtail US-India solar PV trade, diminish margins on exports, and even slow the buildout of new factories in India.

15 On a strictly national basis, India is the second largest producer but is surpassed by ASEAN collectively.

Global investment in battery factories has almost doubled to reach a record-high of USD 74 billion in 2024, driven by the growing demand for energy storage solutions for renewable integration, grid flexibility, EVs and data centres. China made up 84% of investments in 2023–2024 and is well-established as the dominant hub for battery manufacturing (China's battery manufacturing capacity accounts for over 80% of the global total across all major components — cells, cathodes, anodes, electrolytes and separators) (BNEF, 2025f). However, its share is expected to decline to 71% in 2025–2026, as other countries, including several developing economies, launch efforts to localise battery production. India plans to develop a battery gigafactory in Jamnagar, Gujarat by 2026, with an annual production capacity of 30 GWh, positioning it among the largest battery manufacturing plants in the country (Manufacturing Today, 2024). Indonesia also aims to launch its first EV battery manufacturing plant, with an annual capacity of 10 GWh of battery cells (Agarwal, 2024).

Investments in wind turbine factories[16] – although a smaller portion of overall supply chain investments – fell by almost 80% in 2024 and the future outlook remains well below 2022–2023 levels. The sector has faced significant deployment challenges due to inflation, permitting delays and supply chain pressures. As of 2024, a higher share of investments is going to offshore wind turbine manufacturing than to onshore. This is expected to continue in 2025 and 2026.

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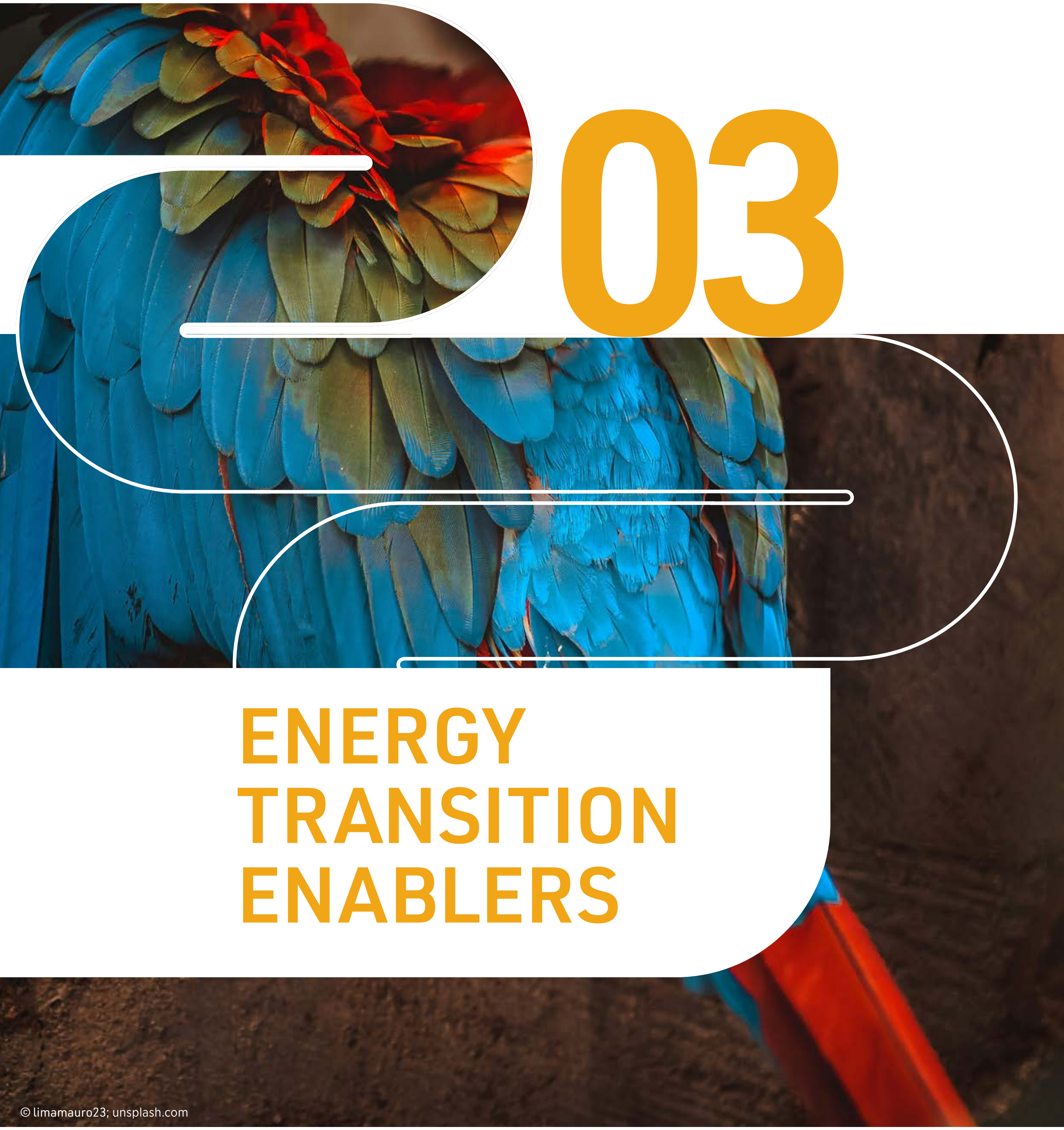
16 This only includes nacelles.

03

ENERGY TRANSITION ENABLERS



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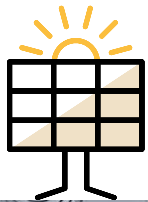
ENERGY TRANSITION SUPPLY CHAINS

Solar PV supply chains

The solar PV industry has undergone rapid expansion of cell and module manufacturing plants. In 2024 alone, global operational module capacity increased by 315 GW to reach 1 554 GW, a growth of 25% (Wood Mackenzie, 2025a). Notwithstanding soaring interest in diversifying supply chains in many countries, China continues to have the lion's share of manufacturing capacities and produced 82% of the world's PV modules in 2024. Southeast Asia had a 7.4% share, India 4.5%, the United States 2.6% and Europe 1.5% (Wood Mackenzie, 2025a).

Driven by intense competition, PV manufacturing suffers from significant overcapacities – capacity utilisation globally was just 46% in 2024, down from 49% the previous year (Wood Mackenzie, 2025a). China's cost advantages are based on economies of scale, strong research and development spending, low-cost inputs like land, electricity and labour, and a high degree of vertical integration (Wood Mackenzie, 2024b).

China is also the dominant exporter. Its PV module exports rose to 241.9 GW in 2024, up from 219.1 GW the year before and more than seven times the volume of shipments in 2017. More than a third (38%) of all shipments went to the European Union, 28.5% to other Asian countries, 14% to Latin America and the Caribbean, 7% to the Middle East, 4% to Africa and just 1% to North America (reflecting import restrictions) (Ember, 2025a). The geography of this trade is shifting. While fewer shipments are destined to the European Union, China's exports to other Asian countries soared in 2024 after a dip in 2020–2022. Though still much smaller, both the volume and the share going to the Middle East and Africa rose strongly in 2023 and 2024. Brazil is the single largest destination of shipments,[17] followed by India, Pakistan, and Saudi Arabia (Ember, 2025a).

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17 Nominally , the Netherlands imports by far the largest volume (some 40 GW), but the bulk of it goes to other, final destinations. The port of Rotterdam serves as a principal entry point for the European market.

Driven by Chinese investments, Southeast Asia is a major solar PV manufacturing hub. Several countries in the region – Viet Nam, Thailand, Malaysia, and Cambodia – are important producers, with output principally destined for export. By year-end 2024, the region's module manufacturing capacity had expanded to 130 GW from 38.7 GW in 2020; cell capacity has quintupled to 135 GW since 2020 (Wood Mackenzie, 2025a). The bulk of US module imports stems from Southeast Asia, but escalating US tariffs led to a drop in shipments in 2024, and are also prompting shifts within the region's supply chain. Facing much lower tariff rates, Indonesia and Lao People's Democratic Republic are emerging as additional producers (Wood Mackenzie, 2024b, 2025a).

India's module manufacturing capacity is growing rapidly, estimated at 68.2 GW in 2024, and up from 49.3 GW in 2023. With a capacity utilisation factor of about 50%, actual output was 34.2 GW. This represents close to a doubling of the 18.3 GW recorded in 2023. It was the third-largest volume after China's massive 587 GW and Southeast Asian nations' combined 62 GW (Wood Mackenzie, 2025a).

Global solar PV installed capacity is expected to reach 6.15 TW by 2030 under IRENA's 1.5°C Scenario – from 1.86 TW in 2024; during the year, a record 452 GW was added (IRENA, 2025a). The expected additional growth in PV installation creates market opportunities for expanding solar PV module manufacturing which is currently concentrated in only a few markets. While the current global supply chain structure has enabled rapid cost reductions and widespread adoption, it also entails potential risks related to concentration, material shortages and supply disruption. A diversified, resilient and sustainable supply chain is essential for maintaining and accelerating the global transition to solar energy, and for ensuring that any unexpected disruptions – such as from disasters or damage sustained by supply chain infrastructure – can be minimised. A diversified structure is also essential for widely shared benefits such as jobs.

China's advantages of scale allow it to produce solar equipment at unrivalled cost. A more diversified manufacturing industry implies higher costs. Other leading markets have demonstrated success by implementing targeted policies to strengthen domestic solar PV manufacturing. These measures include subsidies and incentives to encourage domestic production, access to affordable financing, and investments in technological innovation.[18]

Asian markets demonstrate the most competitive cost structures, driven by lower labour and electricity costs. In contrast, European markets' higher module costs are driven almost entirely by electricity expenses, which significantly impact the cost structure of energy-intensive upstream segments like polysilicon production (IRENA, Forthcoming [c]).

18 For further analysis, see IRENA's supply chain solar PV cost tool, developed as part of the Clean Energy Ministerial Initiative, *Transforming Solar Supply Chains* (IRENA, Forthcoming[b]).

Wind power supply chains

In 2024, 114 GW of new wind capacity was installed worldwide, close to the 2023 peak volume. This was principally driven by China, which single-handedly added a record 79.4 GW, or 69% of the global total. All other countries together added only 35 gigawatts in 2024, down from a peak of 44 GW in 2021 (IRENA, 2025a). The United States, for example, added just 5.1 GW, compared to 14.8 GW in 2020. Germany's 3.3 GW was just over half its record 6.1 GW in 2017, and the UK's pace is only one-fifth of what was deployed in 2017. India's 3.4 GW represents the fifth straight year of increases, yet still falls short of the pace in 2017, when 4.1 GW were added (IRENA, 2025a).

Unlike solar PV, the wind power industry faces a bifurcated supply chain structure. To some extent, this reflects the fact that some components – *e.g.* blades – are large and difficult or costly to transport over long distances. China is the largest manufacturer of wind towers, blades, nacelles and other components. In 2024, Chinese firms accounted for 70% of all turbine orders worldwide, ahead of companies headquartered in Europe (19.4%), the United States (6.5%) and India (0.8%) (Wood Mackenzie, 2025b). However, at present, Chinese companies' production is almost exclusively destined for the massive domestic market. European manufacturers are market leaders outside China, but have faced rising costs. Vestas and Siemens Gamesa have the geographically most diversified portfolio. Their turbines have been deployed in more than 80 countries, compared with 51 for the US firm GE Vernova (Wood Mackenzie, 2025c). Challenges in the wind sector have hampered project bankability in Europe and led to several cancellations in the United States (IEA, 2024); these are expected to continue into the future. Wind manufacturers such as Vestas, Nordex, GE Vernova and Siemens have also faced significant operational and financial difficulties over recent years, owing to high inflation and supply chain disruptions (BNEF, 2025g). As a result, further expansion of wind manufacturing facilities may slow over the next few years whilst these challenges are addressed.

Grid infrastructure supply chains

Grids are central to the tripling goal, as well as to energy security, climate goals and future economic competitiveness. Increased addition of renewables and increased electrification imply the need for expanding and modernising grids. This is not limited to the transmission infrastructure needed to connect new generation to demand centres – distribution systems, where aging infrastructure is limiting the addition of new demand and distributed generation, also need upgrading.

Bottlenecks for grid infrastructure equipment are growing, as is the underlying demand for the replacement of existing aging infrastructure to meet electricity demand growth (from industry, for cooling, data centres and other sources) and gird expansion for decarbonisation. Lead times for transmission and distribution transformers are increasing. For instance, soaring demand for transformers in the United States has seen lead times reach between 2.5 years and 2.8 years in Q2 2025 (Cuthrell, 2025). Similar issues are emerging for high voltage electricity cables, with long lead times and rising prices as demand outstrips supply. Indeed, cable pricing has nearly doubled since 2019 (BNEF, 2025h; IEA, 2025e).

The expansion of grids is impeded by long lead times for projects and permitting timelines. Domestic permitting processes remain the single greatest barrier to the physical build-out of new transmission lines. Concurrent projects across the world and aging infrastructure, leading to increased demand for grid assets, have strained the global supply chain, widening the gap between demand and supplies of grid assets. Transmission lines and transformers now see double the waiting times. This is not a temporary disruption but a structural bottleneck stemming from a surge in global demand confronting limited manufacturing capacity.

Supply chain constraints introduce challenges to developed and developing economies alike. Overcoming this requires political will and improved supply chain resilience. Key requirements include the need for market reforms, workforce upskilling, de-risking investment and expanding global manufacturing.

EV battery supply chains

Electric passenger cars are a key technology for advancing sustainable transport and their battery supply chains form an essential pillar of the global energy transition. The EV battery supply chain encompasses everything from mining raw materials like lithium and cobalt, through refining, manufacturing and assembling battery packs, to the reuse or recycling of batteries at the end of their life.

Depending on battery type and size, the electrification of road transport drives demand for critical materials such as graphite, lithium, cobalt, copper, phosphorus, manganese and nickel. Under IRENA's 1.5°C Scenario, lithium demand from EV batteries could roughly quadruple between 2023 and 2030, while cobalt, graphite and nickel demand could more than triple.

Current planned global battery production capacity for 2030, at 7 300 gigawatt hours (GWh) per year (yr), exceeds the anticipated demand for EV batteries of 4 300 GWh/yr, offering a positive outlook. However, securing critical material supply remains important, even though, according to IRENA's analysis, resource availability is not a constraint on the global level in the long run (IRENA, 2024b).

The EV battery supply chain provides one example of how innovation can help decrease dependency on some materials: cobalt and nickel were absent from nearly half of passenger EVs sold in 2023, driven by the rise of lithium iron phosphate (LFP) and lithium manganese iron phosphate (LMFP) chemistries. Further advances in energy density, emerging sodium-ion batteries and improved mining and processing could mitigate potential shortages, provided that production capacity expands in time to meet demand (IRENA, 2024b, Forthcoming[d]).


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Tariffs and supply chain dynamics

In April 2025, the United States invoked the International Emergency Economic Powers Act (IEEPA), imposing economy-wide tariffs on several countries. With limited time to adjust, a suite of countries affected by the Act levied their own retaliatory trade measures. In the immediate term, the implications may be adverse for most countries globally: this may result in higher prices on goods and services, supply chains disruptions, job cuts and falls in productivity (York and Durante, 2025).

In the context of renewable energy supply chains, protectionist trade measures were already at play before the IEEPA. The United States first applied anti-dumping duties and tariffs on Chinese solar PV cells and modules in 2012. In late 2024, the United States doubled tariffs for polysilicon, wafers, and solar cells imported from China, while China responded with duties of 57% on US-manufactured polysilicon. As a result, US-manufactured polysilicon exports shifted to other markets such as Japan, while China increased exports towards EU countries (Jackson *et al.*, 2024; NREL, 2024). Since tariffs on Chinese solar products were imposed by the United States in 2012, China has strategically invested in factories assembling Chinese-made cells into modules in Southeast Asia. Southeast Asian companies have also shifted some of their exports of PV cells to the Indian market after the US anti-circumvention tariffs were imposed on Southeast Asian–manufactured cells and modules that use Chinese wafers and other Chinese products in 2023 and again in 2024 (NREL, 2024). Modules produced in India with Southeast Asian inputs are now mostly exported to the United States (Raghavan, 2023).

At present, renewable energy equipment production and exports at the higher end of the value chain are concentrated in just a few economies, with China by far the most dominant. Most countries are net importers of renewable energy equipment and services (IRENA and ILO, 2024). At the same time, many resource-rich developing countries remain largely confined to exporting raw materials. Lacking sufficient capacity to move beyond resource extraction into processing, they derive only limited economic benefits and remain vulnerable to commodity price fluctuations. Consequently, most renewable energy jobs in these countries are concentrated in mining, construction, installation, and operations and maintenance (O&M), rather than manufacturing (IRENA and ILO, 2024).

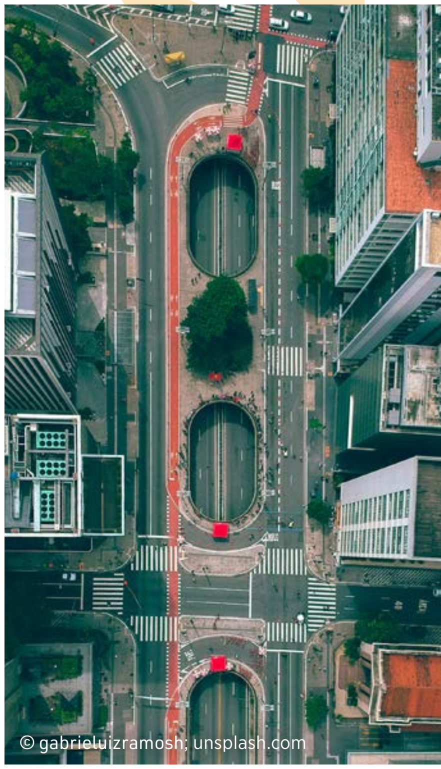
POLICY, REGULATION AND NDCs

NDC 3.0 and national energy plans

As of 1 October 2025, only 60 Parties had submitted their third round of Nationally Determined Contributions (NDCs) to the Paris Agreement (NDC 3.0) (UNFCCC, 2024a).[19] Of these, 21 NDCs explicitly mentioned the UAE Consensus goal to triple renewable energy capacity by 2030. Parties that have submitted their NDC 3.0s so far account for only 20% of global emissions (Climate Watch, 2025).

In the first round of NDCs submitted following the adoption of the Paris Agreement, 45% of UNFCCC Parties included renewable energy within their targets but focused primarily on broad goals for reducing greenhouse gas emissions and increasing energy security. In the second round of NDCs, submitted between 2020 and 2022, the percentage of parties that included renewable energy increased to nearly 60%, while also increasing the quality of their renewable energy targets by making them specific and measurable (NDC Partnership, 2025).

To date, 183 of the 195 parties[20] mention renewable energy in their active NDCs (including both 2.0 and 3.0 rounds), while 151 of those had quantifiable targets. Of these quantifiable targets, 119 were specifically for the power sector, 44 of which were expressed in the form of absolute capacity (MW) or generation output (MWh) (Figure 11). In addition, 44 targets were expressed in terms of share of renewable energy, while 31 targets used a combination of absolute and share-based targets. Out of the 75 Parties in total that have expressed a share-based target, 13 commit to achieving a renewable energy share lower than 24%; 28 commit to a share between 25% and 59%; 22 commit to shares between 60% and 89%; and 12 commit to shares between 90% and 100% – and most of these are small island developing states (SIDS), that have set ambitious targets despite their minute emission footprint.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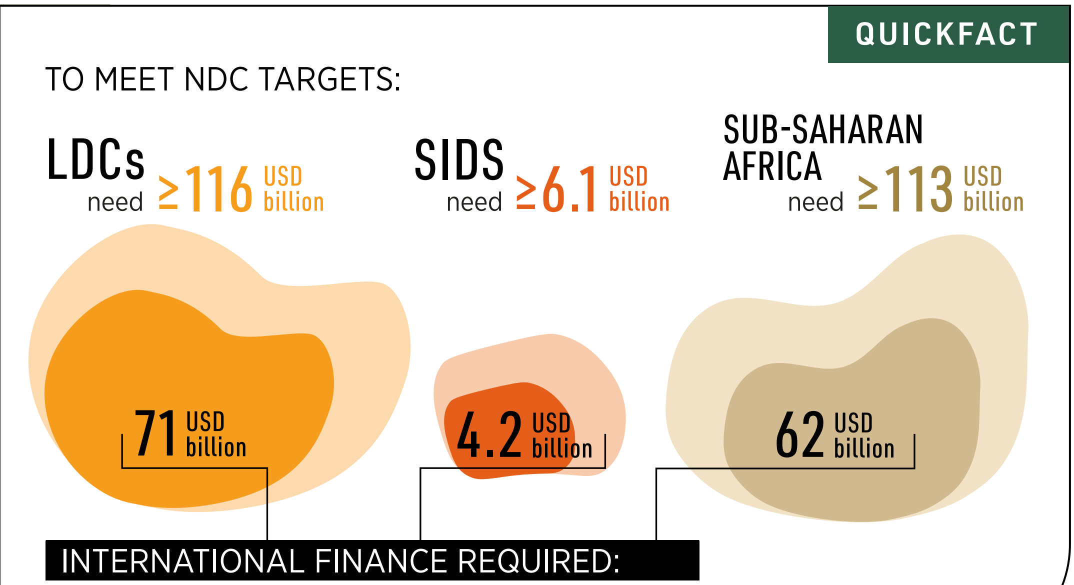
19 The NDC of the United States is considered inactive and therefore excluded from this analysis unless specified. Both Zambia and Zimbabwe have only submitted a provisional NDC or NDC statement – not their full NDCs. They are included here, although these cannot be considered their final NDC 3.0s. Commitments made at the UN Climate Summit in September 2025 have been excluded in the absence of an official NDC 3.0 submitted by 1 October, 2025 – as in the case of China. However, the impact of China's commitment on global renewable energy ambitions is discussed in the notes of Figure 11.

20 The European Union and its 27 Member States communicated one joint NDC that, for this report, has been counted as one NDC representing 27 Parties.

IRENA's quantification of renewable power targets in NDCs submitted as of 1 October 2025 finds that existing targets aim to collectively increase total renewable energy capacity to approximately 5.8 TW by 2030,[21] from 4.4 TW today (IRENA, 2025a) (see Figure 11 and notes). The 60 Parties that submitted NDC 3.0s have committed to installing 244 GW of capacity by 2035 compared to 132 GW (by 2030) in their respective NDC 2.0s (Figure 13), representing an additional 112 GW, albeit over a longer timeline.[22] Currently, they make up 833 GW of capacity (19% of global) (IRENA, 2025a).

Overall, NDC targets collectively need to almost double in order to meet the goal of tripling installed renewable power capacity by 2030 – with less than five years remaining for implementation, urgent and effective action on the ground, accompanied by increased investments in renewable energy, is crucial.

Worryingly, since COP28 and the adoption of the tripling renewable power goal, national plans and targets for renewable power generation capacity have increased by just 2% as of July 2025 (Ember, 2025b). This represents ambitions to raise renewable power capacity to 7.4 TW.[23] Only seven countries outside the European Union have updated their national renewable power targets for 2030, but two of those reduced their ambitions.



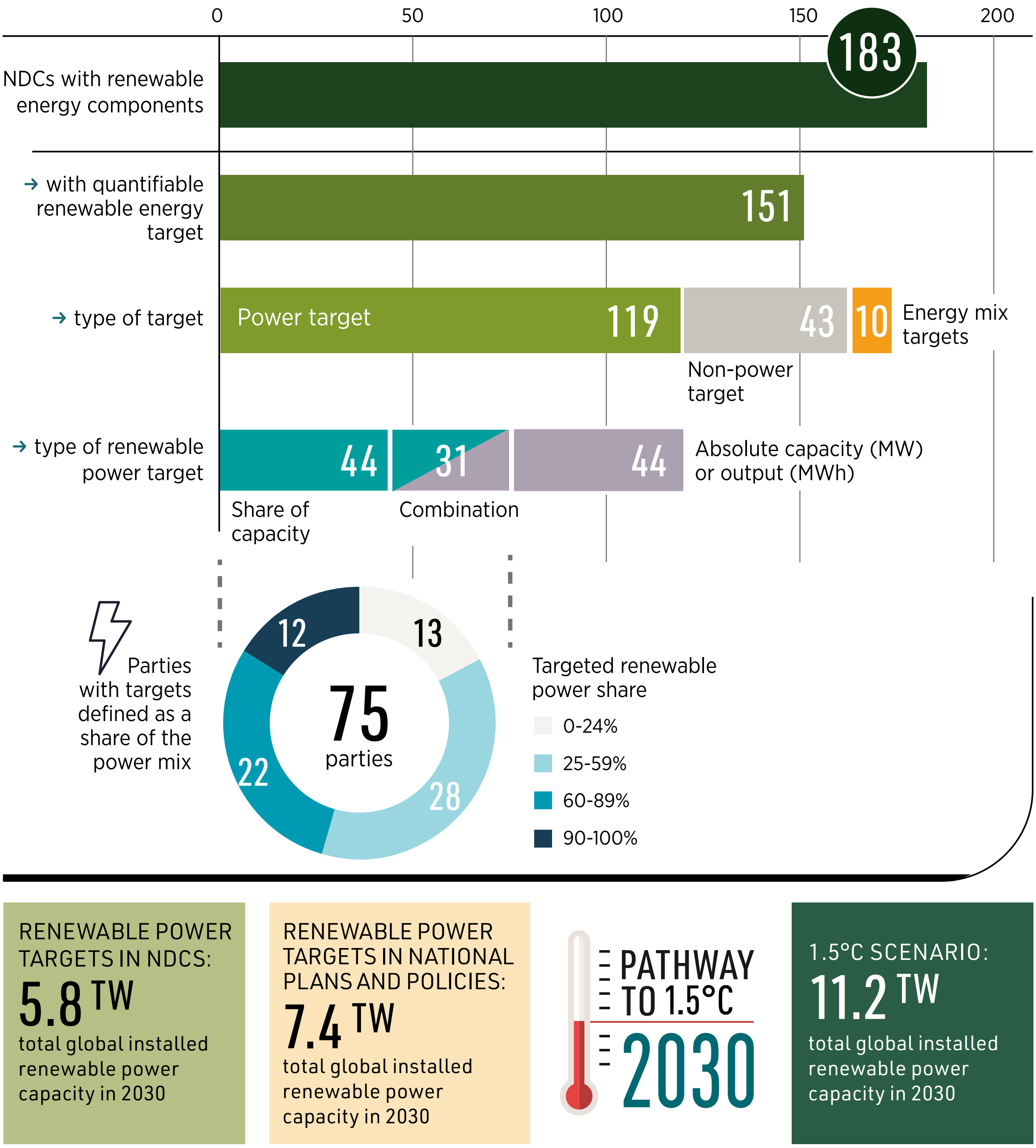
Notes: LDCs = least developed countries; SIDS = small island developing states; USD = United States dollar.

21 Most NDC 3.0 targets are for 2035. For the purpose of this report, in some instances, they have also been interpolated to 2030.

22 Majority of the increase in targeted capacity for 2030 came from additions in countries without a target or countries that have already exceeded their 2030 targets.

23 Not including the announcement from China in September 2025 targetting at least 3.6 TW of solar and wind capacity by 2035.

FIGURE 11 Renewable energy targets in NDCs globally as of 1 October 2025



Source: Renewable power targets in national plans and policies[24] as of July 2025 are based on (Ember, 2025b).

Notes: This analysis is based on countries that have officially submitted NDC 3.0s. As China has yet to officially submit an NDC 3.0 (as of 1 October 2025), China's recent announcement of at least 3.6 TW of solar and wind capacity by 2035 is not included in the analysis. If this was included, the global commitment would rise to 6.9 TW by 2030 (and 8 TW by 2035). Countries without explicit renewable energy targets in their NDCs may still deploy significant renewable capacity, as such targets are often outlined in national policies referenced within the NDCs. For this reason, implicitly mentioned targets *i.e.* targets included in official national policy documents mentioned in the NDCs, are included in the analysis. For instance, Serbia's NDC 3.0 does not have an explicit renewable energy target – however, the NDC refers to the *Integrated Energy and Climate Plan* of Serbia, which includes a target. Therefore, the NDC is considered to have an implicit target and is included in the 5.8 TW estimate. The 7.4 TW estimate based on (Ember, 2025b) includes official strategies, plans, executive orders, official projections and credible third-party studies (not including China's recent announcement). MW = megawatt; MWh = megawatt hour; NDC = nationally determined contributions; TW = terawatts.

24 The Planned Energy Scenario (PES) is based on explicit and implicit country targets, energy plans and policies and will be updated for forthcoming *World energy transitions outlook*.

The third round of NDCs has shown increased inclusion of non-power renewable energy targets; 43 out of 60 parties mentioned renewable energy for other end-use sectors such as heating and transport. By comparison, only eight of those same 60 Parties had done so in the previous iterations of their respective NDCs. Such targets mainly cover the use of biofuels in transport, solar water heaters and direct use of renewable energy for industry. However, of the 43 NDC 3.0s mentioning renewable energy for other end-use sectors, only 21 had quantifiable targets. Such targets can include reaching a specific share of renewables in biofuels, or adding a specific number of solar water heaters, and deployment of renewable energy-based clean cooking solutions. Considering broader policies, plans, strategies and pledges (including NDCs), targets for renewable heat and fuels are significantly less widespread than those in the power sector, reflecting an ongoing policy focus on electricity over other energy carriers (see Box 2).

As of 1 October 2025, Australia, Brazil, Canada, Japan, the Russian Federation, and the United Kingdom were the only G20 parties to have submitted NDC 3.0s. The United Kingdom's Clean Power 2030 Action Plan, upon which the new NDC is based, explicitly states 46 GW of capacity additions in solar PV, and 74.5 GW of both onshore and offshore wind (Government of the United Kingdom, 2024). While Canada's NDC lacks a national target, the NDC refers to several provincial energy policies and strategies that have renewable energy targets for both power and non-power end-uses (Government of British Columbia, 2021; Hydro-Québec, 2023).

Although China has yet to submit its official NDC 3.0 to the UNFCCC, it announced a target of at least 3.6 TW of solar and onshore wind capacity by 2035 at the UN Climate Summit in September (Reuters, 2025a). This is nearly three times the country's previous target of 1.2 TW by 2030, which was achieved six years ahead of schedule in 2024. If this target is taken into account, current commitments amount to at least 6.7 TW by 2030 (and 8 TW by 2035).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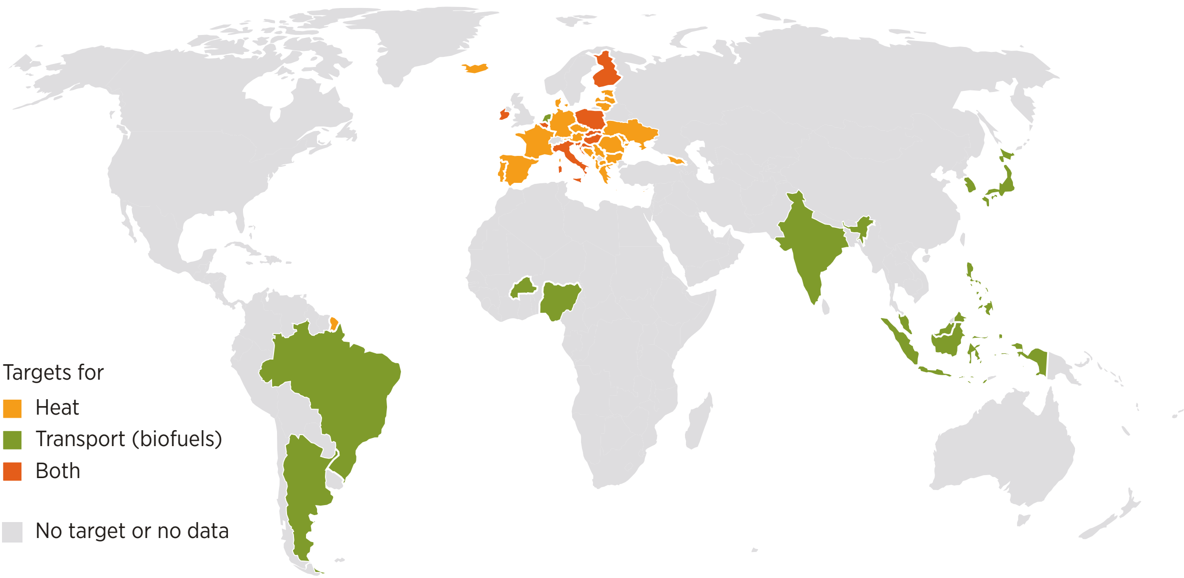
BOX 2 Renewable energy targets by energy carrier based on national policies, plans, strategies and pledges

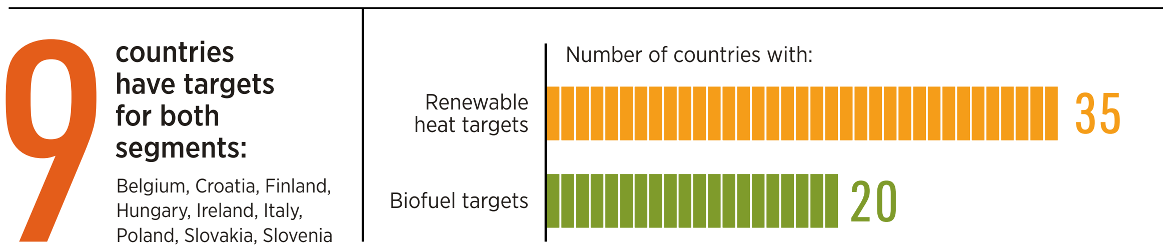
As of 2024, most countries (83) had set a target for just one energy carrier, usually power. Only nine countries, all in the European Union, had targets covering power, heat and fuels. In 2024, just a few countries – such as Montenegro, Ukraine, and Slovenia – announced or updated renewable heat targets, and some like Japan, the Philippines and Poland, revised their biofuel mandates.

Only 35 countries had targets in place for renewable heat, with ambitions ranging from 7% by 2030 in Georgia to 67.5% by 2030 in Lithuania. In the fuels sector, just 20 countries implemented renewable fuel targets, most of which take the form of biofuel blending mandates, with ranges from 7% by 2030 in the Netherlands up to 34% in Finland (Figure 12).

Cross-sector ambitions remain scarce. In 2024, only a small number of countries set new sector-specific renewable energy targets. Latvia established a goal for nearly 65% renewable energy use in industrial consumption by 2030. Germany introduced a policy mandating that all new heating systems must derive 65% of their energy from renewable sources. Seven EU Member States updated their ten-year national energy and climate plans for 2021-2030 including renewable energy targets for the transport sector, generally aiming for renewable shares between 15% and 30%.

FIGURE 12 Renewable energy targets in heat and transport, based on national policies and plans as of 2024





Source: (REN21, 2025a).

Notes: Targets include pledges and announcements, as well as those mentioned in NDCs. Some are enacted in official documents such as national energy strategies.

Despite submitting a NDC 3.0 in December 2024, the United States' commitments are not formally recognised by the UNFCCC due to the country's intended withdrawal from the Paris Agreement for a second time. While the United States' NDC 3.0 submission signalled 100% 'clean' electricity by 2035, an official projection published this year following their withdrawal from the Paris Agreement estimates only around 50% of renewable sources in the electricity sector by 2035 (EIA, 2025). The United States' withdrawal from the Paris Agreement not only raises the uncertainty around its national commitments regarding renewable energy, but also jeopardises the pledged contribution of at least USD 4 billion to the Green Climate Fund (BNEF, 2025i).

Japan's NDC does not specify an explicit renewable power target for its milestone years of 2035 and 2040, but a 40–50% renewable power share in power generation in 2040 is specified in the 7th Strategic Energy Plan (Agency of Natural Resources and Energy of Japan, 2025), launched in 2025, that provided the basis for its NDC development. Brazil's NDCs also mentioned renewable energy without explicit targets but has already achieved a share of 89% renewables in their electricity generation mix as of 2023 (IRENA, 2025a).

The conditionality of NDC targets further highlights the urgency for increased climate financing for the energy transition. An analysis of Least Developed Countries' NDC targets submitted up to October 2025 shows that of the 60 GW of additional capacity targets by 2030, 38 GW (or 60%) are conditional on receiving international financial assistance.[25] While 65% of targeted capacity from SIDS were also conditional (2.8 GW), 56% was conditional in Sub-Saharan Africa (34 GW). In terms of the required investment for capacity additions, in LDCs, it is estimated that USD 71 billion out of USD 116 billion (or 61%) of the investment will need to be provided from international sources, ideally in the form of concessional finance. About 69% (USD 4.2 billion) will be needed for SIDS, and 55% (USD 62 billion) will be needed for Sub-Saharan Africa.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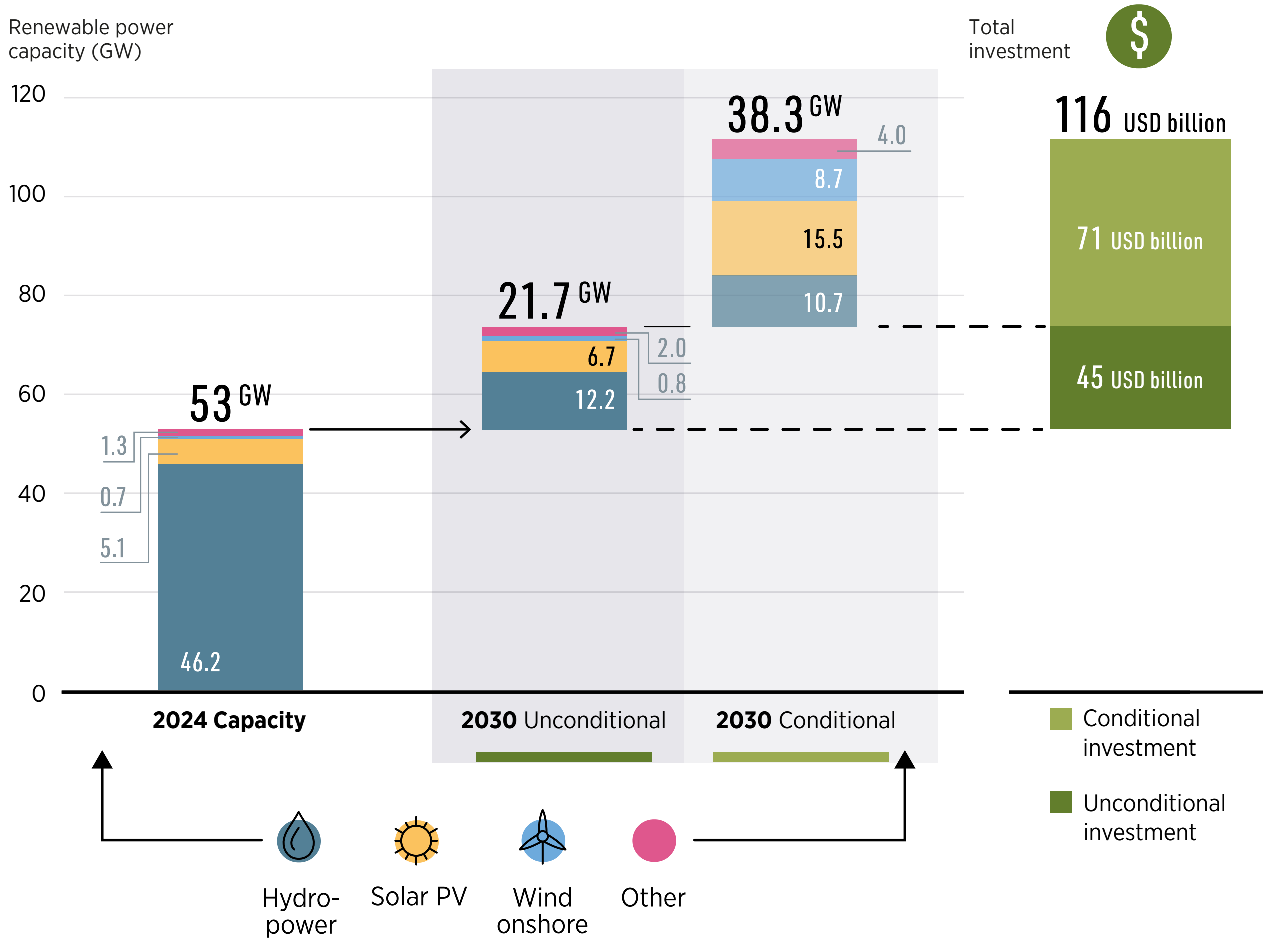
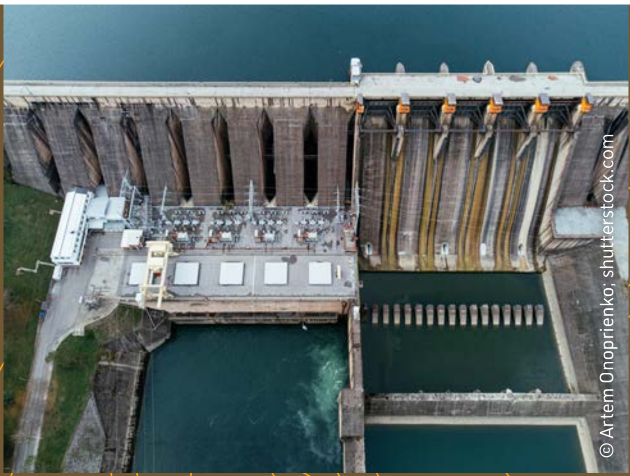
25 Nepal's NDC 3.0 was the main driver of increase in collective renewable energy targets of LDCs compared to the previous analysis, committing nearly 30 GW of renewable energy capacity installation by 2035 conditional upon international assistance.

FIGURE 13 Conditionality and required investment for active NDC targets in LDCs by 2030



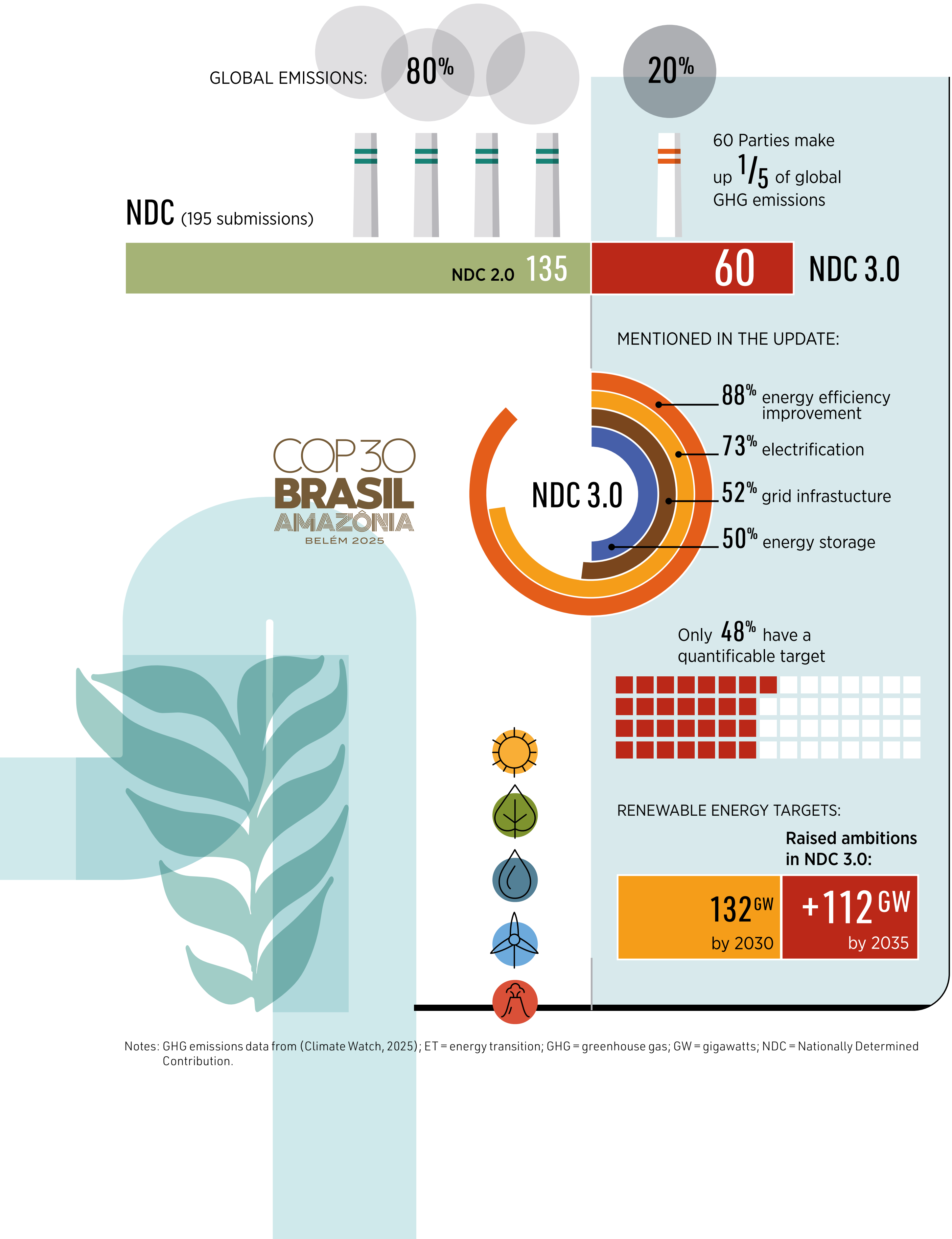


Renewable energy targets in NDCs must be aligned with domestic energy plans and legislation in order to boost credibility and accountability. However, as of October 2025, only 56% of active NDCs (110 out of 195) had their renewable energy targets embedded in a domestic policy document. Furthermore, assessment of national energy plans and NDCs show that NDCs collectively target 5.8 TW of renewable energy capacity by 2030, 22% less than national energy plans and policies' 7.4 TW target. This misalignment between domestic policy and NDC targets can signal a mismatch between domestic priorities and commitments to the international community.

The NDC 3.0 submission can serve as a timely opportunity to address misalignment with national policies, while also enhancing them to reflect the outcomes of the First Global Stocktake, specifically with respect to the Paris Agreement, tripling renewable energy capacity, and alignment with long-term national strategies via targets and sector-specific plans. This will provide clarity on the level of ambition; help to support the private sector in aligning strategies with national goals; and ensures a robust, bankable pipeline of renewable energy projects. As mentioned, 35% of NDC 3.0s mention the pledge to triple renewable energy capacity but actual aggregate targets are not in line. In addition, NDCs and long-term strategies such as long-term low-emission development strategies (LT-LEDS) and energy plans could be further harmonised, which will require strong co-ordination between planning cycles and responsible government institutions (IRENA, 2023c).

To meet the UAE Consensus energy targets, many Parties are also increasingly committing to boosting energy storage, energy efficiency and grid infrastructure. Of the NDC 3.0s submitted to date, 88% mention energy efficiency measures, 73% mention electrification, 52% mention grid infrastructure, and 50% mention energy storage. However, only around half (29) provided a quantifiable target for at least one of these areas (Figure 14).

FIGURE 14 NDC 2.0, NDC 3.0 and other energy transition targets



Notes: GHG emissions data from (Climate Watch, 2025); ET = energy transition; GHG = greenhouse gas; GW = gigawatts; NDC = Nationally Determined Contribution.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Market design and incentives

Policy instruments for renewable-based power

Competitively-set tariff mechanisms, such as auctions, remain the preferential procurement method for utility-scale renewable power projects, and are also increasingly being assessed and employed for national distributed renewable energy programmes. When combined with clear energy transition plans and targets, as well as appropriate regulatory settings, these mechanisms help de-risk projects and give project developers the certainty needed to develop projects and gain access to the necessary finance at reasonable cost.

Between the beginning of 2024 and May 2025, 288 auction rounds for renewable energy had been completed globally, representing 323 GW of capacity, and another 135 auction rounds were announced during that period. Prices for renewables-based electricity generation resulting from competitive auctions have varied widely since 2024, ranging from as low as USD 14.14/MWh in a solar auction in the United Arab Emirates, to as high as USD 220/MWh for tidal stream projects in the United Kingdom, via Contracts for Difference (BNEF, 2025d). These outcomes reflect the diverse cost structures, risks and institutional capacities across markets.

As for other tariff-based mechanisms, six countries (Greece, Ireland, Japan, the Netherlands, Poland and Ukraine) set new feed-in tariffs for renewables between the beginning of 2024 and June 2025, while five countries (Bosnia and Herzegovina, Cyprus, Denmark, North Macedonia and the United Kingdom) ended feed-in tariff support for new players (IEA, n.d.; REN21, 2025b).

In early 2025, China announced a pricing reform for new energy grid-connected electricity. Feed-in tariffs for new energy projects such as wind and solar will be determined through market-based bidding in each region as of June 2025, to capture the increasing maturity of solar and wind technologies and their rapidly decreasing costs (National Development and Reform Commission, 2025). New net billing schemes were put in place in four countries (Greece, Jamaica, South Africa and Spain), while Lithuania converted to net billing from net metering in 2024. Net metering schemes, meanwhile, were established in Cambodia and Malaysia in 2024 (REN21, 2025b).

Financial and fiscal incentives for renewables

Between the beginning of 2024 and August 2025, nine countries had introduced new financial incentives or tax credits for energy transition technologies (IEA, n.d.; REN21, 2025b). Seven of these countries implemented these incentives in 2024: Egypt with VAT exemptions and tax credits on green hydrogen production; Singapore with a Refundable Investment Credit (RIC) scheme that includes manufacture of decarbonisation solutions; Canada with an investment tax credit for clean technologies; France with tax credits for investments in heat pumps, solar panels, wind turbines and batteries; and Italy, Morocco and Portugal with subsidy schemes for the agriculture sector, targeting agrivoltaics and solar pumping kits. In the first half of 2025, two countries introduced financial incentives: Australia put forward tax incentives for renewable hydrogen and critical minerals and Mexico established tax exemptions on electric vehicle imports and a 30% tax credit for investments in charging equipment (IEA, n.d.). While the United States renewed an investment credit in 2024 under the Inflation Reduction Act for investments in clean energy manufacturing, industrial decarbonisation and critical materials processing, it has also rolled back several financial incentives, including a recent executive order published in July 2025 effectively ending tax credits for wind and solar production and freezing new permits for wind energy projects (Reuters, 2025).

Power sector structures

The single buyer model remains the most prevalent power market structure globally, followed by the vertically integrated utility (VIU) model, and finally, wholesale competition. Over the past three decades, 159 countries and territories have transitioned from the VIU model toward either a single buyer or competitive market framework. As of 2024, 72 countries, the majority of which (84%) maintain state-owned VIUs, continue to operate under the vertically integrated model. The model is particularly common in Sub-Saharan Africa and small markets, including those of SIDS (World Bank, 2024b). In 2024, two countries enacted changes in their power market structures. Both Georgia and Kosovo's power markets, currently classified as wholesale competition, evolved from bilateral trading (where bilateral contracting between independent power producers [IPPs] and distribution companies or large customers is allowed) to bilateral trading with bid-based power exchange (World Bank, 2024a). The latter refers to electricity trading through both bilateral contracts and competitive bidding via a spot market.

The increased integration of renewables into power systems continues to influence electricity pricing dynamics. Because most renewable power generation technologies have zero (or close to zero) marginal costs, with the exception of bioenergy, in competitive markets, renewable energy generation operators can bid prices down to near-zero levels. In systems without enough flexibility mechanisms, electricity prices can approach zero or even become negative during periods of high renewable generation relative to demand – a pattern increasingly observed in spring and summer months in Europe and elsewhere. As decarbonisation of the electricity sector with renewables continues, it will become more common in a larger number of countries and throughout the year. For instance, Spain had 404 hours of negative electricity prices in the first five months of 2025 (Mundy, 2025).

While negative prices can benefit consumers in the short term, wholesale markets will increasingly undermine investment signals for new capacity. If left unaddressed, this could jeopardise the business case of renewable energy projects and affect long-term energy transition goals. Another emerging trend is the proliferation of self-generation of electricity, driven by unreliability of grid electricity, high grid power prices, and increasing affordability and accessibility of solar panels (*e.g.* in Pakistan, African countries and some European markets). For example, due to sharp increases in power and fuel prices in Pakistan in 2023, households nationwide have turned to self-production of power through solar PV. Solar accounted for more than 14% of Pakistan's power supply in 2024, up from 4% in 2021 and has now displaced coal as the third-largest energy source (Shahid *et al.*, 2025).

Although most rooftop solar owners stay connected to the grid, rapidly increasing self-generation – especially by large consumers in industry – can strain utility revenues because of a shift of costs. Given the low cost of solar PV panels, self-production can, in some cases, be beneficial to consumers, who can lock in low-cost electricity and reduce their exposure to rising grid electricity charges. While self-producers can save more on their energy bills, reduced overall demand for grid electricity may lead utilities to raise rates on all customers to make up for the shortfall, because expenses such as fuel contracts and upgrades to transmission infrastructure would remain fixed. Cost shifts could disproportionately affect consumers who still largely rely on grid electricity. More often than not, these are less affluent households that are not able to procure their own self-generation assets, as evidenced in Pakistan. For the 2023–2024 fiscal year, fixed costs of USD 2.3 billion were shifted to non-solar consumers, which means they paid 6.3% more per kilowatt-hour than they otherwise would have (Shahid *et al.*, 2025).

National energy regulators and ministries must therefore work towards providing more reliable electricity systems and affordable tariffs to ensure customers relying on power from the grid are not disproportionately burdened.

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Carbon pricing and trading mechanisms

At least 83 jurisdictions (countries and sub-national jurisdictions) had carbon pricing policies in force as of August 2025 (either a carbon tax or an emissions trading scheme) (World Bank, 2025). Between January 2024 and August 2025, seven jurisdictions began implementation of carbon taxes – two at the national level (Thailand, Israel), as well as sub-national entities – within Mexico (Colima, Durango, Mexico City, Morelos and San Luis Potosi), among others. An additional fifteen jurisdictions are exploring carbon taxes; *i.e.* either announced or under consideration (IEA, n.d.; World Bank, 2024b).

While no new emissions trading schemes (ETS) have been enforced since 2024, ETS remain on the agenda in at least 25 jurisdictions considering adoption to date. This includes the European Union's ETS2, which builds on the first ETS and will cover upstream emissions producers (fuel suppliers) instead of consumers (households or car users). Carbon prices set by ETS[26] globally range from less than USD 1/tonne (t) of CO_2 or CO_2 equivalent (*e.g.* Indonesia, Kazakhstan, Saitama-Japan) to USD 70/t CO_2 (EU ETS) as of 2024 (World Bank, 2025).

As of 2025, national carbon tax rates ranged from less than USD 1/t CO_2 (Ukraine and Poland) to USD 159/t CO_2 or CO_2 equivalent in Uruguay, followed by Switzerland and Liechtenstein at USD 136/t CO_2 (World Bank, 2025). While the progress on carbon pricing policies is promising, many of these policies cover either only a small share of national emissions, or just one end-use sector — usually either industry, transport (including aviation) or agriculture (REN21, 2025b). Total revenue from carbon pricing and emissions trading schemes was USD 102 billion in 2024; as a result, the effective price on global energy sector CO_2 emissions[27] was in the region of USD 2.7/t.

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26 Carbon prices from ETS are determined based on market dynamics, even if the government designed the cap/allowance system. This differs from national carbon tax rates, which are set administratively by governments.

27 Global CO_2 emissions are estimated at 37.4 billion tonnes for 2024 (Global Carbon Project, 2024).

Article 6.2 of the Paris Agreement, which concerns international agreements for the direct trade of internationally transferred mitigation outcomes (ITMOs), has been operational since 2021. Since then, 98 bilateral agreements have been signed across 60 countries, 27 of which had been finalised between January 2024 and August 2025 (UNEP, 2025). The operationalisation of these markets may be highly relevant for renewable energy project owners and developing countries seeking access to new sources of financing. Financial additionality[28] needs to be ensured, especially when developing renewable energy projects under Article 6. It is noteworthy that an increasing number of countries are developing their national frameworks on Article 6 with lists of eligible project activities to ensure alignment with national priorities, additionality and environmental integrity.

In January 2024, Thailand made the first official ITMO sale, with Energy Absolute Public Co. Ltd. selling 1 916 ITMOs to Switzerland's KliK Foundation under the Bangkok E-Bus Programme. This was followed by another ITMO transaction in July 2025 between the KliK Foundation and ACT Group for the Transformative Cookstove Activity in Rural Ghana, which will make available improved cookstoves to members of Ghana's agricultural sector at a below-cost price. These will count toward Switzerland's NDC (Gupte, 2024; Klik.ch, 2025).

The implementation of Article 6.4 (the Paris Agreement Crediting Mechanism or PACM, UNFCCC's carbon crediting mechanism), although not complete, is progressing steadily. A total of 1 066 projects had been submitted as notifications of prior consideration to the UNFCCC as of August 2025, seeking participation under the PACM. The majority of notified project activities are energy transition ones, such as solar energy, clean cooking, bioenergy, wind energy, electric vehicles (UNEP, 2025).

Renewable energy project developers, working on either large-scale or distributed projects, can access additional revenues through renewable energy certificate (REC) markets. One REC documents the attributes of one MWh of renewable-based power – independently from the physical electricity – including its environmental, social and non-power attributes. RECs come in several forms at the national and international levels, including distributed RECs (D-RECs), peace RECs (P-RECs), and international RECs (I-RECs). For the year 2024, over 290 million I-RECs were issued for renewable power generated (largely from solar, wind, and hydroelectric power generation) and over 233 million I-RECs were redeemed, of which a substantial amount came from by China, Brazil and Türkiye (International Tracking Standard Foundation, 2025).

28 Financial additionality refers to the principle that public investments should only be committed in the absence of funding from the private sector owing to perceptions of risk.

Permitting and environmental considerations

In order to achieve the UAE Consensus energy goals, it is necessary to streamline permitting processes for renewable energy and grid expansion projects. Lengthy processes, administrative complexities and delays remain an issue. In Europe, while the Renewable Energy Directive mandates that the permit granting process should not exceed two years, in some member states the process for large projects can take up to nine years (European Commission, 2023). Globally, renewable energy project commissioning timelines are increasing (Gumber *et al.*, 2024).

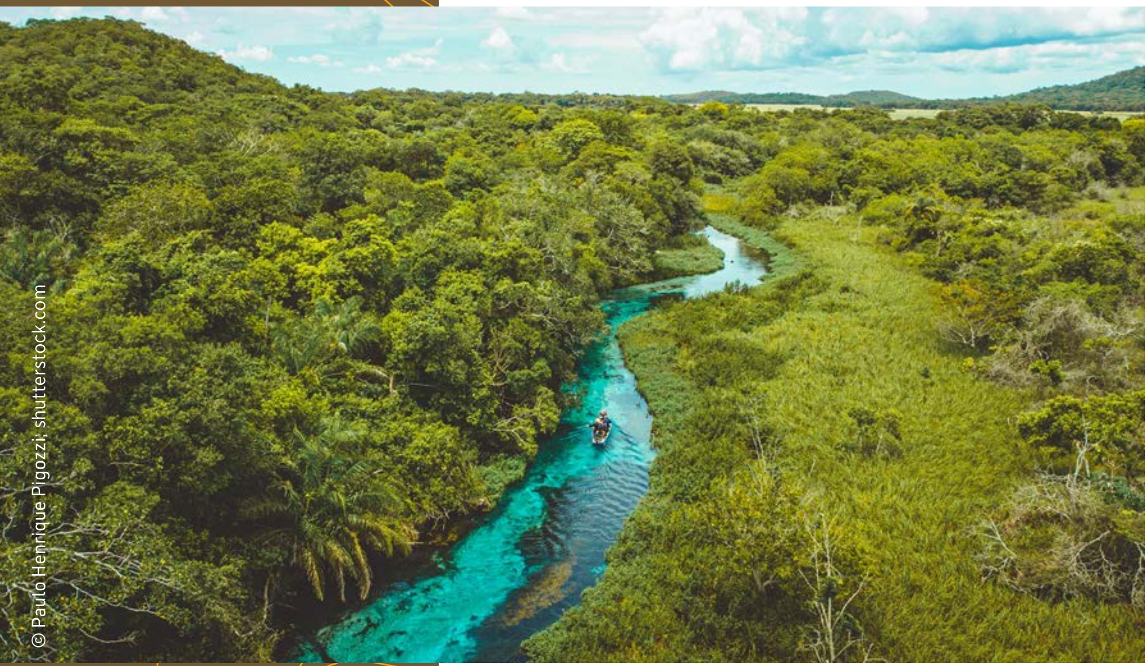
Renewable energy and grid infrastructure permitting should consider potential impacts, both locally and worldwide, on biodiversity and communities, and accelerate development where negative effects are limited. For instance, the European Union directed member states to map Renewables Acceleration Areas (RAAs) where development will have limited negative impacts on the environment and benefit from streamlined permitting and Grids Acceleration Areas (GAAs) for transmission infrastructure that will support renewable energy designated for the RAAs. These directives are also intended to speed up permitting for renewable energy and grid infrastructure.

Multiple countries have implemented measures to encourage rooftop solar installations on public, commercial and residential buildings, albeit at higher cost than ground-mount projects. Policies and regulations that support renewable energy integration on agricultural land enable simultaneous production of food and energy. For instance, in 2024, Italy, Morocco and Portugal launched subsidy schemes supporting agrivoltaics and solar pumping kits (REN21, 2025b). In many countries, degraded land is a prime candidate for renewable power generation sites, although it may require greater grid expansion. With proper community consultation and benefit-sharing mechanisms, such developments can also boost local incomes and the economy.

Solutions are available to identify, assess, avoid, minimise and mitigate the potential impacts of renewables on the local environment. Sustainable design of renewable products and project planning, taking into consideration environmental impacts, can avoid most negative effects from the outset. Digital-based platforms and mapping tools can assist in identifying optimal project sites and assessing possible conflicts. Adopting circular economy-based measures can ensure sustainable end-of-life management of renewable technologies and generate secondary raw materials, addressing both environmental challenges associated with mining activities and waste treatment.

Solar, wind and other renewable energy projects also bring benefits to the local environment and biodiversity. Solar PV can have co-benefits with agriculture, water conservation and nature restoration, especially when deployed on degraded land. Offshore wind can also have co-benefits with nature conservation, including the artificial reef effect and preventing seabed erosion through scour protection. Floating solar PV projects can have similar co-benefits to the water ecosystem.

Social acceptance is key to avoid opposition and resistance to renewable energy projects, which can hinder and delay deployment. A study conducted in eight states in the United States found that currently barriers to renewable energy deployment have shifted from techno-economic to institutional and social at regional, state and local levels (Energy Environmental Economics, 2024). Public support can be built through a variety of mechanisms, all of which depend on perceived fairness, trust, and alignment with local values. These include inclusive decision making, such as the provision of adequate information, consultation, Free, Prior and Informed Consent (FPIC). A number of countries, such as Sierra Leone, Bolivia (Plurinational State of) and Philippines, have FPIC in legislation. Benefit sharing schemes also play a role, such as community funds, local employment and training opportunities, or community ownership. Such approaches enable communities to participate in decision making and share in the benefits of local projects strengthening procedural and distributional justice which is the foundation for social acceptance.



INFRASTRUCTURE AND SYSTEM OPERATION

To meet growing electricity demand, electricity generation will need to increase by 36% by 2030, and to triple by 2050, compared to 2023 levels (IRENA, 2024a). Population increase, economic activity, electrification and rapid data centre demand growth in some jurisdictions are powering this demand growth. Meeting this demand with renewable power remains the most efficient and sustainable option (Duarte and Fan, 2023). At the same time, over 665 million people around the world still lack access to electricity (IEA *et al.*, 2025) and renewables can help reduce this number.

In this context, the institutional and regulatory frameworks, as well as the physical infrastructure of power systems, are expanding and adapting, albeit, in some cases, lagging the growth in renewable power generation. This section examines some of the key priority areas for the delivery of the tripling goal in terms of energy sector infrastructure and power system operation.

Electricity grids

Although grids are the backbone of the electricity system and crucial for ensuring low-cost renewable power can reach load centres, investment in grids has fallen behind the expansion of renewable capacity. The surge in renewable deployment since 2022, when the fossil fuel price spike underlined the compelling competitiveness of renewable power and its essential role in boosting energy security and reducing consumer electricity bills, further highlighted this situation.[29]

The accelerated build-out of renewable power capacity, driven by market dynamics, is placing increasing pressure on power grids, which are still adapting to changing system needs. Interconnection wait times have spiked in some markets where grid planning has not taken into account the tripling goal. Grid constraints have also become more impactful, with technical curtailment growing.[30]

29 Average annual growth for investments in renewable energy generation far outpaces grids (16% vs. 6%) over the 2021–2024 period (IRENA & CPI, Forthcoming).

30 Curtailment refers to the amount of energy that could be produced from renewable sources but must be intentionally left unutilised because it cannot be stored or delivered to the demand location. Curtailments can be economic or technical. Economic curtailment is the intentional reduction of output by the producer or system operator for economic or market-based reasons; technical curtailment occurs when renewable energy generation is reduced due to physical or operational limitations in the power system. Major causes of technical curtailment are system imbalances and grid constraints.

Meeting the tripling target and the Paris Agreement goals will require a significant and rapid increase in investments in grid reinforcement, extension and resiliency, not to mention addressing the historical under-investment in grids in some jurisdictions. This will enable the connection of the required new generation capacity, ensure that this capacity is used efficiently, and thereby maintain incentives for further investment.

The Global Energy Storage and Grids Pledge issued at COP29 in Baku calls for efforts to double investment in grids by 2030, and to add or upgrade over 25 million kilometres of transmission and distribution lines (COP29, 2024). Investment in transmission and distribution grids reached USD 359 billion[31] in 2024 (IEA, 2025c; IRENA and CPI, Forthcoming).

Grid reinforcement and expansion, as well as greater system flexibility, will help to limit excessive curtailment, ensuring renewable energy is integrated more efficiently. In 2020, wind curtailment in the United Kingdom was around 3.4 TWh, but this had increased to 8.1 TWh in 2024 (Hawkes, n.d.). While in many markets curtailment of solar and wind power remains low (typically under 3% of their generation), in isolated markets or those supplying large geographic areas with low population density, grid constraints can be more impactful resulting in significant and growing curtailment (IRENA, 2024c). For instance, in Chile, solar and wind accounted for 13% of electricity generation in 2019 and curtailment was under 2%, but in 2024 with solar and wind contributing 41% of total electricity generation, grid constraints saw curtailment for solar rise to 17% of its production and 12% for wind (Coordinador Eléctrico Nacional, n.d.; Ember, n.d.).

Grid connection wait times are also growing, due to limited grid capacities. In the United States alone, solar and wind projects in the grid connection queue totalled 671 GW in 2020, but this had increased to 1 227 GW in 2024. Furthermore, the time between initial connection request and commercial operation has increased from under two years for projects that became operational in the period 2000–2007, to more than four years for those built in 2018–2023 (Rand *et al.*, 2024).

31 Investment in transmission and distribution electricity networks, smart meters and, excluding investment in public EV charging stations.

Beyond supporting renewable energy integration, investments in grid infrastructure are increasingly economical, making it possible to utilise the lowest-cost resources to supply the electricity demand. For instance, in the United Kingdom, the additional investment costs 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 by that time (Sani, 2023).

Analysis has underscored misalignment between needs for generation increase and grid planning to meet the tripling goals. In 2024, in 11 out of 14 European countries examined, the transmission expansion plans from the Transmission System Operators (TSO) were likely to underestimate the level of renewable power expected in 2030 (Cremona and Rosslowe, 2024). A successful energy transition requires an integrated energy planning approach, considering renewable deployment targets and all available options for grid and flexibility enabling infrastructure, balancing investments and operational costs while guaranteeing security of supply.

To meet 2030 goals, plans for grids and flexibility infrastructure should identify and prioritise solutions, according to the characteristics of each system, that can be implemented in the short-term but fit with longer-term visions. In the short term, deploying grid enhancement technologies,[32] supported by digitalisation, can help address immediate bottlenecks, while accelerated investment in grid expansion and resiliency will ensure that new renewable capacity can be effectively connected and utilised in the longer term.

32 For example: dynamic line rating (DLR) to let power lines carry more electricity when the weather allows, instead of always limiting them to a fixed, conservative level; power flow controller (PFC) devices to redirect power flows and relieve congestion; battery energy storage (BES) to manage the amount of power flowing through the network, *etc.*

Flexibility

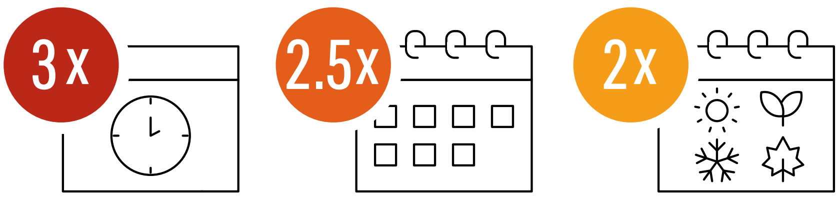
Power systems require both flexibility and grid infrastructure for reliability and cost efficiency. While grid infrastructure enables the connection and effective use of new renewable capacity, flexibility ensures reliable and efficient system operation. A flexible power system efficiently responds to the continuous variation of supply and demand to maintain the balance required for reliable electricity.

Flexibility is needed over different time scales, in the range of seconds to minutes. It is needed to maintain the balance during sudden changes in demand or supply, like the disconnection of an interconnector or a major load or generator. In the time scale of hours and days, flexibility is needed to efficiently balance daily ups and downs of solar and wind generations as well peaks and lows through the day in the demand. In timeframes of weeks or seasons, flexibility is needed to cover longer weather patterns like season changes or low-wind periods.

According to the 1.5°C Scenario, as the share of solar and wind in total generation accelerates by 2030, at a global level the power sector will require around three times more flexibility than in 2019 to efficiently manage daily variability of demand and of solar and wind generation. On a weekly time scale, the flexibility required by the power system in 2030 would need to be approximately 2.5 times higher than at the end of the last decade. On a monthly time scale, to manage the seasonal variability of both demand and variable renewable energy generation, flexibility needs would be approximately twice that of 2019. By 2050 under IRENA's 1.5°C Scenario, flexibility needs would be 3.5, 2.5 and 2.5 times higher than in 2030 for the daily, weekly and monthly timescales, respectively.

QUICKFACT

POWER SYSTEM FLEXIBILITY NEEDS
BY 2030 COMPARED TO 2019:



daily flexibility | **weekly flexibility** | **seasonal flexibility**

Until recently, the bulk of flexibility needs have been provided by available dispatchable power plants that can adjust their output on demand, with some plants only being used for as little as few hundred hours per year, or less. In recent years, however, there has been a surge in the use of battery storage to provide flexibility, from Texas to China, and this trend is accelerating. Also, in India, for example, hybrid solar and wind systems with batteries have been established to increase the availability of power when needed (REN21, 2025c).

In the future, the increasing need for flexibility over different time scales is expected to be met using a portfolio of dispatchable renewable generation, storage solutions (both short- and long-duration), active demand participation, sector coupling and interconnections. In EMDEs that are experiencing continuous strong demand growth, systemic planning of flexibility and grid infrastructure – aligned with renewable targets for the power sector – offers opportunities to build cleaner, cheaper, more resilient and secure power systems while efficiently benefiting from new flexibility solutions.

In power markets, the increasing occurrence of negative prices, driven by inflexible power plants during periods of solar and wind power abundance, is a signal for the need for more flexibility. For instance in Germany in 2023 negative wholesale prices were recorded in 301 out of 8 760 hours, while in 2024, 457 out of 8 784 hours were recorded (Bundesnetzagentur, 2025). In markets where revenue certainty is not part of the policy mix (*e.g.* contracts for difference), this situation can reduce investment incentives for renewable power.

The key role and the costs required to implement flexibility solutions to enable a secure and affordable energy transition are increasingly recognised by policy makers and industry. Leading countries are taking steps to move forward. As presented in the first section of this report, 2024 was a record year for installation of battery storage. Pumped hydro storage – a long duration solution – also saw considerable growth.

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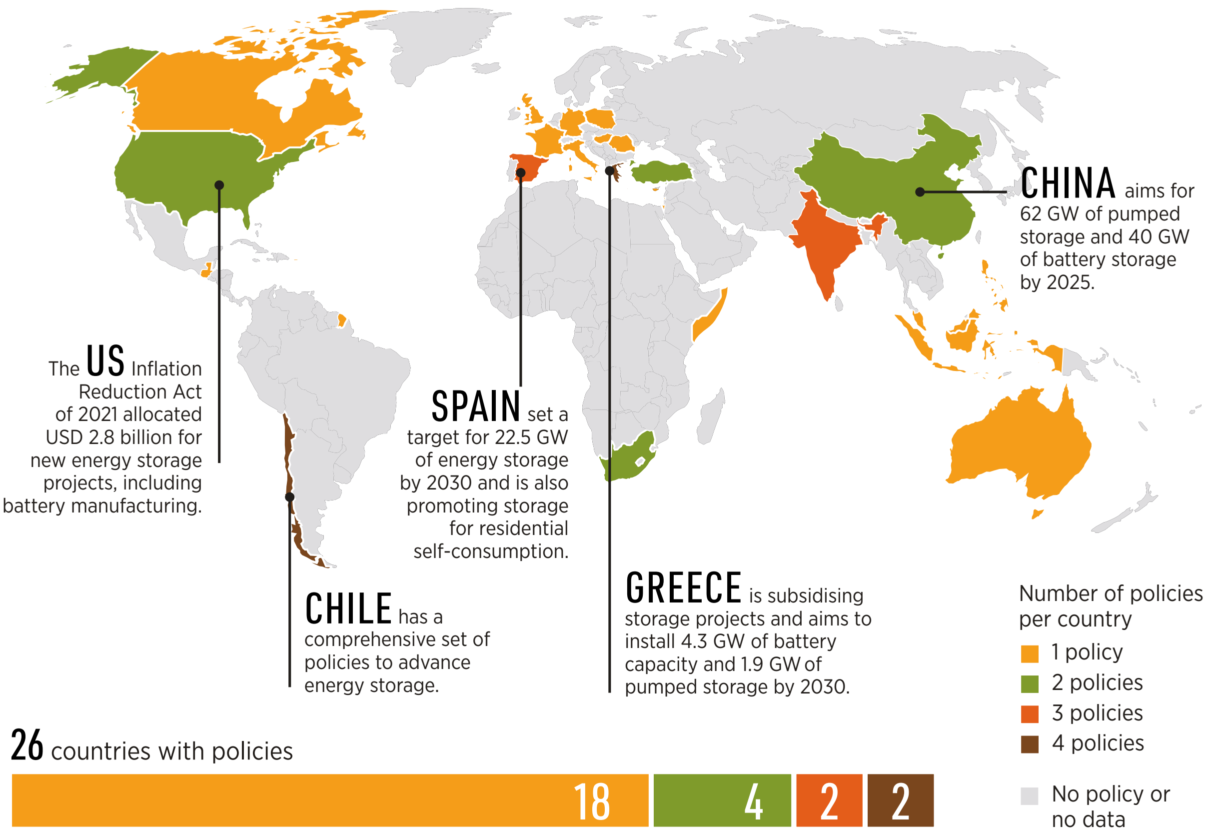
BOX 3 Targets, regulations and financial incentives for energy storage

By the end of 2024, at least 26 countries had announced or enacted national policies to support energy storage, a slight increase from the previous year. While about half of these countries have set storage targets, fiscal and financial incentives remained the predominant policy approach. Most policies focused on battery storage, offering incentives to expand capacity to support grid operation and promote domestic battery manufacturing. These incentives targeted both utility-scale and residential battery storage development. Some policies – such as in the Dominican Republic – specifically mandated new installed solar or wind capacity to be coupled with battery storage. Also, six countries had specific policies addressing pumped storage in 2024. Interest in long-duration energy storage technologies has grown, with early 2025 seeing new support mechanisms introduced in the United Kingdom and New South Wales, Australia, reflecting a broader recognition of diverse storage needs to complement renewable energy systems.

FIGURE 15 Energy storage targets, regulations and incentives in 2024



Source: (REN21, 2025a).

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

An important landmark for the alignment of decarbonisation targets with the most suitable combination of flexibility measures was the adoption by the EU regulator ACER on July 2025 (ACER, 2025) of a Flexibility Needs Assessment Methodology. Following the approved methodology, EU member countries will need to conduct national assessments to identify the uncovered flexibility that they require to align power system infrastructure with their renewable energy goals. Using the results of the assessments, countries will define in 2027 indicative national targets and promote the deployment of flexibility solutions that do not rely on fossil fuels (ACER, n.d.).

Another notable milestone in 2025 is the implementation in the United Kingdom of a cap and floor mechanism to support investment in long duration electricity storage projects. The implementation of the mechanisms is backed by techno-economic studies demonstrating the savings and the need of having long duration storage to achieve decarbonisation of the power sector by 2050 and the savings associated to it (UK Government, 2024).

Hard-to-abate sectors

Heavy industries (such as steel, cement and chemicals) and transport (aviation, shipping and heavy road transport) remain reliant on fossil fuels. Decarbonising these sectors is essential to achieving global climate goals, but it requires innovative technological solutions, policy support and significant investment to deploy alternatives such as electrification, clean hydrogen and biofuels.

Under IRENA's 1.5°C Scenario, the share of direct use of electricity[33] in hard-to-abate sectors needs to increase from 12% in 2023 to around 14% by 2030. The share of clean hydrogen and its derivatives, and that of biofuels in total consumption,[34] must significantly increase from negligeable levels in 2023 (less than 1% for clean hydrogen and derivatives, and just under 2% for bioenergy) to around 9% each by 2030.[35] Green hydrogen accounts for 40% of the share of clean hydrogen by 2030 in the Scenario. However, in the long term, it would replace blue hydrogen, which is considered an interim solution under the IRENA 1.5°C Scenario (IRENA, 2024a).

33 This share does not include non-energy use.

34 The shares of bioenergy, and clean hydrogen and derivatives use include both energy and non-energy use.

35 The hydrogen analysis is being updated in the upcoming *World energy transition outlook*, and this share is most likely to decrease.

The decarbonisation of hard-to-abate sectors relies not only on the technological readiness, but also heavily on the necessary enabling infrastructure being built, notably:

- the expansion and modernisation of power grids to enable the electrification of end-uses;
- the development of hydrogen networks to supply low-carbon hydrogen to industries;
- transport and storage of CO_2 for carbon management; and
- charging stations for electric trucks, and bunkering of low-carbon fuels at ports and airports.

The technological pathways for achieving net-zero emissions primarily rely on a combination of renewable energy sources and energy efficiency measures. Apart from large-scale physical infrastructure, digital infrastructure must also be adopted and integrated to improve efficiency and facilitate transition to low-carbon production processes (IRENA, 2025e).

Some selected infrastructure developments in 2024 include the approval of the North Coast Transmission Line high-voltage electricity transmission project in Canada, which aims to support the growing need for electricity, including for ports. The first phase includes building a 170-kilometre 500 kilovolt (kV) transmission line between the Williston and Glenannan substations to support port activity. In Europe, to accelerate the development of hydrogen infrastructure, the European Council adopted the Hydrogen and Decarbonised Gas Markets Decarbonisation Package. Also, the Porthos CO_2 transport and storage project received a final investment decision and is expected to be operational by 2026. Under the project, CO_2 captured from several industries will be transported and stored in empty gas fields beneath the North Sea.

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Infrastructure for electric vehicles


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EV infrastructure, including chargers and the smart charging system, remains a key enabler for promoting the deployment of electrification process and increase the share of renewables in the power system. Currently, charging infrastructures remains the major bottleneck for promoting renewables consumption in the road transport sector, which is still less than 1% of the total energy consumption in this sector. In the meantime, improving the energy efficiency of road transport will rely largely on electrification of the sector. Due to the much higher energy conversion efficiency of EV drivetrains compared to internal combustion engine (ICE) drivetrains, EVs can be 4.4 times more energy efficient than petrol ICE vehicles. Therefore, the share of EVs in the total driven distance of road transport can be much higher than the share in energy consumption. In meeting future road transport needs, EVs can deliver considerable energy savings and greenhouse gas (GHG) emissions reductions, even in some markets where fossil-fuels dominate power grids.

Under the backdrop of global efforts to triple renewable power capacity by 2030, countries and cities will need to consider key policy measures that can play a role in enabling the rapid uptake of EVs, especially those that promote charger network growth to match EV growth ambitions. These policy priorities would need to send clear and consistent signals to investors and market players through the adoption of ambitious targets for high shares of EV sales and charger network growth, and by promoting pre-cabling and integrated planning for improved readiness. In 2024, New Zealand announced a national target to deploy 10 000 public charging points by 2030 to address public concerns on "range anxiety" (MoT, 2024). In 2025, China announced a new target to deploy 100 000 fast chargers (which have minimum 250 kW capacity and can fully charge an average EV in 10–20 minutes) in major cities and on highways by 2027 (Xinhua Net, 2025).

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Deployment of EVs must be combined with renewable electricity to access their full decarbonisation potential. In most cases, EV chargers are connected to power grids, and EV owners/operators usually do not have any influence on the source of the electricity used for recharging. However, using renewable electricity for EV charging has become more convenient and affordable. This can be achieved by combining rooftop solar PV with home chargers, fleet or public charging stations, as well as smart charging solutions, while the growth in 24/7 hourly renewable power matching contracts can also play a role.

There is an increasing economic incentive for EV asset owners to use renewable power. A study of German EV owners suggests that the combination with rooftop solar PV systems can reduce the cost of electricity used for charging by 34% (Von Bonin *et al.*, 2022). Another analysis in Yinchuan City (China), where around 1 810 electric buses are in operation, indicates that combining solar PV with battery storage and electric bus depot charging can reduce the costs by 37% within 10 years (taking into account solar rooftop installation costs), compared to direct charging from grids (Ma *et al.*, 2025). In Switzerland, residential solar rooftops using an optimised charging strategy and intelligent control can meet up to 99% (with home storage batteries) of owners' EV electricity demand (Martin *et al.*, 2022). Such combinations can be a win-win for existing EV owners, who are more likely to install solar rooftop system than people who do not own EVs.

Enabling renewable electricity for EVs and smart charging would require comprehensive policies and measures to address major barriers. Investments in smart charging systems can be large, requiring access to affordable financing options or additional financial and fiscal incentives. Co-ordination between electricity/grid utilities and EV service stakeholders can be challenging because utilities are usually on a much larger scale than EV service providers. An overall framework guided by national strategies, with the involvement of key stakeholders from the power and transport sectors, would be necessary to enable the full potential of smart charging and related benefits for a renewable energy-based power system in combination with EVs. In the European Union, the Energy Performance Building Directive was approved in 2024, requiring pre-cabling for at least 50% of parking spots in new residential buildings and those with major renovations, and all charging points to have the capacity for smart charging (Rajon Bernard, 2024).

Strategies and action plans are necessary to bring together stakeholders from the energy and transport sectors and to provide medium- and long-term signals for market players and investors. Financial incentives, including grants and subsidies, can help the deployment of smart charging projects and incentivise business expansion at an early development stage.

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Digitalisation[36]

The rapid growth of renewable energy and electrification is transforming power systems into highly complex, decentralised and variable networks. Digitalisation is no longer optional, it is the backbone for ensuring reliability, flexibility and cost-effectiveness in this new context. Traditional grid management tools are ill-equipped to cope with the variability of renewables, bi-directional flows from distributed energy resources (DERs), and the surge in electricity demand from electrification and data centres. Digital technologies – such as sensors, smart meters, AI-driven forecasting, and automation – enable real-time visibility, predictive capabilities and optimised operations, making them indispensable for maintaining energy security and affordability. The immediate benefits of digital solutions include:

- Cost reduction for end-users: smart charging of EVs and adaptive demand management can cut electricity bills by up to 25% by shifting consumption to low-price periods and leveraging flexibility markets.
- Security of supply: predictive maintenance reduces outages by anticipating failures, while automated fault detection and restoration (FLISR) can restore service within seconds, improving reliability metrics and reducing operational costs.
- Higher renewable integration: AI-enhanced forecasting of wind and solar generation minimises curtailment and reserve requirements, enabling higher penetration of renewables without compromising stability.
- Customer added value: digital platforms and granular renewable energy certificates provide transparency and empower consumers to make informed, sustainable choices.
- Business performance: advanced control centres and diverse automations reduce operational expenditures for companies in the electricity value chain, leading to efficiencies that unlock resources to focus in accelerating the energy transition.

36 This section draws on IRENA's forthcoming work on digital solutions for the energy transition (IRENA, Forthcoming [e]).

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These benefits are already proven through real-world deployments, with examples such as Energinet's AI-based operational reserve procurement in Denmark (saving an estimated USD 9 million annually) and other utilities reporting returns on investment of up to ten times from implemented automations for fault handling.

Despite clear advantages, adoption faces barriers: high upfront costs, regulatory uncertainty, data interoperability issues and cybersecurity concerns, which drive stakeholders' hesitation on near-term feasibility. Demonstrating tangible benefits – cost savings, improved reliability and enhanced consumer experience – is critical to build trust, attract investment and accelerate deployment. Quantifying value for different stakeholders (utilities, consumers, regulators) and showcasing successful use cases can turn digitalisation from a perceived risk into a strategic opportunity (IRENA, Forthcoming [e]).

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WORKFORCE SKILLS AND DIVERSITY

In the last decade, the rapid expansion of the renewable energy sector has translated into growing labour needs. According to IRENA estimates, the global renewable energy workforce reached 16.2 million people in 2023, an 18% increase over the previous year. Projections indicate that renewables could continue to grow at an accelerated pace in the coming years, partially offsetting job losses in the stagnating and declining traditional energy sector. Under the 1.5°C Scenario, IRENA estimates that renewable energy jobs could rise to around 30 million by 2030 and approach 40 million by 2050 (IRENA, 2024a).

Opportunities span the entire value chain. From planning and materials procurement to manufacturing, installation, operations, maintenance and recycling, jobs are being created across many trades and skill profiles (IRENA, 2025f). These opportunities extend into related industries such as energy efficiency (projected to reach 50 million jobs by 2030) and grid flexibility (nearly 27 million jobs) (IRENA, 2024a). However, educational establishments and labour markets are under growing pressure to match the growing demand for skills.

The rapid growth of, and ambitious commitments to, renewable energy are exposing a critical skills gap, with employers reporting increasing difficulty finding experts to fill key vacancies – especially in technical trades such as installation and repair, but also in fast-evolving fields like digitalisation and artificial intelligence in energy systems. Initiatives such as the Global Solar Council's Solar Training Standard Initiative (STSI) can help provide the framework and momentum to ensure qualified personnel are available to deliver on the energy transition.

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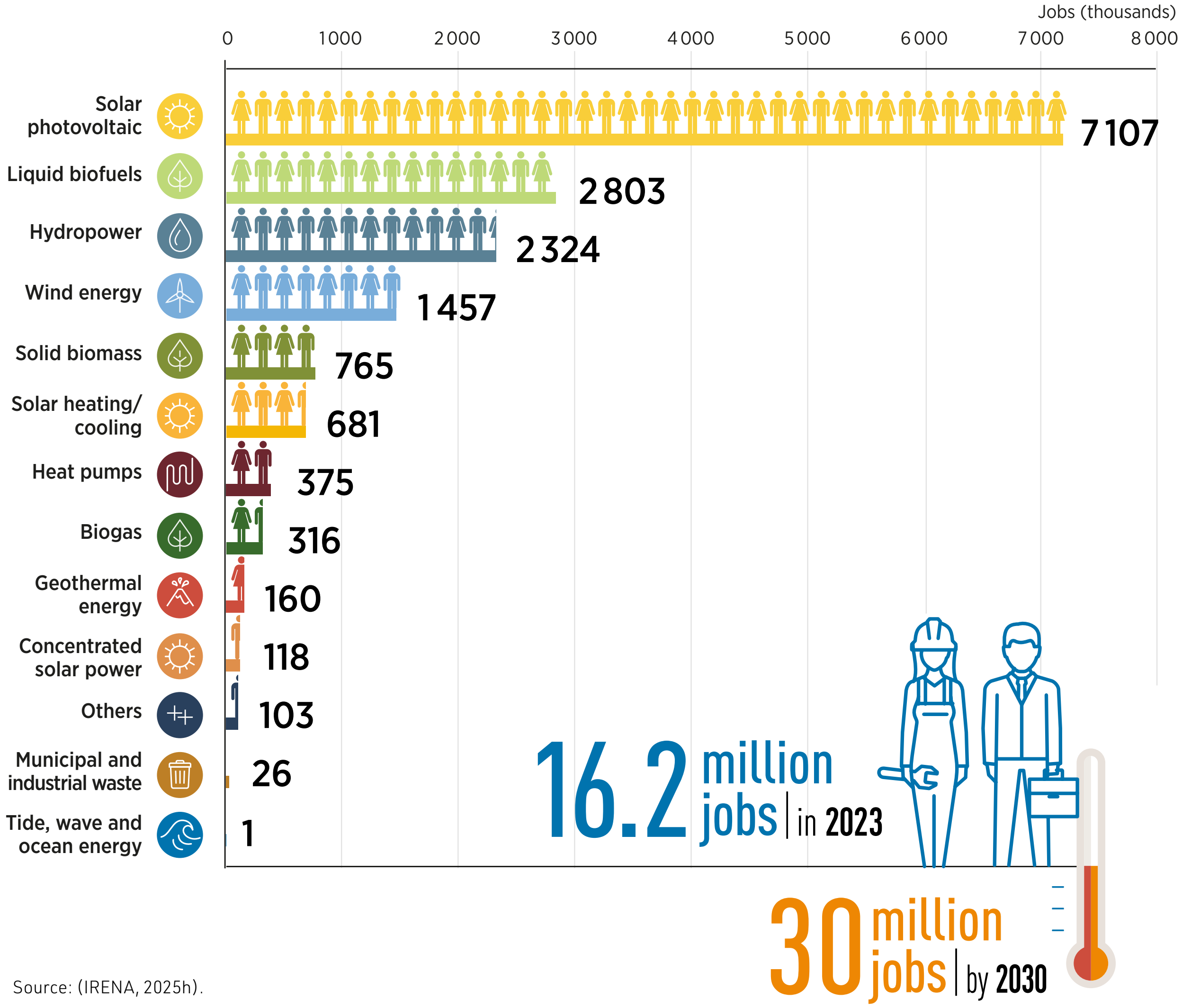
FIGURE 16 Jobs across technologies in 2023 and total projection to 2030



Source: (IRENA, 2025h).

Without proactive measures, these shortages will delay the implementation of national plans and undermine countries' climate pledges. To anticipate these issues, a long-term, multi-level approach is required, aligning vocational and university curricula with industry needs, expanding apprenticeships, and reskilling workers from the fossil fuel sectors wherever possible. IRENA's Call to Action on Skilling for the Energy Transition recognises that achieving energy transition goals while maximising socio-economic benefits and opportunities requires a collaborative effort to develop an inclusive and competent talent pool as well as upskill and reskill current workers in existing energy industries.

The Call to Action identifies the following priority actions for accelerating skill development for a sustainable energy future:

- Undertake targeted skill development to address current and emerging gaps.
- Integrate skill development within energy and climate plans and policies.
- Establish partnerships to accelerate workforce development and promote skills standards.
- Integrate renewable energy competencies into curricula.

In this context, the persistent under-representation of certain groups, particularly women, in the workforce not only reflects a challenge in terms of equity but is also a missed opportunity to expand the talent pool and minimise skills shortages. Ensuring inclusive participation from under-represented groups can help address the issue of individuals and communities being left behind (IRENA, 2025g).

IRENA's latest work in this area shows that women currently make up 32% of the global full-time renewable energy workforce. This is a higher share than in oil and gas (23%) or nuclear (24.9%), but still below the economy-wide average of 43.4% and remains at the same level as in the first study of IRENA's *gender perspective* series in 2019.

Female participation also remains unevenly distributed: women fill 45% of administrative roles and 36% of non-STEM technical jobs – a mere one point above previous IRENA estimations (IRENA, 2019) – but they still account for only 28% of STEM roles and 22% of medium-skilled jobs, such as in installation and construction. Leadership positions remain male-dominated, with women holding just 26% of middle management and 19% of senior or board roles (IRENA, 2025h).

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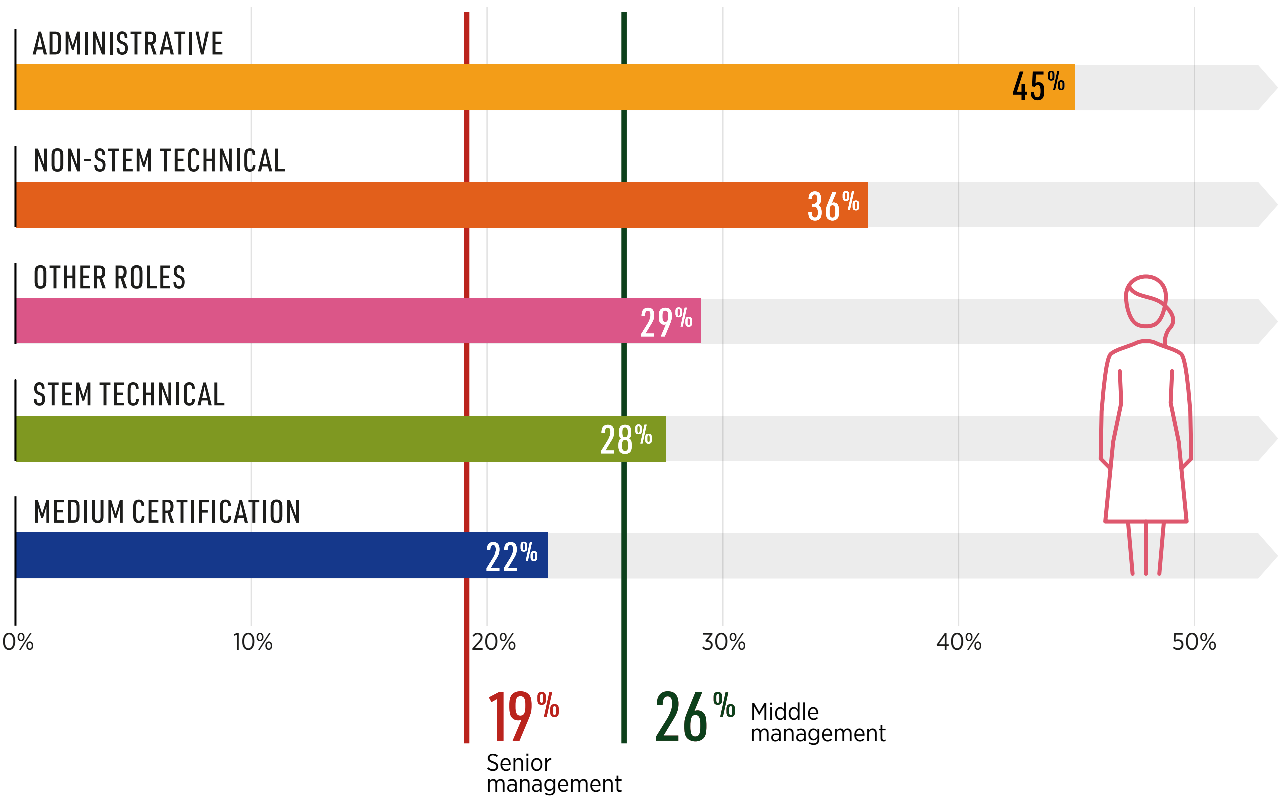
FIGURE 17 Share of women in renewable energy, by role and global average



Source: (IRENA, 2025h).

Addressing gender inequalities in the renewable energy sector requires more than technical training, it entails dismantling outdated cultural norms and transforming workplace cultures and practices. It calls for guaranteeing women's representation in leadership and technical fields, and expanding their voices in decision-making roles. Removing bias in hiring and promotion practices; targeted mentorship; and stronger networks are essential. Flexible work arrangements for women in childbearing years is also critical, but need to be carefully designed to avoid reinforcing structural inequalities that put dual (work- and family-related) responsibilities only on women (IRENA and ILO, Forthcoming).

By broadening the talent pool to include women, youth, indigenous peoples, persons with disabilities, and other marginalised communities, governments, industry and educators can ensure renewable energy not only powers the planet but also drives equitable and lasting prosperity.

MOBILISING INTERNATIONAL FINANCE

Achieving the UAE Consensus energy goals by 2030 hinges not just on ambition and sound policy, but on the availability and affordability of finance; and the strong international partnerships required to deliver it. For EMDEs, the transition depends on whether the right kind of capital can be mobilised and delivered effectively and affordably. Scaling up both public and private sector finance will be vital. Recent developments show both progress and persistent gaps, underscoring the need for scaled-up support.

At COP29, developed countries committed to mobilising at least USD 300 billion annually in climate finance by 2035, drawing from public, private, bilateral and multilateral sources (IEA *et al.*, 2025; UNCTAD, 2024; UNFCCC, 2024b). Developed countries are expected to lead, with voluntary contributions from developing countries (IISD, 2024). This marked a formal target under the new collective quantified goal (NCQG) on climate finance, replacing the non-binding USD 100 billion pledge from 2009. An aspirational goal of USD 1.3 trillion per year by 2035 was also endorsed under the NCQG (UNFCCC, 2024b), forming the basis of the *Baku to Belém Roadmap to 1.3T* – due to be decided at COP30 – that will present a roadmap for reaching the USD 1.3 trillion target (UNCTAD, 2024; UNFCCC, 2024b). These commitments signal growing ambition, but actual disbursements remain far below what is needed. Crucially, this must fund both adaptation and mitigation, with renewable energy being only one component of mitigation investment.

Facilitating the flow of finance from developed to developing nations will be critical to ensuring countries with limited resources are not left behind in the pursuit of global climate and energy goals. In 2023, international public financial flows in support of clean energy in developing countries reached USD 21.6 billion – an upward trend for the third year in a row; yet this remains far below the scale required (IEA *et al.*, 2025).

While the growing volume is a welcome trend, there are several caveats for donors to consider. First, annual flows in the last seven years have yet to match or surpass the 2016 peak of USD 28.4 billion (Figure 18).

Second, the distribution of public finance supporting renewable energy in developing countries is largely uneven, with 80% of the flows going to only 29 countries, out of a total of 183 developing countries. In LDCs, energy access deficits tend to remain high, financing costs are exorbitant, and debt-to-GDP ratios are among the highest in the world. In these contexts, international public financial flows would have the highest impact. However, they received only 3% of the total amount in 2023. Flows to LLDCs and SIDS also remain limited (IEA *et al.*, 2025).

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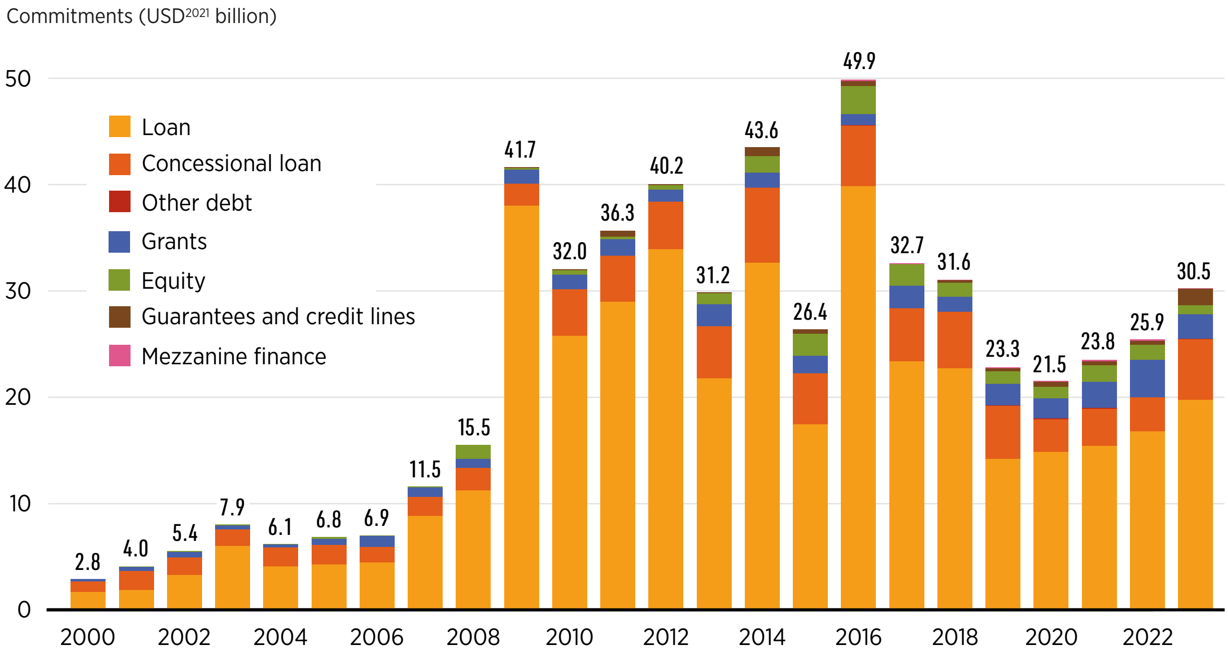
FIGURE 18 Annual international public financial flows for renewables in developing countries, 2010–2023



Source: (IRENA and OECD, 2025).

Public finance has increasingly been disbursed in the form of non-concessional debt. In 2023, debt-based instruments accounted for 83% of international public finance, up from 70% the year before. Standard loans dominated (USD 13.6 billion, 63% of the total), followed by concessional loans (USD 4 billion, 18.8%). Equity contributions remain limited, with only 12 out of 56 donors providing such support (Figure 18), despite the role equity can play in unlocking private investment (IEA *et al.*, 2025).

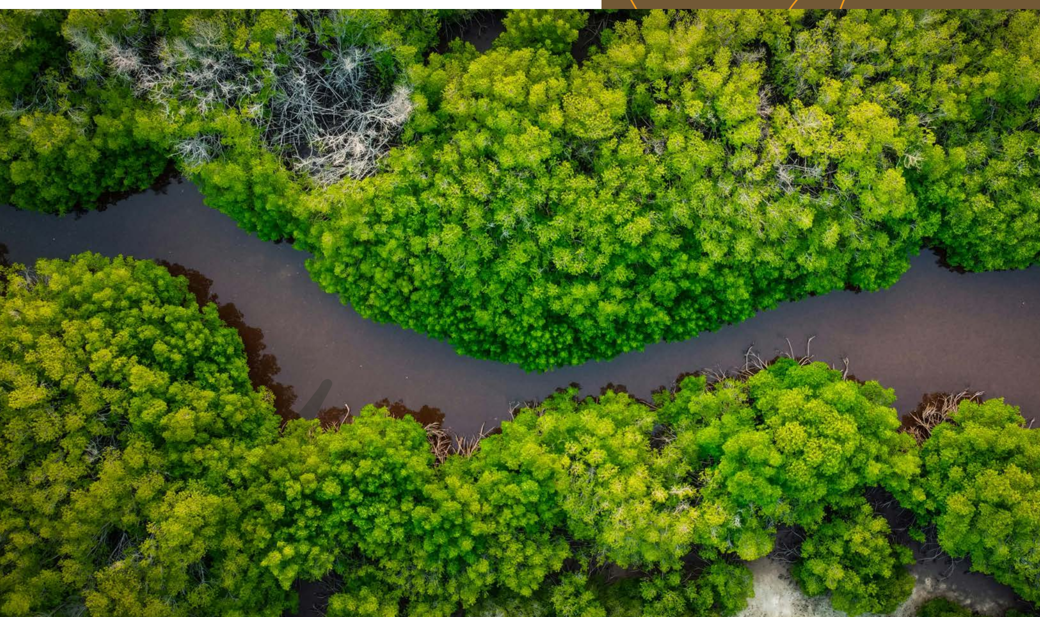
In EMDE's excluding China, equity needs for the tripling goal are estimated at c. 27% and the debt needs at c. 73% of the total investment.[37] The very low share of public financing in the form of equity or grants has a highly negative impact on the ability of developing countries to finance large project pipelines, as equity finance is disproportionately needed for the project development phase. Raising this from financial markets carries high return expectations, that flow through into costs to consumers, while also making raising debt even more difficult and expensive than it needs to be in the absence of more balanced public finance flows to equity and debt.

37 Based on GRA analysis of 36 countries and sub-regions using historical debt-equity ratios by technology and country/market.

Action is needed not just to increase the flow of public and private finance to EMDE's, but also to reduce the cost of this finance. An increase in the proportion of grant funding can help, especially in LDC's that face prohibitively high financing costs. The use of blended finance, that reduces the risk profile of the private sector proportion of the debt, can help increase private sector flows as well as reduce the required cost of finance. Similarly, the use of guarantees and insurance that help derisk projects, or the lender's position, can be used to lower the cost of capital.

The concentration of finance in mature, low-risk markets continues to leave many developing countries without affordable capital to deploy renewables at the scale required to meet the tripling goal. Ensuring financial arrangements are aligned with countries' priorities and capacities will be critical for a just and inclusive transition.

The Fourth International Conference on Financing for Development (FfD4), which took place recently in Sevilla, adopted the 'Sevilla Commitment' (the first inter-governmentally agreed financing-for-development framework since 2015) (UN, 2025) and launched the Sevilla Platform for Action (SPA) with 130 initiatives, including new mechanisms to tackle unsustainable debt (such as the Debt Swaps for Development Hub and the Debt "Pause Clause" Alliance), blended finance platforms, and foreign-exchange risk mitigation tools. These initiatives aim to reform the international financial architecture, strengthen domestic resource mobilisation, and help channel resources more effectively towards underserved markets (UN, 2025).



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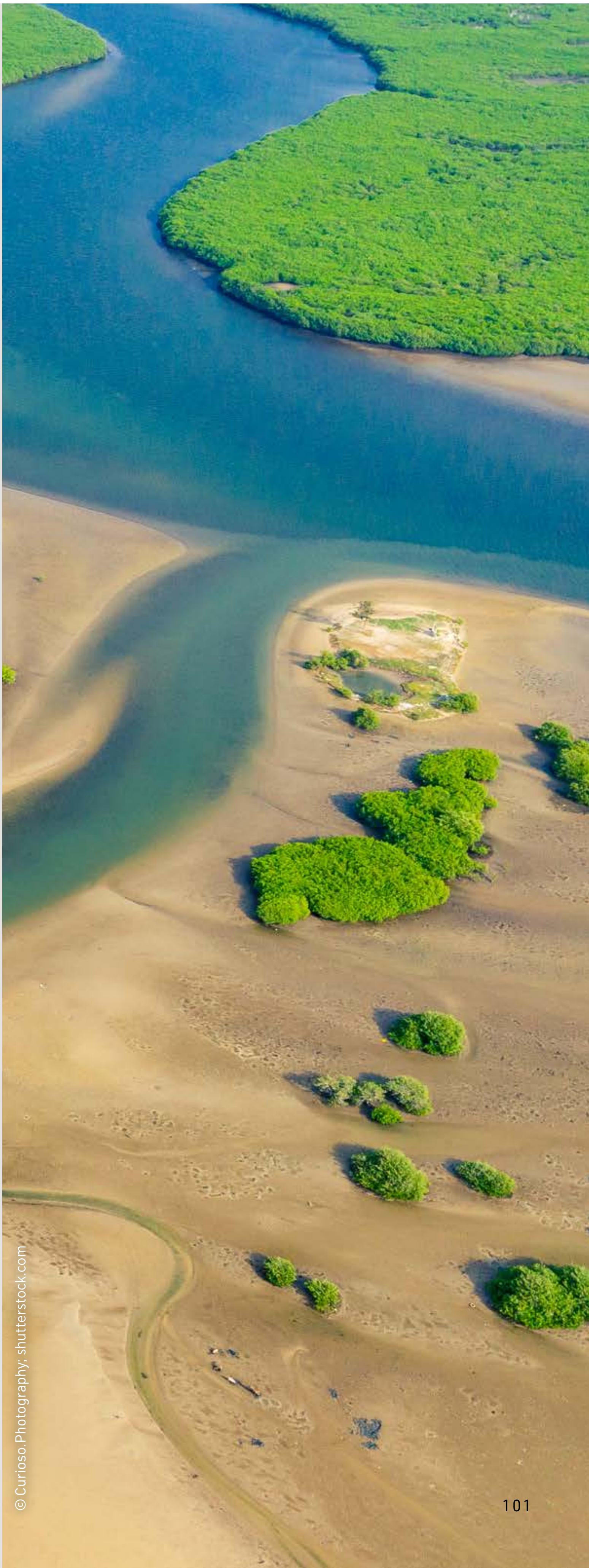

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