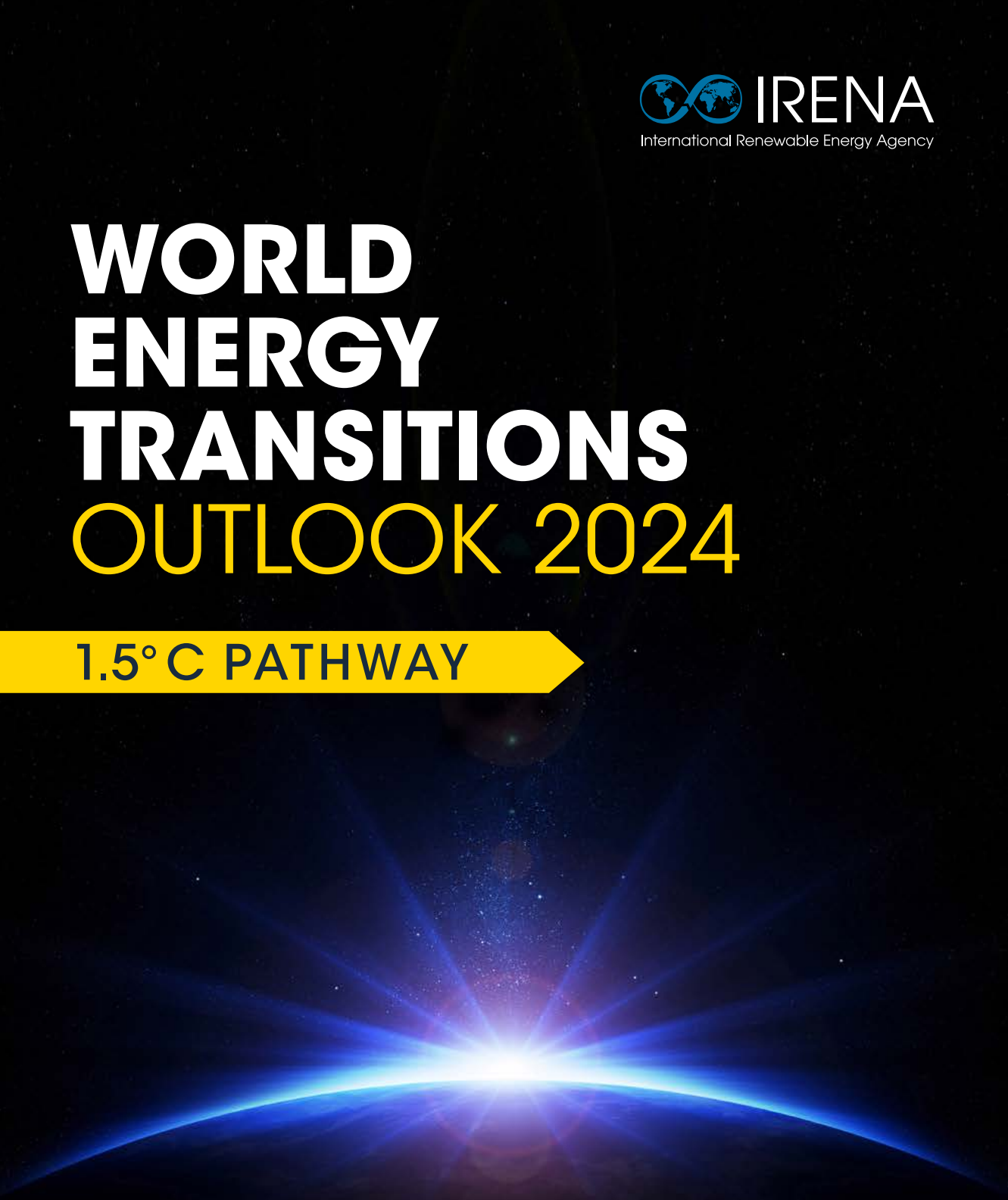
IRENA
International Renewable Energy Agency

WORLD ENERGY TRANSITIONS OUTLOOK 2024

1.5°C PATHWAY



EXECUTIVE SUMMARY

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ABOUT IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. A global intergovernmental organisation established in 2011, 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.

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EXECUTIVE SUMMARY

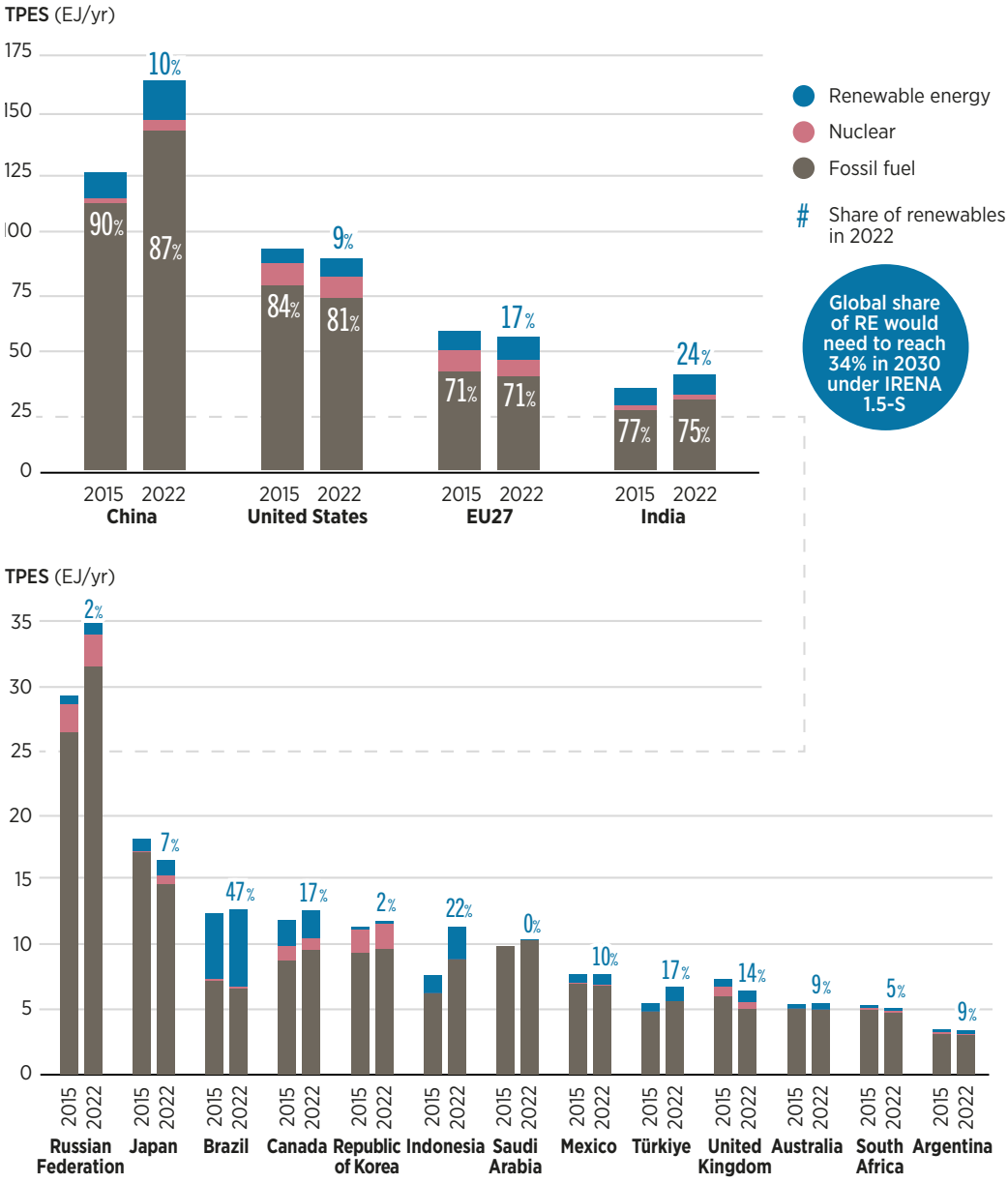
While 2023 saw record growth in renewables deployment in the power sector, progress has been geographically uneven, and lacklustre for other sectors and alternative energy carriers. To meet the 1.5°C climate target, the world must achieve net-zero carbon dioxide (CO_2) emissions by 2050, which will require a systemic transformation of the global energy system. Despite the commitments made at COP28 in Dubai in 2023, and new initiatives from the G20 and G7, the energy transition remains off track. Fossil fuels continue to dominate the energy mix in major economies – the world's largest CO_2 emitters (Figure S1) – and each year the chances of meeting the goals of the Paris Agreement become increasingly remote.

A significant gap remains between recent high-level political announcements and countries' actual plans and policies, both in terms of renewable capacity additions and investments. Current national plans and targets are set to deliver only half of the required growth in renewable power by 2030. While renewable power deployment has exceeded expectations in some countries, other aspects of the energy transition are lagging behind. Lack of progress on energy access under Sustainable Development Goal 7 (SDG7) demonstrates that more needs to be done to ensure the transition is just and inclusive. Many countries in the global South still struggle to attract investment, despite worldwide investments in renewables reaching a new record in 2023.

The New Collective Quantified Goal (NCQG) for climate finance to be agreed at COP29, and NDC 3.0 submission process in 2025, provide unique opportunities to bring the world back to a 1.5°C pathway. Agreement on a robust NCQG is important for supporting investments in the energy transition in the global South. More widespread availability of financial support will also allow countries to step up their NDC 3.0 ambitions. The world's largest emitters – the G20 countries – also need to enhance their own NDCs. These should match commitments to triple renewable power capacity and double the rate of energy efficiency improvement by 2030, as well as the longer-term ambition to decarbonise all sectors.

International collaboration is essential for bringing about a just and inclusive energy transition. Together with specific policies to direct financial resources towards social value creation, there is significant potential for increased international collaboration to improve the global welfare outcomes of the transition. The G20, as the world's largest emitters and richest countries, must therefore increase their commitments to international collaboration.

FIGURE S1 **Total primary energy supply in G20 nations, by energy type, 2015 and 2022**



Note: Historical data from (IEA, 2024); Renewables include hydro, solar, wind, bioenergy, geothermal, and marine energy; TPES = total primary energy supply; EJ = exajoule; yr = year; RE = renewable energy; 1.5-S = IRENA's 1.5°C scenario.

Tripling renewables and doubling energy efficiency: Key milestones for 2030

Tripling installed renewable power capacity and doubling the rate of energy efficiency improvement by 2030 are crucial milestones in the pursuit of the 1.5°C target. The Outcome of the First Global Stocktake at COP28 – known as the UAE Consensus – called on all Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to contribute to global efforts in this regard. Complemented by the preceding pledge by more than 130 countries at COP28 to meet these goals, the UAE Consensus provided new impetus to global efforts to mitigate climate change by accelerating the energy transition.

2023 saw record deployment of new installed renewable power capacity and the highest ever annual increase in solar photovoltaic (PV). In 2023, renewable power capacity grew by 473 gigawatts (GW) (of which 347 GW was solar PV), compared to the 298 GW of renewables (146 GW of solar PV) added in 2022. China, the European Union and the United States accounted for 85% of the additions in 2023. The leading role played by solar PV is expected to continue for the rest of the decade, thanks to its sustained cost-competitiveness, manufacturing over-capacity and flexible scalability.

Deployment must increase more rapidly to achieve the tripling target. The first edition of IRENA's annual tracking report – as custodian of the renewable energy and energy efficiency goals established in the UAE Consensus – finds that average annual additions of 1044 GW will be required to triple installed renewable capacity to 11.2 terawatt (TW) by the end of the decade – representing 16.4% compound annual growth between 2024 and 2030. Expanding renewables in regions and countries outside leading markets, and scaling up renewables other than solar PV, are two key priorities for meeting decarbonisation goals. Intensive international collaboration is needed to deliver on the 2030 target and, more importantly, to achieve net-zero emissions by 2050.

Progress in energy efficiency is also lacking. Achieving the 4% energy intensity improvement rate required to meet the doubling target will depend on sufficient energy efficiency investment and increased electrification across multiple sectors, including transport, buildings and industry. Progress on key indicators has been mixed; while electric cars accounted for a record 18% of total car sales in 2023, the sales of heat pumps – vital for decarbonising the heating sector – fell by 3%.

The world is also in danger of missing another key target in 2030 – achieving universal access to affordable, reliable sustainable and modern energy under SDG7. Around 685 million people lack access to electricity and 2.1 billion continue to cook with polluting fuels and technologies. At the current pace of progress, an estimated 660 million people in developing countries will remain without access to electricity – and 1.8 billion people without access to clean cooking – in 2030, the majority of whom live in sub-Saharan Africa. Renewables could provide a cost-effective solution to these access needs, especially in off-grid settings.

The pathway to 2050

Achieving the 1.5°C target by 2050 is both technically feasible and economically viable. IRENA's decarbonisation pathway comprises a combination of end-use sector electrification and renewable power generation, energy efficiency, direct use of renewables (including biofuels), clean hydrogen, and carbon capture and storage (CCS) – including with bioenergy (BECCS) – and other removals. It requires increased commitment, policy support, investment at scale and project development at speed.

To achieve these aims, the world must overcome structural and systemic barriers that continue to impede the progress of the energy transition. This requires, inter alia, modernising and expanding transition infrastructure, including grids; establishing regulatory frameworks and market designs fit for the age of renewables; and delivering the institutional and human resource capacities required to support the energy transition.

The emissions gap remains significant. Aligning energy planning with climate strategy development may help to close this gap. In many countries, however, energy planning processes and climate policy development should be better integrated to avoid uncertainties among stakeholders regarding policy direction and investment decisions.

By 2050, a deep transformation of the power and end-use sectors is required to enable the high shares of renewable energy required by the transition. Under IRENA's 1.5°C Scenario, 91% of global electricity supply would come from renewable energy sources by 2050. Much of this would be from variable renewable energy (VRE) sources, with solar PV and wind contributing around 70%. Electricity would account for 52% of final energy consumption by 2050. Achieving even higher shares of renewables is possible but challenging in the current technological and regulatory context.

Enabling high shares of renewables in the power system

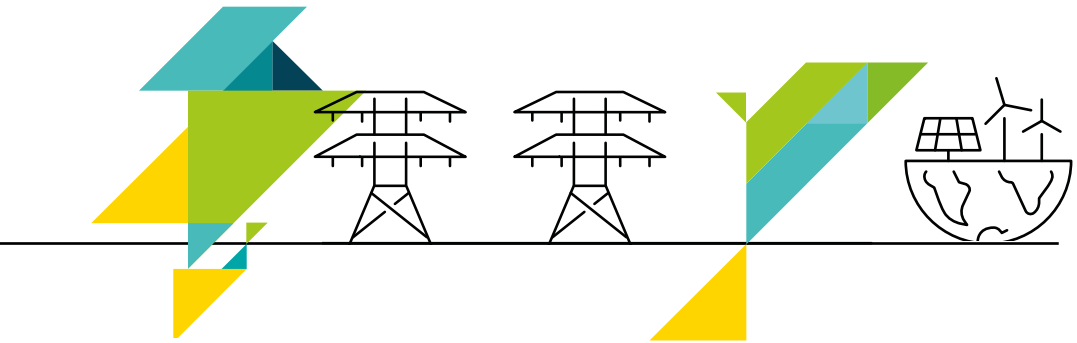
Several countries and regions have set ambitious targets to achieve 100% renewables in their power systems. Aiming for 100% renewable power, whilst also maintaining continuous and reliable energy supply, can be less challenging in power systems with abundant dispatchable renewable resources than in systems relaying on VRE. However, affordable dispatchable renewable resources are not widely available worldwide. Adding grid flexibility, particularly to the extent required for ensuring supply security in a 100% renewable energy system, can be economically costly.

Flexibility is key for enabling high shares of VRE and extensive electrification. Flexibility requires swift and carefully-planned grid infrastructure upgrades, modernisation and expansion on a significant scale. Enhanced power system operation, interconnections for cross-border trade, and various forms of storage capacity (electrical, thermal, *etc.*) are key components for increased system flexibility.

While a range of technical solutions are available to accommodate high shares of renewables, multiple barriers to their deployment must be addressed by policy makers and regulators. These include: outdated power sector regulatory structures – with marginal pricing failing to provide the right signals for investment in flexibility solutions such as storage options; higher costs compared to incumbent technologies in end-use sectors (*e.g.* heat pumps versus gas boilers or electric vehicles versus internal combustion engine vehicles, or the high and uncertain costs of green hydrogen); and lack of investor confidence due to policy uncertainty.

Policy makers must address these barriers through clear targets and strategies, implemented with specific policies, regulations and incentives. Options include: updating electricity market structures and rules to create an enabling environment for increased system flexibility; policies and incentives to help accelerate end-use electrification; and policies that incentivise indirect electrification, including through green hydrogen.

Targets for grid expansion and storage must be defined based on integrated assessments of national generation mixes and flexibility resources. General guidance ranges from 1 megawatt (MW) to 2 MW of energy storage per 10 MW of renewable power capacity added; but national contexts determine storage needs, as they must be efficiently coupled with generation structures and system capabilities. In a similar way, although reinforcement of grids is an urgent need to avoid bottlenecks in renewable flows, proactive grid expansion must be tailored to national needs. IRENA is ready to support member states from developing countries in assessing their grids, storage and flexibility needs.



Overcoming investment gaps

Renewable energy investments have followed an upward trend but remain concentrated in certain geographies – and regional disparities are on the rise. A global energy transition can only be achieved through a massive scaling up of financing covering multiple countries and regions. Global investments in renewable capacity additions reached USD 570 billion in 2023, compared to USD 448 billion in 2022, representing a 27% increase. Most of the investments were concentrated in China, the United States, Brazil, India and Germany. Indeed, in terms of investment in the energy transition as a whole, half of the world's population – comprising more than 150 economies – received only 10% of investments in 2023. African countries, despite their severe needs and high resource potential, have failed to attract significant financial flows, as investments in least-developed countries are often seen as high risk.

Energy transition investments must increase dramatically to meet the renewable energy and efficiency goals outlined in the First Global Stocktake at COP28. Annual investments in renewable power, grids and flexibility, energy efficiency and conservation must increase from USD 1.29 trillion in 2023 to USD 4.5 trillion each year between 2024 and 2030 to meet the UAE Consensus renewable energy and energy efficiency goals.

Annual investment in the global energy sector as a whole must grow by more than 2.5 times to remain on a 1.5°C pathway. In 2023, the energy sector (including renewables, fossil fuels, grids, energy conservation, electrification, hydrogen, and carbon capture and storage) received USD 2.6 trillion in investments; under the 1.5°C Scenario, cumulative energy sector investment would need to reach USD 47 trillion by 2030, or USD 6.7 trillion, on average, each year between 2024 and 2030 (Figure S2).

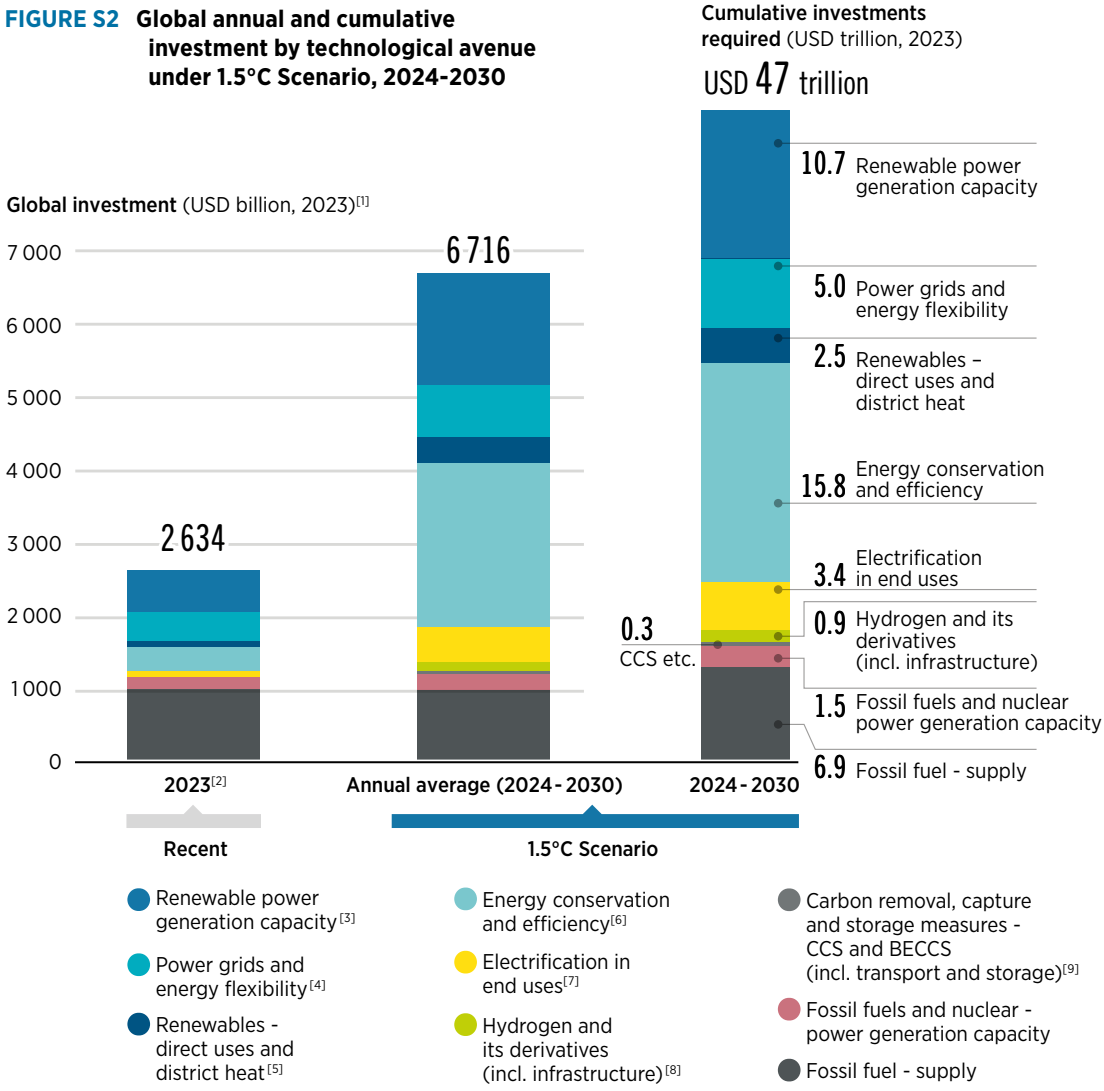
Policies and measures are needed to address prohibitive costs in high-risk environments. Renewable energy investments mainly rely on private capital; the higher the perceived risks, the higher the costs of that capital. As a result, the lowest income populations pay the highest price in meeting their basic energy needs – directly contradicting sustainable development goals such as SDG7. Among the various mechanisms available to policy-makers in collecting revenue to advance a just energy transition, attention is growing concerning the potential of taxation as a means to channel funds to those most in need of energy transition support.

Public financing and policy de-risking must be co-ordinated to shift the focus from bankability to impact potential. Investment decisions should consider factors beyond the immediate financial returns for private investors – including both short- and long-term climate, environmental, socio-economic and development goals – as well as the project's potential to stimulate renewable energy sector growth. More public finance is needed to both de-risk private capital and to channel funds to areas where the private sector is reluctant to engage.

Effective energy planning, backed by robust governance, is needed to establish conditions conducive to private capital investment by reducing risks and transaction costs. This is underscored by the Global Coalition on Energy Planning (GCEP) established under the leadership of the G20 Brazilian presidency, that highlights the critical role of energy planning in accelerating the energy transition.

The New Collective Quantified Goal (NCQG) for climate finance to be agreed at COP29 provides an important opportunity to increase support to the global South. International collaboration will be crucial to better channel funds to a broader range of countries. This will also require larger amounts of public finance, for example to help de-risk projects in high-risk countries and to fund crucial infrastructure. Such funding could, for example, come from a reduction in fossil fuel subsidies.

FIGURE S2 Global annual and cumulative investment by technological avenue under 1.5°C Scenario, 2024-2030



Notes: CCS = carbon capture and storage; BECCS = bioenergy with carbon capture and storage
[1] All figures have been adjusted for inflation and are represented in real terms, *i.e.* 2023 US dollars.
[2] (IRENA estimation as of July 2024; BNEF, 2024; WEI, 2023; WEI, 2024; Siepen *et al.*, 2024).
[3] Renewable power generation capacity: Investment in deployment of renewable technologies for power generation.
[4] Power grids and energy 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. The average annual investment requirement is based on the lower bound estimates for battery storage capacity of 360 GW.
[5] Renewables direct uses and district heat: Biofuels supply, renewables direct uses and district heat applications (*e.g.* solar thermal, modern bioenergy) and ammonia and methanol production from biomass.
[6] 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.). Energy conservation: Investments in energy conservation includes those in bio-based plastics and organic materials, chemical and mechanical recycling and energy recovery.
[7] Electrification in end uses: Investments in EV charging infrastructure, heat pumps in industry and buildings and transport.
[8] Hydrogen and its derivatives (incl. infrastructure): Electrolyser capacity (alkaline and polymer electrolyte membrane) for the production of green hydrogen, infrastructure for the transport of hydrogen and hydrogen long duration seasonal storage. Hydrogen based ammonia and methanol: Production of ammonia and methanol from hydrogen feedstocks. Historical number is based on spending on projects that entered operation in 2023 (IEA, 2024e).
[9] CCS deployment, mainly for process emissions in industry and blue hydrogen production. BECCS deployment in chemicals, power and cogeneration plants. Historical number is based on spending on projects that entered operation in 2023 (IEA, 2024e).

Ensuring a just and inclusive energy transition

A key benefit of the energy transition is its potential to improve global welfare. As well as positive climate outcomes, the transition can generate co-benefits such as improved economic resilience, jobs, and reliable and affordable access to energy. However, IRENA's analysis of the socio-economic dimensions of the energy transition shows that these benefits cannot be taken for granted. Even if the energy transition follows the 1.5°C Scenario pathway, significant disparities are likely to remain in terms of welfare around the globe.

Inclusive development, equity and justice are key socio-economic dimensions of the energy transition (Figure S3). Inclusive development represents a commitment to globally shared prosperity; equity signifies the fair distribution of the benefits and burdens of the transition; while justice means not leaving anyone behind – for example, those who remain heavily dependent on fossil fuels or lack access to energy.

FIGURE S3 The socio-economic dimension of the transition with its three pillars (inclusive development, equity and justice) and international collaboration as a transversal element

Note: The inclusive development component stands for globally shared prosperity, providing space for inclusive development for all. Structural changes in the economy are a key component for opening up space for inclusive development within planetary boundaries (Brand *et al*., 2021; Ensor, and Hoddy, 2021; Richardson *et al*., 2023; Rockstrom *et al*., 2023).

Maximising socio-economic benefits should be a key aim for those planning and implementing the energy transition. The unfolding crises affecting the climate, biodiversity and inequality, only add to the urgency of the energy transition. However, the transition itself could have negative socio-economic and environmental consequences that could intensify biodiversity loss or magnify inequality. Such potential impacts need to be managed through targeted policies and regulations, as well as compensatory measures, where appropriate (*e.g.* financial support for affected communities).

International collaboration is required to secure the significant increase in finance needed for a just and inclusive transition that maximises socio-economic benefits. New sources of finance should be established under guiding principles that emphasise both equity and social or environmental responsibility. These could include, for example, wealth taxation as in the approach spearheaded by Brazil's G20 Presidency in 2024. A needs-based approach should guide the distribution of collaborative international finance.

The energy access deficit exemplifies the way in which the transition currently leaves many behind. Many of the countries facing the most severe access deficits, such as those in sub-Saharan Africa, have abundant renewable energy resources yet cannot harness their potential to provide affordable energy. Better access to capacity building, affordable finance and existing technologies, would enable these countries to achieve the SDG7 goal of universal energy access and provide opportunities for sustainable economic development.

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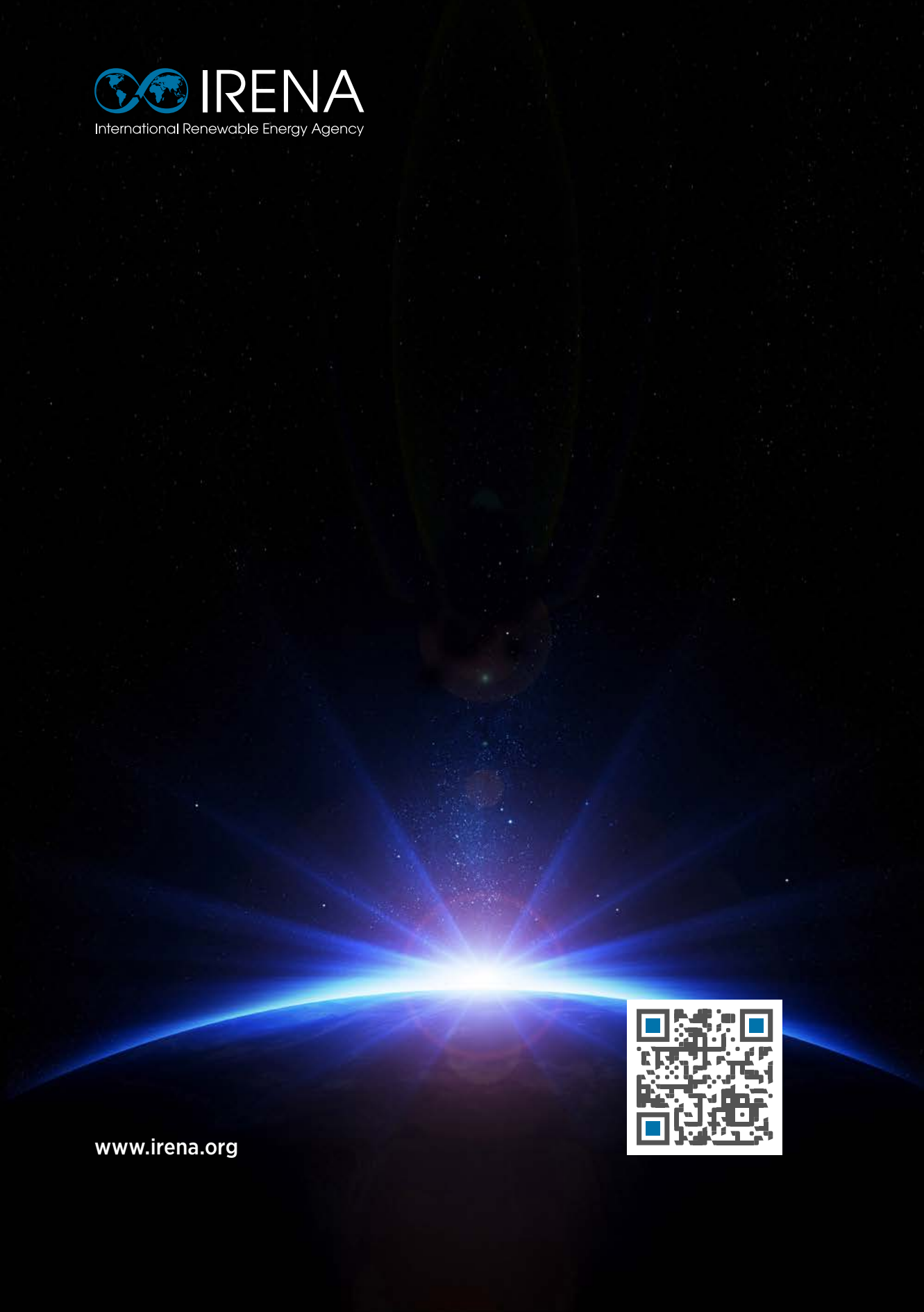

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