# World Energy Outlook 2024

## Executive Summary

International Energy Agency

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# INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 31 member countries, 13 association countries and beyond.



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## *Geopolitical tensions and fragmentation are major risks for energy security and for coordinated action on reducing emissions*

**Escalating conflict in the Middle East and Russia's ongoing war in Ukraine underscore the continued energy security risks that the world faces.** Some of the immediate effects of the global energy crisis had started to recede in 2023, but the risk of further disruptions is now very high. The experience of the last few years shows how quickly dependencies can turn into vulnerabilities; a lesson that applies also to clean energy supply chains that have high levels of market concentration. Markets for traditional fuels and for clean technologies are becoming more fragmented: since 2020, almost 200 trade measures affecting clean energy technologies – most of them restrictive – have been introduced around the world, compared with 40 in the preceding five-year period.

**Fragility in today's energy markets is a reminder of the abiding importance of energy security – the foundational and central mission of the International Energy Agency (IEA) – and the ways that more efficient, cleaner energy systems can reduce energy security risks.** The increasingly visible impacts of climate change, the momentum behind clean energy transitions, and the characteristics of clean energy technologies are all changing what it means to have secure energy systems. A comprehensive approach to energy security therefore needs to extend beyond traditional fuels to cover the secure transformation of the electricity sector and the resilience of clean energy supply chains. Energy security and climate action are inextricably linked: extreme weather events, intensified by decades of high emissions, are already posing profound energy security risks.

**Clean energy transitions have accelerated sharply in recent years, shaped by government policies and industrial strategies, but there is more near-term uncertainty than usual over how these policies and strategies will evolve**. Countries representing half of global energy demand are holding elections in 2024, and energy and climate issues have been prominent themes for voters that have been buffeted by high fuel and electricity prices, and by floods and heatwaves. Yet energy policies and climate targets, influential though they are, are not the only forces behind the continued rise of clean energy. There are strong cost drivers, as well as intense competition for leadership in clean energy sectors that are major sources of innovation, economic growth and employment. More than ever, the energy outlook is complex, multifaceted and defies a single view on how the future might unfold.

## *Robust, independent analysis and data-driven insights are vital to navigate today's energy uncertainties*

**Reflecting today's uncertainties, our three main scenarios are complemented by sensitivity cases for renewables, electric mobility, liquefied natural gas (LNG) and how heatwaves, efficiency policies and the rise of artificial intelligence (AI) might affect electricity demand**. The scenarios and sensitivity cases illustrate different pathways that the energy sector could follow, the levers that decision-makers can use to reach them, and their implications for energy markets, security and emissions, and for people's lives and livelihoods. The Stated Policies Scenario (STEPS) provides a sense of the energy sector's direction of travel today, based on the latest market data, technology costs and in-depth analysis of the prevailing

policy settings in countries around the world. The STEPS also provides the backdrop for the upside and downside sensitivity cases. The Announced Pledges Scenario (APS) examines what would happen if all national energy and climate targets made by governments, including net zero goals, are met in full and on time. The Net Zero Emissions by 2050 (NZE) Scenario maps out an increasingly narrow path to reach net zero emissions by mid-century in a way that limits global warming to 1.5 °C.

### *Geopolitical risks abound but underlying market balances are easing, setting the stage for intense competition between different fuels and technologies*

**The next phase in the journey to a safer and more sustainable energy system is set to take place in a new energy market context, marked by continued geopolitical hazards but also by relatively abundant supply of multiple fuels and technologies**. Our detailed analysis of market balances and supply chains brings an overhang of oil and LNG supply into view during the second half of the 2020s, alongside a large surfeit of manufacturing capacity for some key clean energy technologies, notably for solar PV and batteries. These provide something of a buffer against further market disruptions, but also imply downward pressure on prices and a period of increased competition among suppliers. The rapid rise in clean energy deployment in recent years came during a period of price volatility for fossil fuels. Clean technology costs are coming down, but maintaining and accelerating momentum behind their deployment in a lower fuel-price world is a different proposition. How consumer choices and government policies play out will have huge consequences for the future of the energy sector, and for tackling climate change.

### *How fast will clean energy transitions unfold?*

***C*lean energy is entering the energy system at an unprecedented rate, including more than 560 gigawatts (GW) of new renewables capacity added in 2023, but deployment is far from uniform across technologies and countries.** Investment flows to clean energy projects are approaching USD 2 trillion each year, almost double the combined amount spent on new oil, gas and coal supply – and costs for most clean technologies are resuming a downward trend after rising in the aftermath of the Covid-19 pandemic. This helps renewable power generation capacity rise from 4 250 GW today to nearly 10 000 GW in 2030 in the STEPS, short of the tripling target set at COP28 but more than enough, in aggregate, to cover the growth in global electricity demand, and to push coal-fired generation into decline. Together with nuclear power, which is the subject of renewed interest in many countries, low-emissions sources are set to generate more than half of the world's electricity before 2030.

**China stands out: it accounted for 60% of the new renewable capacity added worldwide in 2023 – and China's solar PV generation alone is on course to exceed, by the early 2030s, the total electricity demand of the United States today.** There are open questions, in China and elsewhere, about how quickly and efficiently new renewable capacity can be integrated into power systems, and whether grid expansions and permitting times keep pace. Policy uncertainty and a high cost of capital are holding back clean energy projects in many developing economies. Recent clean energy trends in advanced economies present a mixed picture, with accelerations in some areas accompanied by slowdowns in others, including a

large fall in heat pump sales in Europe in the first half of 2024. Progress on the other headline commitments from COP28 is lagging: the goal of doubling the global rate of energy efficiency improvements could provide larger emissions reductions by 2030 than anything else, but looks far out of reach under today's policy settings. Tried and tested policies and technologies are likewise available to deliver a major reduction in methane emissions from fossil fuel operations, but abatement efforts have been patchy and uneven.

### *Clean energy momentum remains strong enough to bring a peak in demand for each of the fossil fuels by 2030*

**Demand for energy services is rising rapidly, led by emerging and developing economies, but the continued progress of transitions means that, by the end of the decade, the global economy can continue to grow without using additional amounts of oil, natural gas or coal**. This has not been the case in recent years: despite record clean energy deployment, two-thirds of the increase in global energy demand in 2023 was met by fossil fuels, pushing energy-related $CO_2$ emissions to another record high. In the STEPS, the largest sources of rising demand for energy are, in descending order, India, Southeast Asia, the Middle East and Africa. But growth in clean energy and structural changes in the global economy, particularly in China, are starting to temper overall energy demand growth, not least because a more electrified, renewables-rich system is inherently more efficient than one dominated by fossil fuel combustion (in which a lot of the energy generated is lost as waste heat). Outcomes in individual years can vary in practice depending on broader economic or weather conditions, or in hydropower output, but the direction of travel under today's policy settings is clear. Continued growth in global energy demand post-2030 can be met solely with clean energy.

### *The world has the need and the capacity to go much faster*

**Ample clean energy manufacturing capacity creates scope for faster transitions that move towards alignment with national and global net zero goals, but this means addressing imbalances in today's investment flows and clean energy supply chains**. Over the past five years, annual solar capacity additions quadrupled to 425 GW, but annual manufacturing capacity is set for a sixfold increase to more than 1 100 GW, a level that – if deployed in full – would be very close to the amounts needed in the NZE Scenario. There is a similar story of plentiful manufacturing capacity for lithium-ion batteries. Bringing these technologies at scale to developing economies would be transformative for the global outlook, helping rising demand to be met in a sustainable way and allowing global emissions not only to peak in the coming years, as they do in the STEPS, but also to enter a meaningful decline, which they do not do in the STEPS. This requires concerted efforts to facilitate investment in developing economies by addressing risks that push up the cost of capital. Periods of ample supply make life difficult for new entrants, but improving the resilience and diversity of the supply chains for clean energy technologies and for critical minerals remains an essential task. For the moment, these supply chains are heavily concentrated in China.

### *Demand for electricity is taking off, but how high will it go?*

**The contours of a new, more electrified energy system are coming into focus as global electricity demand soars**. Electricity use has grown at twice the pace of overall energy

demand over the last decade, with two-thirds of the global increase in electricity demand over the last ten years coming from China. Electricity demand growth is set to accelerate further in the years ahead, adding the equivalent of Japanese demand to global electricity use each year in the STEPS, and rising even more quickly in scenarios that meet national and global net zero goals. The projections for global electricity demand in STEPS are 6%, or 2 200 terawatt-hours (TWh), higher in 2035 than in last year's *Outlook*, driven by light industrial consumption, electric mobility, cooling, and data centres and AI.

**Rising data centre electricity use, linked in part to growing use of AI, is already having some strong local impacts, but the potential implications of AI for energy are broader and include improved systems coordination in the power sector and shorter innovation cycles.** There are more than 11 000 data centres registered worldwide and they are often spatially concentrated, so local effects on electricity markets can be substantial. However, at a global level, data centres account for a relatively small share of overall electricity demand growth to 2030. More frequent and intense heatwaves than we assume in the STEPS, or higher performance standards applied to new appliances – notably air conditioners – both produce significantly greater variations in projected electricity demand than an upside case for data centres. The combination of rising incomes and increasing global temperatures generate more than 1 200 TWh of extra global demand for cooling by 2035 in the STEPS, an amount greater than the entire Middle East's electricity use today.

### *The rise of electric mobility, led by China, is wrong-footing oil producers*

**The slowdown in oil demand growth in the STEPS puts major resource owners in a bind as they face a significant overhang of supply.** China has been the engine of oil market growth in recent decades, but that engine is now switching over to electricity: the country's oil use for road transport is projected to decline in the STEPS, although offset by a large increase in oil use as a petrochemical feedstock. India becomes the main source of oil demand growth, adding almost 2 million barrels per day (mb/d) to 2035. Cost-competitive EVs – many of them from Chinese manufacturers – are making inroads in a range of markets, although there is uncertainty over how fast their share will grow. EVs currently have a share of around 20% in new car sales worldwide, and this rises towards 50% by 2030 in the STEPS (a level already being achieved in China this year), by which time EVs displace around 6 mb/d of oil demand. If the market share of electric cars were to rise more slowly, remaining below 40% by the end of the decade, this would add 1.2 mb/d to projected oil demand in 2030, but there would still be a visible flattening in the global trajectory. Additional near-term oil supply is coming mainly from the Americas – the United States, Brazil, Guyana and Canada – and this is putting pressure on the market management strategies of the OPEC+ grouping. The STEPS sees prices around USD 75-80 per barrel, but this implies further production restraint and an increase in spare capacity, which is already at record levels of around 6 mb/d.

### *Who will ride the wave of new LNG?*

**An increase of nearly 50% in global LNG export capacity is on the horizon, led by the United States and Qatar, but the prices that many suppliers need to recover their investments may not entice developing economies to switch to natural gas at scale: something has to give.**

Around 270 billion cubic metres (bcm) of annualised new LNG capacity has been approved and, if delivered according to announced schedules, is set to enter into operation over the period to 2030, a huge addition to global supply. In the STEPS, LNG demand grows by more than 2.5% per year to 2035, an upward revision from last year's outlook and faster than the rise in overall gas demand. Europe and China have the import infrastructure to absorb significantly more gas, but their scope to clear the market is constrained by their investments in clean energy. Gas-importing emerging and developing economies would generally need prices at around USD 3-5/MBtu to make gas attractive as a large-scale alternative to renewables and coal, but delivered costs for most new export projects need to average around USD 8/MBtu to cover their investments and operation. If gas markets are to absorb all the prospective new LNG supply and to continue to grow past 2030, this would require some combination of even lower clearing prices, higher electricity demand and slower energy transitions – with less wind and solar, lower rates of building efficiency improvements, and fewer heat pumps – than projected in the STEPS. However, any acceleration of global energy transitions towards the outcomes projected in the APS or NZE Scenario, or a wild card for supply like a large new Russia-China gas supply deal (which we do not include in the STEPS), would exacerbate the LNG glut.

### *Lower fuel prices ease concerns about affordability and industrial competitiveness in fuel-importing economies*

**The new market context may provide some breathing space for fuel-importing countries and regions – such as Europe, and South and Southeast Asia – that have been hit hard by higher prices for fossil fuels and electricity in recent years**. Consumers around the world spent nearly USD 10 trillion on energy in 2022 during the global energy crisis, around half of which ended up as record revenues for oil and gas producers. An easing of price levels promises some welcome relief, particularly in fuel-importing countries. Lower natural gas prices should lift some of Europe's gloom about its industrial competitiveness, although Europe still faces a sizeable structural energy price disadvantage compared with the United States and China. The breathing space from fuel price pressures can provide policymakers with room to focus on stepping up investment in renewables, grids, storage and efficiency; facilitating the removal of inefficient fossil fuel subsidies; and allowing developing economies to regain the momentum that was lost in recent years behind the provision of access to electricity and clean cooking fuels. However, cheaper natural gas can also slow structural changes by diminishing the economic case for consumers to switch to cleaner technologies, and by making it more difficult to close the cost gap with alternatives like biomethane and low-emissions hydrogen.

### *A sustainable energy system needs to be people-centred and resilient*

**A new energy system needs to be built to last: this means prioritising security, resilience and flexibility, and ensuring that the benefits of the new energy economy are shared**. The STEPS does not see traditional energy security concerns diminishing, particularly for importers in Asia that face a long-term rise in their dependence on oil and gas imports to nearly 90% for oil and around 60% for gas by 2050. At the same time, faster clean energy transitions put the spotlight on electricity security, as growing electricity demand and more

variable generation increase the operational need for flexibility in power systems, both for short-term and seasonal needs. This also requires a rebalancing of power sector investment towards grids and battery storage, as proposed by the IEA in advance of the COP29[1] climate conference in Baku, Azerbaijan. At the moment, for every dollar spent on renewable power, 60 cents are spent on grids and storage. By the 2040s, this reaches parity in all scenarios. Many power systems are vulnerable to an increase in extreme weather events and cyberattacks, putting a premium on adequate investments in resilience and digital security.

**Dividing lines are emerging on energy and climate, which can only be bridged if there is more help provided to poorer countries, communities and households to manage the upfront costs of change, including much greater international support.** High financing costs and project risks are limiting the spread of cost-competitive clean energy technologies to where they are needed most, especially in developing economies where they can deliver the biggest returns for sustainable development and affordability. Lack of access to modern energy is the most fundamental inequity in today's energy system, with 750 million people – predominantly in sub-Saharan Africa – remaining without access to electricity and more than 2 billion without clean cooking fuels. The outlook for access projects is improving thanks to cheaper technologies, new policies, the growing availability of digital payment options and pay-as-you-go business models, but more is needed, including a stronger focus on electrifying productive uses, which can improve project bankability. The climate finance discussions at COP29 and at the G20 will be a barometer of the prospects for scaling up clean energy investment in developing economies, which will also require strengthened national policy visions, policies and institutions, and a willingness to engage with the private sector.

### *Choices and consequences*

**Despite gathering momentum behind transitions, the world is still a long way from a trajectory aligned with its climate goals. Decisions by governments, investors and consumers too often entrench the flaws in today's energy system, rather than pushing it towards a cleaner and safer path.** There are some positive developments in the STEPS, but today's policy settings still put the world on course for a rise of 2.4 °C in global average temperatures by 2100, entailing ever more severe risks from a changing climate. Our scenario analysis highlights the prospect of buyers and consumers having the edge in energy markets for a time, with suppliers competing for their attention as they make fuel and technology choices that have widely different implications for the energy sector and for its emissions. All parties need to recognise that locking in fossil fuel use has consequences. There may be downward pressure on fuel prices for a while, but energy history tells us that one day the cycle will be reversed, and prices will rise. And the costs of climate inaction, meanwhile, grow higher by the day as emissions accumulate in the atmosphere and extreme weather imposes its own unpredictable price. By contrast, clean technologies that are increasingly cost-effective today are set to remain so, with greatly reduced exposure to the vagaries of commodity markets and lasting benefits for people and planet.

[1] See IEA (2024) From Taking Stock to Taking Action: How to implement the COP28 energy goals.

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## World Energy Outlook 2024

The IEA's flagship *World Energy Outlook*, published every year, is the most authoritative global source of energy analysis and projections. It identifies and explores the biggest trends in energy demand and supply, as well as what they mean for energy security, emissions and economic development.

This year's *Outlook* comes against a backdrop of escalating risks in the Middle East and heightened geopolitical tensions globally, and explores a range of energy security issues that decision makers face as they proceed with clean energy transitions. With rising investment of clean technologies and rapid growth in electricity demand, the *WEO 2024* examines how far the world has come on its journey towards a safer and more sustainable energy system, and what more needs to be done to reach its climate goals.

Reflecting today's uncertainties, our three main scenarios are complemented with sensitivity cases for renewables, electric mobility, liquefied natural gas and how heatwaves, efficiency policies and the rise of artificial intelligence might affect the outlook for electricity.