

World Energy Outlook 2023

Executive Summary

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The energy world remains fragile but has effective ways to improve energy security and tackle emissions

Some of the immediate pressures from the global energy crisis have eased, but energy markets, geopolitics, and the global economy are unsettled and the risk of further disruption is ever present. Fossil fuel prices are down from their 2022 peaks, but markets are tense and volatile. Continued fighting in Ukraine, more than a year after Russia's invasion, is now accompanied by the risk of protracted conflict in the Middle East. The macro-economic mood is downbeat, with stubborn inflation, higher borrowing costs and elevated debt levels. Today, the global average surface temperature is already around 1.2 °C above pre-industrial levels, prompting heatwaves and other extreme weather events, and greenhouse gas emissions have not yet peaked. The energy sector is also the primary cause of the polluted air that more than 90% of the world's population is forced to breathe, linked to more than 6 million premature deaths a year. Positive trends on improving access to electricity and clean cooking have slowed or even reversed in some countries.

Against this complex backdrop, the emergence of a new clean energy economy, led by solar PV and electric vehicles (EVs), provides hope for the way forward. Investment in clean energy has risen by 40% since 2020. The push to bring down emissions is a key reason, but not the only one. The economic case for mature clean energy technologies is strong. Energy security is also an important factor, particularly in fuel-importing countries, as are industrial strategies and the desire to create clean energy jobs. Not all clean technologies are thriving and some supply chains, notably for wind, are under pressure, but there are striking examples of an accelerating pace of change. In 2020, one in 25 cars sold was electric; in 2023, this is now one in 5. More than 500 gigawatts (GW) of renewables generation capacity are set to be added in 2023 – a new record. More than USD 1 billion a day is being spent on solar deployment. Manufacturing capacity for key components of a clean energy system, including solar PV modules and EV batteries, is expanding fast. This momentum is why the IEA recently concluded, in its updated *Net Zero Roadmap*, that a pathway to limiting global warming to 1.5 °C is very difficult – but remains open.

This new Outlook provides a strong evidence base to guide the choices that face energy decision makers in pursuit of transitions that are rapid, secure, affordable and inclusive.

The analysis does not present a single view of the future but instead explores different scenarios that reflect current real-world conditions and starting points. The Stated Policies Scenario (STEPS) provides an outlook based on the latest policy settings, including energy, climate and related industrial policies. The Announced Pledges Scenario (APS) assumes all national energy and climate targets made by governments are met in full and on time. Yet, much additional progress is still required to meet the objectives of the Net Zero Emissions by 2050 (NZE) Scenario which limits global warming to 1.5 °C. Alongside our main scenarios, we explore some key uncertainties that could affect future trends, including structural changes in China's economy and the pace of global deployment of solar PV.

We are on track to see all fossil fuels peak before 2030

A legacy of the global energy crisis may be to usher in the beginning of the end of the fossil fuel era: the momentum behind clean energy transitions is now sufficient for global demand for coal, oil and natural gas to all reach a high point before 2030 in the STEPS. The share of coal, oil and natural gas in global energy supply – stuck for decades around 80% – starts to edge downwards and reaches 73% in the STEPS by 2030. This is an important shift. However, if demand for these fossil fuels remains at a high level, as has been the case for coal in recent years, and as is the case in the STEPS projections for oil and gas, it is far from enough to reach global climate goals.

Policies supporting clean energy are delivering as the projected pace of change picks up in key markets around the world. Thanks largely to the Inflation Reduction Act in the United States, we now project that 50% of new US car registrations will be electric in 2030 in the STEPS. Two years ago, the corresponding figure in the *WEO-2021* was 12%. In the European Union in 2030, heat pump installations in the STEPS reach two-thirds of the level needed in the NZE Scenario, compared with the one-third projected two years ago. In China, projected additions of solar PV and offshore wind to 2030 are now three-times higher than they were in the *WEO-2021*. Prospects for nuclear power have also improved in leading markets, with support for lifetime extensions of existing nuclear reactors in countries including Japan, Korea and the United States, as well as for new builds in several more.

Although demand for fossil fuels has been strong in recent years, there are signs of a change in direction. Alongside the deployment of low-emissions alternatives, the rate at which new assets that use fossil fuels are being added to the energy system has slowed. Sales of cars and two/three-wheel vehicles with internal combustion engines are well below where they were before the Covid-19 pandemic. In the electricity sector, worldwide additions of coal- and natural gas-fired power plants have halved, at least, from earlier peaks. Sales of residential gas boilers have been trending downwards and are now outnumbered by sales of heat pumps in many countries in Europe and in the United States.

China has changed the energy world, but now China is changing

China has an outsized role in shaping global energy trends; this influence is evolving as its economy slows and its structure adjusts, and as clean energy use grows. Over the past ten years, China accounted for almost two-thirds of the rise in global oil use, nearly one-third of the increase in natural gas, and has been the dominant player in coal markets. But it is widely recognised, including by the country's leadership, that China's economy is reaching an inflection point. After a very rapid building out of the country's physical infrastructure, the scope for further additions is narrowing. The country already has a world-class high-speed rail network; and residential floorspace per capita is now equal to that of Japan, even though GDP per capita is much lower. This saturation points to lower future demand in many energy-intensive sectors like cement and steel. China is also a clean energy powerhouse, accounting for around half of wind and solar additions and well over half of global EV sales in 2022.

Momentum behind China’s economic growth is ebbing and there is greater downside potential for fossil fuel demand if it slows further. In our scenarios, China’s GDP growth averages just under 4% per year to 2030. This results in its total energy demand peaking around the middle of this decade, with robust expansion of clean energy putting overall fossil fuel demand and emissions into decline. If China’s near-term growth were to slow by another percentage point, this would reduce 2030 coal demand by an amount almost equal to the volume currently consumed by the whole of Europe. Oil import volumes would decline by 5% and LNG imports by more than 20%, with major implications for global balances.

New dynamics for investment are taking shape

The end of the growth era for fossil fuels does not mean an end to fossil fuel investment, but it undercuts the rationale for any increase in spending. Until this year, meeting projected demand in the STEPS implied an increase in oil and gas investment over the course of this decade, but a stronger clean energy outlook and lower projected fossil fuel demand means this is no longer the case. However, investment in oil and gas today is almost double the level required in the NZE Scenario in 2030, signalling a clear risk of protracted fossil fuel use that would put the 1.5 °C goal out of reach.

Simply cutting spending on oil and gas will not get the world on track for the NZE Scenario; the key to an orderly transition is to scale up investment in all aspects of a clean energy system. The development of a clean energy system and its effect on emissions can be reinforced by policies that ease the exit of inefficient, polluting assets, such as ageing coal plants, or that restrict the entry of new ones into the system. But the urgent challenge is to increase the pace of new clean energy projects, especially in many emerging and developing economies outside China, where investment in energy transitions needs to rise by more than five times by 2030 to reach the levels required in the NZE Scenario. A renewed effort, including stronger international support, will be vital to tackle obstacles such as high costs of capital, limited fiscal space for government support and challenging business environments.

Meeting development needs in a sustainable way is key to moving faster

The global peaks in demand for each of the three fossil fuels mask important differences across economies at different stages of development. The drivers for growth in demand for energy services in most emerging and developing economies remain very strong. Rates of urbanisation, built space per capita, and ownership of air conditioners and vehicles are far lower than in advanced economies. The global population is expected to grow by about 1.7 billion by 2050, almost all of which is added to urban areas in Asia and Africa. India is the world’s largest source of energy demand growth in the STEPS, ahead of Southeast Asia and Africa. Finding and financing low-emissions ways to meet rising energy demand in these economies is a vital determinant of the speed at which global fossil fuel use eventually falls.

Clean electrification, improvements in efficiency and a switch to lower- and zero-carbon fuels are key levers available to emerging and developing economies to reach their national energy and climate targets. Getting on track to meet these targets, including net zero goals, has broad implications for future pathways. In India, it means every dollar of value added by

India's industry results in 30% less carbon dioxide (CO₂) by 2030 than it does today, and each kilometre driven by a passenger car, on average, emits 25% less CO₂. Some 60% of two- and three-wheelers sold in 2030 are electric, a share ten times higher than today. In Indonesia, the share of renewables in power generation doubles by 2030 to more than 35%. In Brazil, biofuels meet 40% of road transport fuel demand by the end of the decade, up from 25% today. In sub-Saharan Africa, meeting diverse national energy and climate targets means that 85% of new power generation plants to 2030 are based on renewables. Significant progress is made towards universal access to modern energy, with some 670 million people gaining access to modern cooking fuels, and 500 million to electricity by 2030.

Ample global manufacturing capacity offers considerable upside for solar PV

Renewables are set to contribute 80% of new power capacity to 2030 in the STEPS, with solar PV alone accounting for more than half. However, this uses only a fraction of the world's potential. Solar has become a major global industry and is set to transform electricity markets even in the STEPS. But there is significant scope for further growth given manufacturing plans and the technology's competitiveness. By the end of the decade, the world could have manufacturing capacity for more than 1 200 GW of panels per year. But in the STEPS, only 500 GW is deployed globally in 2030. Boosting deployment up from these levels raises some complex questions. It would require measures – notably expanding and strengthening grids and adding storage – to integrate the additional solar PV into electricity systems and maximise its impact. Manufacturing capacity is also highly concentrated: China is already the largest producer and its expansion plans far outstrip those in other countries. Trade, therefore, would continue to be vital to support worldwide deployment of solar.

Using 70% of anticipated solar PV manufacturing capacity would bring deployment to the levels projected in the NZE Scenario; effectively integrated, this would further cut fossil fuel use – first and foremost coal. In a sensitivity case, we explore how the STEPS projections would change if the world added over 800 GW of new solar PV per year by 2030. The implications would be particularly strong for China, reducing coal-fired generation by a further 20% by 2030 compared with the STEPS. Without assuming any additional retirements, the average annual capacity factor for coal-fired power plants would fall to around 30% in 2030, from over 50% today. The consequences would spread well beyond China: in this case, more than 70 GW of additional solar PV is deployed on average each year to 2030 across Latin America, Africa, Southeast Asia and the Middle East. Even with modest curtailment, this reduces fossil fuel-fired generation in these regions by about one-quarter in 2030 compared with the STEPS. Solar PV alone cannot get the world on track to meet its climate goals, but – more than any other clean technology – it can light up the way.

A wave of new LNG export projects is set to remodel gas markets

Starting in 2025, an unprecedented surge in new LNG projects is set to tip the balance of markets and concerns about natural gas supply. In recent years, gas markets have been dominated by fears about security and price spikes after Russia cut supplies to Europe. Market balances remain precarious in the immediate future but that changes from the middle of the decade. Projects that have started construction or taken final investment

decision are set to add 250 billion cubic metres per year of liquefaction capacity by 2030, equal to almost half of today's global LNG supply. Announced timelines suggest a particularly large increase between 2025 and 2027. More than half of the new projects are in the United States and Qatar.

This additional LNG arrives at an uncertain moment for natural gas demand and creates major difficulties for Russia's diversification strategy towards Asia. The strong increase in LNG production capacity eases prices and gas supply concerns, but comes to market at a time when global gas demand growth has slowed considerably since its "golden age" of the 2010s. Alongside gas contracted on a longer-term basis to end-users, we estimate that more than one-third of the new gas will be looking to find buyers on the short-term market. However, mature markets – notably in Europe – are moving into stronger structural decline and emerging markets may lack the infrastructure to absorb much larger volumes if gas demand in China slows. The glut of LNG means there are very limited opportunities for Russia to secure additional markets. Russia's share of internationally traded gas, which stood at 30% in 2021, is halved by 2030 in the STEPS.

Affordability and resilience are watchwords for the future

A tense situation in the Middle East is a reminder of hazards in oil markets a year after Russia cut gas supplies to Europe. Vigilance on oil and gas security remains essential throughout clean energy transitions, and our projections highlight how the balance of trade and potential vulnerabilities shift over time. In the STEPS, the share of seaborne crude oil trade from the Middle East to Asia rises from some 40% of the total today to 50% by 2050. Asia is also the final destination for almost all of additional Middle East LNG supply.

The global energy crisis was not a clean energy crisis, but it has focused attention on the importance of ensuring rapid, people-centred and orderly transitions. Three interlinked issues stand out: risks to affordability, electricity security and the resilience of clean energy supply chains. Sheltering consumers from volatile fuel prices in 2022 cost governments USD 900 billion in emergency support. The way to limit such expenditures in the future is to deploy cost-effective, clean technologies at scale, especially in poorer households, communities and countries that struggle to finance the upfront investments required. As the world moves towards a more electrified, renewables-based system, security of electricity supply is also paramount. Higher investment in robust and digitalised grids needs to be accompanied by a role for batteries and demand response measures for short-term flexibility and lower-emissions technologies for seasonal variations, including hydropower, nuclear, fossil fuels with carbon capture, utilisation and storage, bioenergy, hydrogen and ammonia.

Diversification and innovation are the best strategies to manage supply chain dependencies for clean energy technologies and critical minerals. A range of strategies are in place to strengthen the resilience of clean energy supply chains and reduce today's high levels of concentration, but these will take time to bear fruit. Exploration and production investments are rising around the world for critical minerals like lithium, cobalt, nickel and rare earths, but the share of the top three producers in 2022 is either unchanged or has increased from 2019 levels. Our tracking of announced projects suggests concentration levels

in 2030 are set to remain high, especially for refining and processing operations. Many midstream projects are being developed in today's major producing regions, with China holding half of planned lithium chemical plants and Indonesia representing nearly 90% of planned nickel refining facilities. Alongside investments in diversified supply, policies encouraging innovation, mineral substitution and recycling can moderate trends on the demand side and ease market pressures. They are vital components of critical minerals security.

We need to go much further and faster, but a fragmented world will not rise to meet our climate and energy security challenges

Proven policies and technologies are available to align energy security and sustainability goals, speed up the pace of change this decade and keep the door to 1.5 °C open. The STEPS sees a peak in energy-related CO₂ emissions in the mid-2020s but emissions remain high enough to push up global average temperatures to around 2.4 °C in 2100. This outcome has improved over successive editions of the *Outlook* but still points towards very widespread and severe impacts from climate change. The key actions required to bend the emissions curve downwards to 2030 are widely known and in most cases very cost effective. Tripling renewable energy capacity, doubling the pace of energy efficiency improvements to 4% per year, ramping up electrification and slashing methane emissions from fossil fuel operations together provide more than 80% of the emissions reductions needed by 2030 to put the energy sector on a pathway to limit warming to 1.5 °C. In addition, innovative, large-scale financing mechanisms are required to support clean energy investments in emerging and developing economies, as are measures to ensure an orderly decline in the use of fossil fuels, including an end to new approvals of unabated coal-fired power plants. Every country needs to find its own pathway, and it needs to be inclusive and equitable to secure public acceptance, but this package of global measures provides crucial ingredients for any successful outcome from the COP28 climate change conference in Dubai in December.

No country is an energy island, and no country is insulated from the risks of climate change. The necessity of collaboration has never been higher. Especially in today's tense times, governments need to find ways to safeguard co-operation on energy and climate, including by embracing a rules-based system of international trade and spurring innovation and technology transfer. Without this, the chance to limit the rise in global temperatures to 1.5 °C will disappear. The outlook for energy security will also look perilous if we lose the benefits of interconnected and well-functioning energy markets to ride out unexpected shocks.

Fifty years on from the first oil shock, the world has lasting solutions to address energy insecurity that can also help tackle the climate crisis. The first oil shock 50 years ago brought two crucial policy responses firmly into play: energy efficiency and low-emissions power, led at the time by hydropower and nuclear. Today's energy decision makers are once again facing geopolitical tensions and the risk of energy shocks, but they have a much broader range of highly competitive clean technologies at their disposal, and an accumulated wealth of policy experience on how to accelerate their deployment. The crucial step is to put these readily available solutions to work.

International Energy Agency (IEA)

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Typeset in France by IEA - October 2023
Cover design: IEA
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The *World Energy Outlook 2023* provides in-depth analysis and strategic insights into every aspect of the global energy system. Against a backdrop of geopolitical tensions and fragile energy markets, this year's report explores how structural shifts in economies and in energy use are shifting the way that the world meets rising demand for energy.

This *Outlook* assesses the evolving nature of energy security fifty years after the foundation of the IEA. It also examines what needs to happen at the COP28 climate conference in Dubai to keep the door open for the 1.5 °C goal. And, as it does every year, the *Outlook* examines the implications of today's energy trends in key areas including investment, trade flows, electrification and energy access.

This flagship publication of the International Energy Agency is the energy world's most authoritative source of analysis and projections. Published each year since 1998, its objective data and dispassionate analysis provide critical insights into global energy supply and demand in different scenarios and the implications for energy security, climate change goals and economic development.