World Energy Outlook 2022

Executive Summary

International Energy Agency

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Russia's invasion of Ukraine has sparked a global energy crisis

The world is in the midst of its first global energy crisis – a shock of unprecedented breadth and complexity. Pressures in markets predated Russia's invasion of Ukraine, but Russia's actions have turned a rapid economic recovery from the pandemic – which strained all manner of global supply chains, including energy – into full-blown energy turmoil. Russia has been by far the world's largest exporter of fossil fuels, but its curtailments of natural gas supply to Europe and European sanctions on imports of oil and coal from Russia are severing one of the main arteries of global energy trade. All fuels are affected, but gas markets are the epicentre as Russia seeks leverage by exposing consumers to higher energy bills and supply shortages.

Prices for spot purchases of natural gas have reached levels never seen before, regularly exceeding the equivalent of USD 250 for a barrel of oil. Coal prices have also hit record levels, while oil rose well above USD 100 per barrel in mid-2022 before falling back. High gas and coal prices account for 90% of the upward pressure on electricity costs around the world. To offset shortfalls in Russian gas supply, Europe is set to import an extra 50 billion cubic metres (bcm) of liquefied natural gas (LNG) in 2022 compared with the previous year. This has been eased by lower demand from China, where gas use was held back by lockdowns and subdued economic growth, but higher European LNG demand has diverted gas away from other importers in Asia.

The crisis has stoked inflationary pressures and created a looming risk of recession, as well as a huge USD 2 trillion windfall for fossil fuel producers above their 2021 net income. Higher energy prices are also increasing food insecurity in many developing economies, with the heaviest burden falling on poorer households where a larger share of income is spent on energy and food. Some 75 million people who recently gained access to electricity are likely to lose the ability to pay for it, meaning that for the first time since we started tracking it, the total number of people worldwide without electricity access has started to rise. And almost 100 million people may be pushed back into reliance on firewood for cooking instead of cleaner, healthier solutions.

Faced with energy shortfalls and high prices, governments have so far committed well over USD 500 billion, mainly in advanced economies, to shield consumers from the immediate impacts. They have rushed to try and secure alternative fuel supplies and ensure adequate gas storage. Other short-term actions have included increasing oil- and coal-fired electricity generation, extending the lifetimes of some nuclear power plants, and accelerating the flow of new renewables projects. Demand-side measures have generally received less attention, but greater efficiency is an essential part of the short- and longer-term response.

Is the crisis a boost, or a setback, for energy transitions?

With energy markets remaining extremely vulnerable, today's energy shock is a reminder of the fragility and unsustainability of our current energy system. A key question for policy makers, and for this *Outlook*, is whether the crisis will be a setback for clean energy transitions or will catalyse faster action. Climate policies and net zero commitments were

blamed in some quarters for contributing to the run-up in energy prices, but there is scant evidence for this. In the most affected regions, higher shares of renewables were correlated with lower electricity prices, and more efficient homes and electrified heat have provided an important buffer for some – but far from enough – consumers.

Times of crisis put the spotlight on governments, and on how they react. Alongside short-term measures, many governments are now taking longer-term steps: some seeking to increase or diversify oil and gas supply; many looking to accelerate structural change. The three scenarios explored in this *World Energy Outlook* (WEO) are differentiated primarily by the assumptions made on government policies. The **Stated Policies Scenario (STEPS)** shows the trajectory implied by today's policy settings. The **Announced Pledges Scenario (APS)** assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net zero and energy access goals. The **Net Zero Emissions by 2050 (NZE) Scenario** maps out a way to achieve a 1.5 °C stabilisation in the rise in global average temperatures, alongside universal access to modern energy by 2030.

Policy responses are fast-tracking the emergence of a clean energy economy

New policies in major energy markets help propel annual clean energy investment to more than USD 2 trillion by 2030 in the STEPS, a rise of more than 50% from today. Clean energy becomes a huge opportunity for growth and jobs, and a major arena for international economic competition. By 2030, thanks in large part to the US Inflation Reduction Act, annual solar and wind capacity additions in the United States grow two-and-a-half-times over today's levels, while electric car sales are seven times larger. New targets continue to spur the massive build-out of clean energy in China, meaning that its coal and oil consumption both peak before the end of this decade. Faster deployment of renewables and efficiency improvements in the European Union bring down EU natural gas and oil demand by 20% this decade, and coal demand by 50%, a push given additional urgency by the need to find new sources of economic and industrial advantage beyond Russian gas. Japan's Green Transformation (GX) programme provides a major funding boost for technologies including nuclear, low-emissions hydrogen and ammonia, while Korea is also looking to increase the share of nuclear and renewables in its energy mix. India makes further progress towards its domestic renewable capacity target of 500 gigawatts (GW) in 2030, and renewables meet nearly two-thirds of the country's rapidly rising demand for electricity.

As markets rebalance, renewables, supported by nuclear power, see sustained gains; the upside for coal from today's crisis is temporary. The increase in renewable electricity generation is sufficiently fast to outpace growth in total electricity generation, driving down the contribution of fossil fuels for power. The crisis briefly pushes up utilisation rates for existing coal-fired assets, but does not bring higher investment in new ones. Strengthened policies, a subdued economic outlook and high near-term prices combine to moderate overall energy demand growth. Increases come primarily from India, Southeast Asia, Africa and the Middle East. However, the rise in China's energy use, which has been such an important driver for global energy trends over the past two decades, slows and then halts altogether before 2030 as China shifts to a more services-orientated economy.

International energy trade undergoes a profound reorientation in the 2020s as countries adjust to the rupture of Russia-Europe flows, which is assumed to be permanent. Not all Russian flows displaced from Europe find a new home in other markets, bringing down Russian production and global supply. Crude oil and product markets, especially diesel, face a turbulent period as EU bans on Russian imports kick in. Natural gas takes longer to adjust. The upcoming northern hemisphere winter promises to be a perilous moment for gas markets and a testing time for EU solidarity – and the winter of 2023-24 could be even tougher. Major new additions to LNG supply – mainly from North America, Qatar and Africa – arrive only around the mid-2020s. Competition for available cargoes is fierce in the meantime as Chinese import demand picks up again.

Today's stronger policy settings bring a fossil fuel peak into view

For the first time, a *WEO* scenario based on prevailing policy settings has global demand for each of the fossil fuels exhibiting a peak or plateau. In the STEPS, coal use falls back within the next few years, natural gas demand reaches a plateau by the end of the decade, and rising sales of electric vehicles (EVs) mean that oil demand levels off in the mid-2030s before ebbing slightly to mid-century. Total demand for fossil fuels declines steadily from the mid-2020s by around 2 exajoules per year on average to 2050, an annual reduction roughly equivalent to the lifetime output of a large oil field.

Global fossil fuel use has risen alongside GDP since the start of the Industrial Revolution in the 18th century: putting this rise into reverse while continuing to expand the global economy will be a pivotal moment in energy history. The share of fossil fuels in the global energy mix has been stubbornly high, at around 80%, for decades. By 2030 in the STEPS, this share falls below 75%, and to just above 60% by 2050. A high point for global energy-related CO_2 emissions is reached in the STEPS in 2025, at 37 billion tonnes (Gt) per year, and they fall back to 32 Gt by 2050. This would be associated with a rise of around 2.5 °C in global average temperatures by 2100. This is a better outcome than projected a few years ago: renewed policy momentum and technology gains made since 2015 have shaved around 1 °C off the long-term temperature rise. However, a reduction of only 13% in annual CO_2 emissions to 2050 in the STEPS is far from enough to avoid severe impacts from a changing climate.

Full achievement of all climate pledges would move the world towards safer ground, but there is still a large gap between today's ambitions and a 1.5 °C stabilisation. In the APS, a near-term peak in annual emissions is followed by a faster decline to 12 Gt by 2050. This is a bigger reduction than in the *WEO-2021* APS, reflecting the additional pledges that have been made over the past year, notably by India and Indonesia. If implemented on time and in full, these additional national commitments – as well as sectoral commitments for specific industries and company targets (considered for the first time in this year's APS) – keep the temperature rise in the APS in 2100 at around 1.7 °C. However, it is easier to make pledges than to implement them and, even if they are achieved, there is still considerably further to go to align with the NZE Scenario, which achieves the 1.5 °C outcome by reducing annual emissions to 23 Gt by 2030 and to net zero by 2050.

Led by clean electricity, some sectors are poised for a faster transformation

The world is in a critical decade for delivering a more secure, sustainable and affordable energy system – the potential for faster progress is enormous if strong action is taken immediately. Investments in clean electricity and electrification, along with expanded and modernised grids, offer clear and cost-effective opportunities to cut emissions more rapidly while bringing electricity costs down from their current highs. Today's growth rates for deployment of solar PV, wind, EVs and batteries, if maintained, would lead to a much faster transformation than projected in the STEPS, although this would require supportive policies not just in the leading markets for these technologies but across the world. By 2030, if countries deliver on their climate pledges, every second car sold in the European Union, China and the United States is electric.

Supply chains for some key technologies – including batteries, solar PV and electrolysers – are expanding at rates that support higher global ambition. If all announced manufacturing expansion plans for solar PV see the light of day, manufacturing capacity would exceed the deployment levels in the APS in 2030 by around 75% and approach the levels required in the NZE Scenario. In the case of electrolysers for hydrogen production, the potential excess capacity of all announced projects relative to APS deployment in 2030 is around 50%. In the EV sector, the expansion of battery manufacturing capacity reflects the shift underway in the automotive industry, which at times has moved faster than governments in setting targets for electrified mobility. These clean energy supply chains are a huge source of employment growth, with clean energy jobs already exceeding those in fossil fuels worldwide and projected to grow from around 33 million today to almost 55 million in 2030 in the APS.

Efficiency and clean fuels get a competitive boost

Today's high energy prices underscore the benefits of greater energy efficiency and are prompting behavioural and technology changes in some countries to reduce energy use. Efficiency measures can have dramatic effects – today's light bulbs are at least four times more efficient than those on sale two decades ago – but much more remains to be done. Demand for cooling needs to be a particularly focus for policy makers, as it makes the second-largest contribution to the overall rise in global electricity demand over the coming decades (after EVs). Many air conditioners used today are subject only to weak efficiency standards and one-fifth of electricity demand for cooling in emerging and developing economies is not covered by any standards at all. In the STEPS, cooling demand in emerging and developing economies rises by 2 800 terawatt-hours to 2050, which is the equivalent of adding another European Union to today's global electricity demand. This growth is reduced by half in the APS because of tighter efficiency standards and better building design and insulation – and by half again in the NZE Scenario.

Concerns about fuel prices, energy security and emissions – bolstered by stronger policy support – are brightening the prospects for many low-emissions fuels. Investment in low-emissions gases is set to rise sharply in the coming years. In the APS, global low-emissions hydrogen production rises from very low levels today to reach over 30 million tonnes (Mt)

per year in 2030, equivalent to over 100 bcm of natural gas (although not all low-emissions hydrogen would replace natural gas). Much of this is produced close to the point of use, but there is growing momentum behind international trade in hydrogen and hydrogen-based fuels. Projects representing a potential 12 Mt of export capacity are in various stages of planning, although these are more numerous and more advanced than corresponding projects to underpin import infrastructure and demand. Carbon capture, utilisation and storage projects are also advancing more rapidly than before, spurred by greater policy support to aid industrial decarbonisation, to produce low- or lower-emissions fuels, and to allow for direct air capture projects that remove carbon from the atmosphere.

But rapid transitions ultimately depend on investment

A huge increase in energy investment is essential to reduce the risks of future price spikes and volatility, and to get on track for net zero emissions by 2050. From USD 1.3 trillion today, clean energy investment rises above USD 2 trillion by 2030 in the STEPS, but it would have to be above USD 4 trillion by the same date in the NZE Scenario, highlighting the need to attract new investors to the energy sector. Governments should take the lead and provide strong strategic direction, but the investments required are far beyond the reaches of public finance. It is vital to harness the vast resources of markets and incentivise private actors to play their part. Today, for every USD 1 spent globally on fossil fuels, USD 1.5 is spent on clean energy technologies. By 2030, in the NZE Scenario, every USD 1 spent on fossil fuels is outmatched by USD 5 on clean energy supply and another USD 4 on efficiency and end-uses.

Shortfalls in clean energy investment are largest in emerging and developing economies, a worrying signal given their rapid projected growth in demand for energy services. If China is excluded, then the amount being invested in clean energy each year in emerging and developing economies has remained flat since the Paris Agreement was concluded in 2015. The cost of capital for a solar PV plant in 2021 in key emerging economies was between two- and three-times higher than in advanced economies and China. Today's rising borrowing costs could exacerbate the financing challenges facing such projects, despite their favourable underlying costs. A renewed international effort is needed to step up climate finance and tackle the various economy-wide or project-specific risks that deter investors. There is immense value in broad national transition strategies such as the Just Energy Transition Partnerships with Indonesia, South Africa and other countries, that integrate international support and ambitious national policy actions while also providing safeguards for energy security and the social consequences of change.

The speed at which investors react to broad and credible transition frameworks depends in practice on a host of more granular issues. Supply chains are fragile, and infrastructure and skilled labour are not always available. Permitting provisions and deadlines are often complex and time-consuming. Clear procedures for project approval, supported by adequate administrative capacity, are vital to accelerate the flow of viable, investable projects – both for clean energy supply as well as for efficiency and electrification. Our analysis finds that permitting and construction of a single overhead electricity transmission line can take up to 13 years, with some of the longest lead times in advanced economies. Developing new

deposits of critical minerals has historically taken over 16 years on average, with 12 years spent lining up all aspects of permitting and financing and 4-5 years for construction.

What if transitions don't pick up?

If clean energy investment does not accelerate as in the NZE Scenario then higher investment in oil and gas would be needed to avoid further fuel price volatility, but this would also mean putting the 1.5 °C goal in jeopardy. In the STEPS, an average of almost USD 650 billion per year is spent on upstream oil and natural gas investment to 2030, a rise of more than 50% compared with recent years. This investment comes with risks, both commercial and environmental, and cannot be taken for granted. Despite huge windfalls this year, some Middle East producers are the only part of the upstream industry investing more today than prior to the Covid-19 pandemic. Amid concerns about cost inflation, capital discipline rather than production growth has become the default setting for the US shale industry, meaning that some of the wind has gone from the sails of the main source of recent global oil and gas growth.

Immediate shortfalls in fossil fuel production from Russia will need to be replaced by production elsewhere – even in a world working towards net zero emissions by 2050. The most suitable near-term substitutes are projects with short lead times that bring oil and gas to market quickly, as well as capturing some of the 260 bcm of gas that is wasted each year through flaring and methane leaks to the atmosphere. But lasting solutions to today's crisis lie in reducing fossil fuel demand. Many financial organisations have set goals and plans to scale down investment in fossil fuels. Much more emphasis is needed on goals and plans for scaling up investment in clean energy transitions, and on what governments can do to incentivise this.

Russia loses out in the reshuffling of international trade

Russia's invasion of Ukraine is prompting a wholesale reorientation of global energy trade, leaving Russia with a much-diminished position. All Russia's trade ties with Europe based on fossil fuels had ultimately been undercut in our previous scenarios by Europe's net zero ambitions, but Russia's ability to deliver at relatively low cost meant that it lost ground only gradually. Now the rupture has come with a speed that few imagined possible. In this *Outlook*, more Russian resources are drawn eastwards to Asian markets, but Russia is unsuccessful in finding markets for all of the flows that previously went to Europe. In 2025, Russia's oil production is 2 million barrels a day lower than in the *WEO-2021* and gas production is down by 200 bcm. Longer-term prospects are weakened by uncertainties over demand, as well as restricted access to international capital and technologies to develop more challenging fields and LNG projects. Russian fossil fuel exports never return – in any of our scenarios – to the levels seen in 2021, and its share of internationally traded oil and gas falls by half by 2030 in the STEPS.

Russia's reorientation to Asian markets is particularly challenging in the case of natural gas, as the market opportunity for large-scale additional deliveries to China is limited. Russia is targeting new pipeline links to China, notably the large-capacity Power of Siberia-2 pipeline

through Mongolia. However, our demand projections for China raise considerable doubts about the viability of another large-scale gas link with Russia, once the existing Power of Siberia line ramps up to full capacity. In the STEPS, China's gas demand growth slows to 2% per year between 2021 and 2030, compared with an average growth rate of 12% per year since 2010, reflecting a policy preference for renewables and electrification over gas use for power and heat. Chinese importers have been actively contracting for new long-term LNG supplies, and China already has adequate contracted supply to meet projected demand in the STEPS until well into the 2030s.

Were the 2010s the "golden age of gas"?

One of the effects of Russia's actions is that the era of rapid growth in natural gas demand draws to a close. In the STEPS, the scenario that sees the highest gas consumption, global demand rises by less than 5% between 2021 and 2030 and then remains flat at around 4 400 bcm through to 2050. The outlook for gas is dampened by higher near-term prices; more rapid deployment of heat pumps and other efficiency measures; higher renewables deployment and a faster uptake of other flexibility options in the power sector; and, in some cases, reliance on coal for slightly longer. The Inflation Reduction Act cuts projected US natural gas demand in 2030 in the STEPS by more than 40 bcm compared with last year's projections, freeing up gas for export. Stronger climate policies accelerate Europe's structural shift away from gas. New supply brings prices down by the mid-2020s, and LNG becomes even more important to overall gas security. But momentum behind natural gas growth in developing economies has slowed, notably in South and Southeast Asia, putting a dent in the credentials of gas as a transition fuel. Most of the downward revision to gas demand to 2030 in this year's STEPS is due to a faster switch to clean energy, although around one-quarter is because gas loses out to coal and oil.

A focus on affordable, secure transitions based on resilient supply chains

A new energy security paradigm is needed to maintain reliability and affordability while reducing emissions. This *Outlook* includes ten principles that can help guide policy makers through the period when declining fossil fuel and expanding clean energy systems co-exist. During energy transitions, both systems are required to function well in order to deliver the energy services needed by consumers, even as their respective contributions change over time. Maintaining electricity security in tomorrow's power systems calls for new tools, more flexible approaches and mechanisms to ensure adequate capacities. Power generators will need to be more responsive, consumers will need to be more connected and adaptable, and grid infrastructure will need to be strengthened and digitalised. Inclusive, people-centred approaches are essential to allow vulnerable communities to manage the upfront costs of cleaner technologies and ensure that the benefits of transitions are felt widely across societies. Even as transitions reduce fossil fuel use, there are parts of the fossil fuel system that remain critical to energy security, such as gas-fired power for peak electricity needs, or refineries to supply residual users of transport fuels. Unplanned or premature retirement of this infrastructure could have negative consequences for energy security.

As the world moves on from today's energy crisis, it needs to avoid new vulnerabilities arising from high and volatile critical mineral prices or highly concentrated clean energy supply chains. If not adequately addressed, these issues could delay energy transitions or make them more costly. Demand for critical minerals for clean energy technologies is set to rise sharply, more than doubling from today's level by 2030 in the APS. Copper sees the largest increase in terms of absolute volumes, but other critical minerals experience much faster rates of demand growth, notably silicon and silver for solar PV, rare earth elements for wind turbine motors and lithium for batteries. Continued technology innovation and recycling are vital options to ease strains on critical minerals markets. High reliance on individual countries such as China for critical mineral supplies and for many clean technology supply chains is a risk for transitions, but so too are diversification options that close off the benefits of trade.

The energy crisis promises to be a historic turning point towards a cleaner and more secure energy system

Energy markets and policies have changed as a result of Russia's invasion of Ukraine, not just for the time being, but for decades to come. The environmental case for clean energy needed no reinforcement, but the economic arguments in favour of cost-competitive and affordable clean technologies are now stronger – and so too is the energy security case. This alignment of economic, climate and security priorities has already started to move the dial towards a better outcome for the world's people and for the planet. Much more remains to be done, and as these efforts gather momentum, it is essential to bring everyone on board, especially at a time when geopolitical fractures on energy and climate are all the more visible. This means redoubling efforts to ensure that a broad coalition of countries has a stake in the new energy economy. The journey to a more secure and sustainable energy system may not be a smooth one. But today's crisis makes it crystal clear why we need to press ahead.

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With the world in the midst of the first global energy crisis – triggered by Russia's invasion of Ukraine – the *World Energy Outlook 2022 (WEO)* provides indispensable analysis and insights on the implications of this profound and ongoing shock to energy systems across the globe.

Based on the latest energy data and market developments, this year's *WEO* explores key questions about the crisis: Will it be a setback for clean energy transitions or a catalyst for greater action? How might government responses shape energy markets? Which energy security risks lie ahead on the path to net zero emissions?

The *WEO* is the energy world's most authoritative source of analysis and projections. This flagship publication of the IEA has appeared every 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 targets and economic development.