Overcoming the Energy Trilemma: Secure and Inclusive Transitions

IEA report to G7 Leaders

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Rationale

Since 2022, in the context of the global energy crisis, the G7 has responded strongly and made a massive pivot towards building the new global clean energy economy through collective commitments and major country-level policy shifts.

The International Energy Agency (IEA) has been mandated by G7 Leaders to develop advice on how to address the triple challenges of energy security, climate change and rising geopolitical risks through concrete actions that lower exposure to immediate risks while moving towards a more resilient and sustainable energy system for the future. Diversity is a key watchword: diverse energy sources and supplies, diverse clean energy supply chains, including manufacturing and critical minerals.

As Japan is handing over the G7 Presidency to Italy, the IEA is pleased to track the progress of G7 commitments on energy security and climate actions towards a 1.5°C-aligned pathway, and to provide recommendations on the future priorities for the G7. These include guidance on the implementation of global commitments and opportunities to build bridges between advanced and emerging economies across the G7, G20 and the Conference of Parties (COP) processes.

This report intends to respond in detail to the invitation by the G7 Leaders Meeting in Hiroshima in May 2023 expressed in its G7 Hiroshima Communiqué (paragraph *25): "While acknowledging various pathways according to each country's energy situation, industrial and social structures and geographical conditions, we highlight that these should lead to our common goal of net zero by 2050 at the latest in order to keep a limit of 1.5°C within reach. In this regard, we invite the IEA to make recommendations by the end of this year on options how to diversify the supplies of energy and critical minerals as well as clean energy manufacturing. Through this, together with our partners, we seek to holistically address energy security, climate crisis, and geopolitical risk including the expansion of global use of renewable energy in order to achieve net-zero emissions by 2050 at the latest and keep a limit of 1.5°C temperature rise within reach."*

Defining and tackling the trilemma

The energy policy trilemma has traditionally been that of meeting sustainability, security and competitiveness goals. The mandate from the G7 Leaders Communique uses the concept of trilemma to describe risks to energy security, climate and geopolitical stability. This definition is well-justified by today's heightened supply security, climate and geopolitical concerns.

New energy security, geopolitical and climate risks

New risks have emerged for the energy sector since the Covid-19 pandemic, with the Russian Federation's (hereafter Russia) invasion of Ukraine, the global energy crisis of 2022/23 and today's instability in the Middle East. These events have reinforced the need for the G7 to remain strongly committed to a comprehensive and modernised energy security agenda that addresses current and future risks as the energy system undergoes a profound transformation.

Energy security concerns were heightened by the global energy crisis triggered by Russia's invasion of Ukraine. Natural gas prices hit all-time highs after Russia cut gas supplies to Europe, as did coal prices. The IEA activated co-ordinated emergency oil stock releases, representing only the fourth and fifth collective actions undertaken by the IEA since its creation, with each representing the largest in its history.

Geopolitical tensions continue to be a major risk factor for energy markets. In particular, Russia's involvement in actions to control oil supply by the OPEC+ alliance has tightened global oil markets and created upward pressure on oil prices. A sudden escalation in geopolitical risk in the Middle East, a region accounting for more than one-third of the world's seaborne oil trade, has put oil markets on edge.

In line with its mission to uphold energy security, the IEA will continue to monitor energy markets closely through winter 2023/24 and beyond. As ever, the Agency stands ready to act if necessary to ensure markets remain adequately supplied.

Drastic spikes in oil, gas and coal prices in 2022 led to higher electricity costs in many parts of the world during the past two years. In Europe, electricity prices in 2022 reached levels four or five times above historical levels. These price hikes turned out to be a very heavy burden for energy consumers, and G7 governments put in place protective measures to shield the most vulnerable. In many G7

economies, energy prices remain a key driver for inflation and cloud the outlook for financial markets and investment as we turn to 2024.

Concerns over the climate crisis have deepened. 2023 is set to be the hottest year on record. Global energy-related carbon dioxide (CO_2) emissions declined in 2020 as a result of the Covid-19 pandemic but rebounded sharply in 2021 and grew by a further 1% in 2022. Global demand for both coal and oil, the two largest sources of energy-related CO_2 emissions, is expected to reach a new all-time high in 2023. Extreme weather events such as heatwaves, droughts, wildfires, tropical storms and floods were more frequent than ever. The latest United Nations Intergovernmental Panel on Climate Change (IPCC) report shows that this has led to widespread adverse impacts and related losses and damages to nature and people. Vulnerable communities who have historically contributed the least to current climate change are disproportionately affected.

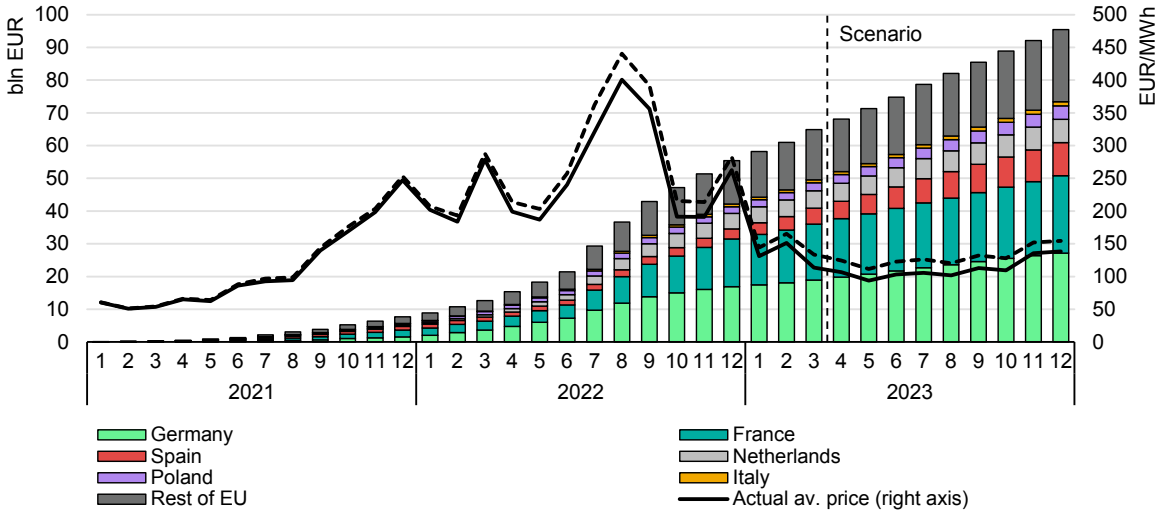
In this context, the Global Stocktake agreed at COP28 in December 2023 sets out important 2030 targets, which are aligned with IEA analysis, notably the tripling of global renewable energy capacity, doubling the rate of energy efficiency improvements, reducing methane emissions and transitioning away from fossil fuels.

A new clean energy economy is emerging fast

G7 countries are among the global leaders in the deployment of cost-competitive clean energy technologies that represent lasting solutions to today's challenges. A rapid pick-up in clean energy deployment is keeping the door open to a 1.5°C aligned pathway, although much more needs to be done to get on track. Moreover, the emerging clean energy economy also brings with it some potential vulnerabilities that governments need to address.

Clean energy can play a vital role in addressing energy security concerns. The IEA's Renewable Market Update in June 2023 estimated that electricity consumers in the European Union have saved EUR 100 billion between 2021 and 2023 due to additional electricity generation from newly installed solar PV and wind capacity. New wind and solar PV installations have displaced an estimated 230 terrawatt hours (TWh) of more expensive fossil fuel generation in the period, leading to a reduction in wholesale electricity prices on all European markets. Without this additional renewable power generation, the average wholesale price of electricity in the European Union in 2022 would have been 8% higher.

Figure 1 Savings in electricity costs thanks to solar PV and wind additions in the European Union, 2021-2023



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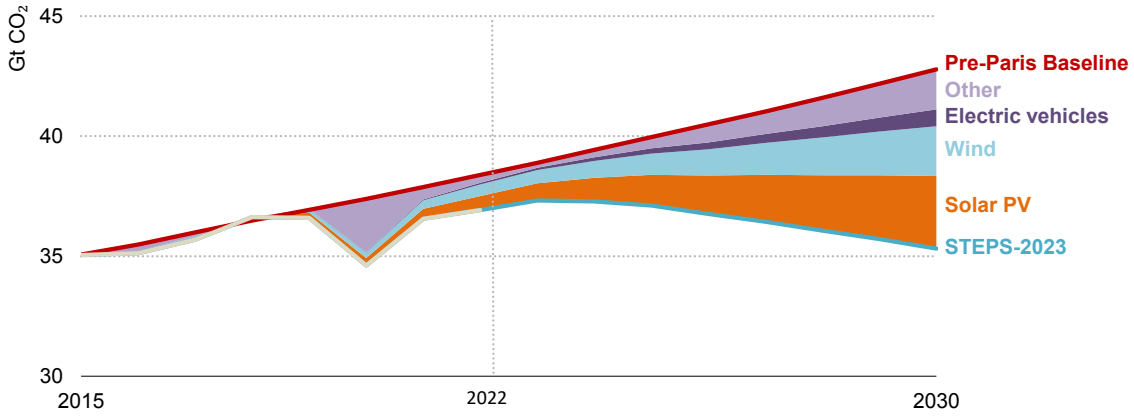
Note: Cumulative costs are calculated based on EU wholesale spot electricity prices.
Source: IEA (2023), Renewable Energy Market Update – June 2023.

Figure 2 Global energy sector CO_2 emissions in the pre-Paris Agreement Baseline Scenario and the Stated Policies Scenario, 2015-2030



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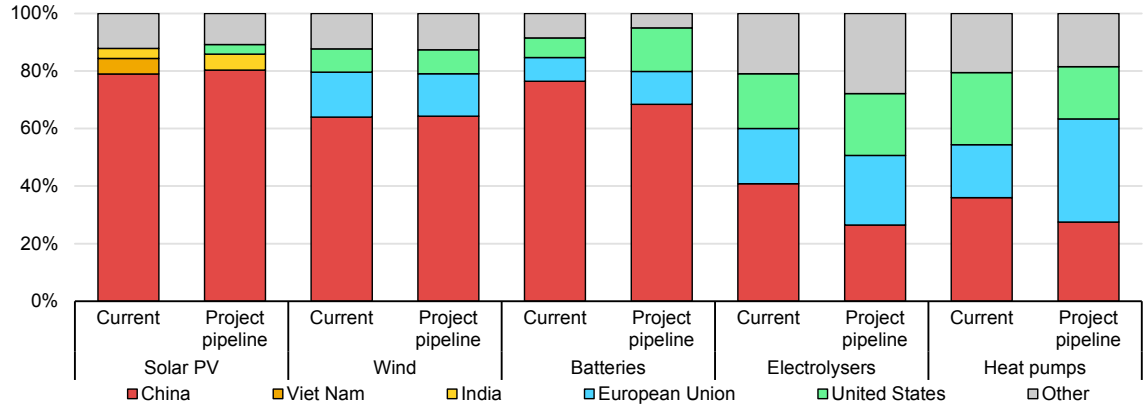
Source: IEA (2023), World Energy Outlook 2023.

Such contributions from low-emissions technologies are changing the energy outlook, even if they are not yet enough to align with global climate goals. The IEA's World Energy Outlook 2023 highlights that today's energy and climate policy settings are already set to lead to a peak in demand for each of the fossil fuels before 2030 and a peak in global energy-related CO_2 emissions by 2025. This change in the outlook is the result of efforts by governments to promote clean energy technologies such as renewables, energy efficiency and heat pumps, not only for the climate but also for energy security and affordability objectives.

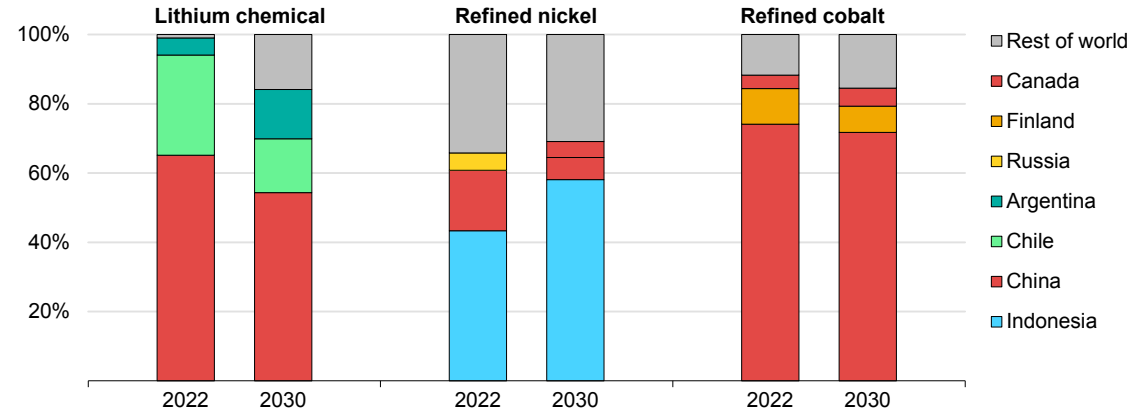
Analysis in the IEA's Energy Technology Perspectives 2023 also underscores that many clean energy supply chains exhibit a high degree of geographical concentration, both for the mining and processing of critical minerals and ultimately in the manufacturing of clean technologies, many of which rely on critical minerals. This analysis highlights the crucial importance of resilient and diverse supply chains. Today, the People's Republic of China (hereafter China) leads global clean energy investment and has a dominant position in the refining and processing of critical minerals, as well as in the manufacturing of relevant clean energy technologies.

Figure 3 Share of top three manufacturing regions for key clean energy technologies in 2023 and 2030 based on announced projects



Source: IEA (2023), World Energy Outlook 2023.

Figure 4 Geographic concentration of refined key mineral supply in 2022 and in 2030 based on announced projects



Source: IEA (2023), World Energy Outlook 2023.

Japan's G7 Presidency has strengthened the G7's clean technology manufacturing agenda. The implementation of the G7 Clean Energy Economy

Action Plan remains a priority to maintain high investment and efforts to diversify and strengthen global clean energy supply chains. The implementation of the G7 Clean Energy Economy Action Plan is an important lever for the next wave of manufacturing investment.

G7 partnerships to support transitions in emerging market and developing economies

Delivering the emissions reductions to achieve net zero by 2050 will require high levels of co-operation and co-ordination across all geographies, jurisdictions and industries, as well as unprecedented levels of finance and technology sharing. The updated 2023 IEA Net Zero Roadmap shows that leadership by advanced economies, notably the G7, can create more favourable conditions for EMDEs to make progress in their energy transitions. In the updated net zero pathway, advanced economies reach net zero emissions sooner than emerging and developing economies (EMDEs).

The G7 needs to work closely with EMDEs, including the G20 and other fora – demonstrating a new commitment to international co-operation in support of energy for development, acknowledging that pathways for energy transitions will vary by country due to such factors as different resource endowments and stages of development. Behind the single global goal to achieve a secure, affordable energy transition lies a multitude of different national approaches.

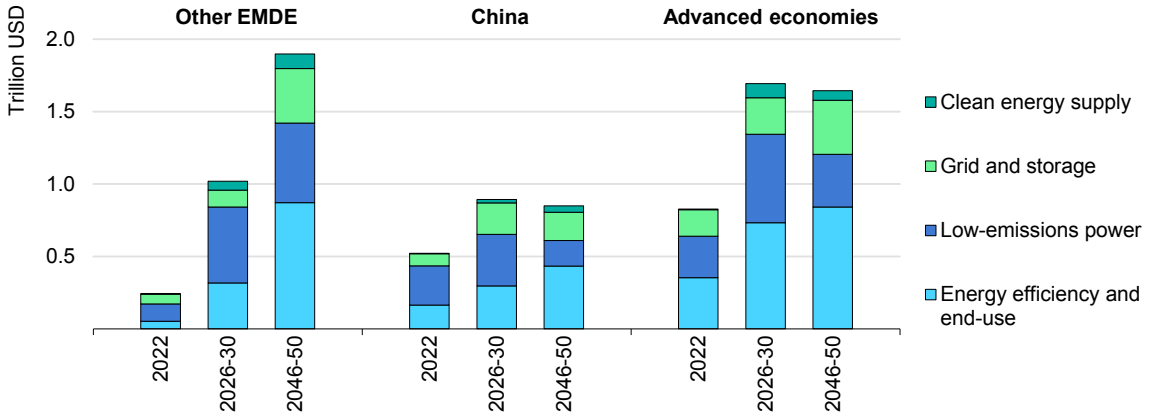
EMDEs need much stronger support in planning and achieving clean energy transitions and economic development in a way suited to their circumstances. Advanced economies and multilateral institutions should play a major role – particularly when it comes to mobilising a significant increase in investment in EMDEs. In the IEA's net zero pathway, global clean energy spending rises from USD 1.8 trillion in 2023 to USD 4.5 trillion annually by the early 2030s, with the largest increases seen in many EMDEs outside China. This drives multiple benefits for sustainable growth, including cleaner air, industrial opportunities and clean energy employment.

This can be facilitated by G7 leadership and dialogue with major energy consumers and producers in standard-setting for trade in zero and near-zero emissions commodities and greater co-operation on technology transfer and intellectual property issues. In addition, the G7 needs to redouble its support for the energy-related Sustainable Development Goals, so that all people and communities who currently do not have access to electricity or clean cooking achieve this by 2030. At COP28, the IEA has called for action on clean cooking, based on a vision outlined jointly with the African Development Bank in 2023 and will host a major Summit on 14 May 2024 in Paris to leverage a historic commitment to most consequential investments in Africa's and the world's future.

Clean energy investments in emerging market and developing economies

Today, clean energy investment is concentrated in a few markets and has major shortfalls in most EMDEs. Of the USD 770 billion invested each year in clean energy in EMDEs, most of it is concentrated in a few countries. Two-thirds of the total is in China, and more than three-quarters is in three countries: China, India and Brazil. Investment barriers vary by country but include higher interest rates; weak policy frameworks and market designs; insufficient grid infrastructure; financially strained utilities; and the high cost of capital. Much more needs to be done by the international community to drive investment in lower-income economies and mobilise private sector investment.

Figure 5 Average annual clean energy investment needs by region/country in the net zero emissions scenario, 2022-2050



Source: IEA (2023), World Energy Outlook 2023.

The new global energy economy represents a huge opportunity for growth and employment in EMDEs, according to the special report on Scaling Up Private Finance for Clean Energy in Emerging and Developing Economies, published by the IEA and the International Finance Corporation (IFC) in 2023. Public and private spending in clean energy in EMDEs needs to more than triple from USD 770 billion per year in 2022 to USD 2.2-2.8 trillion per year by the early 2030s. The most urgent investment needs will be in clean electrification, grid infrastructure and energy efficiency.

Africa accounts for around 20% of the world's population but attracts less than 2% of its spending on clean energy. Energy investment in Africa has been falling in recent years. Achieving African countries' energy development and climate goals will require energy investment to more than double from today's levels by 2030, at which point clean energy would account for over two-thirds of energy investment

across the region. The cost of capital in African countries for clean energy projects is often more than two to three times higher than in North America or Europe. Concessional funds can play a vital role in scaling up investments and mobilising private capital. In a recent report on Financing Clean Energy in Africa, the IEA estimated that USD 28 billion in concessional capital is required to mobilise private investment in Africa's clean energy sectors by 2030, more than a tenfold increase from today. Concessional finance providers are able to draw on a range of evolving credit enhancements and de-risking mechanisms, such as guarantees and insurance, risk sharing and pooling products, liquidity support, and currency hedging.

Diversification of fossil-fuel dependent power systems and economies

Secure and orderly energy transitions will only unfold with countries working together co-operatively and in a way that recognises their shared interests. This includes countries that are highly dependent on fossil fuels, including power systems that rely heavily on coal and those with major oil and gas supply chains.

Comprehensive, integrated policies addressing emissions from all sources are essential for climate action, but reducing emissions from coal needs to be a first-order priority. Every pathway that avoids severe impacts from climate change involves early and significant reductions in coal-related emissions. International co-operation, public financial support and well-designed integrated approaches that incorporate the need for fair and inclusive transitions will be essential.

Coal transitions are complicated by the relatively young age of coal plants across much of the Asia Pacific region. Plants in EMDEs in Asia are on average less than 15 years old compared with more than 40 years in North America. Industrial facilities using coal are similarly long lived. For coal-dependent heavy industries such as steel and cement, the year 2050 is just one investment cycle away.

Governments and international institutions need to remove roadblocks that can prevent more cost-effective and cleaner options from entering the energy system. An important condition is the efforts made towards ending the construction of new unabated coal-fired power plants while supporting coal transitions. Packaging together different elements of coal transitions in ways that include social elements as well as a rapid scale-up in clean energy, as with the Just Energy Transition Partnerships in South Africa, Indonesia and Viet Nam, are promising ways to build momentum, mobilise international support and ensure overall policy coherence.

In a world where demand for energy services is increasing, resource-rich countries will continue to seek value from their endowments, hydrocarbon or otherwise, and importers will value secure, affordable energy supplies. The task ahead is to make

these quests compatible with net zero transitions and the gathering pace of change in global energy. There are four main routes to promote effective international co-operation in this area: ensuring the right market signals; co-operating to unlock investment in low-emissions fuel trade; collaboration on technology; and bilateral and multilateral engagement. There are several existing policy efforts looking to promote action in these areas.

For producer economies, effective multi-year programmes and partnerships could be designed with the close involvement of international finance, including multilateral development banks. Increasing the resilience of major producer economies, particularly as energy transitions gather pace, is a matter of importance beyond the producers themselves. The capital generated by energy trade can make a major contribution towards the large-scale changes required in producer economies, while helping to ensure that consumers have a stable supply of energy as they make the shift to a net zero emissions future.

One key area in which importing and exporting countries can work together is tackling methane emissions. If consumer economies send support or signals to producer economies – which could take the form of financial and technical assistance, financial penalties such as CO_2 border taxes, or import restrictions – producer economies would have a clear incentive to reduce these emissions.

The oil and gas industry could play an important role in energy transitions. New IEA analysis on the sector's role in net zero transitions highlights that some 30% of the energy consumed in 2050 in a decarbonised energy system comes from technologies that could benefit from the industry's skills and resources – including hydrogen, carbon capture, offshore wind and liquid biofuels. However, this would require a step-change in how the sector allocates its financial resources. The oil and gas industry invested around USD 20 billion in clean energy in 2022, or roughly 2.5% of its total capital spending.

Energy security in energy transitions

Achieving net zero emissions goals ultimately boosts global energy security, but the pathways to get there are unlikely to be linear or smooth. Energy transitions require adding new clean energy infrastructure while reducing reliance on existing CO_2-emitting infrastructure, and managing the co-existence of these systems is challenging, especially during a time of elevated geopolitical risks.

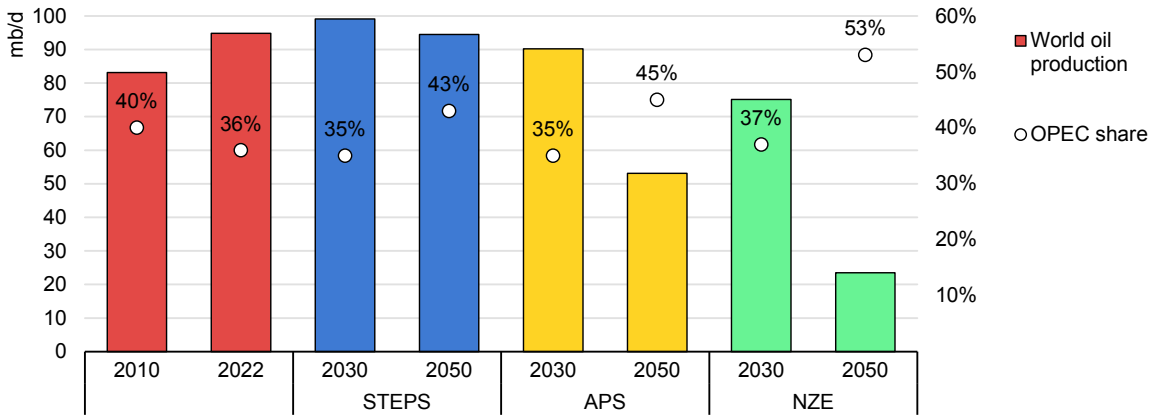
The need to look at a broad range of energy security issues during energy transitions was a core pillar of new mandates given to the IEA at its Ministerial meeting in March 2022. The Ministerial Communiqué recognised the need for the IEA to remain vigilant in an increasingly complex energy security environment. Building on core principles – notably the benefits of diversified energy sources, supplies, routes and means of transport – the communiqué reflects on evolving security issues for oil, gas and electricity markets and infrastructure as well as new areas such as climate resilience, clean energy supply chains and critical minerals.

Some core elements of a new approach to energy security are outlined below, with particular attention to the importance of diversified and resilient clean energy supply chains.

(1) Remain vigilant on traditional risks to energy security

Traditional risks to energy security evolve but do not disappear in energy transitions, so constant vigilance along with well-designed security policies and safety nets remain essential. Today's volatile situation in the Middle East comes against a backdrop of delicately balanced global oil markets. It should also be noted that in the long term, as oil consumption declines due to the progress in clean energy transitions, the share of producers in the Middle East region will increase in global oil supply.

Figure 6 World oil production and OPEC share in 2010 and 2022 and scenarios for 2030 and 2050



Note: STEPS = stated energy policy scenario, APS = announced pledges scenario, NZE = net zero emissions scenario.
Source: IEA (2023), World Energy Outlook 2023.

Natural gas is expected to play a role in important aspects of energy transitions, including as a source of flexibility to ensure the integration of variable renewables into energy systems and to meet growing energy demand and industrialisation needs in EMDEs. The context for the security of natural gas supply has also shifted dramatically in recent years as a result of Russia's cuts to pipeline deliveries to Europe, highlighting the importance of well-functioning liquefied natural gas (LNG) markets. Enhanced dialogue between producers and consumers, transparent information sharing, and reliable short- and medium-term analysis, taking into account risk factors, remains important for the stability of oil and gas markets. Gas reserve mechanisms and policy measures including joint procurement and flexible use of LNG storage tanks, tailored to each country's circumstances, could also contribute to global market stabilisation.

(2) Ensure well-sequenced and co-ordinated actions across energy demand and supply

The global energy crisis was not a clean energy crisis, but it has focused attention on the importance of ensuring rapid and orderly transitions. Orderly transitions require a well-balanced set of actions across energy demand and supply. Economic drivers increasingly support the adoption of mature clean energy technologies, but co-ordinated actions are still essential to ensure a smooth transition. Consumption patterns will not shift at scale unless affordable and reliable low-emissions options and more efficient technologies are readily available in the market. Suppliers will not commit to large-scale investments unless they have reliable expectations of rising demand for low-emissions

products and services. All market participants rely on adequate, modern and smart infrastructure, notably electricity grids, to bring them together.

The faster a new clean energy economy can emerge to meet rising global demand for energy services, the sooner fossil fuel demand and emissions will start to decline. Truly structural and sustainable solutions for ensuring market stability and meeting climate targets include improving energy efficiency, broader and faster electrification of end-use sectors including transport and industry, and the development and deployment of low-emissions fuels. The IEA's updated Net Zero Roadmap sees this technology uptake resulting in a 25% decline in the use of fossil fuels in 2030 in a pathway aligned with limiting global warming to 1.5°C. G7 efforts to phase out inefficient fossil fuel subsidies that encourage wasteful consumption in line with the G7 pledges need to continue even more consistently. Greater energy efficiency progress is a key solution for this.

(3) Prioritise energy efficiency across end-use sectors

Energy efficiency is an indispensable tool to accomplish multiple policy aims, easing pressures on consumers and reducing their vulnerability to high and volatile fuel prices, cutting reliance on fuel imports, and driving progress towards climate goals while supporting jobs and economic growth. However, the rate of improvement in global energy efficiency has slowed over the past decade and new efforts are needed toward 2030 to double the current pace of progress. The IEA's Global Energy Efficiency Conference 2023 and the related Versailles Statement highlighted a path forward for governments, which should implement effective policy packages that may include measures related to behaviour change, sufficiency measures, and technological improvements such as digitalisation and decarbonised heating. With the public sector leading by example, other sectors including industry, services, buildings, transport and agriculture will all have an important role to play in improving energy efficiency and driving investment.

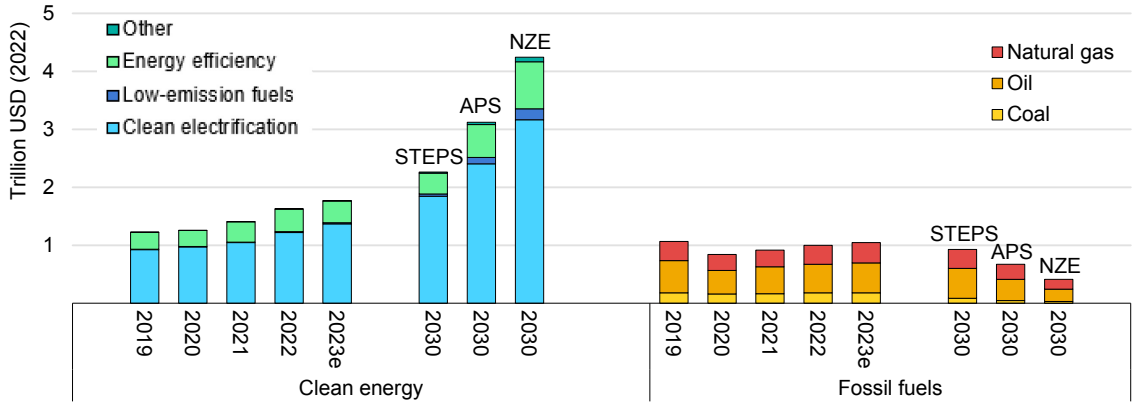
Lessons from the global energy crisis confirm that managing demand can be a powerful tool to cut energy bills, emissions and energy consumption. Many countries have sustained these behavioural changes and enjoy still a lower energy consumption than before the crisis. Demand-side responses are more important than ever during energy transitions as high fuel prices may not readily trigger new supply investments.

(4) Scale up clean energy investment in order to reduce fossil fuel use

The latest IEA estimates suggest that some USD 2.8 trillion has been invested in energy in 2023, with USD 1.8 trillion on clean energy and USD 1 trillion on unabated fossil fuel supply and power. Five years ago, clean energy and fossil fuels attracted the same level of investment of around USD 1 trillion. The rise in clean energy investment is a very positive sign but comes with some caveats.

First, today's clean energy investments remain well short of the amounts needed to align with the net zero emissions by 2050 pathway, which requires spending of well over USD 4 trillion annually by 2030. Second, there are profound geographical imbalances in this investment, with almost all of the increases in recent years coming in advanced economies and China. Third, there are wide variations across sectors. Some technologies such as solar PV and electric vehicles are moving at a pace that is aligned with a 1.5°C pathway, but many others are not. The IEA has highlighted grid investments as an area of particular concern.

Figure 7 Historical investment in energy benchmarked against needs in IEA scenarios in 2030



Source: IEA (2023), World Energy Investment 2023.

Rapid increases in clean energy spending will reduce the investment required in the fossil fuel sector. As things stand, oil and gas investment is expected to more than double the levels needed in 2030 in the IEA's Net Zero Emissions by 2050 (NZE) Scenario, and coal investments are six times higher.

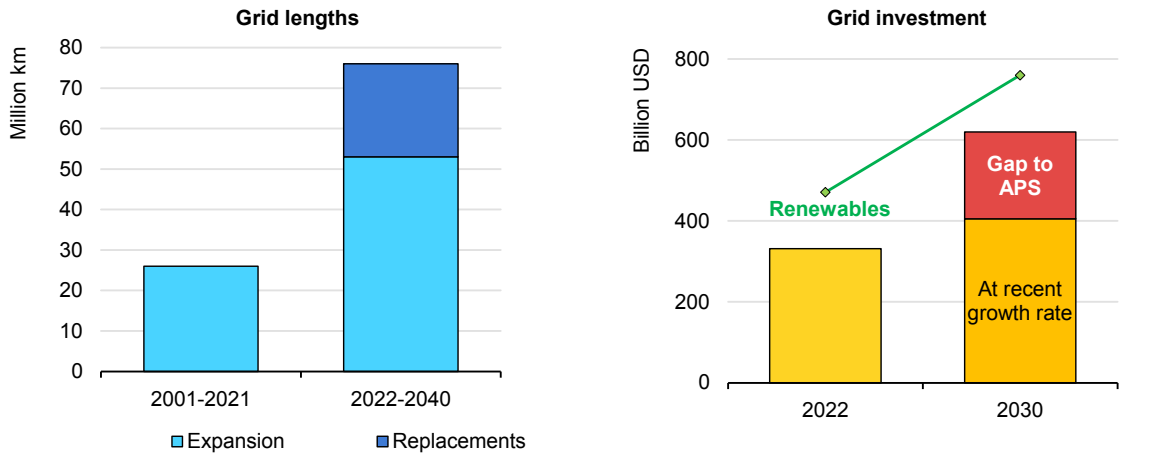
Changes to demand are important, as simply cutting investments in fossil fuels will not get the world on track for this scenario but lead to higher prices and volatility. Without demand-side action, there is also serious risk of fossil fuel use lock-in which would make the net zero path harder to achieve. Governments should implement

much stronger and effective measures to accelerate low-emissions deployments, reduce fossil fuel demand and send much clearer signals to market to guide investors.

(5) Put electricity security at the heart of transitions

In the case of electricity markets, ensuring the availability of sufficient dispatchable resources has become the major test for ensuring the reliability of power systems that have increasing variable renewable sources. The vast majority of dispatchable resources currently are fossil fuel thermal power plants. These flexibility resources should also be decarbonised with batteries, demand-side response and the use of low-emissions fuels. Before such options become available on a large commercial scale, existing thermal capacities can play a role in providing flexibility and adequate capacity in power systems. Governments should carefully design power market systems to avoid the premature phase-out of existing thermal power plants before alternative resources become available at sufficient scale, especially where there are large seasonal swings in electricity demand. The Managing Seasonal Variability of Renewables report by the IEA, which was produced for the G7, highlights that a mix of flexibility resources is needed to manage variability across all timescales and seasons. In particular, systems with very high level of wind and solar PV require seasonal flexibility services, which can be provided from existing thermal power capacities and from hydropower plants. Eventually, as energy systems transition towards net zero emissions, all flexibility services will need to be fully decarbonised. Accelerating investments in power grids is crucial for faster clean energy transitions and electricity security, as identified in the Electricity Grids and Secure Energy Transitions report by the IEA.

Figure 8 Length of grid expansion and replacements and grid investment needed for the announced pledges scenario

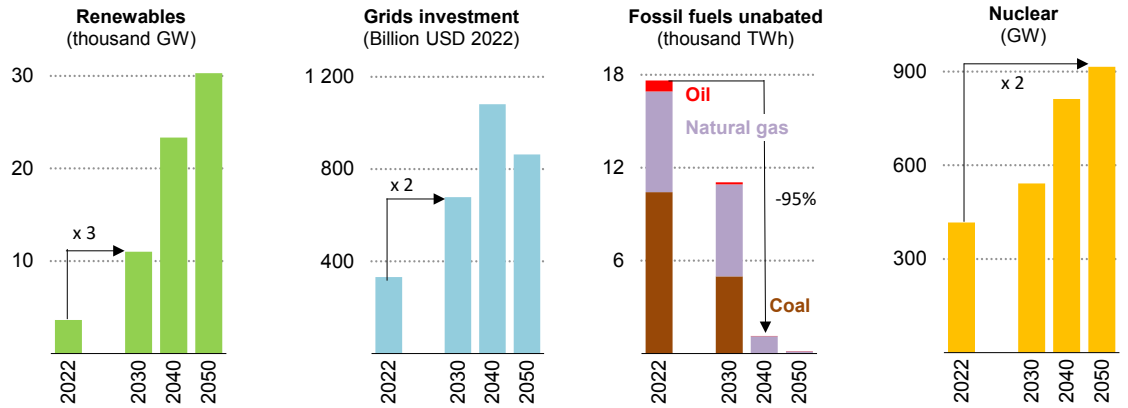


Source: IEA (2023), Electricity Grids and Secure Energy Transitions.

(6) Deploy a broad range of low-emissions technologies

There is no single or simple technology solution for secure energy transitions, and a range of interlocking and complementary options are required across a complex energy system. A large suite of technologies needs to be mobilised to lower emissions. In the power sector, for example, nuclear power is a proven dispatchable low-emissions power generation source, alongside renewables. The IEA's NZE Scenario shows a doubling of global nuclear power capacity to achieve a cost-optimal transition to net zero, led by countries which support its use. Achieving net zero with a lower nuclear contribution is technically possible but comes with a higher burden for electricity tariff payers, and with further strains on clean energy technology supply chains and critical minerals. But reaching net zero emissions requires more than decarbonising the power sector alone. In the NZE Scenario, electrification of energy end-uses happens at massive scale through the major deployment of batteries, heat pumps and numerous other technologies, increasing the share of electricity in energy end-use to 50% from 20% currently. The other half is covered by low-emissions fuels in solid, liquid or gaseous forms, requiring the use of sustainable bioenergy, ammonia and sustainable aviation fuels, among others. Ensuring fast progress in low-emissions fuels is necessary to achieve net zero by 2050 and to guard against risks to the security of supply of critical minerals and other materials needed for rapid electrification. Achieving net zero emissions would require new technologies that are not yet commercially viable, including advanced battery designs, hydrogen-based steel making, ammonia-powered ships, CO_2 capture at cement plants, negative emission technologies like direct air capture (DAC) and bioenergy with carbon capture and storage (BECCS), innovative nuclear technologies such as small modular reactors (SMRs), and others.

Figure 9 Key milestones for the electricity sector in the net zero emissions scenario, 2022-2050



Source: IEA (2023), World Energy Outlook 2023.

(7) Ensure diverse and resilient clean energy supply chains

The development of clean energy technology supply chains has made impressive strides since 2015. Progress has been particularly fast in the manufacturing segment, notably for solar panels and batteries, where new facilities are benefiting from standardisation and short lead times. The pipeline of announced manufacturing projects is expanding rapidly. If all announced solar PV module manufacturing projects come to fruition, their combined output globally, together with that from the increased utilisation of existing capacity, would exceed the deployment needs seen in the IEA's NZE Scenario in 2030; EV and grid storage battery needs for 2030 would almost be met on the same basis.

The expected pace of growth in critical mineral supplies does not match that of clean energy technology manufacturing capacity additions, although announcements of new projects are gathering pace. The overall speed of the transition is usually determined by the slowest-moving component, and that makes it important to strengthen efforts to scale up investment in critical mineral supplies.

A high degree of supply chain concentration remains a major concern for both clean energy technology manufacturing and critical minerals, as it can make the entire supply chain vulnerable to individual country policy choices, company decisions, natural disasters or technical failures. For critical minerals, recent IEA analysis revealed that limited progress has been made in terms of diversifying supply sources; the situation has even worsened in some cases, especially for cobalt and nickel. For both clean energy technologies and critical minerals, a broad and bold strategy is needed that brings together investment, innovation, recycling and rigorous sustainability standards to build more resilient and diverse clean energy supply chains. Greater international co-operation will be essential.

On 28 September, the IEA Critical Minerals and Clean Energy Summit brought around 90 countries, business leaders, investors and heads of international organisations and civil society organisations. The discussions yielded six key action areas to help turn risks into opportunities through greater international collaboration:

- **Accelerate progress towards diversified minerals supplies.** A high level of supply concentration must be reduced by bringing new projects online across a diverse range of geographical regions, facilitating cross-investment opportunities between producer and consumer countries, strengthening co-operation through multilateral initiatives and introducing financial tools to de-risk investment. Supporting diversity in the midstream processing and refining sectors is needed urgently.

- **Unlock the power of technology and recycling.** Through expanding research, development and deployment, full potential of technology and recycling need to be tapped to alleviate potential strains on supply by reducing the volume of critical minerals required in products, as well as the energy and water requirements for extraction and processing. Robust material tracing and tracking, as well as new methods to improve circularity, mineral re-use and end-of-life practices, should be explored through a progressive focus on collection of e-waste, end-of-life batteries, permanent magnets, solar panels and wind turbines, along with incentives for recycling activities.
- **Promote transparency in the markets.** Some critical mineral markets have limited price transparency, which introduces volatility and hinders new investments. There is a need to develop transparent markets and enabling environments that facilitate new investments, while strengthening due diligence and traceability practices. Transparency in markets and policies on access to raw materials are needed.
- **Enhance the availability of reliable information.** Accurate, accessible and timely data is vital. However, information on investment levels, trade flows and environmental, social and governance (ESG) performance is limited. The IEA should conduct regular market assessments to deliver the required transparency and support informed decision making. Countries should also consider international mechanisms for data sharing while enhancing the availability of IEA data that will enable stakeholders to gauge risks and identify bottlenecks.
- **Create incentives for sustainable and responsible production.** All stakeholders should commit to adopting sustainable and responsible practices that protect workers and communities and mitigate various ESG risks. There is a need to encourage mechanisms that reward good ESG performance by embedding ESG considerations into policy and investment decisions and by expediting approvals of new facilities without loosening legal and regulatory protections. Systematic tracking of ESG performance and strengthened efforts to improve public reporting of data on ESG indicators should also be encouraged.
- **Foster efforts on international collaboration.** All stakeholders should explore new opportunities to coordinate efforts, especially on data sharing, security of supply, competitiveness in refining and processing, sustainable and responsible practices, and long-term strategic planning. One specific area is efforts to enhance the security of supply by exploring mechanisms that include voluntary stockpiling that do not adversely impact markets, alongside other measures to help enhance the resilience of supply chains. There is also a need to ensure complementarity and interoperability of initiatives, standards and norms.

Building on the outcome of the Summit, the IEA will continue to work with its member countries through the Working Party on Critical Minerals on the specific design of the IEA Voluntary Critical Mineral Security Programme, as well as systematic market monitoring through comprehensive demand and supply outlook and other topical analyses.

Addressing the high degree of geographical concentration of clean energy technology manufacturing will require additional policy efforts to be successful. While the mining of critical minerals is linked to resource endowment, the ability of countries to reap the potential economic benefits from the manufacturing of clean energy technologies will depend on a variety of circumstances. There are four crucial considerations:

- It is important to recognise that clean energy technology supply chains are at the nexus of climate, energy and industrial policy. This means that tapping into the industrial opportunities that come with clean technology manufacturing requires an all-of-government approach that includes different ministries and policy makers.
- High geographical concentrations can threaten supply security across all steps of clean technology supply chains. There are different policies for different supply chain steps. For example, while upstream risks in mining can be addressed through stockpiling or recycling, other supportive policies are needed further along the supply chain.
- Industrial strategies that build on a mapping of domestic competitive strengths and identify strategic partnerships are critical to effectively benefit from, and participate in, the new energy economy. For most countries, it is not realistic to effectively compete in all supply chain steps, nor in all supply chains. Understanding relative strengths and competitiveness, which can be boosted by building complementary strategic partnerships, is a key consideration for industrial strategies.
- Time is of the essence for clean energy technology supply chains. It is not too late to capitalise on the opportunities of the new energy economy. Success here builds on reducing permitting times, including for large infrastructure projects; on mobilising investment and financing for key supply chain elements; on developing skills; and on accelerating innovation in early-stage technologies.

To support decisionmakers in the G7 and beyond with the design of strategies for diversifying clean technology manufacturing, the IEA will release a report during the first half of 2024 in response to a request of G7 Leaders.

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Typeset in France by IEA - December 2023
Cover design: IEA
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