In collaboration with Accenture

Securing the Energy Transition

WHITE PAPER

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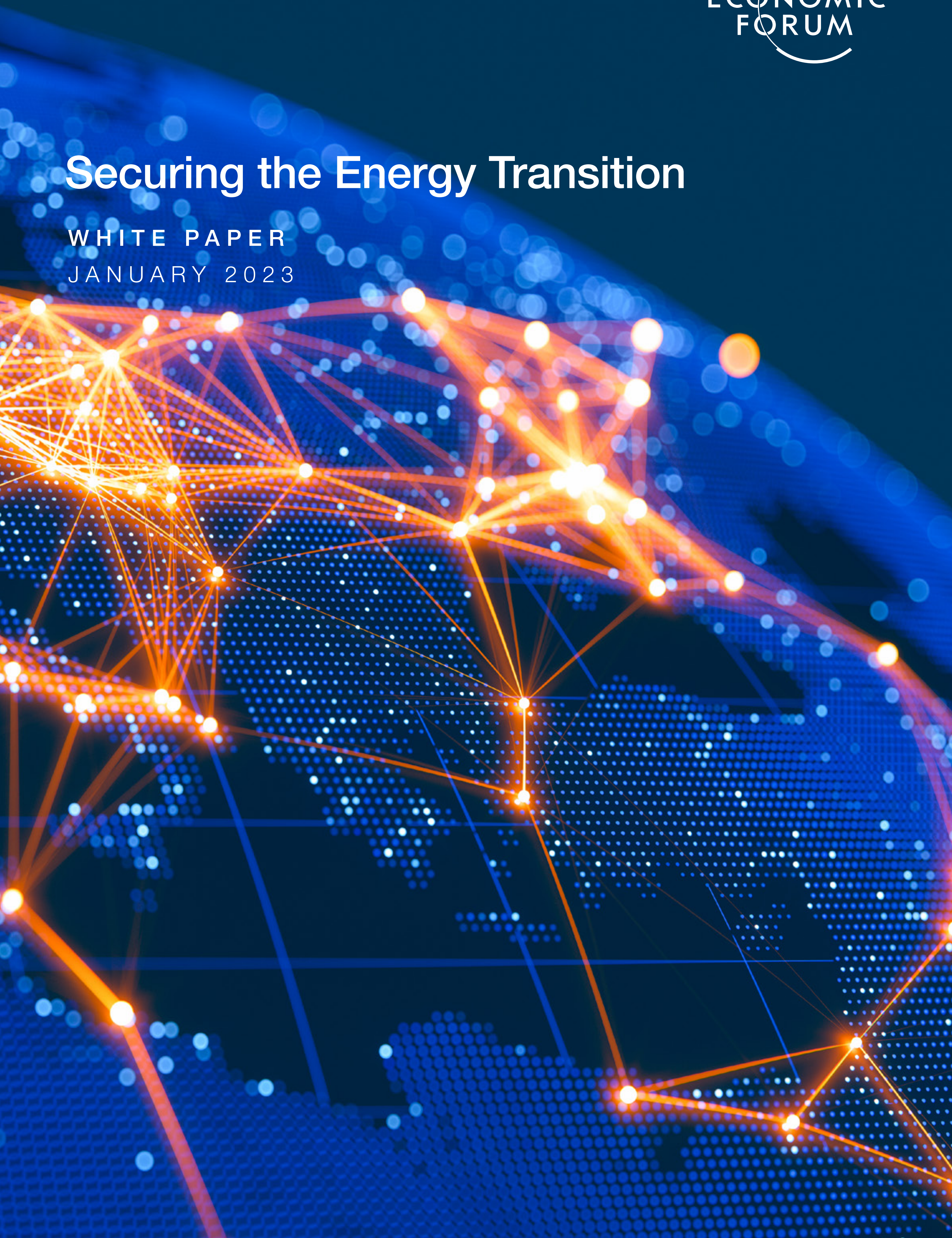

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Foreword

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Energy security is one of the key pillars of energy system performance, a primary concern for governments and economic players across the globe, and a dimension whose impacts multiply across supply chains, countries and international systems. People, companies and nations depend on secure and uninterrupted access to energy at affordable prices.

Yet, we are in the middle of an unprecedented energy crisis, afflicting countries across the world with cascading macroeconomic implications. Worse still, this energy crisis is hitting a world left more vulnerable by the COVID-19 pandemic, during a full-fledged global energy transition process. It is clear from the current crisis that several distinct dimensions of energy security remain unaddressed. We need a new strategic perspective to effectively assess and monitor global energy security on an ongoing basis.

During the past months, short-term measures implemented by countries to address the energy crisis include fuel substitution, market interventions, fiscal measures and voluntary demand-reduction. These actions may address immediate security needs. But unless they are aligned with a long-term energy transition – based on goals of sustainability, economic growth and justice – they will offer only a patchwork solution.

The challenges underpinning today's energy context are so complex and interconnected that they can only be resolved with structural solutions. Relying on short-term fixes will potentially hamper the transition to a sustainable, clean and affordable energy system. This is something the world cannot afford. However, this energy crisis also provides an opportunity for countries to redesign their approach to energy security, in light of advancing technologies and a changing fuel landscape.

The objective of this report is to understand how energy security has evolved amid the current crisis and against a backdrop of the ongoing energy transition. It reflects on the long-term sustainability of measures currently being deployed and proposes 10 ways to align immediate interventions with the long-term energy transition. It also proposes a structured framework to balance energy security as part of the effective energy transition.

An exceptional level of multi-stakeholder collaboration is necessary. Governments are primarily responsible for ensuring their countries' energy security. But addressing this crisis in a sustainable manner must involve everyone. Companies, international organizations and individual consumers all play critical roles.

We offer this framework to help foster global common ground on ways forward for the energy sector to support much needed, co-ordinated stakeholder action at speed and scale. What is now a global crisis could become an opportunity to steer a more direct course towards a secure, sustainable and affordable energy future for everyone.

Executive summary

Energy security and climate goals are not mutually exclusive. The energy crisis should not derail the energy transition – but the emerging energy system requires a new strategic approach to secure the transition.

Energy security and affordability present global challenges, but both are integral elements of a successful energy transition, alongside sustainability to mitigate climate change. The current energy crisis is driving inflation, slowing economic growth and contributing to social turmoil.

Some choices made by countries in response to the crisis, such as improving energy efficiency and scaling renewables, will be beneficial for the wider energy transition. But other actions – including increased production of electricity from coal and broad-based consumption subsidies – put long-term energy transition imperatives at risk, while leaving those countries more vulnerable to future crises and putting global climate goals out of reach.

The energy crisis highlights the impact of trends and structural challenges that have been years in the making. It is a consequence of factors that include underinvestment in the energy system and its transition over many years, as well as shocks induced by COVID-19. The global pandemic led to a historically sharp drop in energy demand and investment in 2020. While post-pandemic demand rebounded in 2021, global energy supply and investment were unable to keep up. Climate change-induced extreme weather events, such as wildfires, heatwaves and droughts further strained the conventional energy infrastructure.

Energy markets and systems were therefore already under pressure when Russia started its war in Ukraine. The war's shock waves were felt throughout interconnected energy markets and led to a global energy crisis with severe economic consequences.

Short-term responses to the crisis have pushed global CO_2 emissions to record highs[1] as several countries have reverted to coal for power generation in a bid to save their natural gas for other uses. Policies to mitigate the impacts of rising energy prices have stressed public finances and led to emergency energy curtailment. To pursue the energy transition at pace, short-term interventions should align with climate goals, protect market signals, target fiscal discipline and incentivize demand response.

As the energy transition unfolds, shifts in technology, commodities, infrastructure and supply chains, along with geopolitical dynamics, will create new security constraints. A comprehensive reappraisal of energy security is necessary, to build resilience to potential shocks. Without a robust framework and a clear articulation of stakeholder roles within that framework, it would be challenging to co-ordinate the collective action necessary.

This paper proposes 10 ways to align immediate interventions with the long-term energy transition, along with a comprehensive framework to highlight how energy security can be strengthened in a way that responds to the crisis and helps accelerate a just and sustainable energy transition. The framework features the following elements:

Supply security:
Conventionally, these actions have involved reducing import dependence by boosting domestic self-sufficiency. Increasing the domestic low-carbon energy mix and diversifying fuel and renewable energy systems can address both security and sustainability needs. Securing the supply chain for critical materials is another key pillar in supply security, as progress on clean-energy technologies is heavily reliant on affordable and sustainable access to these materials.

Demand management:
Rapid demand-side responses have included consumption curtailment actions. Demand-side management must now include incentives to shift energy demand permanently towards clean energy, as well as initiatives to drive energy efficiency, materials efficiency, electrification, behavioural change, digitalization and demand-response programmes at scale.

Markets and regulation:
The current landscape forms the basis for directing the capital allocation necessary for the energy transition. Policy structures and incentives play a crucial role by driving innovation and scale, and by shaping the

energy systems to accommodate new technologies. A transparent and predictable regulatory landscape is a pre-requisite to manage and accelerate clean energy investments, while co-ordinating the retirement and reuse of existing infrastructure. For example, liquefied natural gas (LNG) regasification assets should be designed or retrofitted to ensure compatibility with future low-carbon fuel infrastructure.

Global and regional trust:
Trust enables countries to rely on diverse energy supply sources, invest in cross-border super grids, increase trade in low-carbon power, manage cross-border carbon emissions and enhance system flexibility – all while deploying effective energy security plans. Trust and collaboration are needed to reduce risks and the cost of capital for the transition; they are also needed to set up new international centres of expertise in finance and technology, to help countries share knowledge on energy supply chains, privacy and the cyber challenges of the future.

System stability:
This enables energy systems to withstand operational disturbances, such as grid outages, planned maintenance, extreme weather events or financial shocks (e.g. price volatility). Stability enhancements, which strengthen the reliability and resilience of the system, have never been more important or more challenging. For example, a key enabler of energy security is an increased reliance on distributed solar and wind. However, introducing more wind and solar in turn brings additional requirements for system stability, such as grid modernization, greater energy storage and backup generation capabilities.

System security:
Security of energy systems is evolving from a focus on physical security and protection of critical infrastructure towards protection from cyber threats, defence of critical supply chains and resilience to climate risks. Delivering on energy security requires effective risk management across both traditional and emerging priority areas of energy security.

A comprehensive and long-term approach helps to strengthen energy security in the face of changing risks and to embed security-by-design in the overall transitioning of energy systems. This white paper highlights the imperative to focus on solutions that advance both security and sustainability ambitions and calls for an acceleration of strategies that can deliver speed and scale.

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1

Securing the energy transition – a perpetual priority

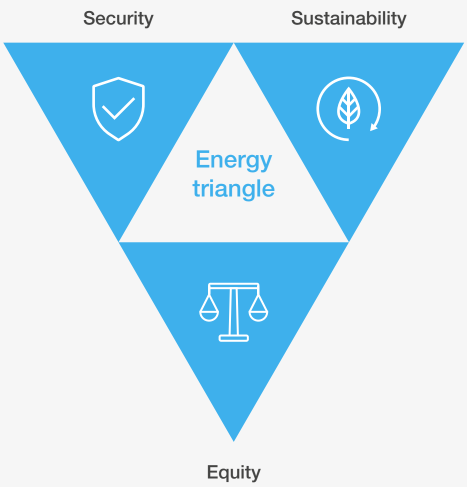
War in Ukraine and accelerating climate shocks have exploited pre-existing weaknesses in energy systems and have exposed vulnerabilities in the world's energy mix. A successful transition cannot happen without a secure energy system.

1.1 Energy security in the context of an effective energy transition

Energy security is defined[2] as the uninterrupted availability of energy sources at an affordable price. During the current energy crisis, it has risen to dominate the headlines due to energy market volatilities and supply disruptions.

An effective energy transition is a timely transition towards a more inclusive, sustainable, affordable and secure energy system – one that addresses global energy-related challenges, creates value for business and society, and balances the three dimensions of the energy triangle: Equity, Security and Sustainability.

FIGURE 1 **The energy triangle**



Security
A reliable, uninterrupted, evolving energy system that can withstand and respond to demand-supply dynamics and recover rapidly from disruptions.

Sustainability
An energy system that is consumption-conscious and decarbonized, supporting the ambition of a cleaner and less polluted earth for current and future generations.

Equity
An energy system in which energy is fairly distributed, accessible and affordable; a system in which sustainability initiatives (and benefits) are shared to enable inclusive, equitable economic growth and improved standards of living.

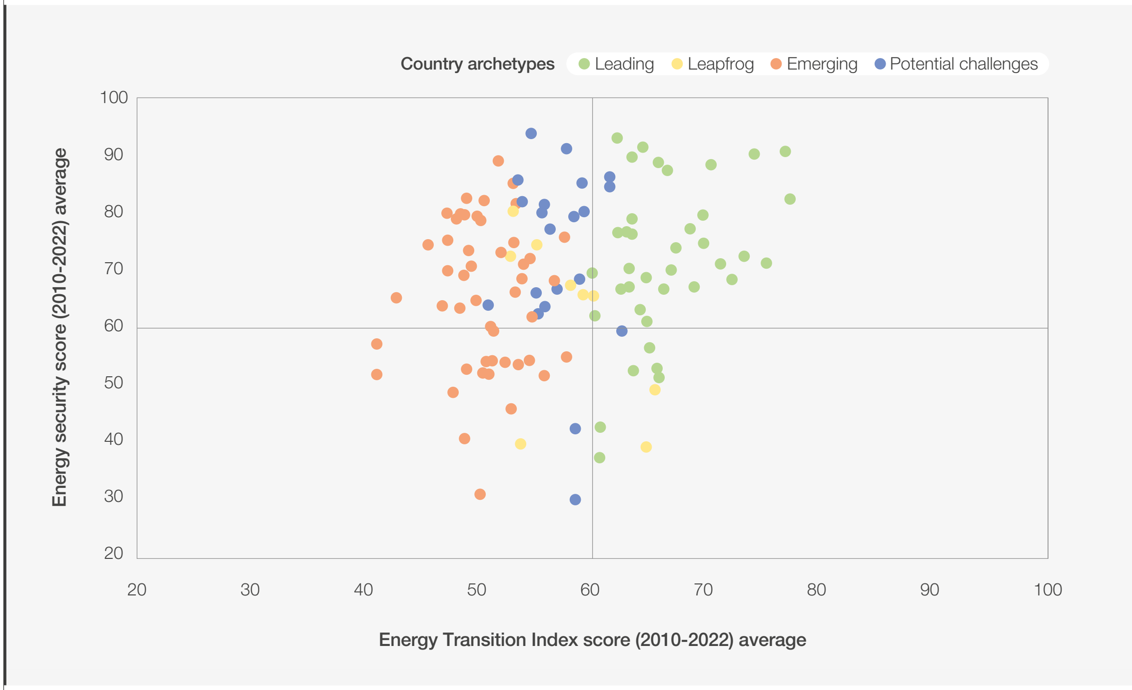
Source: World Economic Forum, Energy Transition Index (ETI) 2022

The ongoing energy crisis has impacted all three dimensions of the energy triangle. Supply disruptions have forced some economies to delay coal phase-outs, to expand LNG infrastructure or to invest in new hydrocarbon assets. Meanwhile, high energy prices are contributing to inflation (with 87% of emerging and developing economies, and 100% of advanced economies seeing inflation above national targets in 2022)[3] and reducing global GDP by between 2.8% and 3.6% – an impact which, coupled with falling incomes and rising interest rates, could potentially push economies into recession.[4]

The World Economic Forum's Energy Transition Index (ETI)[6] looks at countries' energy systems performance and their readiness for an effective energy transition. One of the ETI's central insights is that energy security and energy transition go together (see Figure 2). On average, from 2010-2022, 63% of leading countries (those with well-performing energy systems and high transition readiness) have also led in energy security (defined by a country's net energy imports dependence, diversity of import partners and diversity of total energy supply). The twin concept of energy transition and energy security cannot be delinked.

> **One of the central insights from the Forum's Energy Transition Index is that energy security and energy transition go together**

FIGURE 2 **Energy security versus Energy Transition Index score (average 2010-2022)**



Note: Refer to Appendix for ETI methodology; analysis from [World Economic Forum's ETI 2010-2022](#).

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1.2 The current energy crisis highlights the underlying structural vulnerabilities that have been years in the making

Energy security has always been a strategic priority, but an era of supply abundance resulted in some regions paying less attention to security and underinvesting in legacy energy sources and overall system resilience. Long-term vulnerabilities coupled with short-term, unforeseen events have created a crisis on top of a crisis.

Long-term pre-existing vulnerabilities

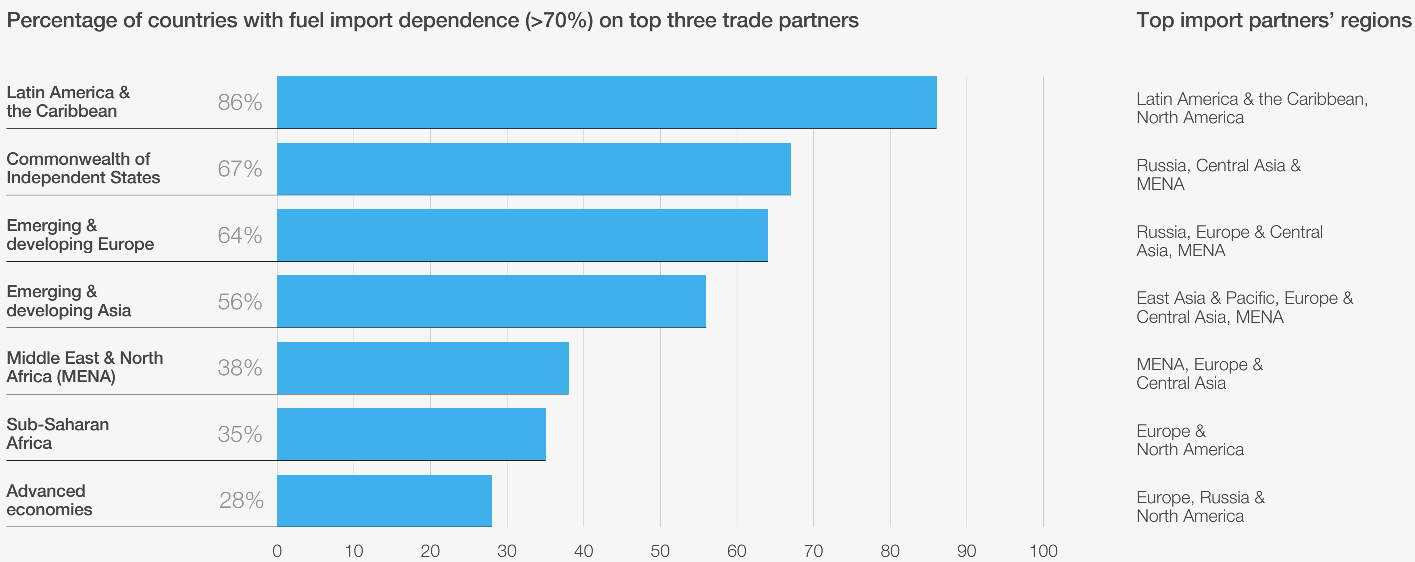
Long-term pre-existing vulnerabilities include the following:

- **A** **Vulnerability from limited import partner diversification**
- **B** **Inadequate penetration of renewable and low-carbon energy sources to compensate for the drop in fossil fuel supplies**
- **C** **Slow progress on energy efficiency**
- **D** **Reduced investment in upstream oil and gas**
- **E** **Distant nuclear considerations**

A Vulnerability from limited import partner diversification

Countries that experience energy security challenges have typically failed to diversify either their domestic energy mix or their energy import partners, or both. The Forum's 2022 Energy Transition Index (ETI) reveals that out of 29 advanced economies, eight countries have fuel import dependency on just three trade partners for over 70% of their net energy imports. Of these eight countries, seven are in Europe. Figure 3 illustrates that countries with low diversification in the number of import counterparts are more exposed to supply disruptions from adverse climatic, geopolitical and supply chain events.

FIGURE 3 **Fuel import diversification**



Note: Analysis from World Economic Forum's ETI 2022.

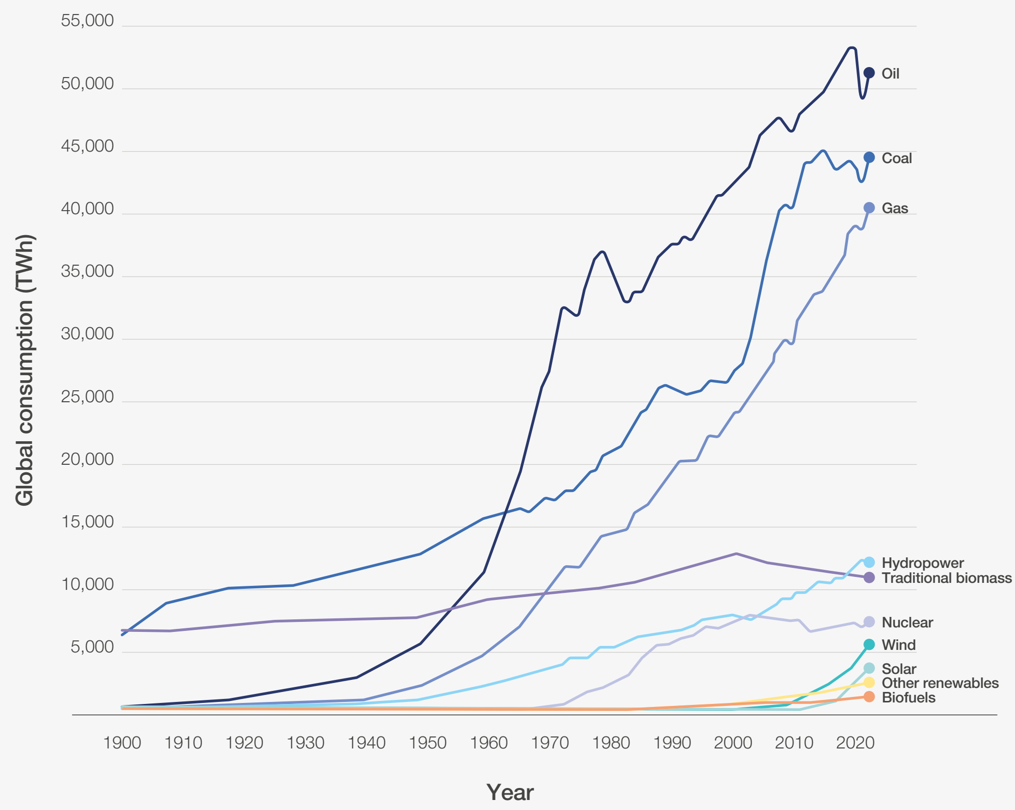
B	Inadequate penetration of renewable and low-carbon energy sources to compensate for the drop in fossil fuel supplies

From 2015 (when the Paris Agreement was adopted) to 2020, investments in energy transitions remained flat at around $1 trillion per year. That falls far short of the $4 trillion or more which the International Energy Agency[5] (IEA) says is needed annually to bring about a peak and decline in fossil fuel demand, and to support the creation of a clean, sustainable energy system. Figure 4 showcases the world's ongoing dependence on fossil fuels, which remains stubbornly fixed at around 80% today.

The $1 trillion per year invested from 2015-2020 in the energy transition falls far short of the $4 trillion or more per year which the IEA says is needed to reduce fossil fuel demand and support a clean, sustainable energy system

FIGURE 4

Global primary energy consumption by source (1900-2021),[6] showcasing ongoing dependence on fossil fuels



Source: Our World in Data, 2022.

C	Slow progress on energy efficiency

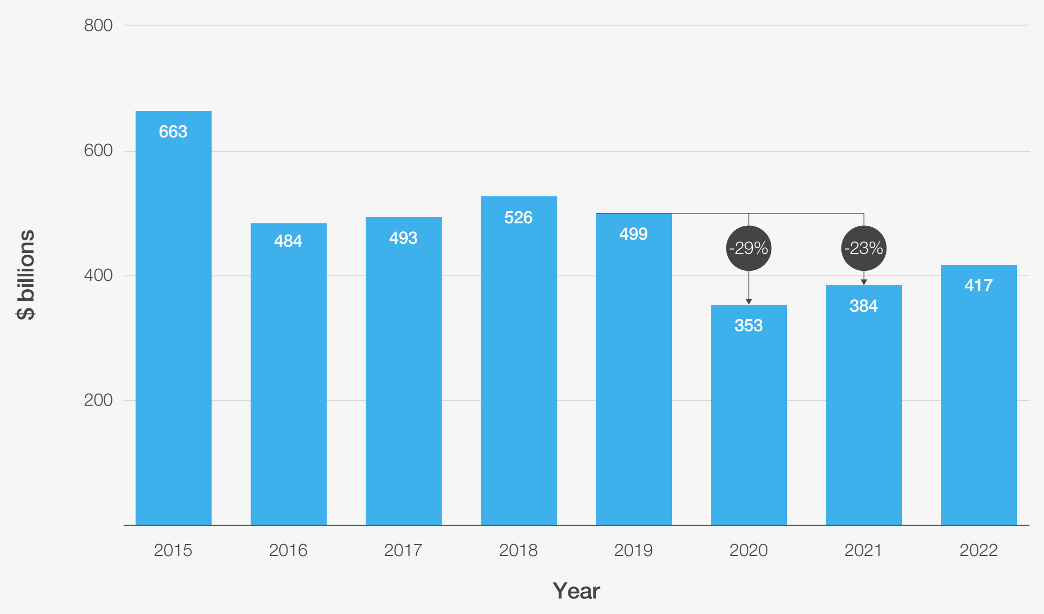
Insufficient investments in energy efficiency and demand-side responses have compromised the flexibility of the energy system and led to higher levels of energy demand than would have been the case with a stronger, sustained emphasis on efficiency. While strong economic growth over much of the last decade has been accompanied by growth in energy demand from industry and households, progress in energy efficiency has lagged. Over the past five years, the rate of energy efficiency improvements averaged 1% per year, well short of the 4% annual improvement required under the IEA's net zero emissions (NZE) by 2050 scenario.[7]

D

Reduced investment in upstream oil and gas

While new investments in hydrocarbons may seem at odds with net-zero goals, the immediate need for energy security and affordability may prompt further investment in fossil fuel projects while the system is in transition. Investments in the oil and gas sector in 2020-21 were about 26%[8] below pre-pandemic levels; 2022 marked the third consecutive year of spending shortfalls compared to 2019, thus creating tight energy markets (see Figure 5).

FIGURE 5 **Global investment in upstream oil and gas ($ billions), 2015-2022**



Source: International Energy Agency, World Energy Investment 2022.

E

Distant nuclear considerations

Following the Fukushima disaster in 2011, nuclear power fell out of favour in many countries. In Europe, many states announced nuclear phase-outs in the following years and centre of gravity for nuclear electricity production shifted to Asia. According to the IEA, as of 2019, investment in nuclear power was nearly 40% less than the spending required in the sustainable development scenario (SDS), with the largest gaps in Europe, the United States and China. Additionally, concerns around nuclear fuel and waste storage limited countries from increasing investment.

Short-term events exacerbating the crisis

The following short-term, unforeseen events have aggravated the current energy crisis:

– **A spike in energy prices** following the faster-than-predicted rebound of demand after COVID-19 and the exceptional recovery in global GDP growth (~5.9%) in 2021.[10]

– **Amplified demand due to extreme climate events**, which necessitated longer home-heating and home-cooling periods in countries experiencing temperature changes.

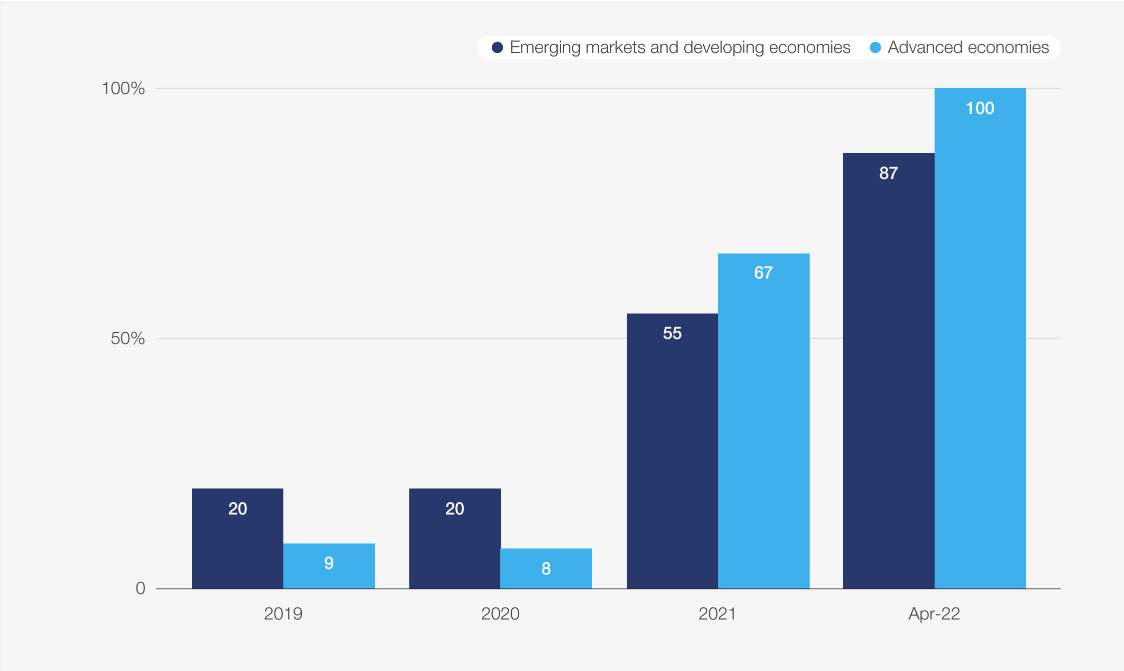
– **Extreme weather-related natural hazards**, including droughts, heatwaves, lower than average wind speeds and extreme temperatures, which exposed the vulnerability of grids. In addition, more frequent and intense climate events have left those affected little time to recover between disasters.

– **Growing cyber threats** targeting grid infrastructure, nuclear plants, gas pipelines and safety systems for oil production operations over the past five years have elevated system security concerns.

With a system already left vulnerable by the long-term insecurities and short-term shocks outlined above, it is perhaps not surprising that the Russia-Ukraine war then sparked a global energy crisis, leaving countries scrambling to secure supply and ensure affordability. The war has also disrupted global trade, pushing up transport costs and limiting farmers' access to agricultural supplies such as fertilizers. The soaring prices of global energy and food have in turn triggered cascading effects[11] on inflation, economic growth and food security.

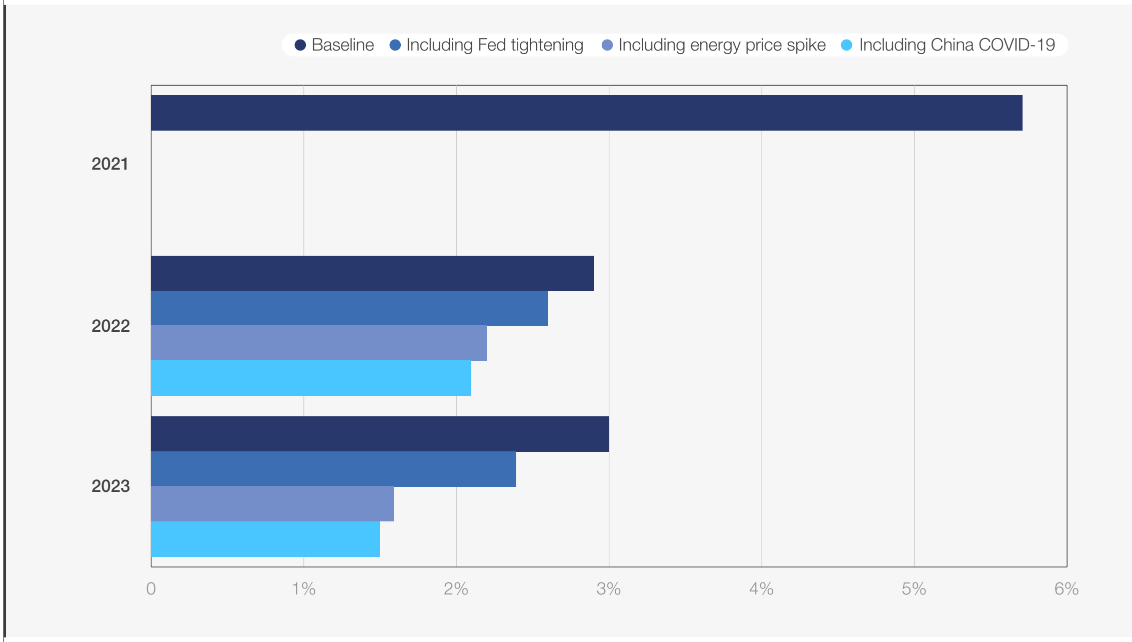
As of April 2022, every advanced economy and 87% of emerging and developing economies were experiencing above-target inflation (see Figure 6). The prospects for global GDP growth have shrunk from over 5.5% in 2021 to just 1.5% in 2023 (see Figure 7). Meanwhile, the number of people suffering from acute food insecurity around the world is expected to increase to 205 million in 2022.[12]

FIGURE 6 **Rising global inflation: % of countries with inflation above target**



Source: The Inflation Factor: How Rising Food and Energy Prices Impact the Economy, September 2022 (based on data from the World Bank).

FIGURE 7 Slower economic growth: global growth scenarios (GDP forecasts %)



Source: The Inflation Factor: How Rising Food and Energy Prices Impact the Economy, September 2022 (based on data from the World Bank).

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1.3 Landscape of emerging risks to energy systems is changing fast

The low-carbon transition is exposing new risks as the energy system becomes more decentralized, electrified, digitalized and decarbonized. These emerging risks are fundamentally different from the traditional risks around supply, demand and system stability – although these traditional security threats remain (see Figure 8).

The current crisis creates a strong case for a longer-term and more holistic view on energy security – one that embeds security as a key element of a successful transition.

FIGURE 8 **Emerging energy security risks**

Geopolitics

- Realigning energy trade flows of renewable energy technologies and components
- Rising protectionism
- Intellectual property barriers

Decentralization

- Risks to system reliability and stability due to wide range of power generation and management assets
- Lack of economies of scale
- Likelihood of more stranded legacy assets

Digitalization

- Exposure to more cyber risks, with increasingly connected systems
- Digital assets more prone to critical system failures and lack stability to handle fluctuations

Physical climate events

- Unpredictable weather and extreme events (e.g. wildfires, floods, droughts) impact operation of renewables, with implications on energy system stability and planning

Critical minerals supply

- Concentration of minerals in specific locations brings challenges in supply, accessibility, affordability
- Aggravated by policy push towards diversification

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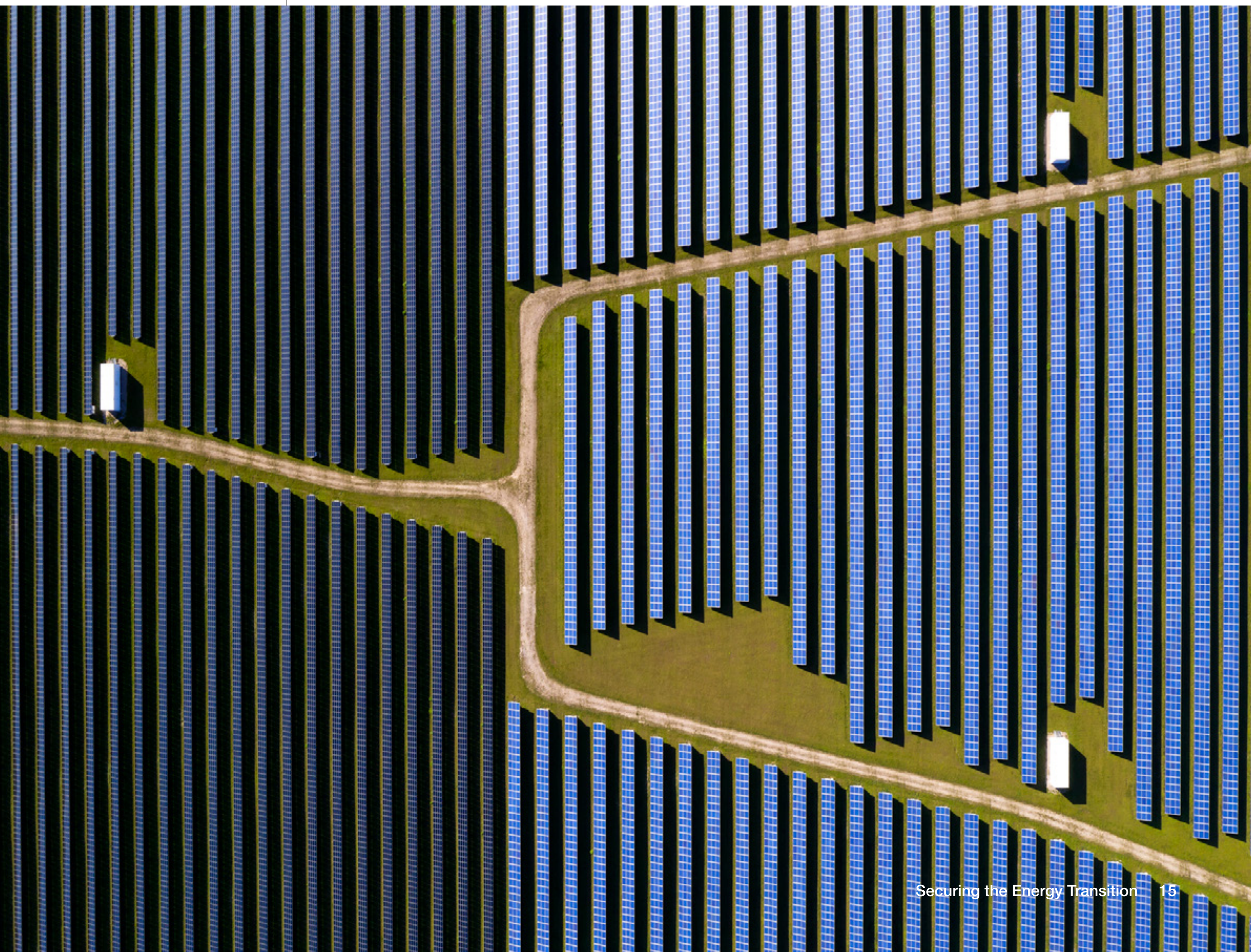
2

Energy crisis as a catalyst for the energy transition

The current energy crisis provides an opportunity for countries to redesign their approach to energy security, in light of advancing technologies and a changing fuel landscape.



The current energy crisis is the first to affect the energy system at a truly global scale. After a prolonged period of under-investment in upstream fossil fuels, there is not enough natural gas to make up for supplies traditionally sourced from Russia. Consequently, countries have rushed to secure liquefied natural gas (LNG) shipments. Unlike traditional natural gas pipelines that connect regions, LNG markets and supply chains are connected globally. This means that gas price volatility and, by extension, higher electricity prices are now affecting countries around the world. In fact, 2022 is set to become the first year in decades in which the number of people without access to electricity will increase (a rise of about 20 million in 2022).[13]

> “ 2022 is set to become the first year in decades in which the number of people without access to electricity will increase

The integrated nature of global energy, food and industrial supply chains compounds the challenges and spreads them across regions. In response, governments have taken measures to deliver immediate relief. These include fiscal measures, energy market interventions, demand-management programmes and new LNG trade deals and infrastructure development. Many such emergency measures are targeted to address near-term energy supply and affordability concerns.

The emergency measures being enacted now will have implications on the future trajectory of the energy transition. For example, sunk upstream and infrastructure investments, fiscal costs, and institutional and behavioural lock-ins may stall the transition’s forward momentum. It is therefore necessary to align these emergency measures with the long-term energy transition goals of sustainability, security, affordability and equity. The energy crisis presents several opportunities to catalyse the energy transition through well-designed, targeted measures.

2.1 Ten actions to align energy crisis responses with energy transition

The near-term consequences of the energy crisis require immediate interventions. Socio-economic effects and market shifts resulting from the energy crisis offer a window of opportunity to target breakthrough progress in the energy transition, by aligning immediate interventions with long-term energy transition goals.

There are 10 immediate actions that should be taken into consideration, organized around four themes of supply reinforcements, demand management, fiscal measures and investments, and co-ordination and long term strategy.

- A **Supply reinforcements**
- B **Demand management**
- C **Fiscal measures and investments**
- D **Co-ordination and long-term strategy**

A Supply reinforcements

1 Prioritize augmenting supply from renewable energy, keeping fossil fuel reinforcements constrained to committed emission reduction targets

In response to the ongoing natural gas supply-demand imbalance, countries are ramping up domestic gas production, entering new energy trade agreements to bolster supply and investing in regasification import infrastructure facilities. Nonetheless, this new LNG capacity will take several years to materialize. As a result, competition for existing LNG will keep prices elevated and increase costs for energy-importing countries substantially.

The risk is that the high costs of gas will dampen investments needed to develop low-carbon energy sources, thereby keeping emissions high. It is imperative, therefore, that new fossil fuel production is accompanied by a simultaneous acceleration in the development of renewable energy capacity. For every $1 spent on new fossil fuel production and infrastructure, the IEA recommends $5 of investment in developing renewable energy capacity.[14]

> For every $1 spent on new fossil fuel production and infrastructure, the IEA recommends $5 of investment in developing renewable energy capacity

2 Advocate for a diversified energy and trade matrix

Emerging energy-trade relationships should target higher levels of diversification than before. Natural gas supply disruptions from Russia to Europe and subsequent price volatilities in the global LNG market have prompted countries to secure alternative sources of supply through new bilateral energy trade agreements.

The energy crisis is expected to accelerate the substitution of natural gas with renewable energy, shifting the timeline of peak gas demand earlier.

However, the long-term outlook for natural gas remains positive, as the decline in demand for gas in advanced economies is offset by an increase in emerging economies. Therefore, concerns around energy security necessitate finding new supply sources, to address near- and medium-term gas demand. An over-concentration on a few energy suppliers was a key contributor to the current energy crisis. As energy trade flows realign, keeping diversification as a core tenet of the emerging energy-trade matrix can strengthen energy security.

3 Address methane leakage from hydrocarbon supply chains

Recent evidence suggests that total methane emissions from fossil fuel sources have been vastly underestimated. Natural gas, for example, consists mainly of methane. The climate benefits of natural gas compared to coal become marginal if between 3.2% and 3.4% of the gas produced escapes into the atmosphere before combustion. The average global leakage rate of methane from gas production is estimated to be around 2.2%, but some studies into individual gas fields have found fugitive emission rates of 6% or more.[15]

Addressing methane leaks and non-essential flaring from gas production and infrastructure can mitigate climate change and strengthen energy security. If potential gas exporters to the EU implemented measures to reduce gas flaring and methane leaks, it could save the equivalent of one-third of total Russian gas exports to the EU in 2021.

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B Demand management

4 Maximize electrification and energy efficiency to alleviate and decarbonize energy demand

The replacement of gas for industrial and residential applications with electricity and energy efficiency measures can accelerate decarbonization, while making more gas available for essential services. The likely high gas prices over the next few years will enhance the economic feasibility of industrial electrification and energy efficiency investments,[16] while improving business resilience and competitiveness.

Similarly, electric heat pumps are now more cost-effective to run than fossil fuel-based heating in residential settings, due to high gas prices. A co-ordinated policy response[17] can unlock faster deployment of heat pumps through, for example: incentives for home-heating retrofits, stable policy signals to encourage heat-pump supply, and supporting an ecosystem for financing, installation and maintenance of heat pumps.

5 Nudge social behaviour towards responsible energy consumption

There are extreme levels of inequality in global energy consumption, with the top 10%[18] income-earning households consuming roughly 20 times more energy than the bottom 10%. Encouraging top-end consumers to make simple lifestyle changes, such as choosing fuel-efficient or electric vehicles, increasing use of public transport and energy-efficient housing could reduce their energy demands substantially.While behavioural barriers have been persistent in energy efficiency efforts, the energy crisis is an opportunity to nudge consumers towards responsible energy consumption through targeted information campaigns, regular insights on household energy costs and usage, and incentives linked to reducing energy consumption.

> **Globally, the top 10% of households consume roughly 20 times more energy than the bottom 10%**

C Fiscal measures and investments

6 Leverage excess profits from energy market volatilities to bridge the clean energy investment gap

To reach net-zero emissions by 2050, investments in clean energy need to triple from the current level of $1.2 trillion to $4.4 trillion annually by 2030.[19] That represents approximately 4.5% of current global GDP. Given the heavy fiscal burden imposed by the energy crisis on governments, more of these investments need to come from the private sector – including oil and gas producers, whose excess profits are estimated to be $4 trillion in 2022.[20]

By accelerating their capital deployments in low-carbon energy sources and technologies, energy companies can help bridge the investment gap. Additionally, these measures will lower the carbon intensity of energy companies' asset portfolios, thereby strengthening their capability to attract capital from investors looking to lower the emissions exposure of their portfolios.

> **More investments in clean energy need to come from the private sector – including oil and gas companies, whose excess profits are estimated to be $4 trillion in 2022**

7 Craft crisis-induced fiscal measures to target vulnerable consumers, without interfering in market signals

During the energy crisis, governments enacted fiscal measures to shield consumers and businesses from the direct impact of rising energy prices. In Europe, the aggregate cost of such measures is expected to be approximately $600 billion in 2022.[21] Fiscal actions such as tax reductions or price caps are necessary to alleviate affordability constraints and protect energy-intensive industries from insolvency.

However, these measures to support consumers should not impede market signals. Price caps, where necessary, can be kept to a level that still allows energy companies to invest in incremental supply increases and incentivize consumers to consume prudently. Similarly, subsidy programmes should be targeted at the most vulnerable consumers, for example, through lump-sum cash payments (rather than consumption-based support) and energy-saving incentives. Such measures will elicit the necessary demand correction while also ensuring energy equity and justice.

8 Provide reliable signals to investors in energy supply and infrastructure, considering revised outlook of energy mix

The short-term outlook for LNG demand is positive, given the increased demand in Europe to compensate for Russian gas from pipelines and the role played by gas as an industrial input and source of peak power generation in many countries. Clear guidance from policy-makers around the outlook for gas demand, flanked by an accelerated deployment of low-carbon sources, can provide certainty to investors and align new capacity with demand projections.

To make LNG infrastructure compatible with the energy transition, emissions reduction measures should be integrated early on, for example through carbon capture and storage (CCS) and reliable carbon offsets. In addition, LNG infrastructure should be designed and built in a way that is compatible with future repurposing to produce blue hydrogen and ammonia.

D Co-ordination and long-term strategy

9 Co-ordinate with regional peers to maximize efficiency and minimize cost of energy crisis mitigation

Unilateral actions by countries to address short-term security challenges risk creating inefficiencies in resource allocation. Co-ordination among countries would bring numerous benefits. For example, new LNG import facilities planned by countries in the EU could supply a quarter more gas to the EU than before.[22] Co-ordinating such infrastructure investments could prevent overcapacity, reduce the risk of stranded assets and limit locking-in emissions.

Similarly, where permitted in regional markets, joint efforts to procure LNG and develop gas storage infrastructure can be more cost-effective than unilateral measures. Meanwhile, co-ordination of fiscal measures can minimize the risk of regional and global energy market distortions.

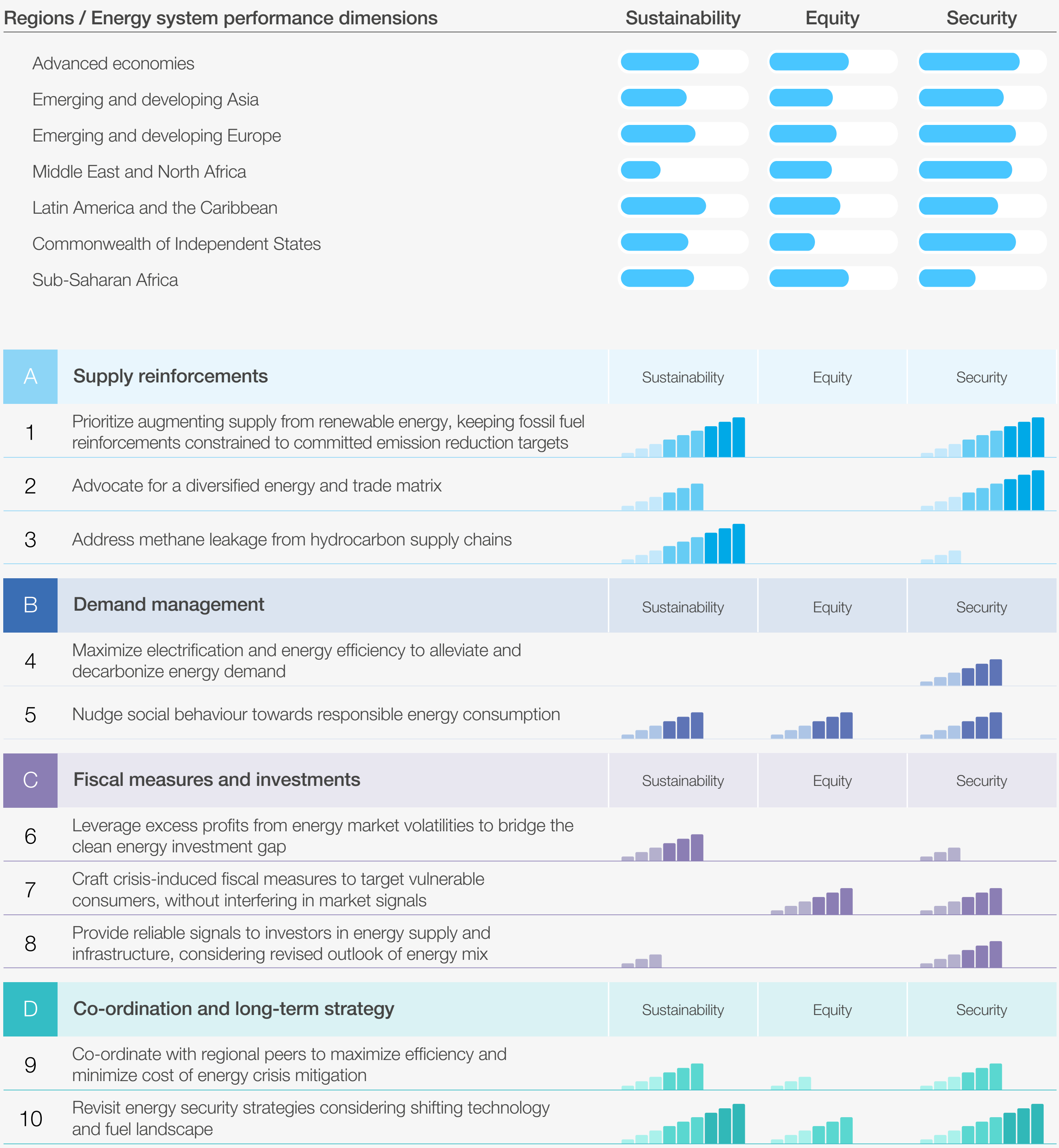
10 Revisit energy security strategies considering shifting technology and fuel landscape

The cascading effects created by the current energy crisis will have lasting impacts on countries' energy security strategies, their future energy mixes and ultimately their energy transition trajectories. While near-term pressures require a supportive response, this crisis also provides an opportunity for countries to comprehensively redesign their energy security approaches, considering the shifting of technologies and the fuel landscape within the energy mix, as well as emerging geopolitical balances.

Figure 9 showcases the relative impacts of the 10 actions against the three dimensions of the energy triangle (Sustainability, Equity, Security).

FIGURE 9

Regional average scores on energy triangle dimensions and summary of 10 actions to align energy crisis responses with energy transition



Source: World Economic Forum's ETI 2022.

Below: @CHUNYIP WONG/Gettyimages

3

Emerging energy security dimensions in a time of transition

Energy systems in transition face opportunities and risks from changing energy markets as well as from decentralized, digitalized, decarbonized and distributed energy supplies. Securing this transition requires strategic evaluation and actions across six dimensions.

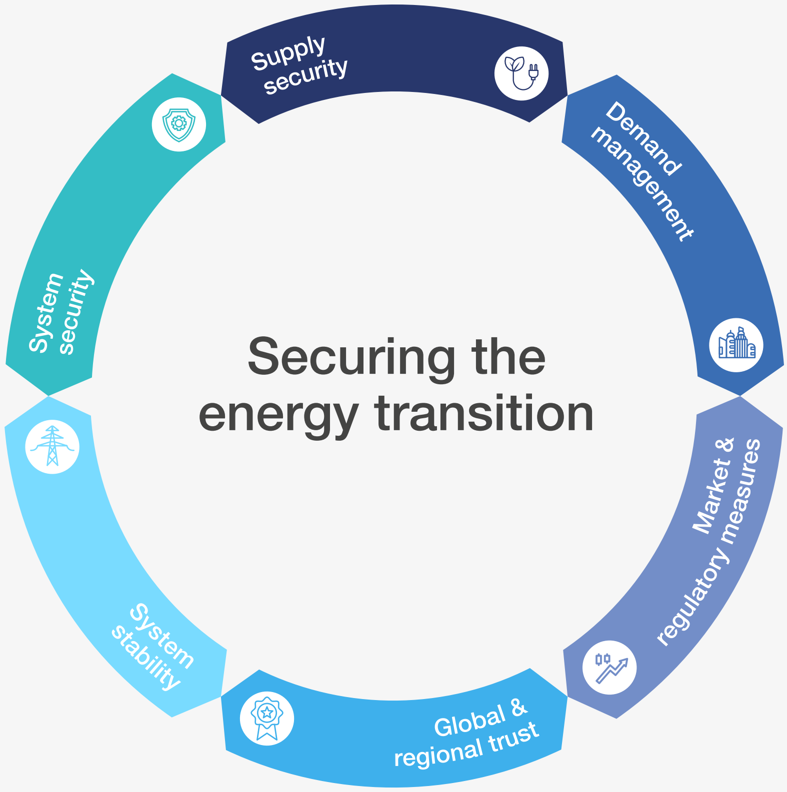
Energy security is typically understood in terms of supply security, reliability and resilience. But there are other dimensions that need to be addressed to secure the energy transition, considering the emerging energy security risks and opportunities from a decentralized, digitalized, decarbonized and distributed energy system under transition.

To build resilience into an energy system in transition, a comprehensive and strategic evaluation of energy security is necessary. Unaddressed security risks not only have economic and social consequences but will also affect the pace and trajectory of the energy transition.

This chapter proposes a framework of six dimensions to energy security in a time of transition (see Figure 10):

- Supply security
- Demand management
- Market and regulatory measures
- Global and regional trust
- System stability
- System security

FIGURE 10 **The six dimensions of the secure energy transition framework**



These six dimensions should guide countries and policy-makers to plan strategic actions, policies and regulations. Across these dimensions, companies and consumers have their own roles to play. Energy security is a collective responsibility, not simply a matter for governments to address. The chapter will examine each of these dimensions in turn.

3.1 Supply security

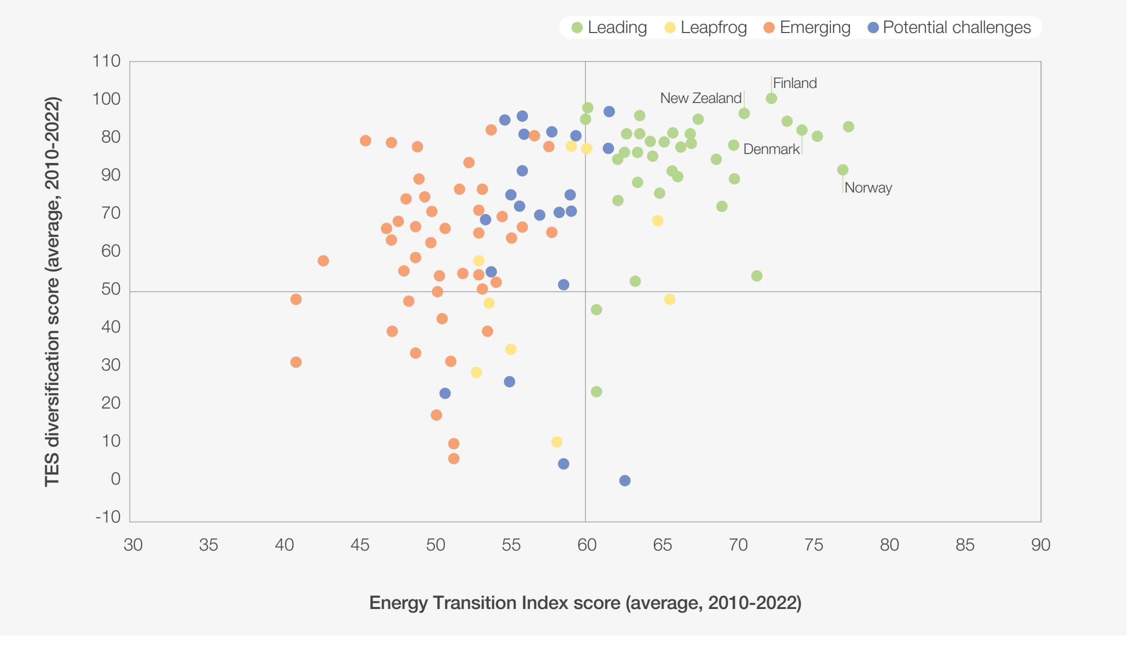
In addition to becoming more self-sufficient, countries looking to improve supply security should embrace a smart combination of energy trade and diversification to keep overall costs in check.

A	Diversify supply by increasing domestic low-carbon energy mix
B	Diversify imports to reduce trade exposure
C	Secure supply of critical minerals

A Diversify supply by increasing domestic low-carbon energy mix

The IEA's net zero emissions (NZE) by 2050 scenario calls for low-emission energy sources to grow by around 125 EJ by 2030, which is equivalent to the growth of world energy supply from all sources in the last 15 years.[23] Under this scenario, a diversified approach to domestic energy supplies will reduce dependence on fossil fuels in favour of alternative energy sources with lower emissions. Fossil fuels will continue to be a part of the energy mix in the medium term, but new approaches can be used to mitigate their impact on the transition. For example, additional gas capacity can be used to produce blue hydrogen and ammonia, while new infrastructure can be equipped early-on with carbon capture, utilization and storage (CCUS) technologies.

FIGURE 11 Increasing diversification of energy mix improves chances of successful transition



Note: TES stands for Total Energy Supply; analysis from World Economic Forum's ETI 2022.

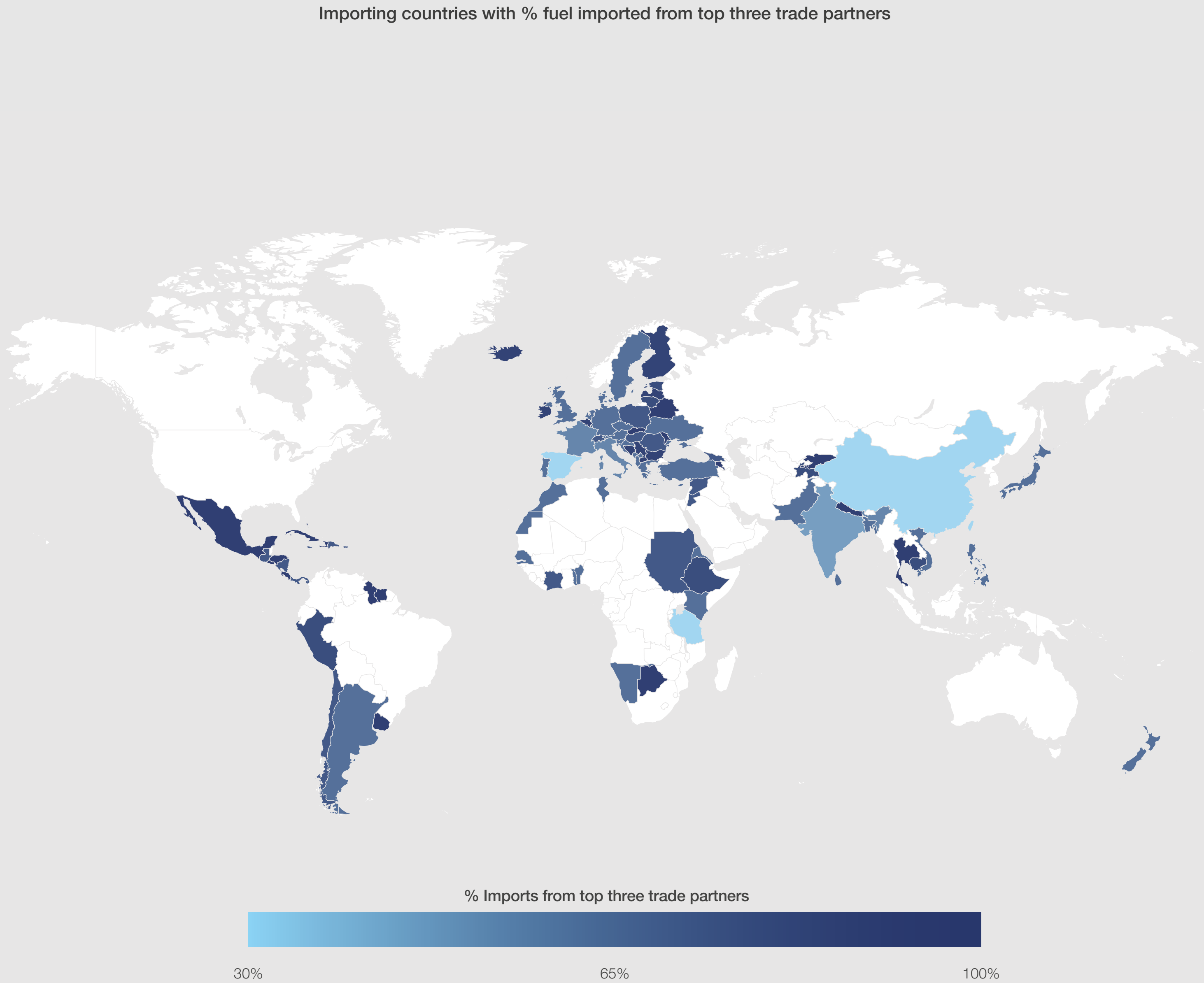
Countries like Norway, New Zealand and Denmark score well in terms of their energy mixes. Respectively, they sourced ~72%, ~36% and ~33% of their energy from renewables in 2021.[24] These countries also score among the top 10 for energy security (based on average scores from 2010-2022), according to the Forum's ETI. Finland (scoring top for energy security in 2022) has a highly diverse energy mix, with renewables holding a 48% share. It also demonstrates diversity across its renewable energy sources (e.g. nuclear, hydro, wind, solar, biofuels and other sources), which further reduces its risk of being dependent on any single clean energy source.

B

Diversify imports to reduce trade exposure

A lack of diversity in energy imports means countries' energy systems have less "cushion" to deal with supply disruptions, which could precipitate into national security concerns. Security around imports can be achieved by diversifying the network of fuel and electricity import partners. This dual diversification reduces exposure to concentrated supply shocks. Countries with over 70% of their fuel imported from their top three trade partners are more exposed to supply disruptions than those with a more diversified import partner mix. China, Spain and Singapore, with less than 35% of their fuel imported from their top three trade partners, are examples of less-exposed countries. Furthermore, China's and Spain's top import partners come from three different regions, which further reduces these countries' exposure to concentrated regional supply disruptions.

FIGURE 12 **Increased dependence on top three partners for energy imports increases exposure to trade risk**



Source: World Economic Forum's ETI 2022.

C Secure supply of critical minerals

As the energy transition gains momentum, deployment of clean energy technologies in the IEA's NZE by 2050 scenario will require four times the volume of critical minerals in 2030, compared to current demand. Concerns about price volatility, resource availability and security of supplies are driven largely by the regional concentrations of minerals. For example, Chile holds 44% of global lithium reserves,[25] the Democratic Republic of Congo holds 50% of global cobalt reserves and China holds 38% of rare earth minerals. This concentration combined with long lead times to expand supply makes supply security of critical minerals to power the energy transition an important dimension to consider.

> **Deployment of clean energy technologies will require four times the volume of critical minerals in 2030, compared to current demand**

A comprehensive critical minerals strategy should incorporate recycling, reuse of electric vehicle batteries and end-user energy efficiency measures. Enhanced research and development efforts can help further reduce mineral intensity and enable mineral substitution in key applications. Additionally, funding of new mineral exploration and mapping can strengthen domestic supply chains. This is the goal of the US's Bipartisan Infrastructure Law, which aims to invest $74.6 million in scientific research, data mapping and preservation of critical minerals.[26] For recommended actions to secure supply chains for critical minerals, see Box 1.

BOX 1

Key recommendations to secure supply chains for critical minerals

Recommended actions	Stakeholders
– Fast-track and streamline planning, permitting and regulatory processes for critical minerals – Foster international co-ordination to expand and diversify manufacturing capacity of critical minerals and materials globally	Government/policy-makers
– Lead the innovation and commercialization of technologies and manufacturing processes that are less energy consuming and reliant on critical minerals – Develop circular products and circular supply networks to maximize the reuse and recycling of materials	Industry leaders

3.2 Demand management

Reducing energy demand is synonymous with reducing energy dependency and reducing emissions. Demand management is crucial and needs to be formalized as a long-term proactive strategy, rather than a short-term reactive measure. Energy efficiency, materials efficiency and behavioural change can yield energy savings of around 110 EJ by 2030. This is equivalent to the total final energy consumption of China today.[27] These areas of focus can also provide 80% of the emissions reductions required in the buildings sector by 2030.

This dimension of energy security comprises three elements, detailed below:

A	**Prioritize energy efficiency**
B	**Accelerate the materials transition**
C	**Scale up demand response[28] and advocate for consumer behavioural change**

> **Energy efficiency, materials efficiency and behavioural change can yield energy savings of around 110 EJ by 2030 – equivalent to the total final energy consumption of China today**

A Prioritize energy efficiency

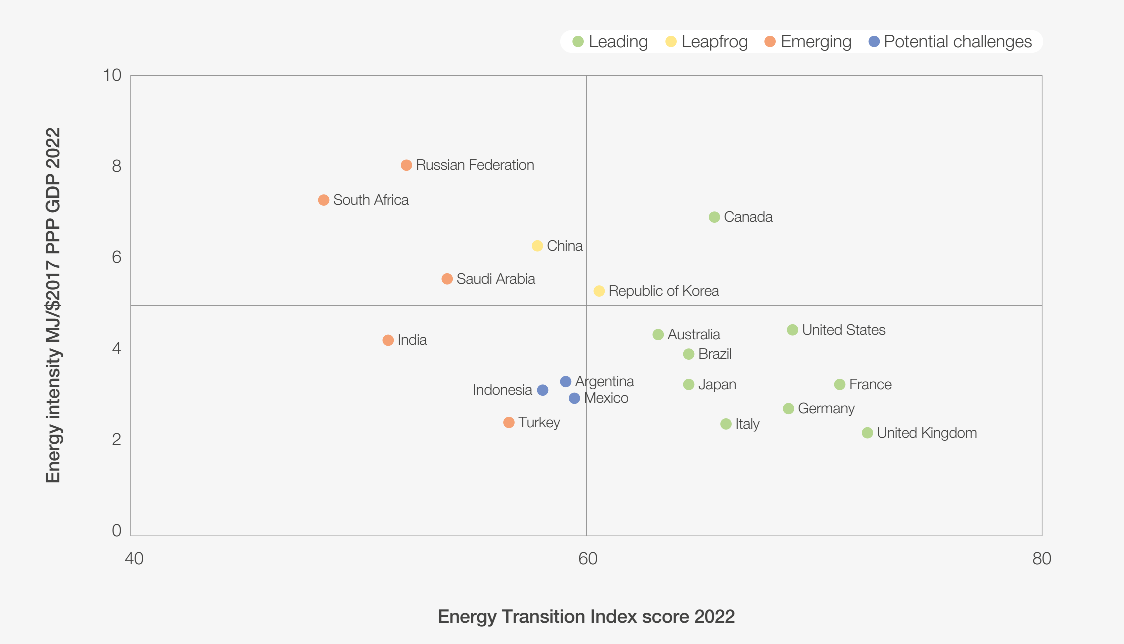
Efficiency measures can work with emergency conservation measures and active participation of end consumers in demand management to reduce demand during disruptions. This was evident during the supply shortfalls experienced by Japan from 2011-2014, following the tsunami that damaged the Fukushima nuclear power plant, when demand curtailment from industry and households helped reduce electricity consumption by 26%.[29]

Long-term efficiency measures include large-scale retrofit programmes, the adoption of high-efficiency appliances and the integration of industrial processes to drive benefits such as waste-heat recovery and improving energy intensities.

Analyses from the ETI show that lowering energy intensity, a measure of economic reliance on energy consumption, contributes positively to the energy transition (see Figure 13). Between 2000 and 2019, global efforts to lower energy intensity resulted in 8 billion tonnes (gigatonnes or Gt) of avoided carbon dioxide emissions in 2019, offsetting almost half of the emissions growth that could otherwise have happened.[30] Since 2019, there has been less focus on reducing global energy intensities. Improvements of lower than 1% per year were observed in 2020 and 2021 – well below the 4% per year required on average from 2020 to 2030 in the IEA's NZE by 2050 scenario.[31]

Looking ahead, investments in technology innovation will be needed to enable more efficient use of energy and materials, to allow substitution and to unlock new supplies. Targeted investments in energy efficiency and electrification, the share of which is expected to grow from 17% of final energy consumption today to 52% in 2050,[32] will be particularly important.

FIGURE 13 **Energy intensity versus Energy Transition Index score for G20 countries (excluding EU)**



Note: Analysis from World Economic Forum's ETI 2022.

B Accelerate the materials transition

Industries can evolve their current use of materials by seeking greater efficiencies, substituting emissions-intensive materials and enhancing circularity. This includes replacing conventional materials with substitutes that are superior in terms of performance, weight durability to extend a product's life and optimize its energy consumption.

For example, using carbon-fibre reinforced polymers (CFRPs) can reduce the weight of large rotor blades for wind turbines by 30%,[33] which leads to more efficient energy generation. In automobiles, next generation carbon-fibre composites can reduce the weight of a passenger car by 50%, resulting in a ~35%[34] improvement in fuel efficiency. By enhancing energy efficiency throughout product lifecycles and substituting emissions-intensive materials, the materials transition contributes to a stronger energy supply.

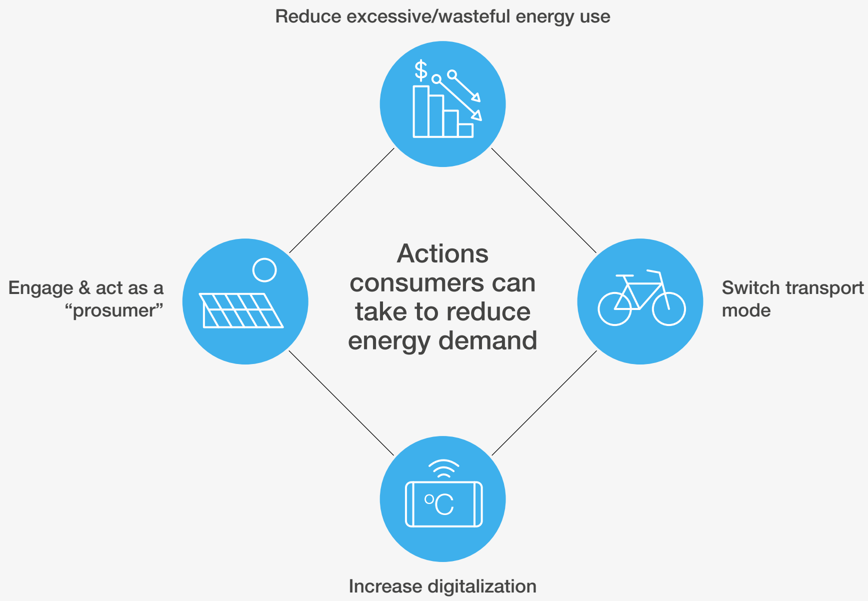
C Scale up demand response and advocate for consumer behavioural change

Demand-response mechanisms are either price-based (to encourage consumers to reduce demand at peak hours) or incentive-based (with direct payments to consumers who modify their consumption). Such measures help balance electricity supply and demand and lessen the risk of power outages and damage to devices connected to the grid.

Flexibility in the emerging power system is increasingly reliant on demand response mechanisms. Approximately 25% flexibility is expected from demand response by 2050,[35] to replace the 20-30% flexibility offered by unabated fossil fuels in 2021. The current energy crisis represents an opportunity to accelerate policy frameworks that reward end-users, demand aggregators, industrial consumers and other potential providers of demand-side response with greater flexibility in electricity, capacity and ancillary service markets. Innovative business models for demand aggregation, communication and education programmes, coupled with distributed power sources and connected end-use devices will be important to drive consumer and community participation in demand-response schemes. Changing consumer behaviour is critical to curtail energy demand and carbon emissions. Behavioural changes, such as adjusting thermostats, could reduce energy demand by 8 EJ and CO_2 emissions by 1.15 Gt across transport, building and industry sectors in 2030 – amounting to 9% of total required emissions reductions.[36]

Changing behaviour begins with increasing consumers' awareness of the impacts of climate change, carbon footprints and the individual actions that can be taken to support national energy security and sustainability ambitions (see Figure 14).

FIGURE 14 | Actions consumers can take to reduce energy demand



Reduce excessive/wasteful energy use
Adjust thermostat settings, adopt energy-saving practices in homes, take shorter showers, limit driving speeds on motorways to 100 kilometres per hour etc.

Switch transport mode
Shift to cycling, walking or ridesharing; take buses for trips in cities that would otherwise be made by car; replace regional air travel by high-speed rail in regions where feasible etc.

Engage & act as a "prosumer"
Install a solar water heater and home solar panels, switch to electric cooking and heating, buy an EV instead of a combustion engine car, fly less etc.

Increase digitalization
Use smart appliances such as smart thermostats, space-differentiated thermal controls etc.

Note: Prosumers are consumers who produce part or all of their energy through locally installed (often renewable) assets.

3.3 Market and regulatory measures

This dimension of energy security comprises three elements, detailed below:

A	Rationalize capital funding and allocation
B	Adapt to re-designed energy market structures
C	Manage policy mechanisms

A Rationalize capital funding and allocation

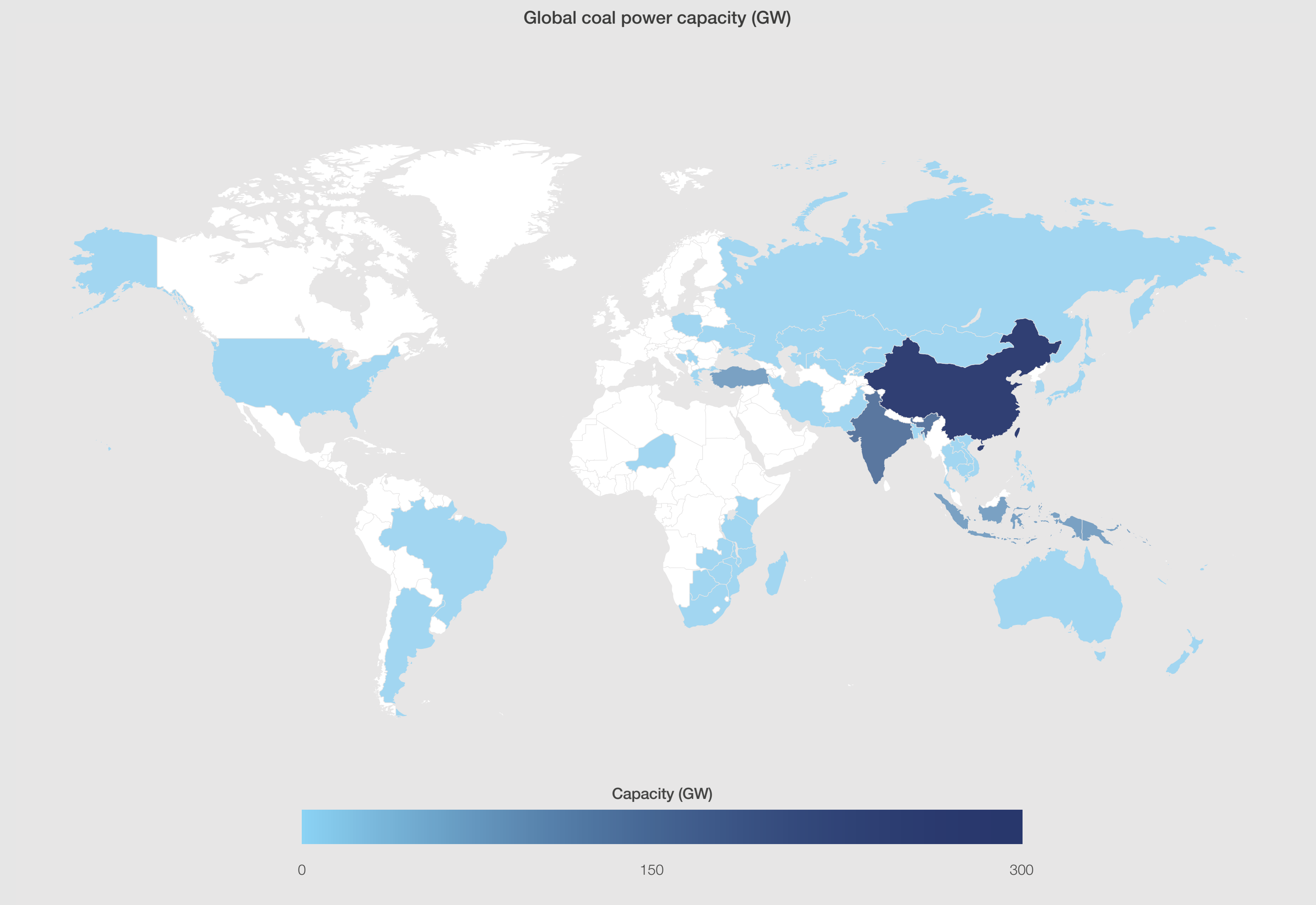
New investments needed to keep the energy transition on track could exceed $4 trillion per year by 2030,[37] nearly a four-fold increase from the average annual investments in clean energy over the past five years. Channelling new energy investments to low-emissions sources and technologies is essential. However, current investments indicate the continued development of unabated coal power plants. With a typical coal power plant lifetime of 30-50 years, this represents a risk of stranded assets to the tune of $1.4 trillion on a 1.5-degree pathway.[38]

Countries are currently re-wiring their energy systems to accommodate shifting trade flows driven by recent geopolitical events. For example, Europe is investing at least $15-20 billion[39] (and likely more) to develop new pipelines, regasification terminals and other infrastructure upgrades as a consequence of the war in Ukraine.

The scale of this investment underscores the exposure to stranded asset risks – and the need for natural gas and LNG infrastructure to be designed with emerging low-carbon energy applications in mind.

Investments to replace the energy supply disruptions using fallback fuels such as natural gas and coal play an important role. Yet investing in these fuels can be tricky during a crisis, since countries are already spending more to secure energy imports as well as offering consumers subsidies to maintain affordability. Furthermore, short-term needs for natural gas infrastructure and coal capacities should not lead to over-investment in assets designed to operate for 30-40 years, since this can lead to emissions lock-in as well as increase the risk of stranded assets, as policy measures to mitigate emissions become increasingly stringent (see Figure 15).

FIGURE 15 | **Global coal power capacity (GW), (status: announced, pre-permit, under construction)**



Note: Global coal capacities total approximately 476 GW from 941 coal plant units[40] (status: announced, pre-permit, permit, under construction). Increasingly competitive renewables will cause much of the coal capacity planned for development to be underutilized and potentially stranded. Source: Global Energy Monitor's Global Coal Plant Tracker, July 2022.

Flexible, short-cycle investments in abating hydrocarbons (e.g. methane abatement, flaring reductions), combined with a step-change towards clean, renewable power investments is a pathway that can secure the transition tomorrow while strengthening the system today. For a summary of key considerations for rationalizing capital funding and allocation for a secure energy transition, see Figure 16.

FIGURE 16

Key considerations for rationalizing capital funding and allocation for a secure energy transition[41]

Tackle stranded assets and repurpose infrastructure

– Consider low-cost and long-term financing to fund the required investments and retrofits (ensure stewardship of capital and reduce stranded asset risks)

– Repurpose existing infrastructure to support the low-carbon supply chain and create a new revenue stream for existing assets

– Rationalize investments to minimize the wasted capital from unplanned and pre-mature stranded assets

Allocate capital to align with long-term goals

– Aggregate energy projects into portfolios that can be securitized, giving investors the opportunity to finance small-scale assets, while spreading risks and lowering financing costs

– Address the risks of cashflow uncertainty and financing costs stemming from new business models (with policy changes and emerging technologies)

– Ensure co-ordination among investors, companies and governments

– Use good data and analysis to support decision-making for scaling investible opportunities aligned with long-term goals

Accelerate commercialization of clean technologies and solutions

– Accelerate the deployment of solutions such as wind, solar, hydrogen, biofuels and CCUS, as well as solutions that improve energy efficiency and circularity

– Investments in energy efficiency solutions need to grow by 94% over the next eight years

– Investments in low-carbon fuels and CCUS will need to grow by more than 850% over the same period

– Develop more full-scale demonstration projects to accelerate the commercial readiness of low-emission technologies and drive costs down

Opt for targeted investments in the renewables value chain

– Targeted investments can spur adoption and scale the benefits of abated fossil fuel and renewable technologies

– Hydrogen, sustainable fuels and carbon capture offer potential to reduce dependence on solar and wind alone, while supplying clean power for energy uses that cannot be electrified

– By 2035, the global biofuels market is set to at least double; 64% of 80 sector-specific decarbonization solutions are expected to be economically attractive; and the market for combined CCUS and hydrogen solutions is expected to be worth $220 to $780 billion

Source: @/Gettyimages

B Adapt to re-designed energy market structures

Redesigning energy market structures can hedge the system against extreme price volatilities and in a manner that reduces dependence on a single fuel type as the sole driver of energy prices. Natural gas alone accounts for more than 50%[42] of electricity price increases, despite contributing only 23% of global electricity generation in 2021.

This is because the average cost of production for the electricity mix in a country can often be considerably lower than the price of the marginal capacity needed in tight market situations. Consequently, electricity prices for the marginal supply are generally higher for consumers.

A potential market reform is to split the wholesale market into a clean power market (CPM) for renewables and a fossil power market (FPM) for conventional generation.[43] The CPM is remunerated via long-term contracts or spot-markets[44] with a price cap, while the FPM competes in a short-term spot market to meet the residual demand. The price paid by energy purchasers in these markets would be a weighted average of the CPM clearing price and the FPM clearing price. Markets re-designed in this way could allow consumers to access the cost savings of renewables while still allowing clean technologies to compete with fossil fuels in the production of electricity on the spot market.

C Manage policy mechanisms

There are many ways governments can influence energy demand. These include subsidies, tax benefits or waivers, capital grants, energy-efficiency mandates and more. Such policy mechanisms can serve many purposes – from fostering implementation of green solutions to de-risking markets to unlock private financing. An example would be policies driving excess oil and gas profits towards investment in renewables and production of low-emissions hydrogen.

Carbon pricing is one of the strongest policy instruments available to help incentivize the scaling-up of low-emission production technology. However, much remains to be done. Globally, emissions trading schemes (ETSs) and carbon taxes cover only 30% of emissions, with prices rising as high as $90 per tonne (in the EU).[45] Carbon pricing has the potential to change the behaviour of consumers, businesses and investors, while unleashing technological innovation and generating revenues that can be invested in a cleaner energy mix favouring supply security and sustainability imperatives.

> **Carbon pricing is one of the strongest policy instruments available to incentivize the scaling-up of low-emissions energy – but globally, carbon pricing covers only 30% of emissions**

3.4 Global and regional trust

This dimension of energy security comprises two elements, detailed below:

A	Strengthen collaboration for energy security
B	Build trusted interconnections

A Strengthen collaboration for energy security

Improved trust and co-ordination not just across regions and countries but within countries and sectors and among stakeholders is the need of the hour. Collaboration between public and private sectors, including risk-sharing as low-carbon solutions mature, will attract the diversified sources of capital needed for multi-year investments in energy systems. Collaboration will be especially important over the next five to 10 years to develop large infrastructure projects and to scale-up technologies in the demonstration or prototype phases today, such as clean hydrogen and CCUS applications. Multilateral public-private partnerships to finance low-emissions projects would help channel the necessary capital into the first commercial-scale assets.

Trust between countries is an essential driver of accelerated energy transition. Given regional distributions in technology development, manufacturing of renewable energy components and availability of critical materials, global trade flows will increasingly influence the ability of countries to support mutual energy transition. Protectionist policies that restrict trade in low-carbon materials and technologies risk eliciting similar responses from other countries.

Additionally, trust in institutions is a critical factor in implementing successful demand-management programmes, which require broader societal acceptance and participation. Lessons from COVID-19 pandemic management demonstrate that social behaviour adaptation is possible in the short-term, given a high degree of transparency, adherence to scientific evidence and consistent information-sharing.

B Build trusted interconnections

The impacts of a grid interconnection on energy security can be quite complex. Any given interconnection project, evaluated from a particular national point of view, will require trade-offs between different dimensions of energy security. For example, an interconnected grid might improve energy supplies, but it comes with greater import dependence and potential national security implications. It may yield cost savings by enabling the substitution of electricity for other fuels and increase incentives for investors to finance new energy capacity. However, it may also increase exposure to energy price volatility from international markets.

On the positive side, reinforced power grids and additional interconnections can help even-out fluctuations in the supply of weather-dependent renewables, within and between countries and regions. They can also connect additional providers to the system. Certain shared grid assets, such as high voltage direct current interconnections, can provide highly flexible services such as fast ramping or voltage control directly.

Countries can create new cross-border super grids to increase trade in low-carbon power, reduce emissions, improve energy security and enhance system flexibility, while creating more opportunities for energy imports diversification. By tying comparable neighbouring economies through the sharing of very valuable power interconnections, energy security is improved through diversification and by building cross-border trusted mechanisms that foster bilateral co-operation – much needed in the current uncertain geopolitical environment.

3.5 System stability

The share of electricity in the total final energy consumption is bound to increase globally, from 20% today to 28% by 2030 and 52% by 2050 in the IEA's NZE scenario. System stability takes centre stage in electricity security, to allow systems to withstand and respond to disturbances such as generator or grid outages from load changes or extreme weather events.

With more renewables being added to the grid, maintaining stability requires operators to address the variability of renewable energy supply, the role of storage, changes in demand patterns and the impact of transmission outages (which may require a co-ordinated inter-regional response). Weather-proofing the energy infrastructure is also part of a strategy to increase the stability and resilience of the system.

This dimension of energy security comprises three elements, detailed below:

A	**Build a reliable system with adequate dispatchable generation,[46] demand response and network capacity**
B	**Integrate system resilience to survive and quickly recover from extreme and unexpected disruptions**
C	**Programme grid expansion and modernization**

A Build a reliable system with adequate dispatchable generation, demand response and network capacity

Electricity customers have high expectations for electricity reliability from their utility providers. Virtually every sector of the economy depends on electricity – from food production to banking, health care and transportation. This places a high premium on reliability.

Traditional threats to reliability include the loss of generation, loss of transmission or loss of consumer demand. Operational reliability is the ability of the power system to balance supply and demand in real time by managing variability and flexible loads – including immediately following an event like a large failure in a power plant or transmission line. As more and more variable renewable generation sources are added to the grid, a stronger focus on grid stability and reliability is critical. This necessitates market structures that appropriately price and incentivize both supply- and demand-related reliability services. A reliable system can reduce or shift energy demand to meet supply, provide information about electricity production and use, and access or store renewable energy for use when it is needed.

B Integrate system resilience to survive and quickly recover from extreme and unexpected disruptions

Grid resilience is crucial as energy systems transition towards more variable and distributed generation. Diversifying into alternatives like wind and solar can enhance resilience. Small-scale generators, such as distributed wind and solar PV, have the potential to facilitate recovery from large-scale blackouts, while large thermal power plants take longer to resume normal operations, since they need a large part of the system to be restored.

A rapid scale-up of energy storage is critical to meet the need for flexibility in a decarbonized and distributed electricity system. Energy storage solves clean energy sources' intermittency problem, ultimately making them as reliable and consistent as fossil fuels. The IEA's NZE by 2050 scenario calls for a 44-fold expansion of installed grid-scale battery storage between 2021 and 2030 (from 6 GW in 2021 to 680 GW in 2030).

Storage is used to integrate renewables, support smart grids, create more dynamic electricity markets, provide ancillary services, and improve self-sufficiency and stability. Among other storage technologies, pumped hydro[47] is the largest source of electricity storage today and is set to increase further over the next ten years.[48] In addition, using excess renewable energy capacity (e.g. during times of high wind or sunshine) to produce hydrogen is emerging as a solution to store seasonal peaks of renewable electricity, while mitigating renewables' intermittency of supply. Finally, investing in energy storage should not be limited to storage of power, but include enhancement of storage for fuel products.

> **The IEA's net zero scenario calls for a 44-fold expansion of installed grid-scale battery storage from 6 GW in 2021 to 680 GW in 2030**

C Programme grid expansion and modernization

Projects to expand grid infrastructure and enhance grid flexibility need to proceed in step with variable renewable capacity additions to avoid grid congestion and ensure the success of clean energy transitions. Grid modernization is emerging as a key priority for policy-makers looking to address both energy security and energy transition. This is already evident in the United States,[49] where $1 trillion has been set aside to revamp the nation's infrastructure.

Notably, grid upgrades are prone to cost pressures and tight markets for critical minerals. Recent price spikes in critical minerals have pushed up the cost of new grid investments by 10%[50] compared to the period 2010-2020.

Smart grids are critical elements of any modernization strategy. They use sensors, monitoring devices and automation to improve performance and uptime, and also give utilities control over fluctuating voltage levels, thereby improving overall stability and resilience. Global investments in digital technologies account for more than 15%[51] of total investment in electricity grids, a significant fiscal consideration to be addressed in modernization plans.

Some key recommendations to bolster energy system stability are proposed in Box 2.

BOX 2

Key recommendations to bolster energy system stability

Recommended actions	Stakeholders
– Promote and provide incentives for technologies that enhance system stability, such as smart grids, distributed and dispatchable energy generation, demand response, energy efficiency, distribution system planning and energy storage capacity – Create and share strategic grid modernization plans with industry leaders for effective grid architecture planning – Share draft policies that affect the power sector with appropriate parties for their consultation – Ensure transmission and distribution planning processes are better integrated with generation planning, for example through planning processes co-ordinated by system operators	Government/policy-makers
– Reimagine operations, circular supply chains and workforce management to build resilience against supply disruptions and climate-related events – Strengthen the energy grid through integrated energy solutions that include digitalization, decarbonization and diversification – Invest in comprehensive stakeholder engagement programmes to support local communities, first responders and other stakeholders in the face of difficult energy supply conditions	Industry leaders

3.6 System security

The energy sector provides the enabling infrastructure for all other sectors. The impact from its disruption is felt across the entire economy and wider society. As a uniquely critical sector, energy must pay special attention to physical and cyber security.

This dimension of energy security comprises two elements, detailed below:

A	**Develop risk management capabilities**
B	**Strengthen cyber security and physical security of energy infrastructure**

A Develop risk management capabilities

A strategic approach to risk management enables more informed decision-making around technology, policies and operating models. Near-term and long-term risk management is increasingly critical to the ongoing stability of the electricity system.

A decentralized energy system with effective risk management plans can bolster a country's preparedness for disasters and ensure energy security during any crisis. Effective risk management enables an examination of system vulnerabilities and targeted mitigation and contingency plans. Monitoring tools and data analytics can provide a holistic, proactive view of threats across the industry and region, including technical vulnerabilities and the various factors (e.g. geopolitical, economic, legal) that shape the threat environment.

Partnerships, information-exchange programmes and research initiatives across the electricity sector and beyond can facilitate the development of robust energy system risk management capabilities and strategies. As a result of the energy security crisis in 2022, numerous governments have had to redraw their contingency plans to prepare for different supply disruption scenarios. In the future, such preparedness ought to be the norm, conducted well in advance of and reflecting different supply security threats.

B Strengthen cyber security and physical security of energy infrastructure

Energy security requires adequate protection of critical infrastructure against physical threats and cyberattacks. Increasing digitalization makes the energy system smarter. However, it also increases exposure to cyberattacks, which can compromise energy supply and consumer data privacy.

Cybersecurity is among the top 10 risks[52] that have escalated the most since the start of the COVID-19 crisis. Over the past 18 months, industries have undergone rapid digitalization platforms and devices facilitating this have proliferated. At the same time, cybersecurity threats are growing – in 2020, malware and ransomware attacks increased by 358% and 435% respectively – and are outpacing societies' ability to effectively prevent or respond to them. The current state of international risk mitigation efforts in managing cross-border cyberattacks and misinformation is worrying, according to the World Economic Forum's Global Risks Report 2022. Just 2% of such efforts are considered effective and only 23% are established. This means that three-quarters of all the cyber risk mitigation efforts that are required are either in early development or have not yet started.

Physical infrastructure security is essential for maintaining the integrity of sensitive locations, such as data centres, and transmission and distribution sites – these systems are also critical in responding to a cyberattack. Although there is a growing cybersecurity threat, most incidents are never reported. Some attacks may even go undetected. Policy-makers must raise awareness of the issues and work with stakeholders to identify, manage and communicate emerging vulnerabilities and risks.[53]

Some key recommendations to fortify system security are proposed in Box 3.

BOX 3

Key recommendations to fortify system security

Recommended actions	Stakeholders
– Develop emergency response strategies and improve response capabilities (e.g. robust response and recovery procedures) – Improve mandatory reporting requirements for cyber incidents – Develop response strategies to cyber intrusions in collaboration with the electric power industry, federal agencies, and state and local governments	Government/policy-makers
– Establish state-level task forces dedicated to study incidents and provide recommendations to policy-makers – Ensure new systems are designed for cyber resilience and upgrade existing systems to be in line with state-of-the-art cyber protection – Learn from historical incidents and via information-sharing and analysis centres (ISACs) or knowledge-sharing platforms	Industry leaders

Below: @hxdyl/ Gettyimages

Conclusion

Energy security is firmly back on the agendas of countries, companies and consumers. Improving it requires focusing on six key dimensions:

1. Supply security

2. Demand management

3. Market and regulatory measures

4. Global and regional trust

5. System stability

6. System security

Meanwhile, to sustain energy security requires making it a cornerstone of the energy transition.

Emerging energy security risks raise the question of whether all the risks from a decentralized, digitalized, decarbonized and distributed energy system under transition are addressable (or even known). Is achieving energy security really feasible? We believe the answer is yes. The framework proposed in this paper provides a roadmap for mitigating threats and creating a highly secure and sustainable energy system.

The priority actions that accompany the six dimensions of our proposed framework provide opportunities for countries to re-think their current strategies, perform assessments, quantify energy security performance and ask the right questions (see Figure 17). This will enable them to gain a better understanding of the energy security risks facing them and to formulate plans to mitigate those risks as part of their overall energy transition.

While a decarbonized future energy system can provide energy security dividends from abundant and localized low-carbon energy sources, ensuring energy security and affordability through the transition will require fossil fuels in the medium-term. There will have to be a gradual phasing down of hydrocarbon energy sources and an accelerated phasing up of cleaner energy sources to deliver on climate targets, both by adjusting demand and by improving the economics of supply.

Countries will need a range of cleaner technologies such as hydrogen, sustainable fuels, carbon capture and others. Most of them have existed for decades but will need greater and more targeted investment. To ensure a just transition, greater investment will also be needed in skills training, research and innovation, and incentives to build sustainable supply chains that protect ecosystems and cultures.

Governments are in the driving seat when it comes to ensuring a country's energy security, but companies and private consumers play important roles as well. Multi-stakeholder collaboration and co-ordination are the need of the hour to ramp up clean energy investments, decarbonize industries and meet consumer demands. Open dialogue and policy co-ordination among stakeholders and governments can play a vital role in making energy security a reality.

The proposed six dimensions of our framework are not intended to be addressed in isolation. Finding the right balance between energy security and energy transition means looking for ways to progress on all six dimensions simultaneously.

FIGURE 17 | The six dimensions of the secure energy transition framework – priority actions

System security

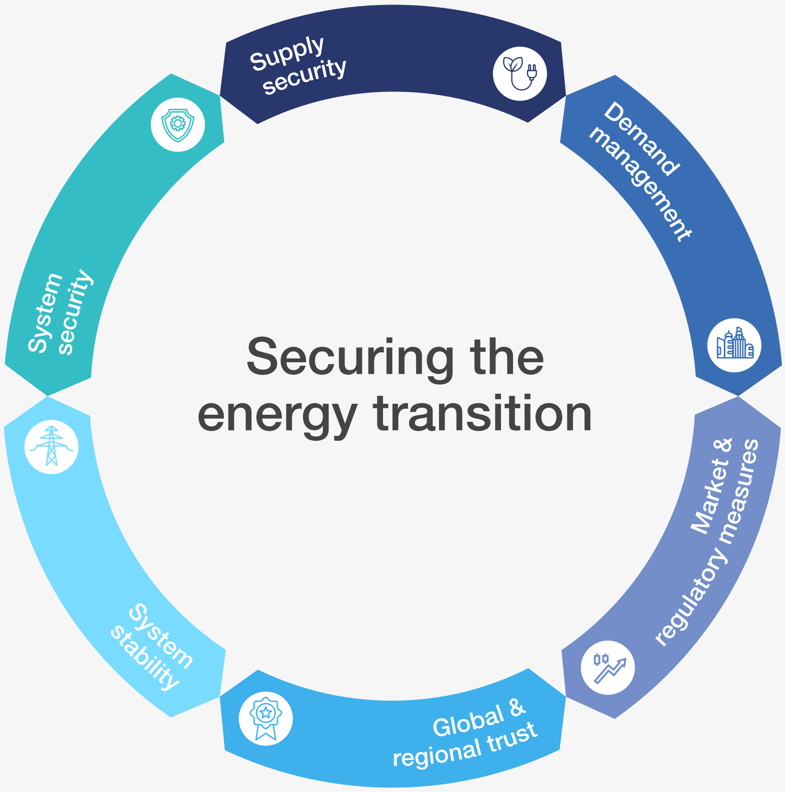
- Develop capabilities and prioritize risk management across traditional (physical) and emerging priority areas (cybersecurity) of energy security risks from increasing digitalization and connectivity

Supply security

- Unlock increases in domestic clean energy mix
- Secure critical minerals supply chains to reduce import dependence
- Diversify trader networks

Demand management

- Drive effective demand management by prioritizing energy efficiency and materials transition
- Stimulate behavioural change measures and demand responses using effective policy, tools and communication



System stability

- Accelerate stability enhancements to strengthen the reliability and resilience of the system
- Invest in transmission and distribution networks to accommodate tomorrow's power systems

Global & regional trust

- Collaborate to reduce risks and cost of capital for transition, and leverage international centres of expertise in finance and technology
- Build trusted interconnections to increase trade in low-carbon power, to lower emissions and to enhance system flexibility

Market & regulatory measures

- Opt for strategic and targeted clean energy investments while managing the retirement and reuse of existing infrastructure
- Restructure markets and adopt regulatory platforms to address market failures and introduce targeted policies

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ANNEX I

Energy Transition Index (ETI) framework and methodology

To calculate the Energy Transition Index (ETI), a total of 39 indicators are used highlighting the aspects of system performance and transition readiness. Performance dimensions are calculated against economic development, environmental sustainability and energy security. Readiness dimensions are calculated against political regulations, infrastructure, innovation, human capital and financial investments.

Available public data for 115 countries is used and a reasonable weighting is allocated to each of the indicators – this is further aggregated to give a country score and ranking.

For more information, see:
The Energy Transition Index Methodology and Technical Notes

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