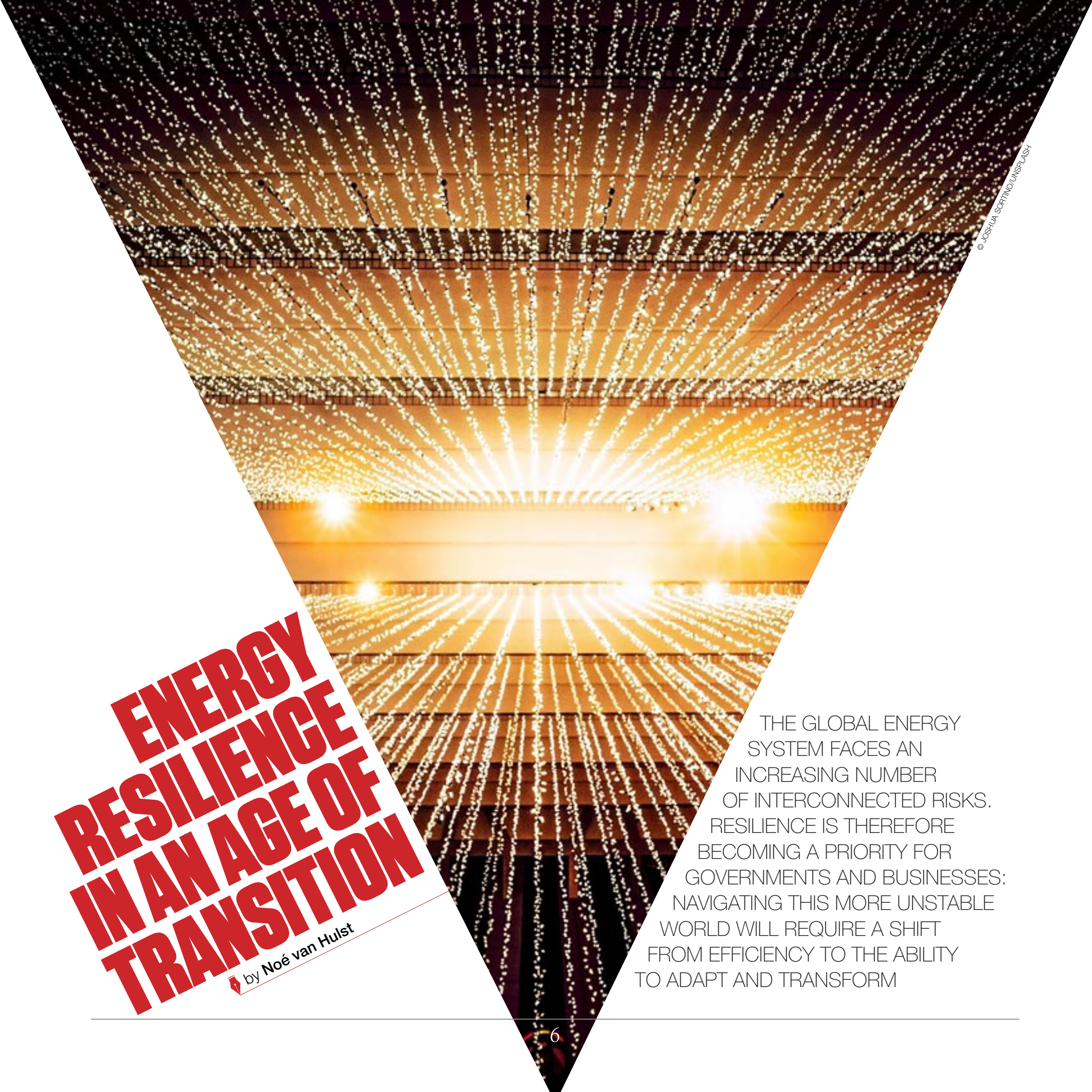




ENERGY RESILIENCE IN AN AGE OF TRANSITION

by Noé van Hulst

THE GLOBAL ENERGY SYSTEM FACES AN INCREASING NUMBER OF INTERCONNECTED RISKS. RESILIENCE IS THEREFORE BECOMING A PRIORITY FOR GOVERNMENTS AND BUSINESSES: NAVIGATING THIS MORE UNSTABLE WORLD WILL REQUIRE A SHIFT FROM EFFICIENCY TO THE ABILITY TO ADAPT AND TRANSFORM

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THE TERM RESILIENCE has risen to the top of the agenda of decision-makers in business and government, and has moved centre stage in the public debate. One illustration is that the frequency of resilience-related keywords in the transcripts of earnings calls and investor meetings across S&P 1500 utility firms has increased by 70% since 2016 according to J.P. Morgan (2026). A simple check on the term ‘resilience energy’ on Google Trends shows how the global interest has skyrocketed in the last five years. Another indicator is how the strengthening of ‘energy system resilience’ has become a key component of the International Energy Agency (IEA) policy messaging, most recently highlighted in the IEA Ministerial Meeting in February 2026.

So, why has resilience suddenly become the talk of the town?

To quote a well-known song from the musical Jesus Christ Superstar, ‘what’s the buzz?’ That’s easy to understand if we take a step back to review the multitude of various shocks the global energy system has endured this decade. This ranges from energy price shocks due to the wars in Ukraine and the Middle East, major blackouts (e.g. on the Iberian Peninsula), extreme weather events (storms, droughts, floods, wildfires, heatwaves), supply chain disruptions to cyber-attacks and deliberate destruction of energy infrastructure by war or terrorist acts. Paraphrasing the historian Adam Tooze, it’s no exaggeration to use his term

‘polycrisis’ to describe the state of the global energy system. Looked at from this perspective, it is quite amazing that we haven’t yet seen a larger negative impact of the energy disruptions on the global economy. However, many energy-importing developing economies have been severely impacted and are still in dire straits according to the IMF.

THE EVOLUTION OF RESILIENCE AS A CONCEPT

We can distinguish several ways to think about resilience. Applied to the energy system there is what might be called ‘engineering’ resilience which can be interpreted as bouncing back to the status quo ante after a shock. An example is how fast the electricity grid recovers after blackouts caused by a storm. Another way to approach this can be characterised as ‘adaptive’

resilience, meaning it’s not just about bouncing back but also about learning and adapting. Using again the example of the storm, it’s important to improve the robustness of the electricity grid to diminish the probability of blackouts caused by future storms (e.g. by better vegetation management along the transmission lines). The third way to think about this is ‘transformational’ resilience which goes beyond preserving and improving the existing system and transitions into a fundamentally different system that is better-suited to the new conditions. In a way we are then thinking about evolving from ‘bouncing back’ to ‘bouncing forward’. Applied to our example of the storm, we could imagine that a switch from a centralised electricity grid to a network of connected mini-grids could make the entire electricity supply less vulnerable to disruptions and

shocks. We will circle back to these different concepts of resilience in the sections below.

RESILIENCE IN THE AGE OF ENERGY TRANSITION...

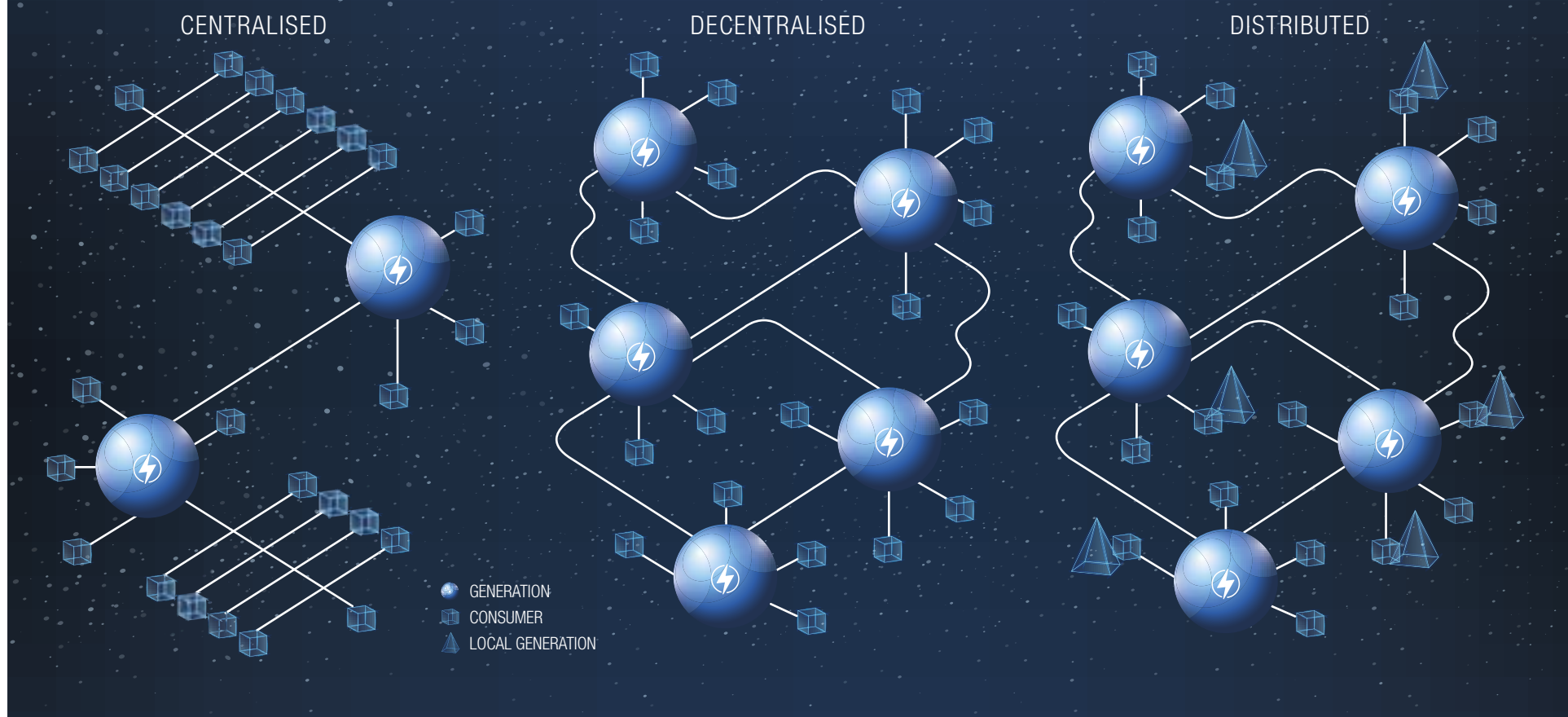
The global energy transition is facing strong headwinds and advancing slower than expected at the beginning of this decade. Political sea changes like the current US administration and the rise of populism, as well as the experience that the transition is turning out to be more difficult and costlier, all play a role. However, despite all this, the global energy transition is nowadays also widely considered un-

stoppable. The road may be long and bumpy, but the direction of travel is clear for most governments and companies and will profoundly impact resource-rich countries, as highlighted in my upcoming book *From Dutch Disease to Energy Transition*, to be published by Springer. In particular, solar energy has skyrocketed and is booming around the world, and so are electric vehicles and batteries. The global energy transition is posing at least three key tests of resilience to our energy system. The first test is around climate change which is already visibly affecting our lives but also the energy system itself. Extreme weather events like droughts, storms, wildfires, floods and heatwaves are increasingly disrupting or adversely affecting the functioning of key components of the energy system like power plants (hydro, nuclear), the electricity grid (blackouts) inter



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DECENTRALISED AND DISTRIBUTED SYSTEM ARCHITECTURES



Centralised systems rely on few large supply nodes, creating single points of failure. Decentralised systems distribute supply across multiple nodes, reducing vulnerability. Distributed systems additionally provide backup resources at demand nodes, enabling continued operation during network disruptions.

Source: International Energy Agency (IEA)

alia. It is important for the energy system to adjust to operating in much harsher climate conditions than we were used to in the old days, as we have all witnessed this summer across the world (e.g. in Nepal, Canada, Southern Europe).

The second key test is around the electricity grids that are struggling with the need to integrate a rapidly increasing volume of intermittent power from wind and solar into the energy system. Almost without exception this has caused major grid congestion and bottlenecks because even advanced economies were ill-prepared for this tremendous challenge. As a consequence, significant amounts of renewable power production at peak hours get curtailed in many countries on a daily basis, just because the grid can't absorb nor store these excessive volumes. What are the reasons? They range from ageing infrastructure, underinvestment and lagging innovation and digitalisation to overly rigid regulation of network operators and lack of flexibility and storage options, depending on the country. The bigger picture is still that the global energy transition and the electrification trend are slowed down by slow modernisation of the electricity grids and insufficient storage.

The third big test of resilience to our energy system is around the emerging vulnerability of critical minerals (like copper,

cobalt, lithium and rare earths) which are underpinning the energy transition. China has been leading the way in the global energy transition in the last two decades, now occupying a dominant position in nearly every low-emission energy market. Think of solar PV, wind turbines, electric vehicles and batteries. In addition, China is very dominant in mining and even more so in the processing of critical minerals. Furthermore, it has demonstrated it is entirely capable and willing to weaponise this dominant position, e.g. in the case of rare earths against Japan and the US. This raises important new questions of resilience to which countries like the US, Japan, India and the EU have only recently started to respond with initiatives to geographically diversify their supplies of critical minerals and its refined products.

... AND GEOPOLITICAL UPHEAVAL

The Russian invasion of Ukraine in 2022 caused an energy shock with huge price spikes. In response, many governments took measures to shield households and companies from the full impact of the price hikes at significant public budget costs. Governments also reacted with policies to reduce dependence on fossil fuels through measures to boost energy efficiency, re-

newable and nuclear energy, low-emission and renewable hydrogen, and in some cases by using more domestic coal, oil and gas. This shift is reflected in global investment flows, with investments in low-emission energy only starting to outpace those in fossil fuels since 2022, reaching a projected level of \$2.2 trillion, almost twice those of fossil fuels. These policies have definitely helped to improve the resilience of energy systems. Some countries were more successful than others in this respect, as became clear when the US/Israel war against Iran started in February 2026. This latest war rapidly spread to the neighbouring countries in the Gulf, leading to the closure of the Strait of Hormuz, which triggered what the IEA has called the largest energy shock in recent history. Oil and gas prices spiked once more, although less than expected in view of the large disruptions of oil and LNG flows out of the Strait. Part of the reason that oil prices went up less is that China, as the largest oil importer, managed to halve its oil imports, demonstrating remarkable flexibility on the demand side combined with ample drawing on its oil stockpiles. It turns out that China has stepped up its energy system resilience significantly by relying much more on electric vehicles and increasing its emergency oil stock reserves. Most other countries struggled a lot more, particularly those in South-East Asia reverting to rationing and working from home inter alia.

Another area where the resilience of the energy system is increasingly tested in this age of geopolitical turbulence is cybersecurity. The energy sector is not alone in being the subject of cyber-attacks. Obviously, this can be extremely disruptive for society when causing blackouts and interruptions of key energy flows. According to the IEA, the cyberattacks on energy organisations have tripled between 2020 and 2024 to over 1500 per week. Energy systems need to become more resilient in this area. One example drawing attention recently is the vulnerability of inverters (electronic devices) in solar, wind and battery installations.

Last but not least, we need to mention the experience of the two wars this decade that have highlighted the vulnerability of the energy system to deliberate destruction. The Russia-Ukraine war has increasingly turned into an energy war with both sides targeting each other's energy infrastructure (power grids, refineries, gas distribution stations etc.). Ukraine in particular is demonstrating remarkable resilience in many ways. This ranges from hardening of energy infrastructure, rapid recovery and repairs to starting a transformation path from the previously highly centralised power grid to a more decentralised and distributed energy system with a network of mini-grids that is less vulnerable to attacks and major disruptions. The IEA graph below offers a good illustration of this example of transformational resilience. While more than half of Ukraine's centralised generation capacity has been damaged or destroyed, this was only the case for 7% of distributed generation. Dis-





China, the world's largest oil importer, helped curb the rise in crude oil prices by cutting its imports in half, thanks to considerable flexibility in demand and extensive use of its stockpiles. This has highlighted just how much the country has strengthened the resilience of its energy system by placing much greater emphasis on electric vehicles and increasing its emergency oil reserves. Pictured: Shanghai.



Developing countries, such as Pakistan and Bangladesh, could even face blackouts, disruptions in industrial production, and energy rationing. Pictured: the Imperial Mosque (Masjid Badshahi) in Lahore, Pakistan.

tributed generation assets are more difficult and costly to locate for attackers and can be repaired and rebuilt faster.

In more than one way, the Ukraine experience might contain useful lessons for other countries aiming to improve their energy system resilience in this age of geopolitical upheaval. One example is the plan launched by German defence company Rheinmetall to build a network of decentralised synthetic fuel plants across Europe to be more resilient in case of a future war on European soil.

The extended closure of the Strait of Hormuz will certainly also prompt a reassessment of energy strategies of Gulf countries, energy-importing countries and companies whose supply chains have been affected. Most likely this will lead to measures to improve resilience by diminishing dependence on fossil fuel imports and relying more on homegrown energy sources, boosting energy efficiency, increasing emergency stockpiles, and stronger diversification of fuels, suppliers, trade routes and modes of transportation.

IMPLICATIONS FOR CORPORATION STRATEGIES & GOVERNMENT POLICIES

Winston Churchill was fond of the quote *'learn from history or you will repeat it'*. This is certainly relevant with regard to the resilience of the energy system. The countries that have learned most from the energy shocks that marked this decade have done better than others. China is probably the best example and so is Ukraine. The EU managed to adjust relatively well to the Russian gas supply disruption in 2022 in terms of diversifying suppliers and achieving durable energy efficiency gains, but still has major vulnerabilities to overcome. One example of that is going into the next winter with the lowest gas stocks in 17 years despite the warnings of many experts. It risks having to pay even higher prices than the current three-year high for scarce LNG cargoes later this year, also pushing up electricity prices with adverse economic consequences. Poorer countries like Pakistan and Bangladesh may even face blackouts, factory disruptions and rationing of energy. Other examples of EU vulnerabilities include the electricity grids (congestion, cyber-at-



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tacks) and the supply of diesel and jet fuels, and (refined) critical minerals. Although the energy system in the US is more resilient because it is the largest producer of crude oil and gas, it is also faced with major challenges, in particular electricity grids (absorbing surging demand from AI/data centres), refined oil products and heavy dependence on China for some critical minerals like rare earths.

In a world of unprecedented uncertainty, one thing does seem certain: improving resilience will be top of the agenda of governments and corporations.

And what's also certain is

that this will carry significant costs while we are moving from a world of efficiency and 'just in time' to a world of buffers and 'just in case'. Stronger diversification of fuels, suppliers, supply routes, and transport modes will in most cases imply higher costs and paying a substantial security premium, as will relying more on homegrown energy and (more) stockpiling of fuels, critical minerals and essential equipment. The pathway to greater resilience will be different depending on the specific circumstances of countries and corporations. The complexity of the challenge and the cost of implementing effective strategies and policies can be mitigated by teaming up with trusted partners in international alliances and consortia. With more than half of energy sector leaders saying their organisations lack a clearly defined and regularly updated business resilience strategy in a recent survey by DNV, the urgency to act is higher than ever.

We

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