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The Race to Resilience: Balancing the energy security equation

JPMorganChase

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Key takeaways:

→ **Energy competition is shifting from "who can produce the most" to "who can keep energy flowing under stress."** Since our 2025 report, the core challenge has compounded: resilience is now the differentiator, not sheer supply. This report frames the new contest as the **race to resilience**.

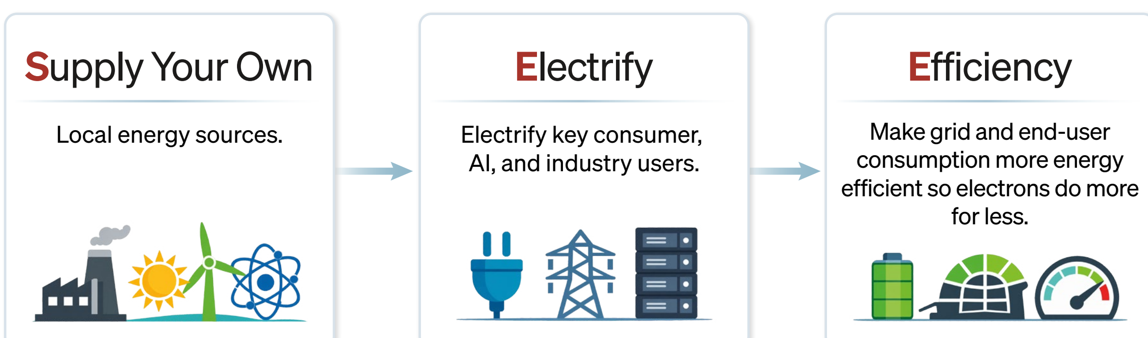
→ **The next energy order will belong to flexible systems builders.** Competitive advantage will come from assembling—and sustaining—full stacks: supply, grids, storage, software modernization, infrastructure, and supply chains that can keep energy flowing under stress for years to come.

→ **Geopolitical shocks won't hit evenly—and resilience is increasingly about optionality.** The 2026 Iran war underscored that countries with strategic reserves, alternative transit routes, diversified suppliers, and flexible power systems absorbed disruption far better than those without those options.

→ **Resilience isn't only about handling immediate impacts—recovering quickly to be prepared for the next disruption is critical**. Successfully mitigating a price or physical supply shock in the short term often simply shifts risk exposure to the future. Systems that can quickly recalibrate are more resilient to repeated volatility. In the long term, decisions made today to invest in frontier technology, execute infrastructure builds efficiently, and build workforce development will become decisive advantages to keep energy flowing under sustained energy demand growth.

→ **Electrification is essential to the resilience story, but timing and delivery matter.** The challenge isn't just generating more power; it's generating it when needed, moving it where required, and storing it for long durations—reliably and at scale.

→ **We distill these lessons into a practical roadmap: the "SEE Framework"—Supply Your Own, Electrify, and Enhance Efficiency.** Together, these three pillars reduce exposure to volatility while improving reliability and illustrate what investments can be made now to build more resilient energy systems in the 2030s and beyond.



Source: JPMorganChase

Introduction

From generation to resilience

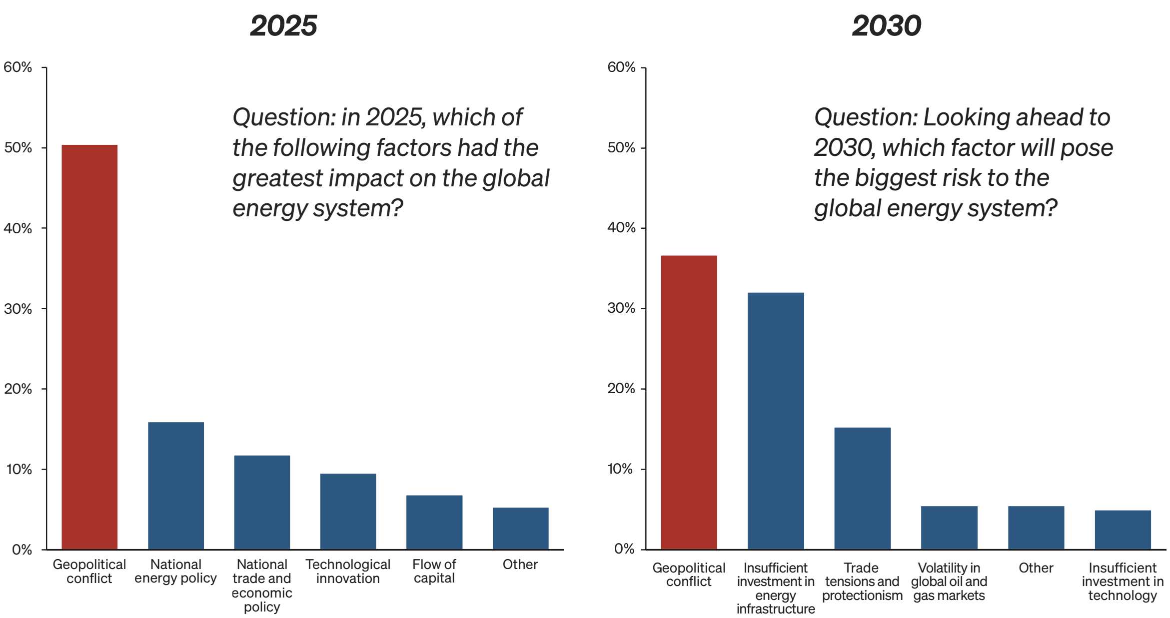
The energy race is no longer only about who can generate the most molecules or electrons—it's about who can keep energy flowing when systems come under stress. This report explains that shift, and why resilience—not supply alone—is now the defining measure of energy security.

In our 2025 energy report, *Power Rewired*, we argued that in an electrifying world, national power would increasingly accrue to those able to produce abundant and reliable energy. We also argued that while policy and capital matter, energy systems remain shaped by the harder realities of geography, geology, and meteorology.[1]

Since then, the conversation has widened from generation to resilience. The war with Iran, repeated attacks on energy infrastructure, a growing push to localize energy systems, and extreme weather have made the core question more operational: **who can keep energy flowing when systems come under stress—from conflict, climate impacts, or other disruptions**.

A recent Atlantic Council survey of **more than 1,000 energy experts from 97 countries** underscores this pivot: **more than half of respondents rank geopolitical conflict as the most consequential factor shaping the global energy system today and in the future.** Looking to 2030, they identify insufficient investment in infrastructure as the second largest risk—suggesting today's investment choices will enable, or constrain, tomorrow's resilience. **(Figure 1).**[2]

Figure 1: Geopolitical conflict had the greatest impact on the global energy system in 2025, a state of affairs expected to remain in 2030



Source: Atlantic Council, 2026 Global Energy Agenda survey results (link)

Those findings motivate this year's framework. We focus on two questions: how geopolitical risk is changing where energy is produced and shipped, and what investments are needed now to build more resilient energy systems in the 2030s and beyond. While a historical view can help ground these questions in data, policymakers, scientists, executives and investors cannot assume that the future will automatically resemble the past. Forward-looking analysis must account for potential step-changes or non-linear shifts that could change the rules of the game.

Our central finding is straightforward: supply is necessary, but it is not sufficient. Alternative trade routes, flexible power networks, and strategic reserves can be just as important as electrons and molecules themselves. And new technologies and evolving physical risks may fundamentally change the calculus around resilience.

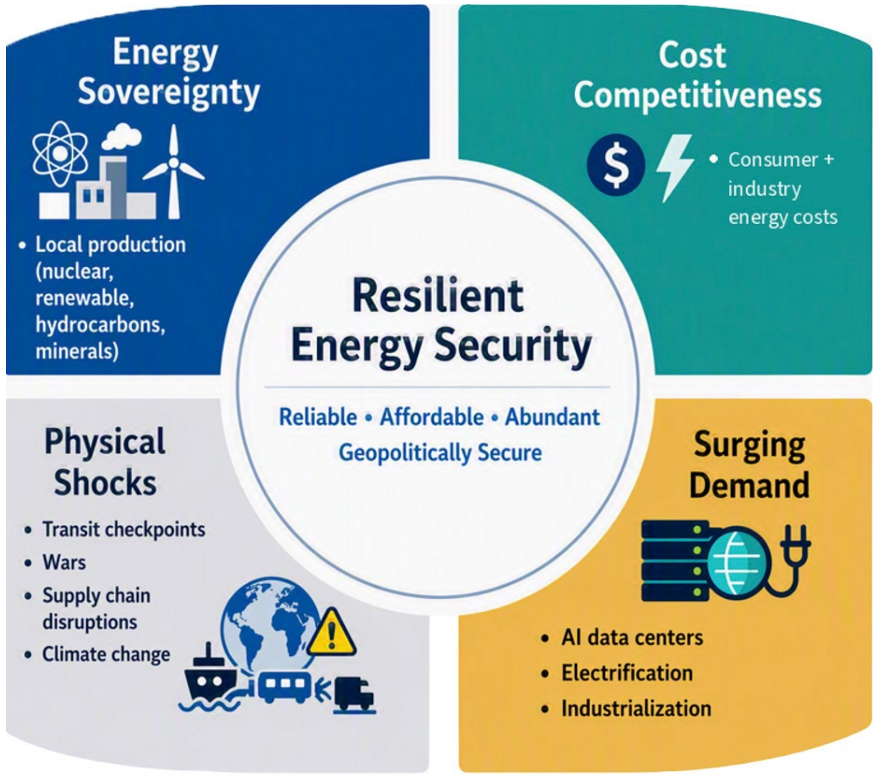
In practice, energy security is a balancing act among affordability, reliability, and long-term resilience. **Different pathways carry different trade-offs.**

→ **Producing more energy at home can reduce dependence on foreign suppliers once infrastructure is operational,** but it can be expensive to start, slow to build, and dependent on imported equipment and critical minerals to develop.

→ **Imported hydrocarbons can be cheaper in the near term but they come with strategic risk,** as demonstrated by the Iran war. Disruptions tied to the Strait of Hormuz quickly translated into higher prices and supply dislocations.

→ **Electrification has both push-and-pull dynamics.** AI data centers, electric vehicles, and industrial electrification all increase the need for abundant power—supporting the financial case for new generation, grid modernization, and clean firm domestic supply. Yet those same trends also add pressure to already strained grids, fuel inputs, and prices if grid infrastructure development cannot keep pace.

Figure 2: Energy security is a constant balancing act



Source: JPMorganChase

We have organized this year's report into **three parts**:

- **Part I** explores the dimensions of energy resilience and looks back at **one of the most momentous** years in energy security in a generation. We trace the consequences of the Iran war for global supply—where shocks concentrated, where they dispersed, and why. We compare different models of response, from market-based adjustment to state-led intervention, and we map the trends that accelerated in its wake: diversification of suppliers, fortification of critical nodes, and the return of strategic supply as a core instrument of national policy.
- **Part II** then moves from diagnosis to framework, introducing our **"SEE Framework"** for energy resilience: **(1) Supply Your Own, (2) Electrify, and (3) Enhance Efficiency.** We apply this framework to assess how countries are racing to resilience: which trade-offs they are making, which vulnerabilities they are reducing, and where the resilience equation still does not balance.
- **Finally, Part III** looks ahead. We assess the technologies and trends that will shape the next phase of resilience—what is changing in supply and storage, what is shifting in transmission and distribution, and how innovation is redefining the frontier of what "secure, reliable energy" can realistically mean.

Part I

Global disruption amidst exploding energy demand

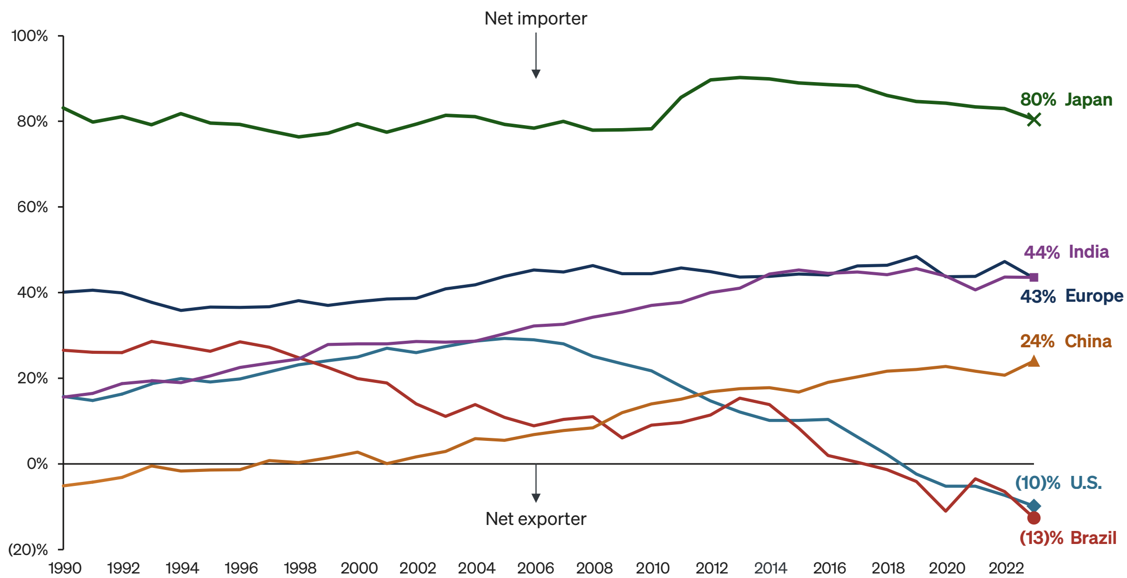
Dimensions of energy security and resilience

Before diving into the specifics of the Iran war, it is helpful to articulate how we view energy resilience conceptually. Because energy resilience has many moving, interconnected parts—and different shocks stress different parts of the system—there is no simple 10-point scale for energy security. Instead, we present a set of indicators across key dimensions to show **where countries appear relatively resilient (or exposed) right now**. The indicators reflect priorities that vary across time and place, shaped by trade relationships, geography, technology choices, and geopolitical tensions—so they are best read as a comparative snapshot, not a definitive ranking.

Key dimensions of energy security and resilience

1. **Reliance on Imported Fuels:** If you are worried that your trading partners or transportation network has weaknesses, you want to reduce imported fuels.

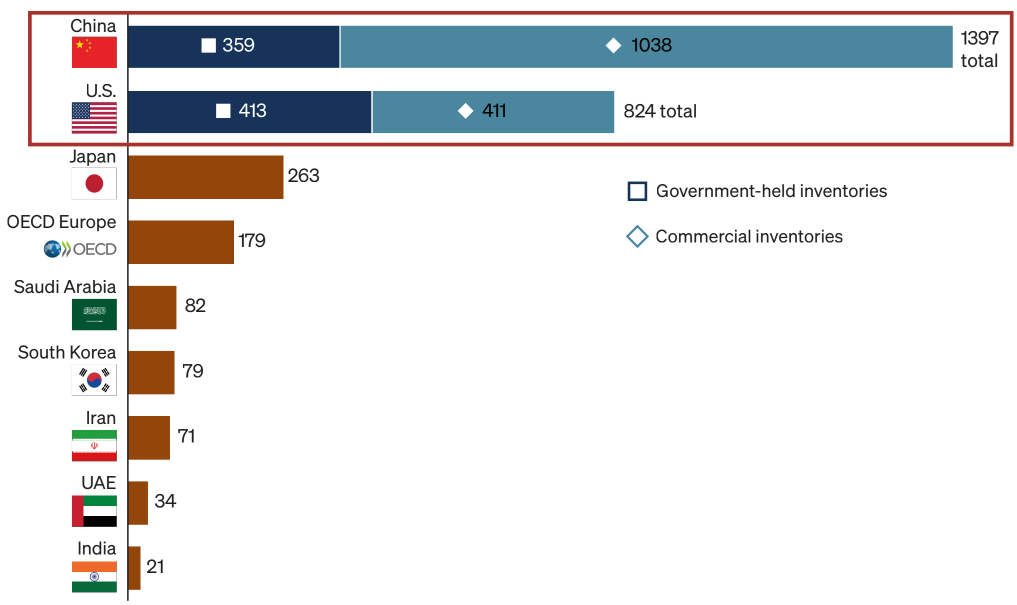
Figure 3: Fossil fortunes – Japan remains heavily import-dependent for fossil fuels (over 80%), while the U.S. and Brazil are net exporters
Net imports of fossil fuels as a percent of primary energy consumption



Source: IEA Energy Statistics Data Browser (link); Energy Institute Statistical Review of World Energy (link)

2. **Robust Strategic Reserves:** If your daily economy runs on oil (or natural gas, or lithium, or any other commodity), stockpiles can soften the impact of a supply disruption.

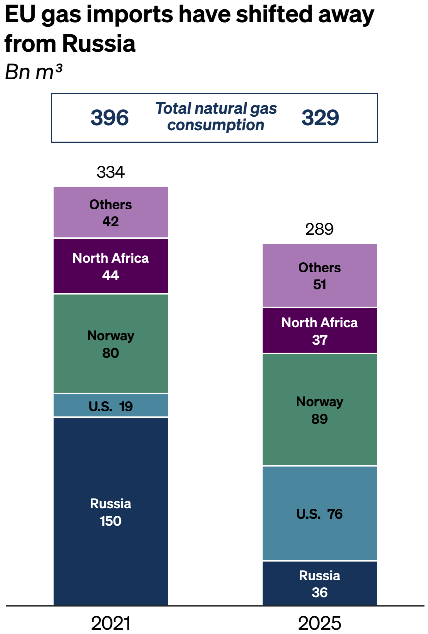
Figure 4: Crude cushions – China and the U.S. have the largest oil inventories globally
Estimated strategic crude oil inventories in select countries as of December 2025 (million barrels)

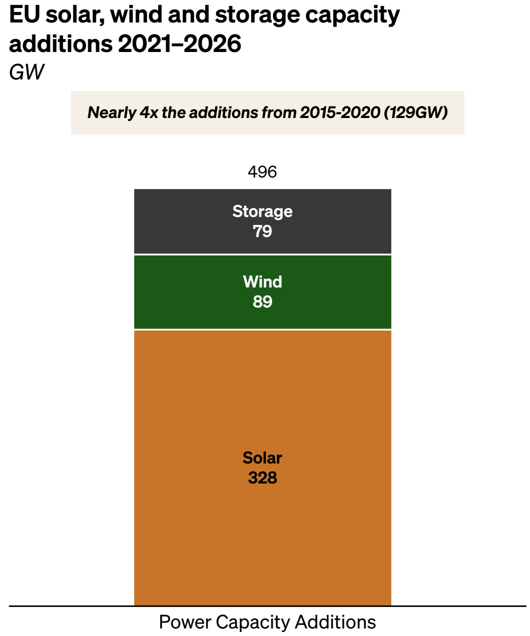


Source: U.S. Energy Information Administration, Short-Term Energy Outlook (STEO), March 2026 (link); Other estimates derived from the International Energy Agency, China National Bureau of Statistics, Vortexa Analytics, Kayrros, Kpler, Argus Media, and Global Trade Tracker. Note: Much of China's commercial inventories are held by national oil companies, which blurs the distinction between commercial and government-held

3. **Diversity of Energy Supply and Transport:** If you're worried about single-source supply concentration or transportation risks, whether domestic or imported, then diversify.

Figure 5: Loosening the (Russian) bear hug – Supply diversification efforts, in type and origin, took place in the EU after the Ukraine war

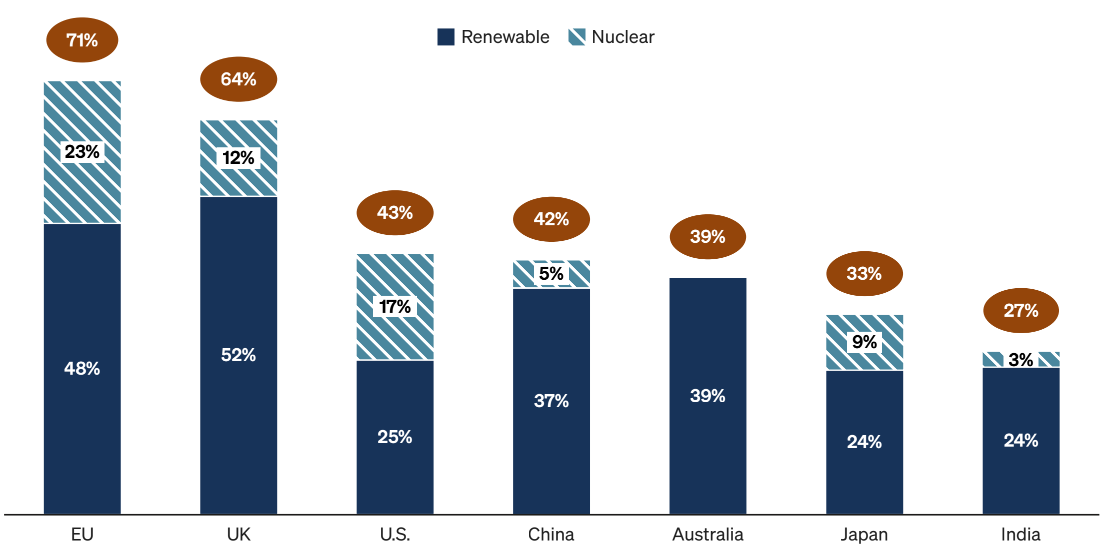




Source: European Commission (link), Energy Institute: Statistical Review of World Energy (link), BloombergNEF Global Power Capacity (link), Mid scenario

4. **Clean Firm Power:** If you think hydrocarbon trading partners aren't reliable or emissions regulations will alter future economic growth, then shift away from hydrocarbons and bolster manufacturing capacity of alternatives (e.g. renewables + storage, nuclear, and geothermal).

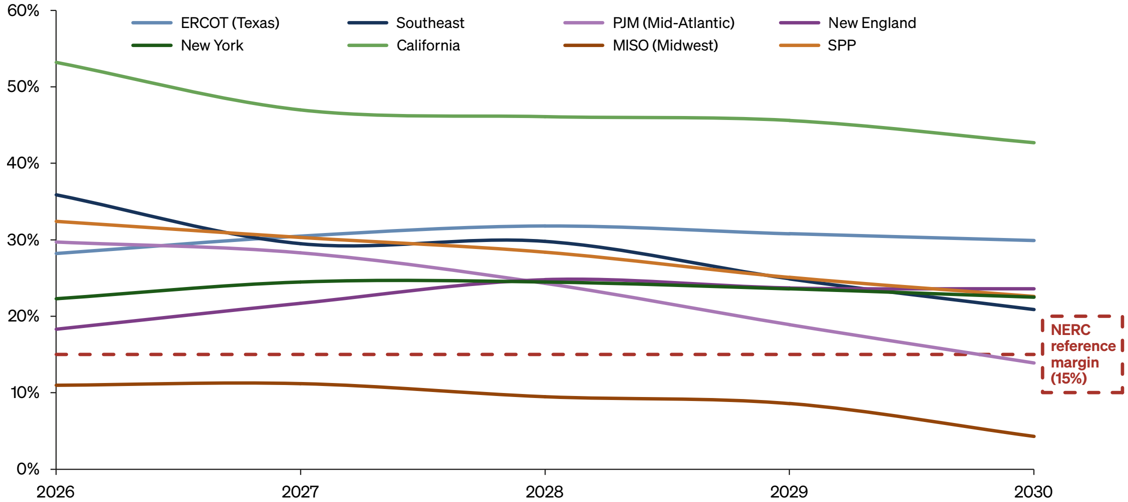
Figure 6: Watts the difference – Europe generates the highest % of electricity from low-carbon sources (~70%), while APAC generates less in part due to lower nuclear generation
% of total electricity generation by wind, solar and hydro, nuclear, and other renewables in 2025



Source: Ember (2026) (link). Note: Renewables includes hydro. Other renewables includes geothermal, tidal and wave generation; Geothermal and other renewables are non-zero but less than 0.5% and not accounted for in total figures

5. **Grid Stability:** If electricity demand is forecasted to grow and the grid will become a bottleneck to development, then optimize the grid that exists today while additional capacity is built.

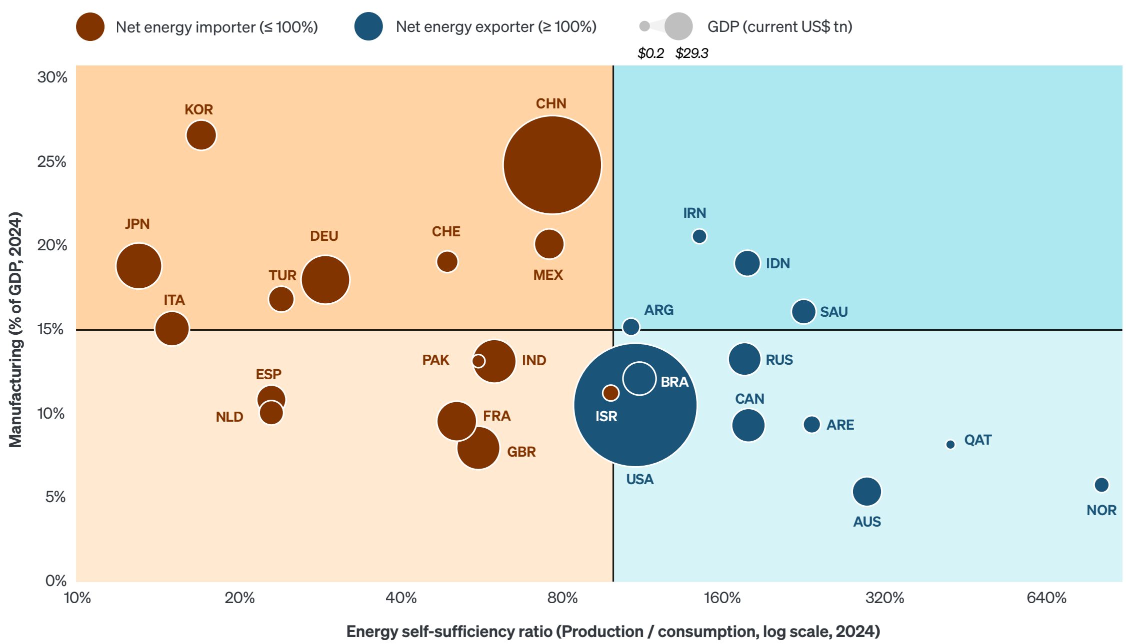
Figure 7: Running out of room – Reserve margin is expected to decline across many power grids in the U.S.
Generation capacity buffer during peak summer demand (e.g. anticipated reserve margin)



Source: 2026 "Long-Term Reliability Assessment," NERC, January 2026 (link)

6. **Robust domestic manufacturing capacity:** If you are worried about imported or volatile energy supplies limiting your ability to expand and sustain robust domestic manufacturing capacity, you want to improve energy self-sufficiency.

Figure 8: Manufacturing intensity and energy self-sufficiency impact economic competitiveness



Source: World Bank, Manufacturing, value added (% of GDP) (link); U.S. Energy Information Administration, International primary energy (link). Note: Figure shows the top 20 countries by GDP, along with selected additional countries, to illustrate distinct economic archetypes. Manufacturing (% of GDP) takes the latest available value if not available in 2024. Size of bubble correlates to GDP size

Global energy disruption

Examining the impacts of the Iran war through the above dimensions of energy resilience shows how unevenly it is distributed across geographies and policy choices. Some countries faced stark supply shortages due to reliance on imported fuels—either from multiple sources or a concentrated one. Others had strategic reserves of oil and natural gas to draw down on and stem the lack of imports. Still others were largely insulated from the market volatility due to domestic economies built on clean firm power.

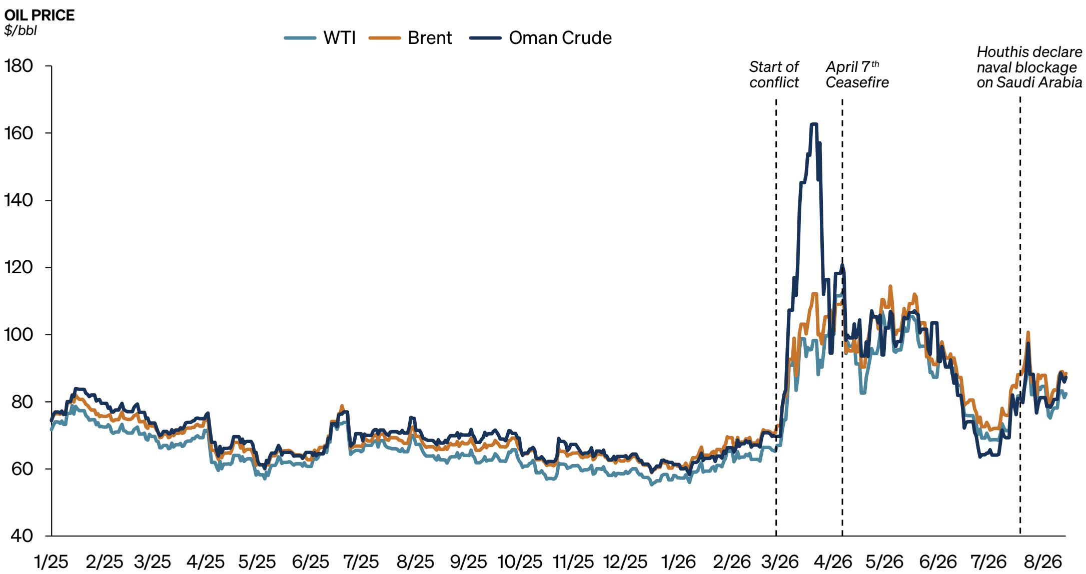
And the market volatility was severe. The conflict led to the largest energy shock since the 1970s and the largest oil-market supply shock in history: one month into the war, Brent crude hit $108, up 48% from the ~$73/bbl pre-war price on February 28 (see figure 9).[3] Given the global nature of the oil market, even the U.S. as a net oil exporter wasn't spared—the West Texas Intermediate (WTI) benchmark hit $94.48/bbl by late March.

And while European and Asian natural gas markets saw similarly sharp price upticks, U.S. Henry Hub prices saw a muted response—illustrating the difference between oil's globally synchronized pricing and natural gas's more regional, fragmented markets (see figure 10). An additional reason why natural gas markets saw a different price response than oil is that while ~20% of total global oil supply flowed through the Strait of Hormuz, only 4% of total natural gas supplies did (given LNG's respective role vs. pipelines in gas transport).[4]

The commodity disruption also extended to oil derivatives, like diesel and jet fuel, as well as beyond energy given the Middle East's role as a major exporter of inputs critical to fertilizers[5], semiconductors, and polymers.

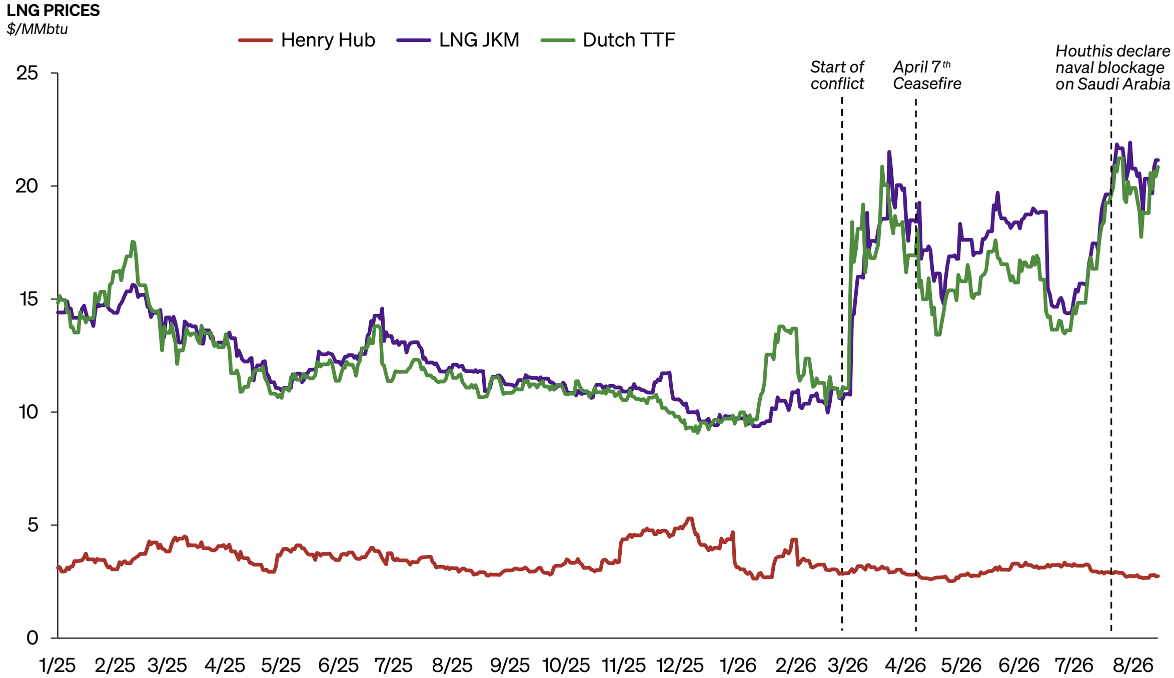
What's more, the disruption took place in the context of rapidly increasing demands for energy globally. This only compounded the impact. Countries necessarily responded to the specific circumstances they faced in different ways depending on the options that their existing energy systems afforded them, or didn't. To illustrate some of the resilience responses employed around the globe we next examine specific case studies.

Figure 9: A combustible market – Global oil prices rose sharply at the onset of the Iran conflict



Source: FactSet financial data and analytics (link), as of 8/14

Figure 10: Feeling the heat – European and Asian natural gas prices spiked due to the war while the U.S. benchmark stayed flat



Source: FactSet financial data and analytics (link), as of 8/14; Assumes a conversion of 3.412142 from MWh to MMBtu for Dutch TTF

Pay up or cut down: Supply vs cost strategies

Two hard-hit regions—Asia and Europe—show how the same shock can land unevenly. Both faced the same surge in prices and disruption risk, but the effects diverged sharply:

→ **In emerging markets in Asia, resilience looked like conservation and demand destruction.**[6] In India, Pakistan, and Bangladesh, higher oil and LNG prices left governments with limited room to keep supplies flowing at normal levels. In each case, the near-term adjustment was not simply finding more fuel; it was using less.

- **India** used emergency powers to take tighter control of gas allocation to protect household supply, including overriding private arrangements, and diverted gas away from some industrial users such as fertilizer and steel.
- **Bangladesh** cut demand by shortening office hours and forcing earlier closing times for markets and shopping centers, alongside tighter limits on non-essential electricity use like decorative or excessive lighting.
- **Pakistan** focused on public-sector demand reduction by cutting government fuel allowances and shifting government offices to a four-day work week with roughly half of staff physically present on rotation.

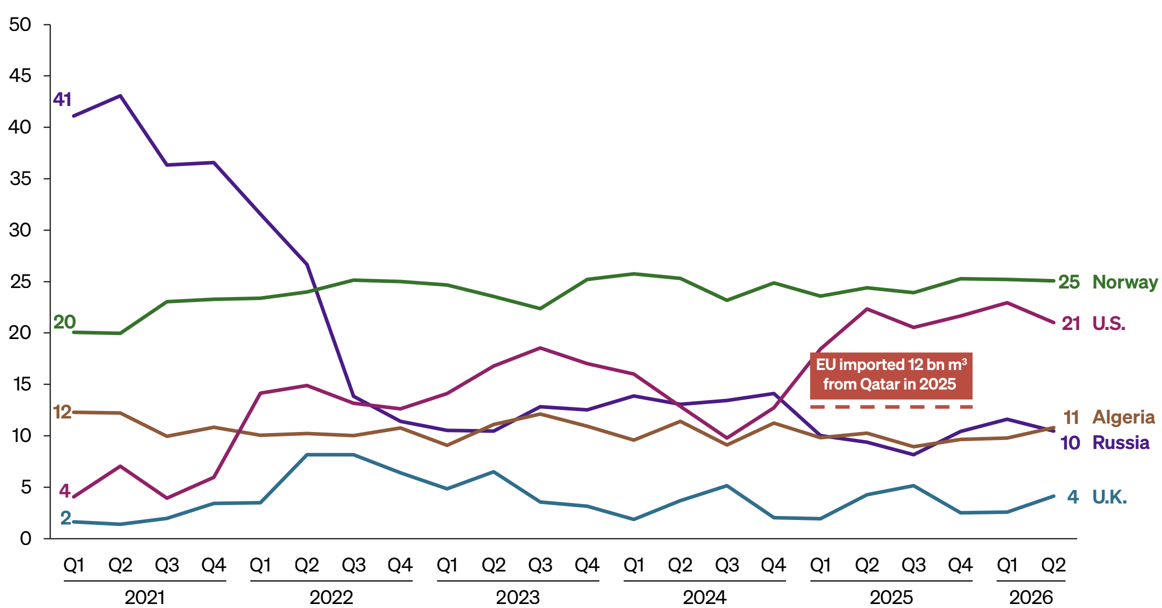
→ **In wealthier Asian countries, resilience showed up in budgets, inventories, and procurement muscle.** Richer Asian importers faced the same price shock but had more tools to manage it and avoid curbing demand. Japan and South Korea could release inventories, subsidize consumers, cap fuel prices, and compete more aggressively for LNG cargoes. They also relied more heavily on coal for power generation when possible. That did not make the crisis painless; it changed where the pain landed—more in government budgets, utility bills, and fiscal support than in immediate shutdowns or rationing.[7] (Note: China is discussed in detail in a following section.)

- For Europe, the war exposed a new, post-Russia vulnerability: dependence on global LNG supply chains that can be disrupted by conflict, maritime chokepoints, and competition from other buyers. Europe entered the crisis in a stronger position than it had after Russia's invasion of Ukraine, but it remained exposed. **Following the 2022 shock, Europe dramatically reduced its reliance on Russian pipeline gas and increasingly turned to U.S. LNG, while maintaining long-standing imports from Norway and a smaller but important stream of Qatari LNG. Yet Norway's production was already a mature resource operating near full capacity, leaving little room for additional supply in a crisis.**

- The crisis also reaffirmed that market forces dictate the flow of uncontracted LNG cargoes. **Even as European prices climbed, Asian buyers frequently outbid Europe for spot cargoes, diverting much of the flexible LNG supply that had become central to Europe's post-Russia energy strategy**. The result was a sharper-than-expected drawdown in storage and a reminder that dependence on global LNG markets creates a new set of vulnerabilities, even as it reduces reliance on Russian gas. Combined with a colder winter and lower carryover inventories, **European storage levels entered the summer at unusually low levels, underscoring the continent's continued exposure to shifts in global LNG demand and supply.**

- The broader lesson is that energy resilience is not binary. **Mitigating one vulnerability effectively may not eliminate risk but simply shift it elsewhere, creating different exposures.**

Figure 11: Full throttle – Europe has shifted its gas supply mix heavily toward American LNG as well as Norwegian pipeline gas
EU gas imports by key source (Bn m³)

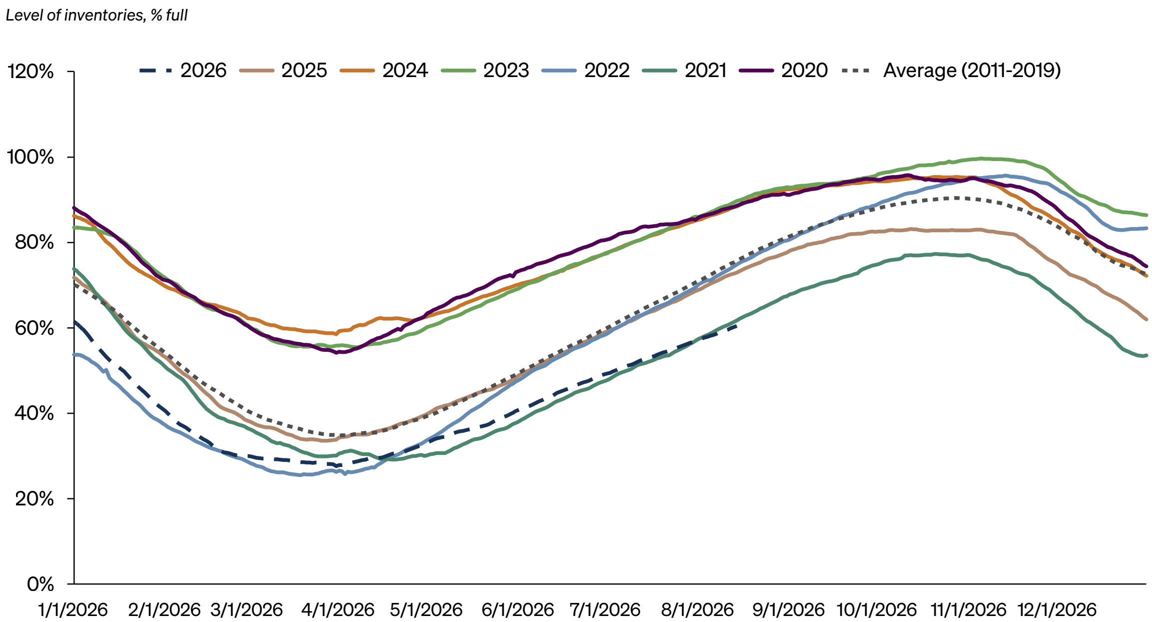


Source: Bruegel (link)

The question confronting Europe's strategic gas reserves

The Iran war also reignited debate in Brussels over the future of strategic gas storage. Although the European Union already requires member states to maintain gas inventories equivalent to roughly 90% of storage capacity ahead of winter, policymakers are increasingly asking whether gas reserves should be treated less as a commercial balancing tool and more as a strategic security asset. The disruption of Gulf LNG supplies reinforced concerns that Europe remains vulnerable to external shocks even after reducing its dependence on Russian gas. **As a result, a growing number of policymakers, regulators, and industry groups are arguing that maintaining larger gas inventories may be an acceptable cost of energy security.**

Figure 12: Storage wars – European gas storage fell to its lowest level in 17 years as high prices stalled summer injections. European utilities typically buy gas in the summer to store for winter, but persistently high costs driven by the war in the Middle East made that uneconomical this year.



Sources: GIE Aggregated Gas Storage Inventory (link) as of 8/14; Data taken as of Gas Day Start, 6AM CEST

A paucity of gas storage in Europe?

→ **Europe's challenge is not a lack of storage capacity.** The continent already possesses one of the world's largest underground gas storage systems, concentrated in Germany, Italy, France, and the Netherlands. **The more important question is who pays to fill it.**

→ While countries such as France and Italy employ stronger regulatory and financial mechanisms to support storage injections, Germany has traditionally relied more heavily on market incentives. As storage economics deteriorated in 2026, **these different approaches for public support for storage became increasingly visible, raising a broader question for Europe: should gas inventories be left to market forces, or treated as strategic reserves that warrant public support?**

→ **Not every European country possesses suitable geology for large-scale storage.** As a result, EU regulations require member states without domestic storage facilities to secure storage capacity abroad equivalent to at least 15% of annual gas consumption. In practice, this has reinforced the strategic importance of major storage hubs while creating a more integrated European system of shared storage obligations and cross-border reserve arrangements.

Detours: Infrastructure workarounds to the Strait of Hormuz

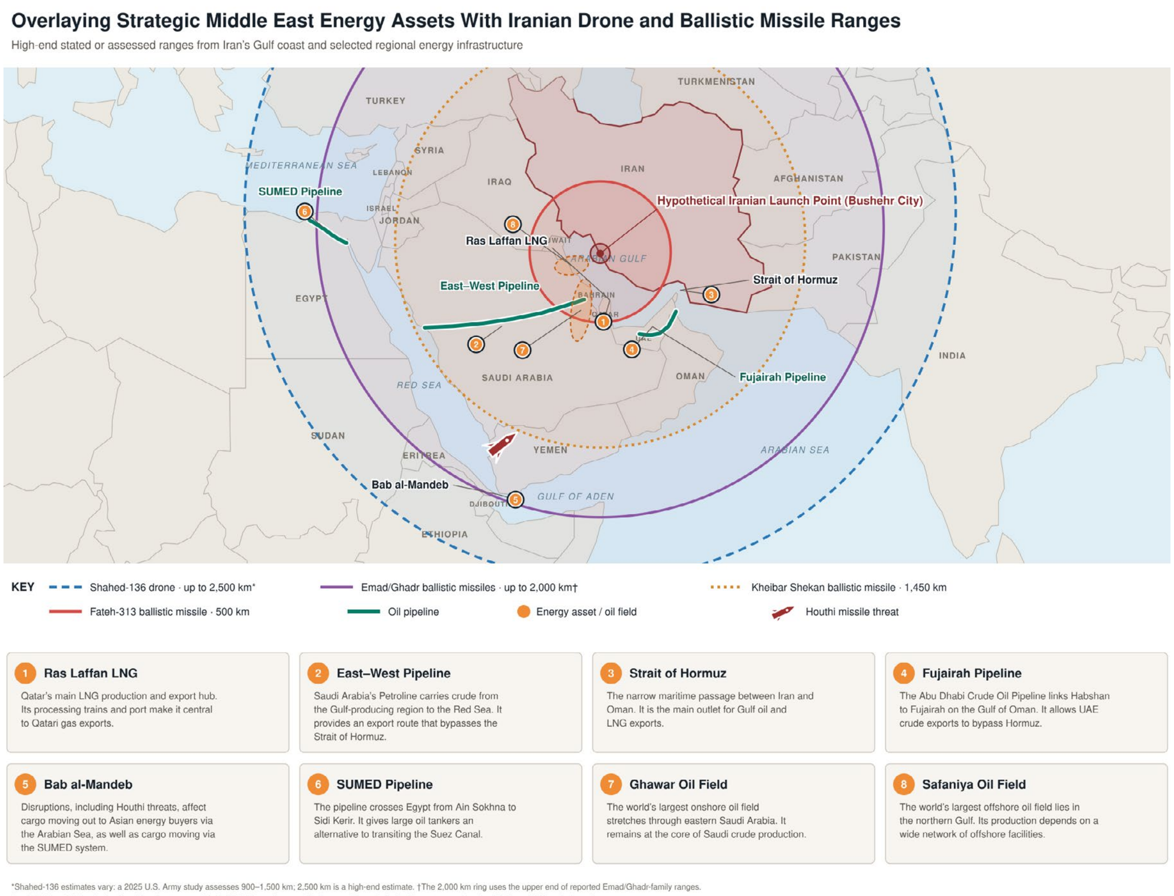
Alternative export pathways became one of the defining energy stories of the Iran war. As the Strait of Hormuz became effectively closed, countries and companies that had ways to move energy around, rather than through, the world's most important oil chokepoint were better positioned. But, as we explore below, even these alternative export pathways still face threats, making it difficult to assert that there is a completely risk-free approach to bypassing the Strait of Hormuz.

- **No asset better captured the interplay of geography and redundancy than Saudi Arabia's East-West Pipeline.** As traffic through Hormuz collapsed, Saudi Arabia rerouted crude across the Arabian Peninsula to the Red Sea port of Yanbu. Exports through Yanbu port surged to approximately **5 million barrels per day**, while the East-West pipeline reached its full **7 million barrels per day capacity**, allowing the kingdom to bypass the Strait altogether. The crisis transformed the line from contingency infrastructure into a primary export corridor and highlighted the premium investors now place on energy routes that supplement geopolitical chokepoints.
- **The UAE's Fujairah corridor became one of the biggest beneficiaries of the Hormuz disruption.** Located outside the Strait on the Gulf of Oman, Fujairah provides Gulf producers with direct access to global markets without transiting Iranian-controlled waters. Flows through the Habshan-Fujairah Pipeline jumped from about **1 million barrels per day before the war to 1.8 million barrels per day during the crisis.**
    - **The UAE is already investing heavily in additional bypass capacity.** ADNOC, the state-owned oil company that produces most of Abu Dhabi's crude, says it has completed nearly half of a second Fujairah pipeline. Once operational in 2027, the line is expected to roughly double the UAE's export capacity outside the Strait of Hormuz.
- **Oman also benefited from its geography outside Hormuz.** Ports such as Duqm and Sohar are located on Oman's Arabian Sea and Gulf of Oman coastlines rather than inside the Persian Gulf, making them attractive alternatives for storage, refining, and transshipment. Duqm, in particular, has been developed as an integrated energy hub, combining deep-water port facilities with large-scale refining, storage, and industrial infrastructure.
- **The ripple effects extended beyond the Gulf.** As more crude was redirected toward Saudi Arabia's Red Sea coast, infrastructure farther downstream also grew in strategic importance. Egypt's SUMED pipeline, which links the Red Sea to the Mediterranean, offers a critical route for moving crude to European markets and could see greater utilization if Red Sea export volumes continue to rise.

However, these alternative routes also come with their own vulnerabilities. The Houthis, an Iran-backed militant group in Yemen, have repeatedly demonstrated an ability to threaten commercial shipping in the Red Sea and Bab el-Mandeb, the narrow maritime gateway linking the Red Sea to the Indian Ocean. As more Saudi crude flows west through the East-West Pipeline to Yanbu and onward through Egypt's SUMED Pipeline, a growing share of global energy trade becomes dependent on waterways vulnerable to Houthi attacks.

The lesson is another important nuance of the diversification story. Similar to how Europe's ability to ride out the immediate drop in LNG cargoes created an exposure for its winter storage volumes, **reducing reliance on Hormuz did not eliminate geopolitical risk in the Gulf but simply shifted strategic importance and security concerns.** In this case from the Persian Gulf to the Red Sea corridor.

Figure 13: In the cross-hairs – Missiles and drone threats from the Islamic Revolutionary Guard Corps (IRGC), Iranian-backed militias, and the Houthis in Yemen place nearly all of the Middle East's critical energy infrastructure within strike range.



Source: JPMorganChase

Hardening critical infrastructure and the impact of asymmetric costs: Physical and cyber vulnerabilities

Another pathway for energy resilience is to harden critical infrastructure against potential physical damage—either from munitions or extreme weather events. **However, a defining infrastructure lesson of the Iran war is *asymmetry***. Adversaries no longer need to match the cost of the assets they target. Missiles, drones, and cyber tools costing thousands or millions of dollars can threaten infrastructure worth tens of billions. And physical proximity is not a limiting factor for all retaliations. Cyberattack capabilities can extend the reach of an adversary beyond its missile range. And while physical climate impacts were not the cause of this supply disruption the same lesson applies—increasingly frequent and severe extreme weather events can have large tail-risks for energy infrastructure and transportation.

- **Iran's attacks on Qatar's Ras Laffan LNG complex were a textbook example of cost-imposition asymmetry.** A drone or missile that may cost anywhere from tens of thousands of dollars to low single-digit millions can impose damage measured in tens of billions. Iranian strikes knocked out roughly **17% of Qatar's LNG export capacity**, creating an estimated **$20 billion per year** in lost revenue.

- **The Iran war also highlights cyber's transnational threat to critical infrastructure.** Even as the conflict unfolded more than 7,000 miles away in the Middle East, suspected Iranian-linked cyber activity reached water and wastewater utilities in Minnesota and several other states.[8] The episode underscored a broader lesson from the war: **critical infrastructure resilience is no longer just about protecting assets from physical attacks such as missiles and drones, but also safeguarding the digital systems that keep essential services running.**

- The increasing frequency and severity of extreme weather and climate events also reveals previously rarely experienced or entirely new vulnerabilities.

    - **Low precipitation values and climate change-enhanced heatwaves have reduced water levels in freshwater riverbeds used for oil and gas tankers, compounding the supply chain disruptions of the Strait of Hormuz closure**. As of August 2026, weight restrictions have removed transport capacity through the Panama Canal, the Rhine in Germany and the Netherlands, and the Danube in Central & Eastern Europe. This will drive various resilience measures: infrastructure (re)construction, nature-based solutions to improve water retention, and/or transportation route substitution.

    - **The heat has also hit energy supplies:** Romania began disconnecting its sole functioning nuclear reactor from the grid because of record low levels of water in the Danube, while a fifth of France's nuclear capacity is offline.[9] In the U.S., after record low snowpack values in the winter of 2025-26 and several record-breaking heat domes starting in the spring, surface waters have evaporated, plunging Lake Mead levels to record lows.[10] The minimum power pool, where turbines are left dry and hydropower production ends, could be reached in the next year if El Niño fails to bring record-breaking rainfall and snowfall to the region. The typical Colorado River Basin wet season begins in October.

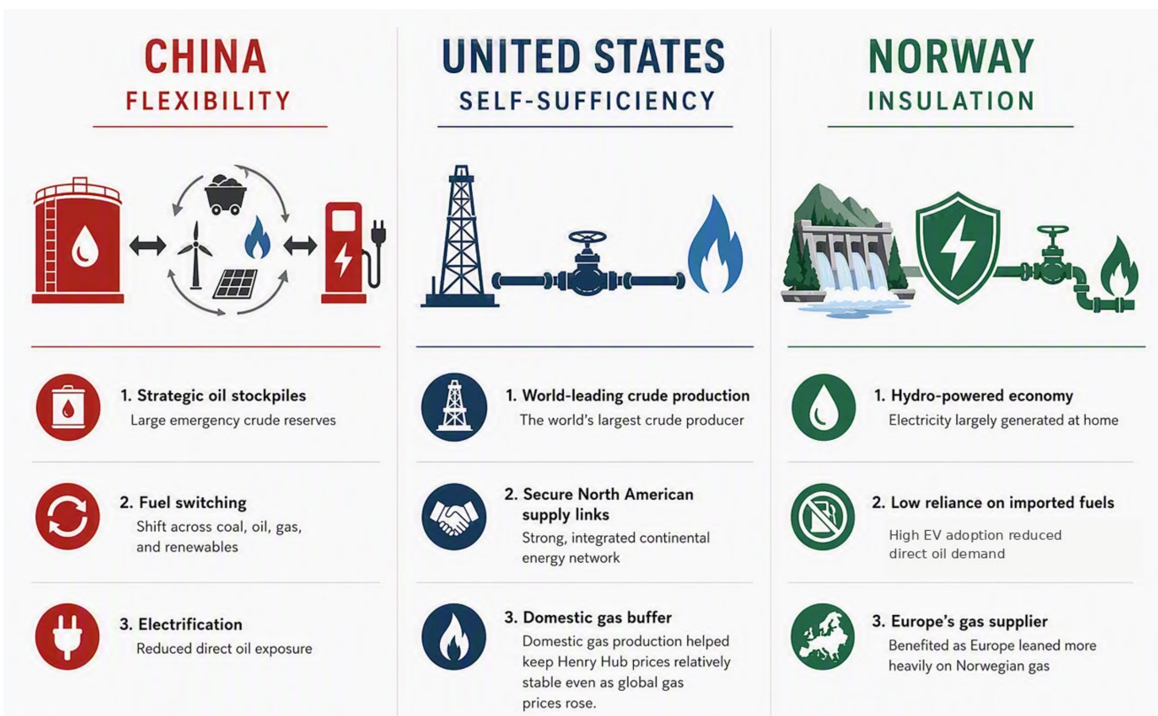
- On a more extreme level, if supply chain disruptions last long enough, entire goods may be substituted (e.g. favoring domestic nuclear requiring less frequent fuel delivery vs far-flung fossil fuels). **Mother Nature can grind commerce to a halt without resilience planning to handle increasing volatility and extreme events. This will happen as long as emissions accumulate in the atmosphere.**

Three national models of energy resilience during the Iran war

How China, the U.S., and Norway weathered the crisis through different strengths

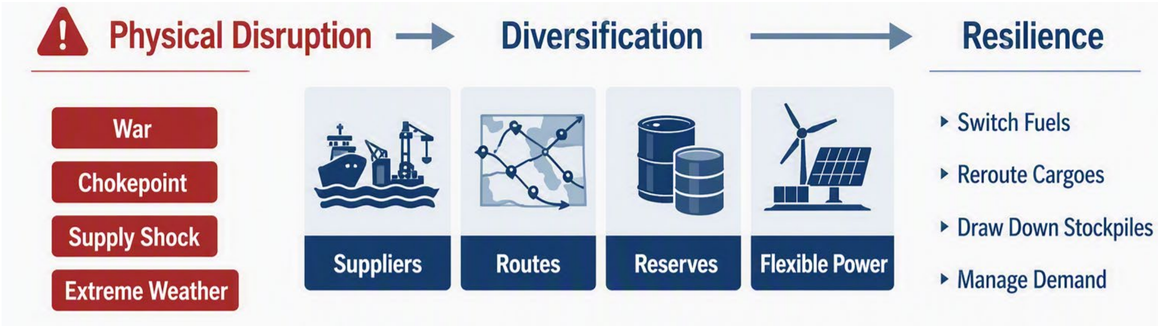
The previous sections examined key dimensions of energy resilience, resilience strategies used in the immediate aftermath of the disruption (e.g. paying up, cutting down, and working around), and the vulnerabilities of those strategies as exposed by the Iran war. **The following cases highlight examples where resilience fared more favorably.** Together, they demonstrate that energy security is not a switch that can be turned on when a disruption occurs. Countries that fared relatively favorably in 2026 did not choose one fuel and shut off others. Rather, they already had, and maintained, alternatives which had been developed over decades of investment and policy choices.

- **China** leaned on stockpiles and fuel switching, and benefited from its efforts to electrify;
- The **U.S.** relied on strong domestic fossil fuel production and secure regional supply links;
- Finally, **Norway** benefited from the fact that it has domestically insulated oil and gas infrastructure, highly electrified households, and a well-developed hydro-powered economy.



Source: JPMorganChase

Together these countries provide insights into different aspects of what constitutes a successful, "all of the above" resilient energy supply.

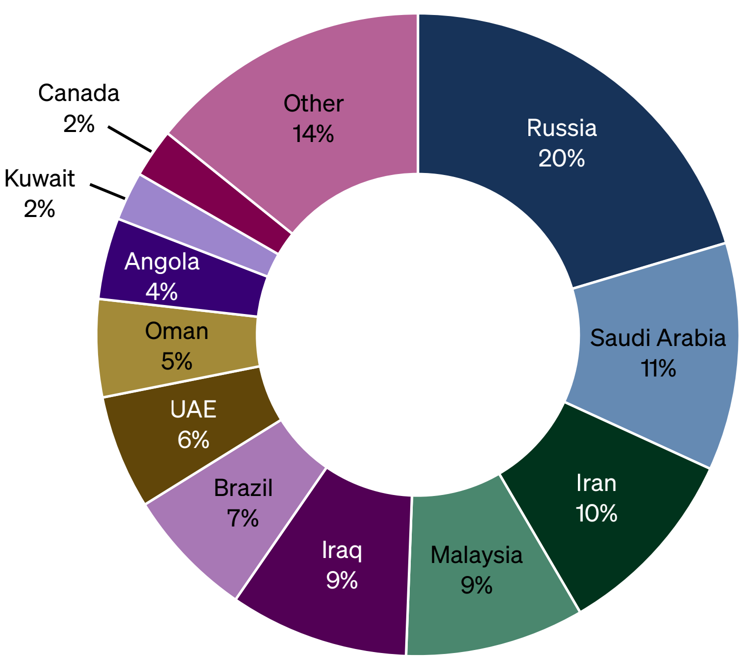


Source: JPMorganChase

China: Resilience through reserves, electrification, and fuel switching

China entered the Iran war highly exposed as the world's largest crude importer, including significant reliance on Iranian supply (about 10% of China's crude oil imports in 2025). However, Beijing had several cushions that helped it absorb the global supply shock: large emergency stockpiles (non-publicly reported), extensive solar and wind generation paired with battery storage capacity, and pipeline supplies from Russia and Central Asia that it also had the domestic refining capacity to process.

Figure 14: Barrels from the bloc – China imported ~30% of its crude from Russia and Iran in 2025
Sources of China's oil imports (%), 2025

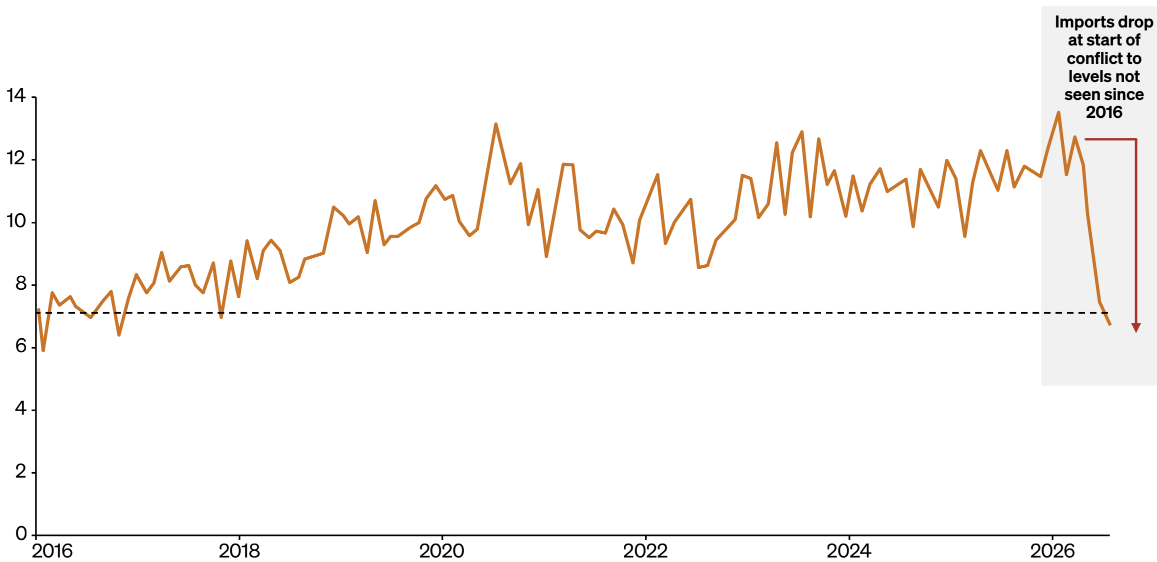


Source: Center on Global Energy Policy at Columbia | SIPA (link), Kpler, China's General Administration of Customs, JPMorganChase

China's strategic petroleum reserve

→ Since the onset of Middle East tensions in 2025, China had been buying more crude than it needed, taking advantage of stable prices and discounted sanctioned barrels from Russia and Iran. **By the time the Iran war began, China had accumulated roughly 1.4 billion barrels in spare oil, or 3 to 4 months of supply.**[11] By way of illustration, at the start of the war, China had more oil stockpiled than the 32 members of the IEA combined, including the United States.

Figure 15: Oil for a rainy day – Drawing upon its strategic reserves and fuel switching, China was able to massively decrease its external imports of crude during the crisis
China's crude oil imports (mbd)



Source: U.S. Energy Information Administration (link)

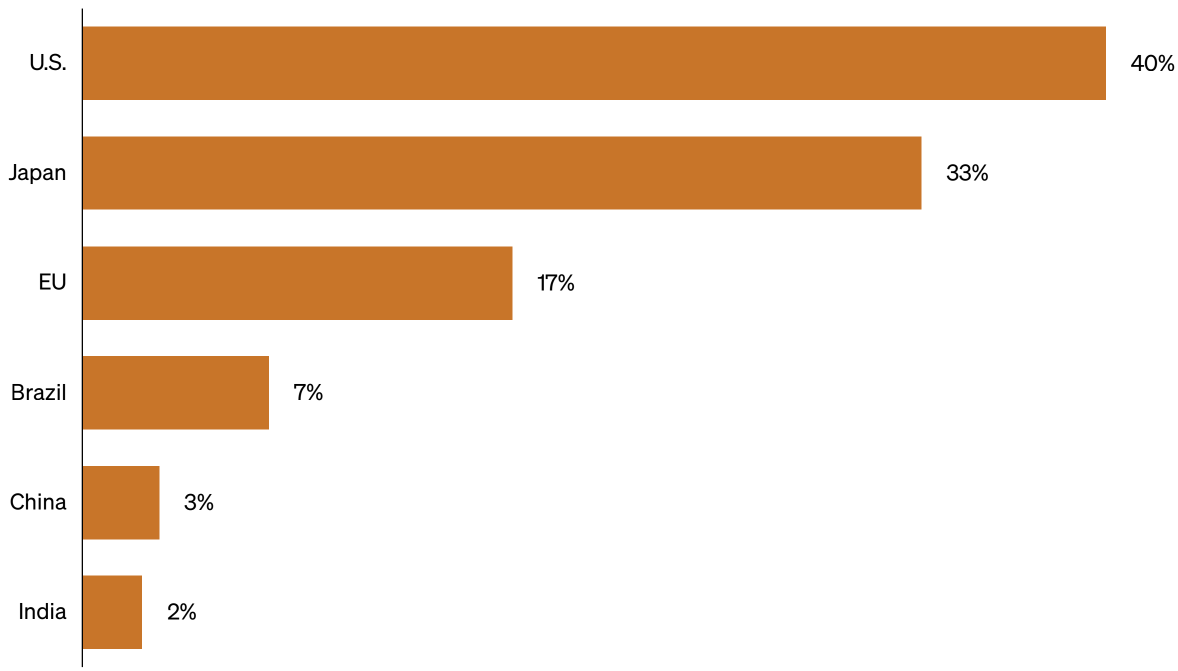
In March, China also suspended exports of refined products to ensure its domestic market was well supplied. Additional fuel switching to coal and renewables helped China weather the storm far better than its neighbors.[12] China's historic electrification of transportation also added another buffer, providing strategic diversification of a key source of energy demand:

- **EVs made up roughly half of new car sales by 2025** in China[13]
- By 2025, **China's EV fleet was already replacing about 1 million barrels per day of oil demand.**[14]

China was also structurally less reliant on electricity generation from gas (~3%) than other countries, helping cushion the effects of a global scramble for LNG (global reliance of 22%).[15] Of course, natural gas is used beyond the power sector. But even when looking at total use (e.g. across power generation + industry, buildings, transportation, chemicals, etc), natural gas represents just ~10% of China's total energy supply (vs ~24% in the EU, for example).[16]

While all of these measures helped China mitigate the worst impacts of the conflict, it has not escaped unscathed. China's economy has experienced a notable deceleration due to both declining domestic consumption and reduced global demand for Chinese exports. And its use of strategic oil stocks has reduced its ability to mitigate future global disruptions, at least until its reserves are replenished.

Figure 16: A lighter gas bill – China is structurally minimally reliant on electricity generation from natural gas (~3%)
Share of national electricity production from gas, 2025

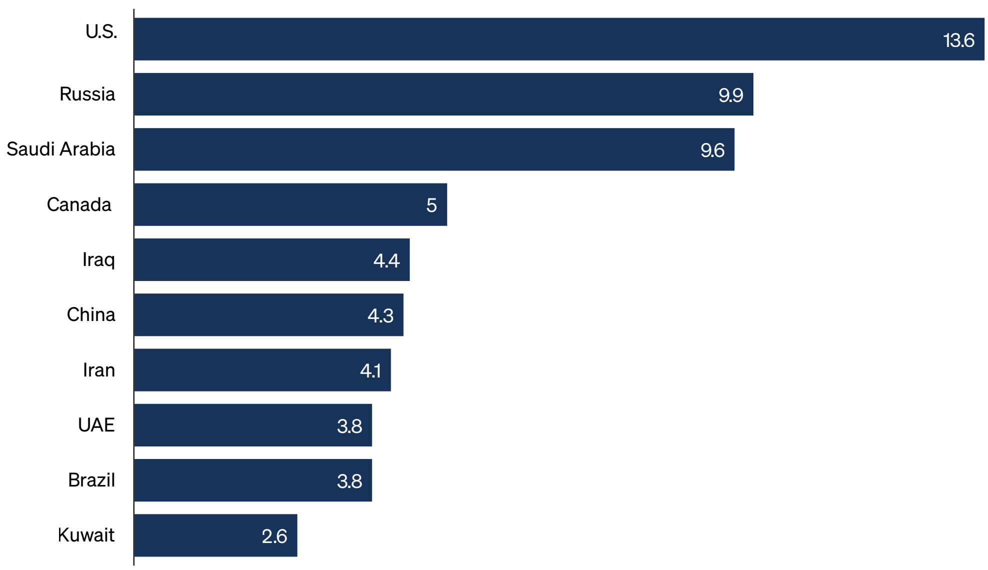


Source: Ember (2026) (link)

U.S.: Resilience through domestic production combined with declining oil intensity of economic growth

The U.S. entered the crisis with unusually strong energy supply at home. It remained the world's largest crude oil producer in 2025, extending a streak that began in 2018.[17]

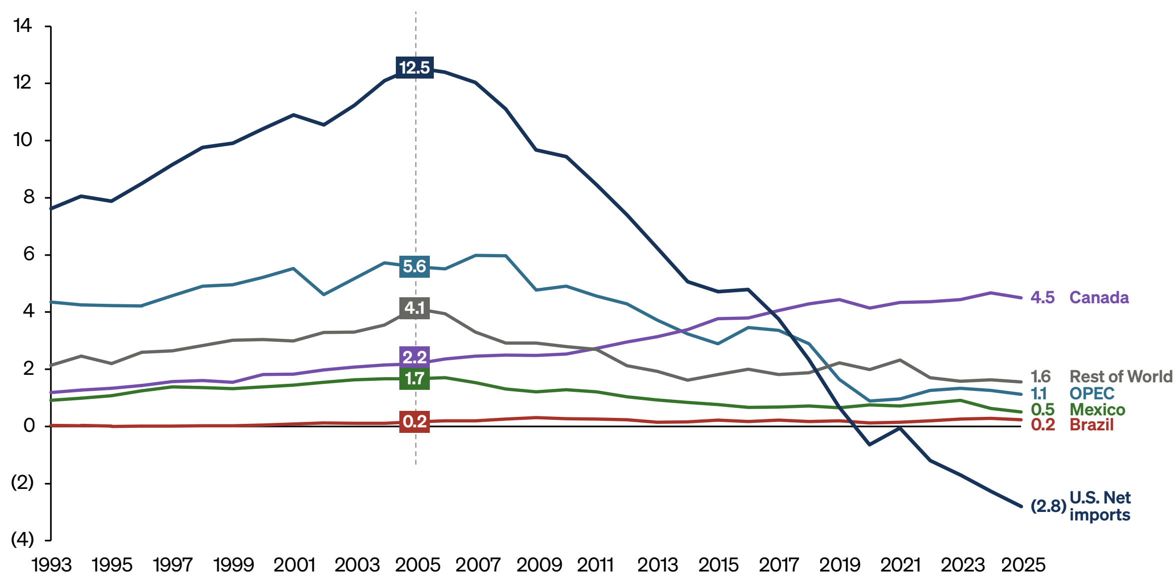
Figure 17: Drill leader – The U.S. produced more crude oil than any other country in 2025 (mbd)



Source: U.S. Energy Information Administration, International Energy Statistics (link)

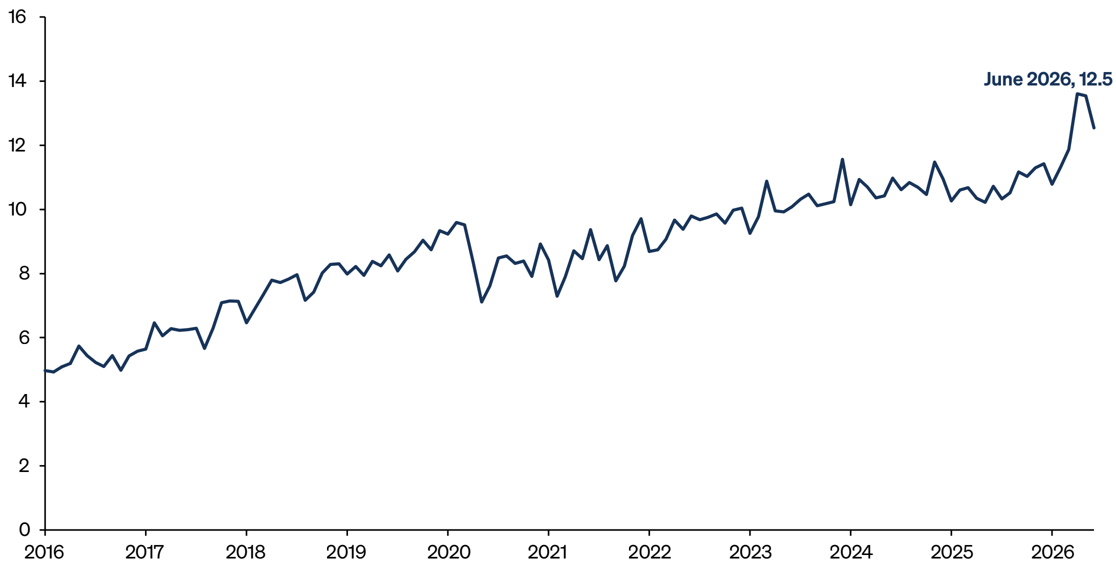
As a result of growing U.S. production, dependence on Middle Eastern crude is limited: the U.S. imported about 490,000 barrels per day from the Middle East in 2025 (only around 8% of its crude imports), and most imports came from Canada through cross-border pipelines.

Figure 18: Breaking the import habit – U.S. crude oil imports have dropped substantially over the last 20 years (mbd)



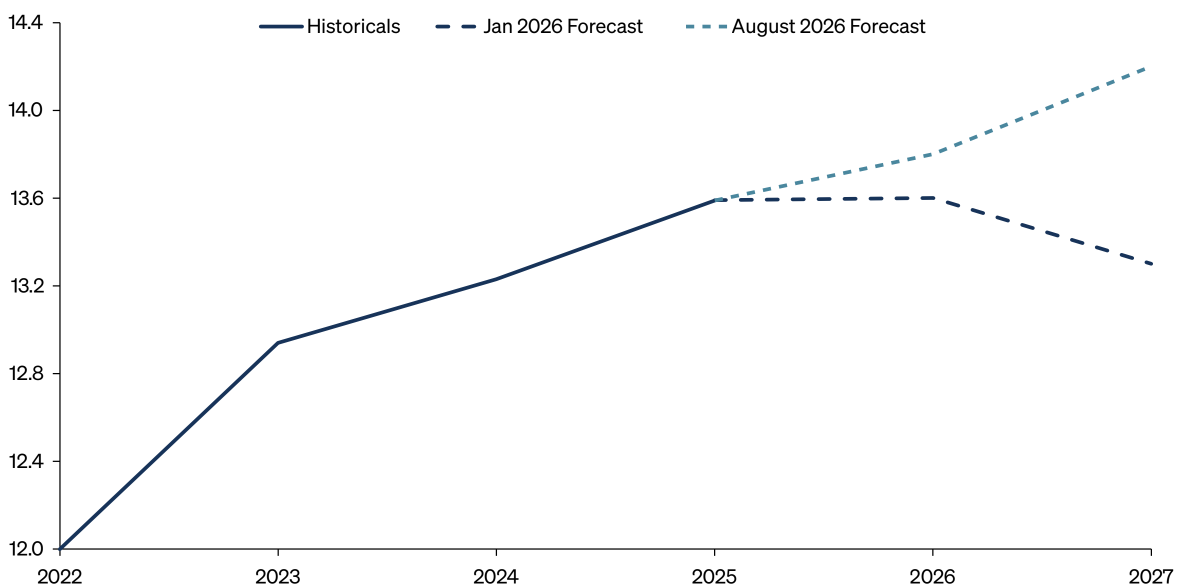
Source: U.S. Energy Information Administration U.S Imports by Country of Origin (link), U.S. Exports of Crude Oil and Petroleum Products, U.S. Energy Information Administration (link)

Figure 19: Gusher diplomacy – In response to global supply shortages, U.S. crude suppliers exported a record number of barrels (mbd)



Source: U.S. Energy Information Administration, Petroleum Supply Monthly, June 2026 (link)

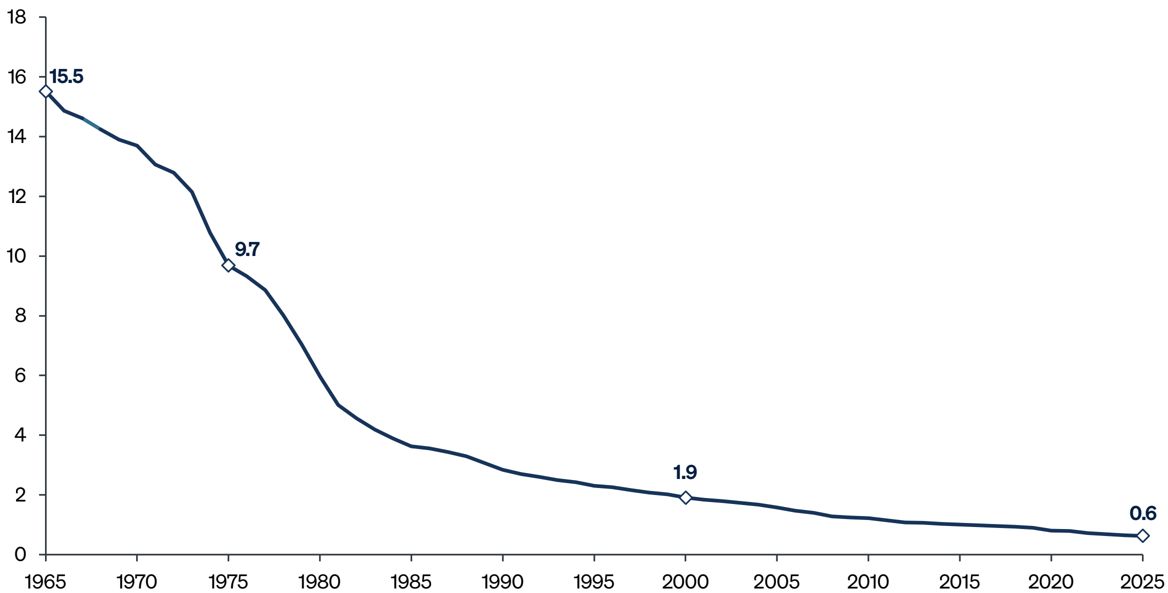
Figure 20: Drilling up expectations – U.S. crude production forecasts were revised upward due to the Iran war (mbd)



Source: U.S. Energy Information Administration, Short term energy outlook

This dynamic made outright *domestic supply* shortages unlikely—but it did not prevent a price spike. Average gasoline prices rose about $1.06 per gallon (36%) in March, topping $4 per gallon for the first time since 2022; by May, gasoline prices had at one point risen more than 50% from pre-war levels, while diesel prices were up more than 40%.[18] **In effect, the U.S. was protected on supply but not on prices given the globally interconnected nature of the oil market.** However, the oil-intensity of the U.S. economy has declined significantly over time making the price shock less impactful than it otherwise would have been.

Figure 21: More GDP to the gallon – The oil intensity of U.S. GDP has declined over time, providing some macro-level insulation to global price spikes (mbd / $GDP,trn)



Sources: Energy Institute: Statistical Review of World Energy (link); World Bank, GDP (current US$). This indicator is expressed in current prices, meaning no adjustment has been made to account for price changes over time

U.S. gas production also provided insulation

While the closure of the Strait of Hormuz triggered a 70% surge in global gas futures and sent international benchmarks like JKM and TTF above $18/MMBtu, U.S. Henry Hub prices remained remarkably stable, trading in a tight range between $2.70 and $2.80/MMBtu. In addition to the more regional market dynamics for natural gas, a primary insulator for the U.S. is the sheer scale of domestic production (**106.9 Bcf/d** in April 2026).[19] The U.S. is a net natural gas exporter, producing ~40% more than it consumes domestically. And while physical liquefaction capacity for exports will grow in the coming years it is currently capped at approximately 18 Bcf/d.[20] Taken together, this dynamic keeps molecules in the domestic market and U.S. prices separate from those in Europe or Asia. On top of this, the U.S. saw the mildest February and March on record in 2026, which collapsed heating demand and filled gas storage just as the Iran conflict began.[21] A developing El Niño on top of a warmer background climate may further reduce the Northern Hemisphere's winter gas demand (especially critical in Europe) as it did in 2023-2024.

Norway: Resilience derived through domestic renewable resources (hydropower) and EVs

Historical policy choices, a commitment to environmental preservation, and market forces have all shaped Norway's current energy landscape. The resulting insulation from global oil and gas markets has occurred despite the fact that Norway is a leading global producer of oil and gas.

Norway has certain characteristics (e.g. high wealth per capita, large sovereign wealth fund, small population, vast domestic hydro resource) that make its specific resilience pathway unlikely to be easily replicable in every part of the world. **Nevertheless**, **Norway serves as an example of how national policy choices can leverage natural resources to build systems that are insulated from fossil fuel disruptions, even when a country has significant oil and gas reserves and production capacity**. An emerging new example of this is the development of nuclear facilities in oil and gas rich United Arab Emirates.

To be clear, Norway was not immune to global prices, but the shock reached the country mainly as a price and trade disturbance, not as a threat to physical energy availability. Indeed, Norway was one of the few European countries positioned to benefit fiscally from the crisis.

A number of geological, hydrological, and geographical factors made Norway unusually favorable:

- **Almost no direct dependence on Gulf supplies.** Norway produces far more oil and gas than it consumes. In 2025, it produced roughly 2 million barrels per day of liquids and exported about 1.5 million barrels per day of crude alone.[22] A disruption of Gulf production therefore did not threaten Norway with domestic oil or gas shortages.

- **Robust domestic oil and gas production outside the conflict geography.** Norway's fields, terminals and pipelines are concentrated in the North, Norwegian and Barents seas. Its exports move directly into northwestern Europe through pipelines or Atlantic and North Sea shipping routes. They do not pass through Hormuz, Bab al-Mandab or Suez, insulating Norwegian supplies from the war's principal maritime chokepoints.

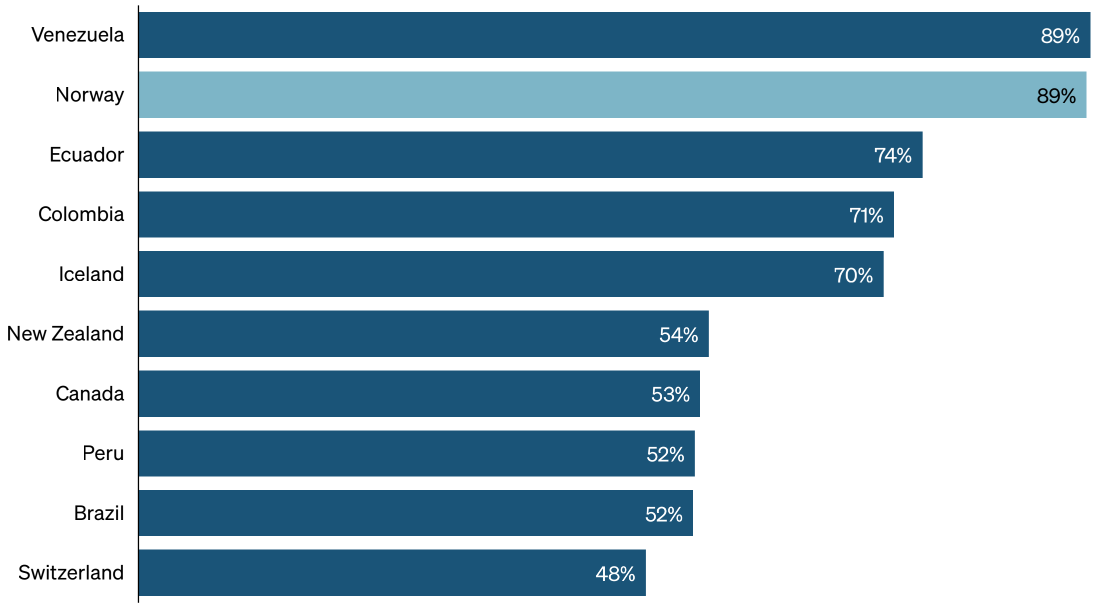
- **An overwhelmingly renewable electricity system.** Hydropower supplies around 89% of Norway's electricity, with wind and other renewable sources bringing the total renewable share to approximately 98%.[23] Norway therefore does not depend on imported oil or gas to keep its power system running.

- **Large reservoirs that make hydropower dispatchable.** Norway's roughly 1,100 hydropower reservoirs can store more than 87 TWh of energy, equal to around half of Europe's total reservoir-storage capacity.[24] This allows Norway to hold water for periods of increased demand and rapidly increase or reduce generation. More than 75% of its power-production capacity is flexible, making Norwegian hydropower dispatchable rather than merely weather-dependent and helping Norway balance both its own electricity system and neighboring European grids.

- **Lower household exposure to fossil fuels.** Electricity supplies 83% of Norwegian household energy consumption, compared with 28% across Europe.[25] Electric vehicles also dominate new passenger-car sales. Norwegian households remained exposed to higher electricity and transport prices, but electrification weakened the direct transmission of the global oil shock into heating and household driving costs.

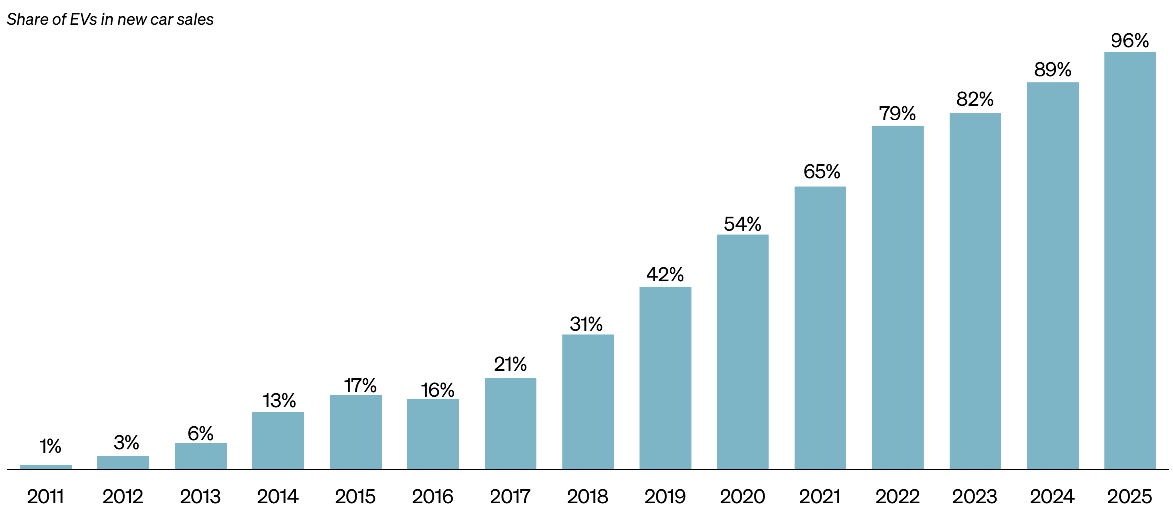
- **In fact, as a result of the war, Norway became more valuable to Europe as alternative supplies tightened.** It already supplied approximately 20% of Europe's oil and 30% of its gas needs.[26] Norwegian gas moved through fixed pipelines into the UK, Germany, Belgium and France, making it one of the principal substitutes for disrupted Gulf LNG.

Figure 22: Dam good power – 10 countries where hydropower represents the largest share of electricity



Source: Energy Institute: Statistical Review of World Energy (link)

Figure 23: Charge of the Norwegians – Norway's path toward selling only electric cars



Source: Norwegian Road Federation (OFV) and Norwegian Public Roads Administration

Part II

How to build energy resilience: Introducing the SEE Framework

As governments and companies race to strengthen energy resilience, a common pattern is emerging across markets. Whether responding to geopolitical shocks, rising electricity demand, or concerns about affordability, countries are increasingly pursuing the same three strategies to balance the energy-security equation of **price, supply, and reliability**.

Based on these trends, we developed the **SEE Framework**—a simple way to understand how leading economies are adapting to the Energy Security Age.

The framework rests on three pillars:

- **Supply Your Own** – Expanding access to domestically available energy resources (produced or stockpiled) while building related domestic manufacturing capacity.
- **Electrify** – Reducing exposure to volatile fuel markets by shifting more economic activity from molecules to electrons, including electric vehicles, heat pumps, batteries, and industrial electrification.
- **Enhance Efficiency** – Getting more economic output from every unit of energy consumed through grid modernization, demand management, and smarter use of electricity.

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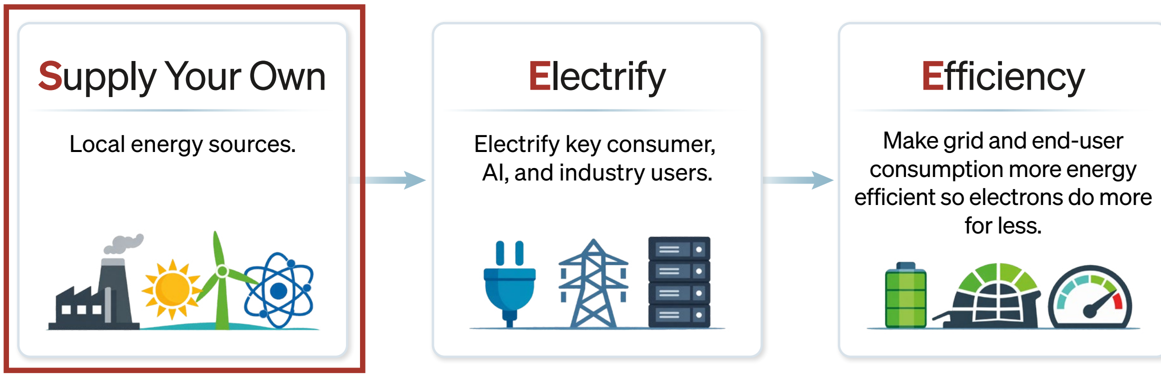
The (S) in SEE – Supply Your Own



Source: JPMorganChase

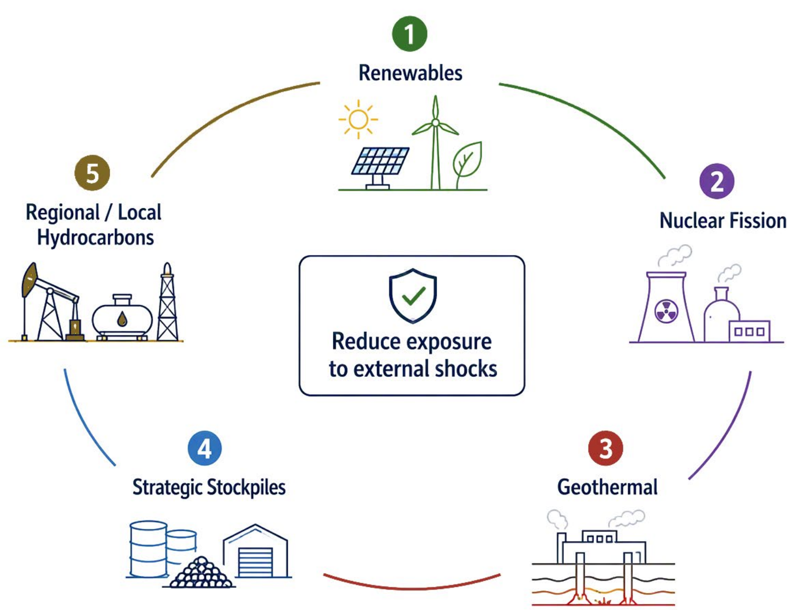
The first part of the resilience race is **supplying your own energy.** The events of 2026 reinforced a simple reality: **energy produced close to home is often more secure than energy imported from abroad.**

→ Whether generated from renewables, nuclear fission, geothermal resources, or domestic hydrocarbons, local energy reduces dependence on foreign suppliers and vulnerable trade routes.

→ Strategic stockpiles are becoming a core part of energy resilience. Governments are expanding or maintaining reserves of oil, gas, and uranium while also increasingly incentivizing electricity storage to ensure domestically available energy remains accessible during periods of disruption.

The goal is not isolation, but resilience—reducing exposure to geopolitical shocks that impact any one energy source while maintaining reliable and affordable supplies.

Figure 24: Supply Your Own – Trends in energy resilience



Source: JPMorganChase

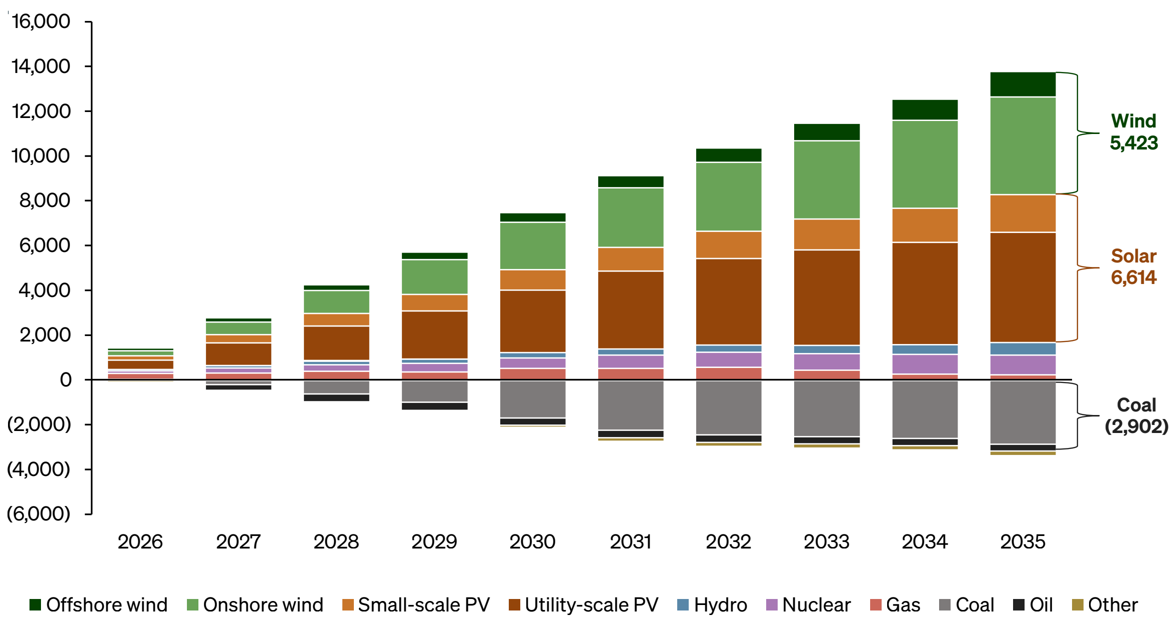
1. Renewables—and the solar surge

Supply shocks linked to the Iran war have again exposed how quickly imported fuels can become scarce—or suddenly unaffordable. Renewables can strengthen energy resilience by reducing exposure to volatile global oil and gas markets, even if electricity cannot substitute for all household and industrial energy needs, particularly where heat, transport, and feedstocks still rely on hydrocarbons.

BNEF expects renewable power generation to surge over the rest of the decade—up nearly 100% from 2025-2030, an increase of 13,400 TWh. Solar is the main engine of that expansion, delivering nearly half of the increase (49%), with wind adding a further 41%. If these projections hold, renewables' share of global electricity generation would rise from 44% in 2025 to 65% by 2030.

Figure 25: The new power couple – Projected global power generation additions are dominated by wind and solar

Cumulative electricity generation change vs 2025, by technology (BNEF Economic Transition Scenario) (TWh)

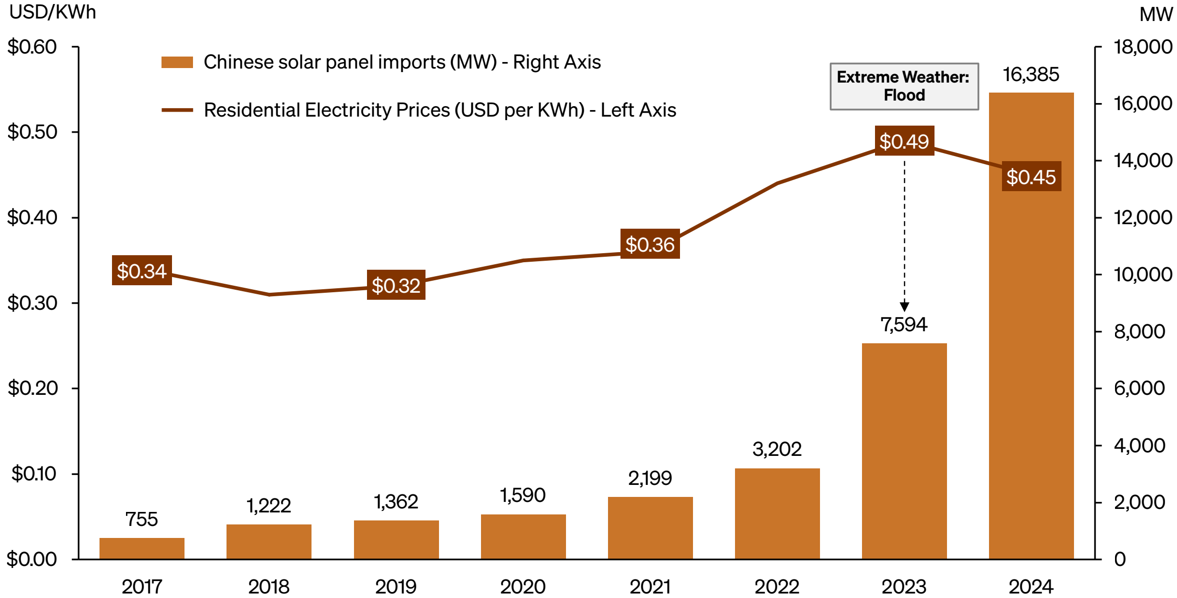


Source: BloombergNEF, New Energy Outlook (link), ETS scenario. Notes: "Other" includes Geothermal, Hydrogen and Bioenergy; "Coal" includes both resources with and without CCS; "Gas" includes CCGT and Peaker plants, both with and without CCS. "Nuclear" is all traditional resources as small modular reactors (SMR) do not generate electricity in this forecast in the time period shown.

This year, a few countries showed both the power of renewables in achieving energy resilience, as well as its limits.

Pakistan shows how quickly solar can become an energy-security tool when consumer demand for self-sufficiency shifts rapidly. Economics explain much of the shift: residential electricity prices increased ~50% from 2019-2023, while Chinese solar manufacturers, facing major overcapacity at home, pushed panel prices sharply lower. Compounding demand developed after severe flooding across Pakistan in 2022, affecting over 33 million people, displacing 8 million people, and costing over $30bn in damages.[27] Solar enabled residential microgrids and power reliability during summer heatwaves as larger scale infrastructure took time to rebuild. Pakistan also provided incentives for solar through feed-in tariffs and other mechanisms during this time period.

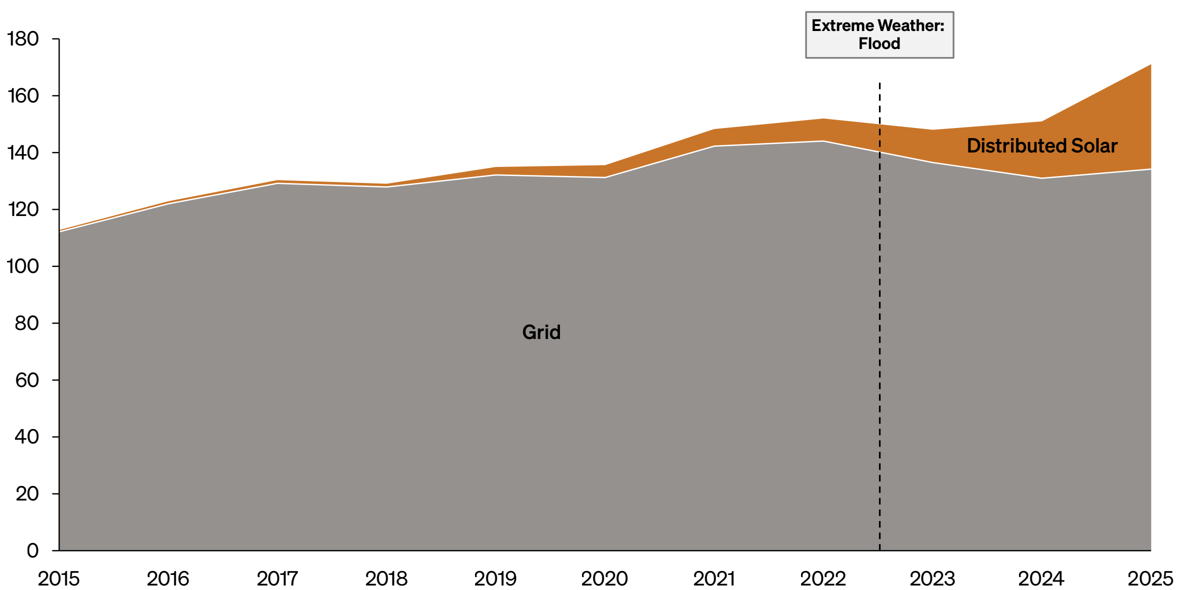
Figure 26: Price shock, solar rush – As residential electricity prices increased in Pakistan solar PV imports from China grew dramatically



Source: OECD Data Explorer Green Growth Data Base (link), Ember China Solar PV export data (link); Note: U.S. dollars per kilowatt hour, PPP converted, 2020. Electricity price data available until 2024. 2025 panel import data for Pakistan grew to 16,860 MW

Figure 27: Solar arbitrage – Pakistan's recent electricity demand growth has been met entirely by distributed solar (Electricity generation, TWh)

Demand and deployment had been growing pre-flood, but accelerated after. In learning how to live with floods and summer heatwaves disrupting energy delivery, consumers adopted self-sufficiency when alternatives were both available and affordable to avoid the alternative: expensive, unreliable, and/or unavailable utility electricity delivery.



Source: Ember (link)

Despite the rapid solar build-out, **natural gas remained Pakistan's Achilles' heel (~28% of total energy supply per the IEA[28]). Large parts of the economy—from transit to heavy industry—** cannot yet be easily electrified and depend on hydrocarbons.[29] That left Pakistan highly exposed to Gulf supply: Qatar provided roughly 90% of its LNG, while Qatar and the UAE together accounted for about 99% of imports.[30]

Lessons learned

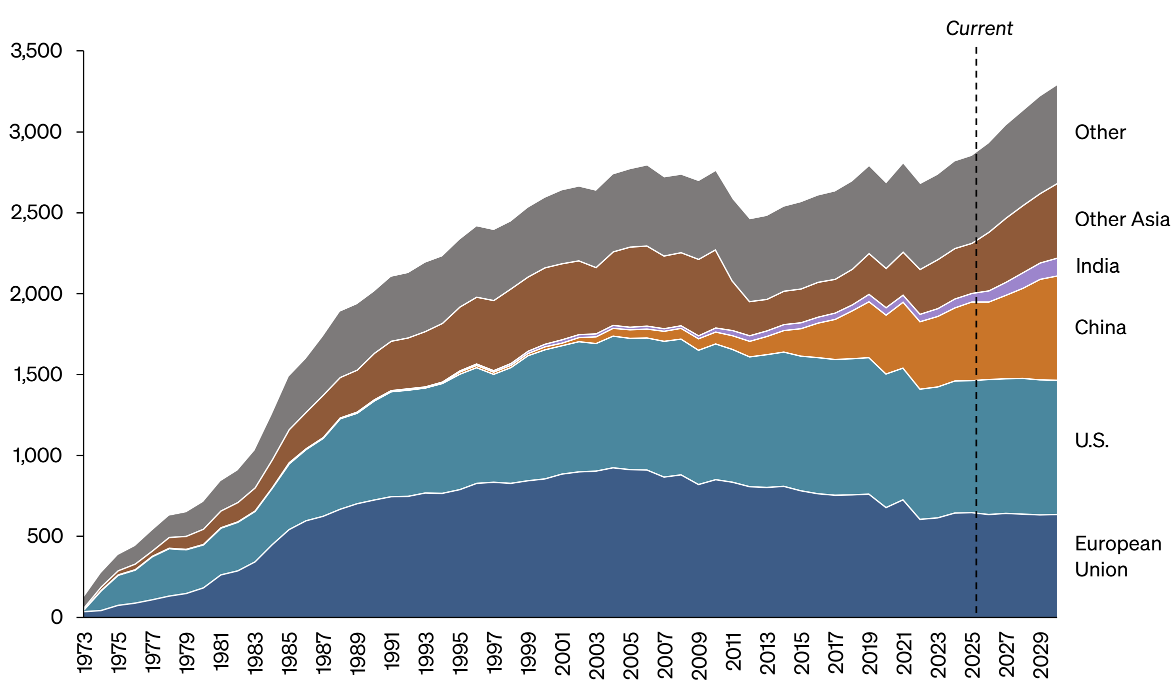
- Solar reduced Pakistan's daytime exposure to imported gas, but did not eliminate its reliance on Gulf LNG for evening demand, industrial energy use, and system balancing.
- **This dynamic reinforces the SEE framework's core logic: building your own energy supply increases resilience but on its own is likely insufficient when imports are still needed and concentrated from one country or region. Further resilience planning and investment (diversification, storage, industrial heat, and technological modernization) would reduce import dependence in the future.**

2. Nuclear fission

Nuclear power increasingly benefits from the same logic as renewables: it provides domestic electricity that is less exposed to daily fuel imports and maritime chokepoints.

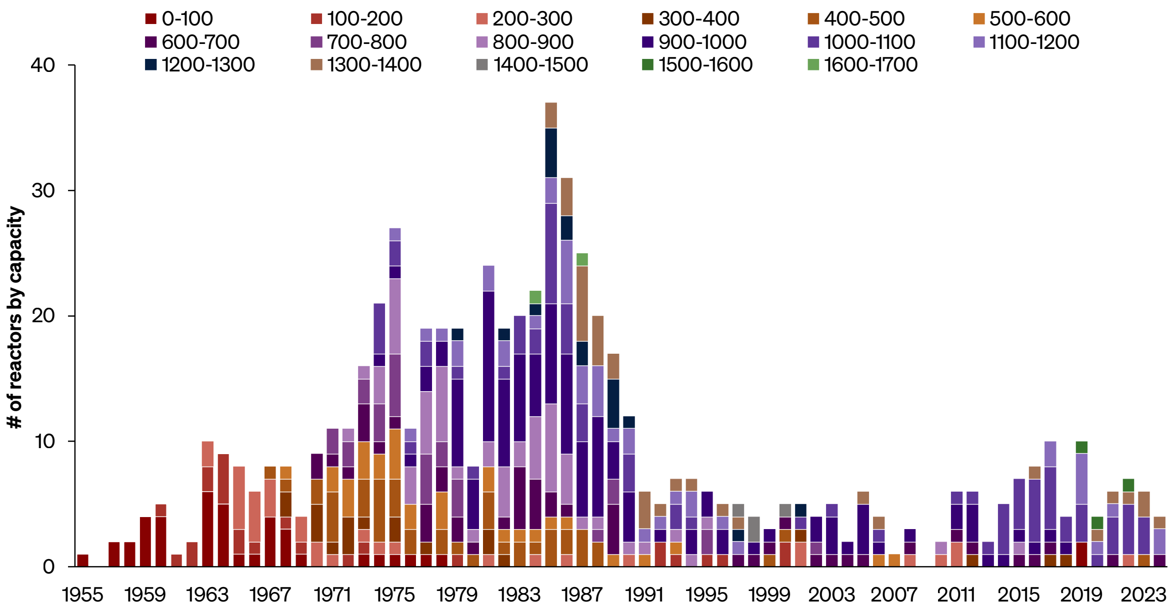
As policymakers look for scalable sources of reliable, domestically produced power to meet growing energy needs for AI, electrification, and industry, nuclear is once again moving to the center of the conversation. Today, about 440 nuclear reactors operate across 31 countries, with combined capacity of roughly 400 GWe. In 2024, they generated about 2,667 TWh—around 9% of the world's electricity. Existing nuclear fission facilities were largely built in the 20th century, and will reach the end of their useful life between now and 2050.[31]

Figure 28: Atomic incumbents – The U.S. and EU currently produce the most power via nuclear, with China expected to grow in the future (TWh)



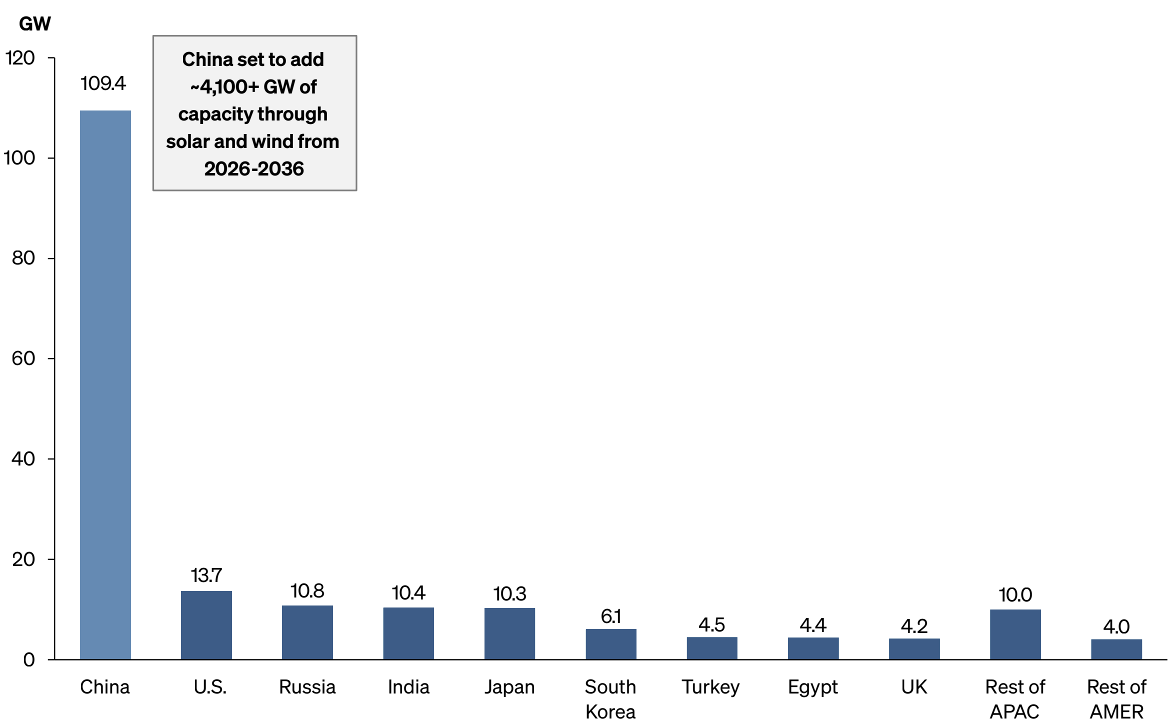
Sources: IEA Energy Statistics Data Browser (link); Last updated Jan 30, 2026

Figure 29: An aging reaction – Most nuclear reactors were built prior to 2000
Number of nuclear reactors by capacity in first year of commercial operation (GWe gross)



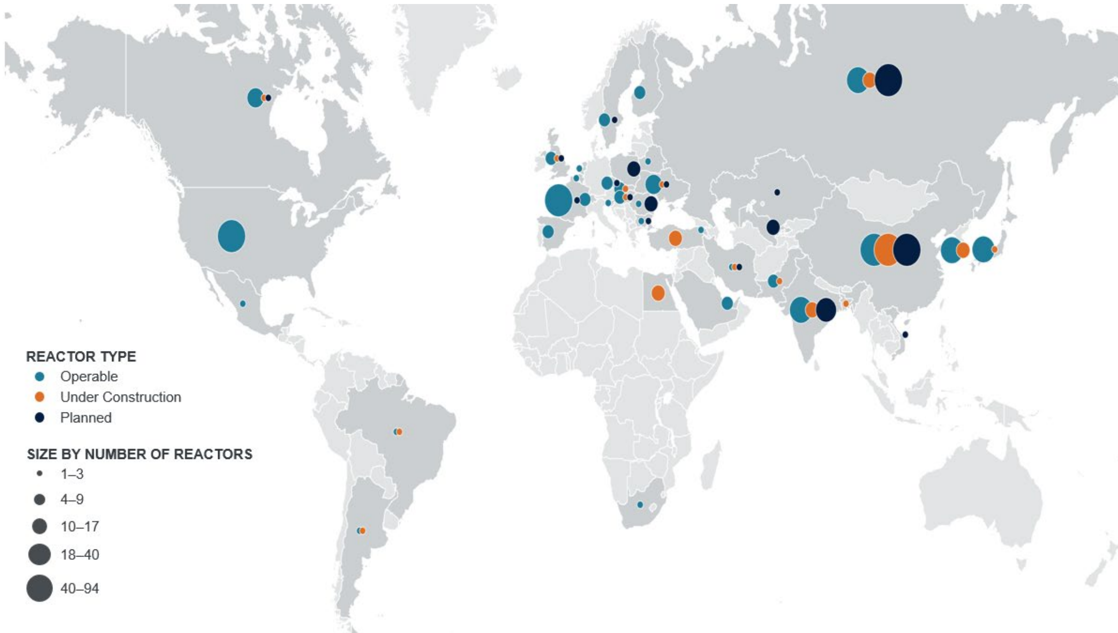
Source: World Nuclear Association (link)

Figure 30: Atomic ambition – China is expected to add the most nuclear capacity over the coming decade
Global nuclear power capacity additions forecast, by market 2026-2036 (GW)



Source: BloombergNEF, Nuclear Power Market Outlook: 1H 2026 (link): Approaches Diverge: global operational nuclear capacity, ETS scenario

Figure 31: Hot spots – Mapping nuclear reactors globally



Source: World Nuclear Association, Reactor and electricity data: International Atomic Energy Agency Power Reactor Information System (PRIS); US Energy Information Administration; company data; World Nuclear Association estimates (link), Note: Operable = Connected to the grid, Under Construction = First concrete for reactor poured, keel laying for floating plants; Planned = Approvals, funding or commitment in place, mostly expected to be in operation within the next 15 years

In terms of new construction, a global nuclear revival is underway. Nuclear growth has been slow in recent decades. Over the past 20 years, 101 reactors entered service while 111 were retired, leaving global capacity largely flat. That dynamic is now beginning to change as governments increasingly view nuclear power as a solution to rising electricity demand, energy security concerns, and decarbonization goals. According to the World Nuclear Association, roughly 80 reactors were under construction worldwide as of July 2026, with another 120 in the planning pipeline, most of them in Asia. Planned and under construction plants are shifting the center of mass of demand for nuclear out of North America and Europe into Asia.

- Around 35 countries are considering, planning, or launching nuclear power programs. In 2025, the U.S. set a goal of expanding nuclear capacity to 400 GW by 2050[32], including 5 GW of uprates at existing plants and 10 new large reactors under construction by 2030. China, India, and the UK have also unveiled ambitious expansion plans.
- Several countries are building a brand-new civilian nuclear power program for the first time, including Bangladesh, Egypt, and Turkey, which currently have their initial nuclear power plants under active construction.
- Poland, one of Europe's fastest-growing economies, has also set an ambitious full-scale start-up schedule, a dramatic shift for a country that remains the EU's second-largest coal producer after Germany and still derived roughly 85% of its primary energy consumption from fossil fuels as of 2024.

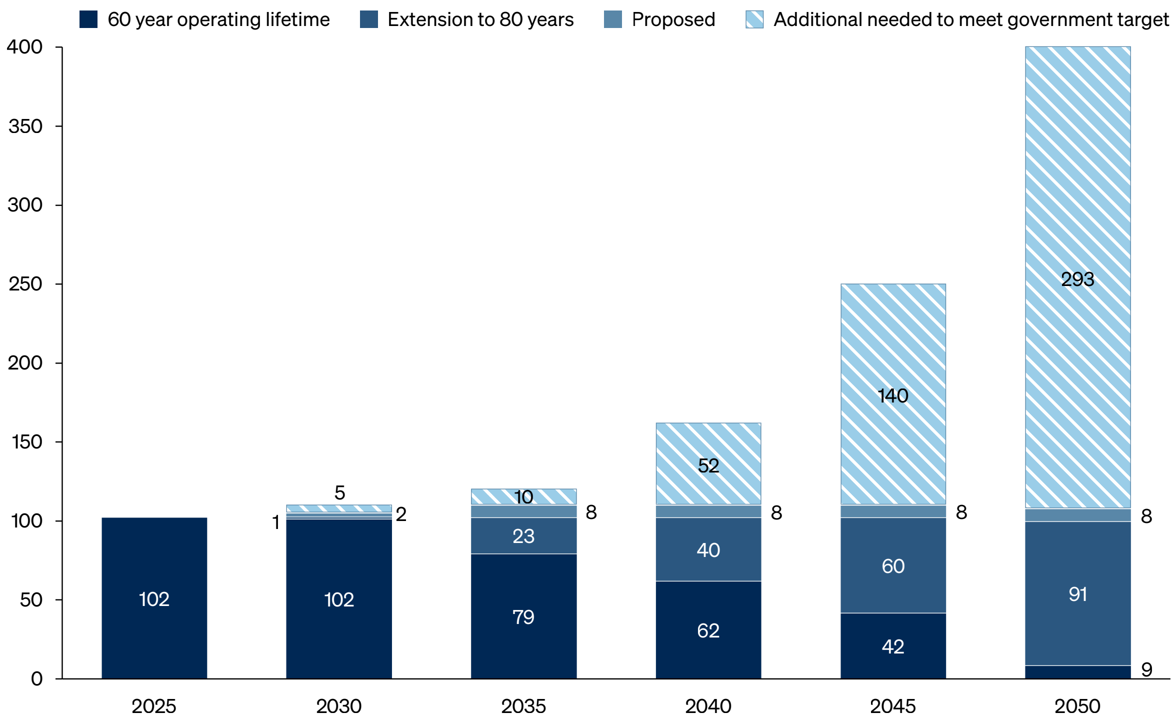
Large scale nuclear ambitions, organized by approaching deadline

COUNTRY	OPERATING CAPACITY TODAY*	TOTAL GOAL	DELTA	TARGET DATE
China	~58.7 GW	110 GW	~2x	2030
Poland**	0 GW	6–9 GW	N/A	2043
India	~7.7 GW	100 GW	~13x	2047
United States	~97 GW	400 GW	~4x	2050
United Kingdom	~5.9 GW	Up to 24 GW	~4x	2050

* Net operating capacity as reported by the PRIS - Power Reactor Information System (link), 2026© IAEA, rounded to the nearest 0.1 GW or whole gigawatt, as of August 2026.

** Poland plans to build six reactors across two power plants. The first reactor is scheduled to begin operating in 2036, followed by two more by 2038. Three additional reactors are planned by 2043, although their location, technology, and exact timetable have not been finalized

Figure 32: Fission, fast – U.S. nuclear capacity has to increase dramatically to meet government targets (GWe)



Source: World Nuclear Association (link)

U.S. nuclear math: The U.S. nuclear target for 2050 is nearly four times China's stated 2030 goal. Meeting that ambition would require the U.S. to ramp quickly and sustain China's current average build pace for the next 25 years. Because the U.S. is building very little today, it would then need to exceed China's current build rate by the 2040s to stay on track for 2050.

That trajectory requires investment to start now, especially in the workforce and supply chains. Nuclear construction and engineering rely on specialized skills that typically take 4–10 years of education[33] and/or training, so the pipeline must be built today to deliver the people needed to construct the required capacity on time. Scaling supply chains for uranium-based nuclear fission plants will require expanding mining, processing, and finished fuel product delivery, while scaling new nuclear will require the acquisition, design, and construction of waste facilities.

Nuclear also offers one possible way to reduce clean-tech supply chain dependence. Solar panels, batteries, and many critical minerals are heavily tied to Chinese manufacturing and processing.[34] Nuclear supply chains are different, with major roles for the U.S., France, South Korea, Japan, Canada, and Russia.

- Today, nuclear has some geopolitical dependencies. The U.S. and Europe still rely on Russia for parts of the nuclear fuel cycle, including enriched uranium and related services.
- Given the decade-plus timeline to scale nuclear (e.g. growth expected in U.S. in late 2030s if current goals are realized), careful supply chain diversification needs to be developed today to avoid dependencies tomorrow.

Figure 33: The U.S. nuclear fuel supply chain has different geopolitical risk exposure than most clean technologies (e.g. it's not overly reliant on China)

Step	Supply chain segments to meet the demand of the final product	Significant domestic suppliers	Domestic Reliance	Top Foreign Reliance
Mining and milling	1 Uranium Mining	No	U.S. has 1% of global resource base[1]	Australia, Kazakhstan
	2 Uranium Production	No	U.S. has 1% of global production[2]	Canada, Kazakhstan
	3 Critical Minerals	No	Minimal (e.g. China has 85+% of graphite mining and refining)[3]	China, Russia
Fuel Cycle	4 Enrichment	Some	~20% domestic production[4]	Kazakhstan, Canada
	5 Conversion	Some	30-60%[5]	Canada, France
	5 Deconversion	Yes	N/A	N/A
	6 Fuel Fabrication	Yes	N/A	N/A
Storage	7 Deep geologic storage	No	N/A	N/A
	7 Near-surface disposal waste	Yes (with constraints)	Yes	N/A

Source: World Nuclear Association, [1] U.S. DOE Nuclear Energy Supply Chain Deep Dive Assessment, [2] NEA & IAEA Uranium 2024 Resources, Production and Demand (link), [3] IEA Global Critical Minerals Outlook 2025, [4] U.S. Energy Information Administration 2025 Uranium Marketing Annual Report, [5] Clean Air Task Force (link), JPM; Critical Minerals include Lithium, Graphite, Nickel, Copper, Cobalt and Rare Earths

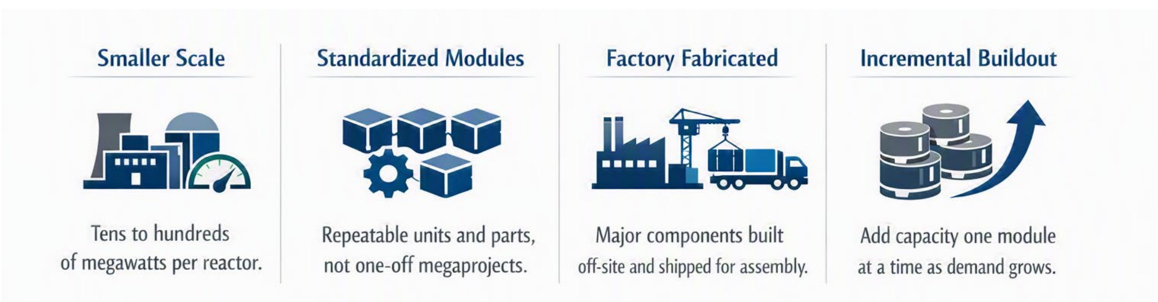
The national security case for small modular reactors (SMRs)

SMRs are nuclear power plants built at a much smaller scale than today's conventional reactors and designed to be manufactured as standardized "modules." The idea is to make nuclear more "off the shelf" in terms of construction. The technology for SMRs has existed since 1955 when it was first used by the U.S. Navy in *Nautilus*—the word's first nuclear-powered submarine.[35]

SMRs leverage industrial manufacturing principles to create modular megawatt-scale facilities over one-off gigawatt-sized megaproject construction. Additional capacity can be added in increments (one module at a time) as demand grows or should a physical threat shut down a single reactor as part of a distributed system. Commercialization efforts have lagged to date as product-market fit has not materialized and cost per MWh remains high, but that may be changing with the rise of AI data centers and increasing national focus on energy security and resilience over cost for some use cases. Manufacturing development and economies of scale are likely to bring costs down as they did for solar, but may require sustained capital and/or a national security nudge to hasten commercialization.

Small modular reactors also fit within a broader energy-resilience shift toward smaller, more geographically distributed generation sites—a lesson reinforced by the war in Ukraine. According to the IEA, Russian attacks reduced Ukraine's available dispatchable generation capacity from roughly 38 GW before the full-scale invasion to just 12 GW by mid-2024. Ukraine responded by adding smaller solar, wind, battery, and gas-fired systems closer to where power is consumed. Connected through microgrids, these systems can keep cities, towns, or villages operating in "island mode" when the wider grid fails. **Smaller, modular generation assets are also harder to disable at once and generally easier to disperse, repair, and replace than large plants built around bespoke equipment.**

Figure 34: Key characteristics of small modular reactors



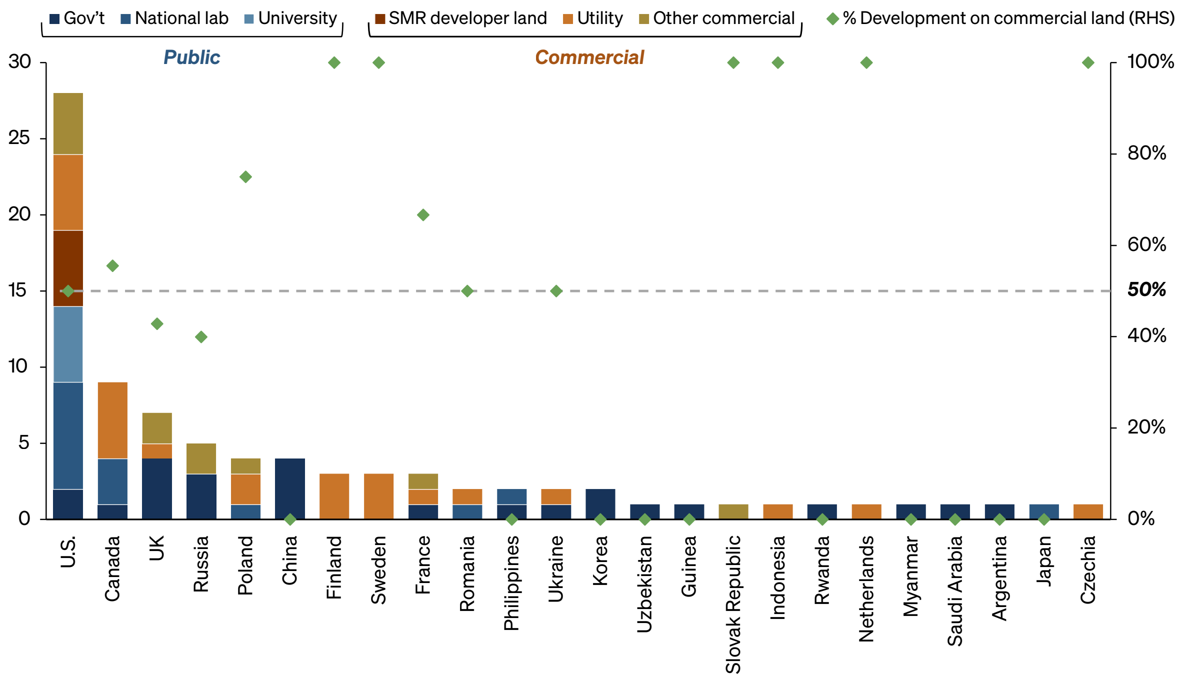
Source: JPMorganChase

Their appeal is straightforward: SMRs could provide dedicated firm, scalable power for military bases and remote locations without relying only on traditional gigawatt-scale plants. Additionally, they could be collocated with data centers, especially for remote locations to maintain security for sensitive operations. In principle, SMRs offer (1) 24/7 output that complements variable renewables and (2) the ability to site power closer to load where transmission is constrained.

SMRs have strategic importance for national security. As a result, they are largely being sited on government-owned land (29%) followed by national/sub-national laboratories (28%). European development is distinct in that SMRs are more likely to be developed on utility-owned land.

Figure 35: America goes modular – The U.S. is the global leader in SMR activity, using a mix of public/private sites for deployment

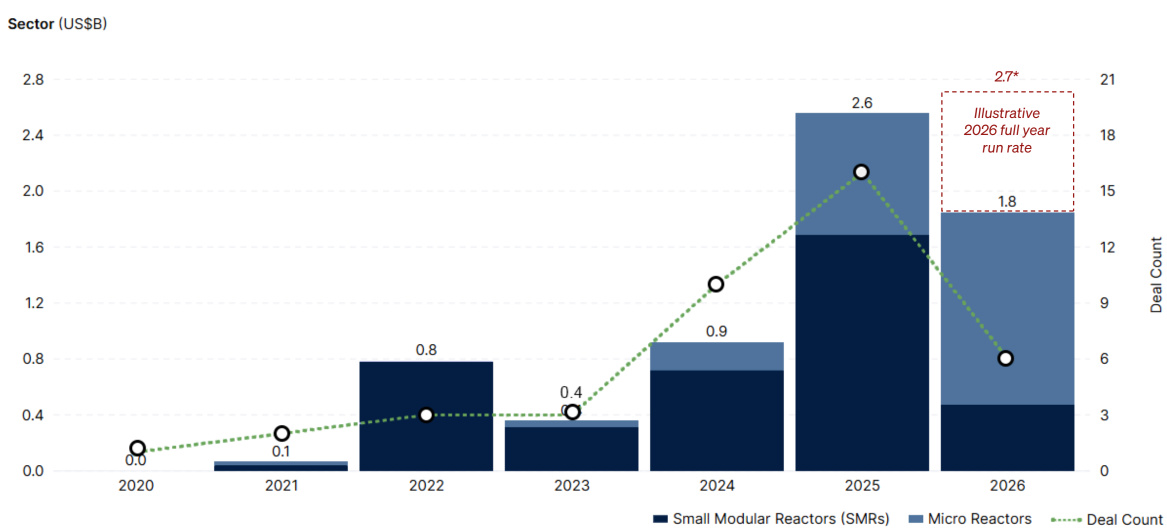
SMR siting activities, by country and site-owner type



Source: OECD, NEA Small Modular Reactors Dashboard: The Third Edition (link). Data as of May 2026

The U.S. and European venture capital markets are active in the SMR space. The EU has recently published its *"Strategy for Small Modular Reactors"* which includes a commitment to develop de-risking schemes for the scaling up of innovative nuclear technologies.[36]

Figure 36: Modular money – VC/PE investments in SMRs across North America and Europe



Source: Currence, 2026 YTD as of 9/2/26. * Run rate annualized based on YTD data

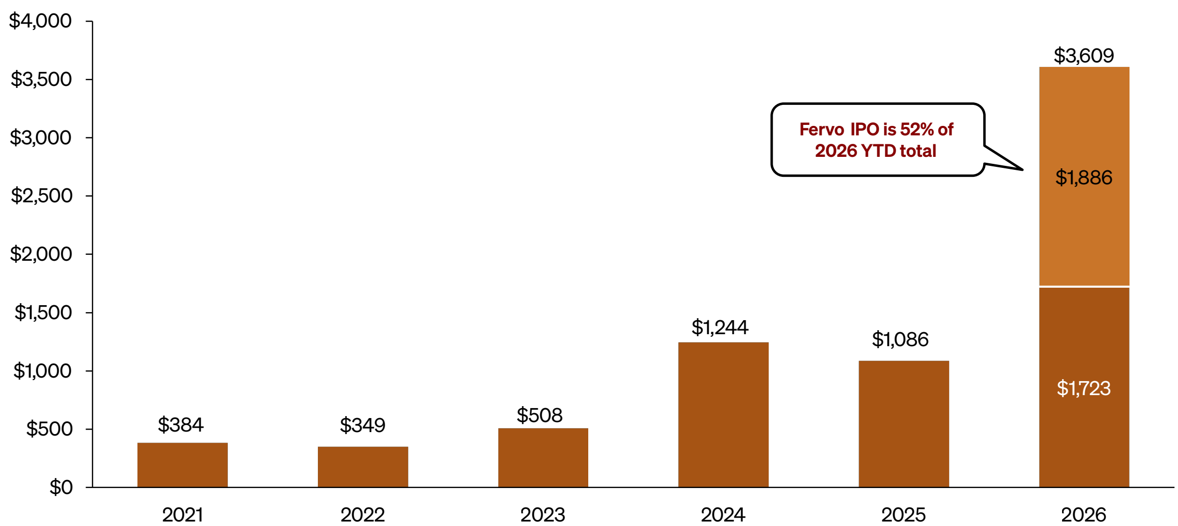
Lessons learned

- While expensive and slow to build, once in operation, nuclear power can be an important hedge against natural gas disruptions as fuel costs are a negligible fraction of operating expenses compared to natural gas.
- Nuclear fuel supply chains are also less reliant on China than those for renewable energy.
- **This dynamic explains why there is renewed focus on nuclear around the globe, specifically SMRs: Building modular baseload power systems can reduce exposure to disruptions in commodity-linked energy markets and reliance on potential adversaries for fuel supplies.**

3. Geothermal

In our 2025 report, we highlighted milestones in geothermal drilling technology to improve well efficiency and expand geothermal access globally. Interest in geothermal has not waned.

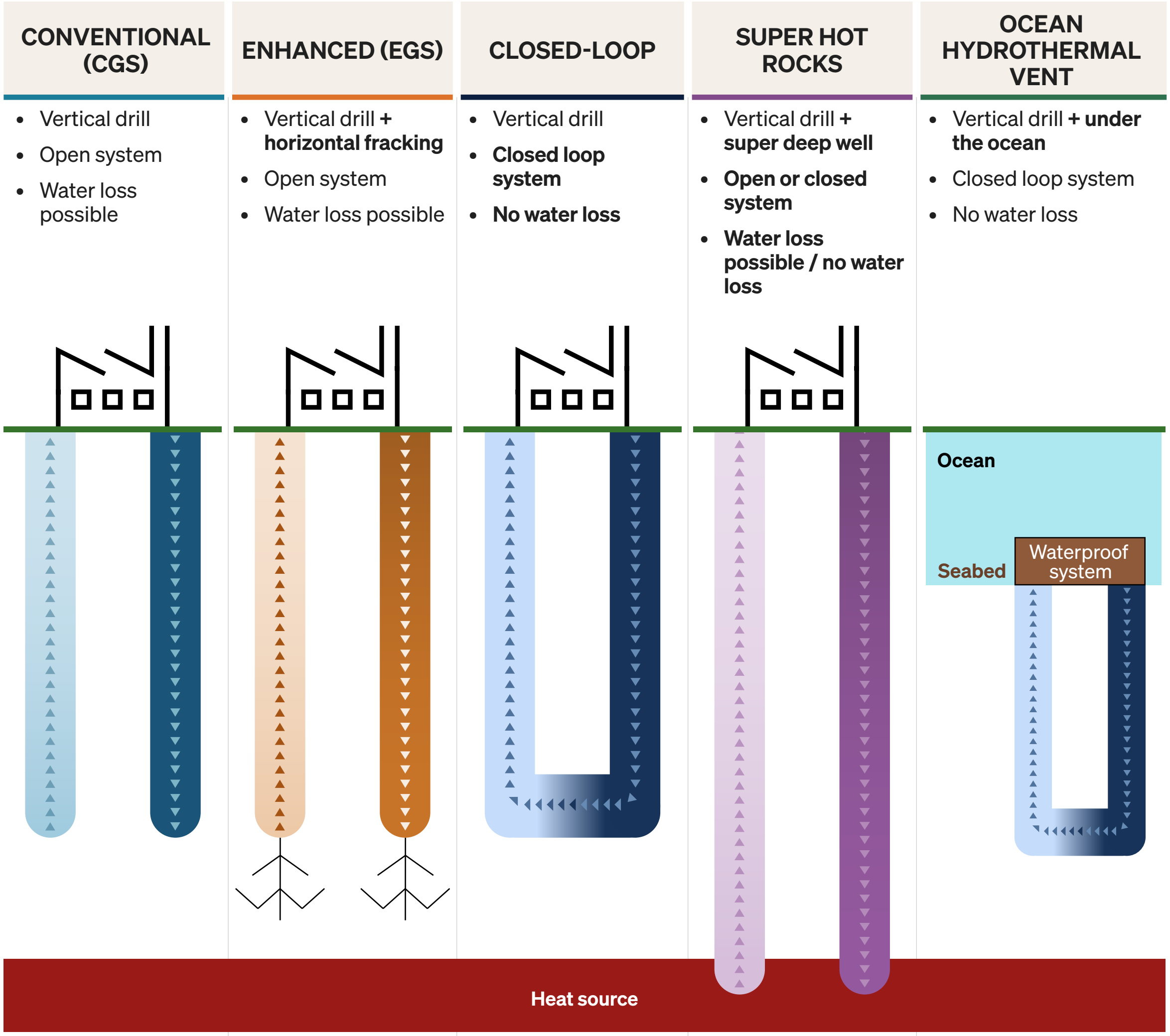
Figure 37: Deep pockets – Global geothermal funding has increased as technology has scaled and commercial proof points have been established ($mm)



Source: Currence, 2026 YTD as of 9/2/26

Private capital is now funding different geothermal technologies that can be applied based on geologic conditions, drilling technology, and water availability.

Figure 38: Tailored to the terrain – Various geothermal technologies are applicable to specific geologies



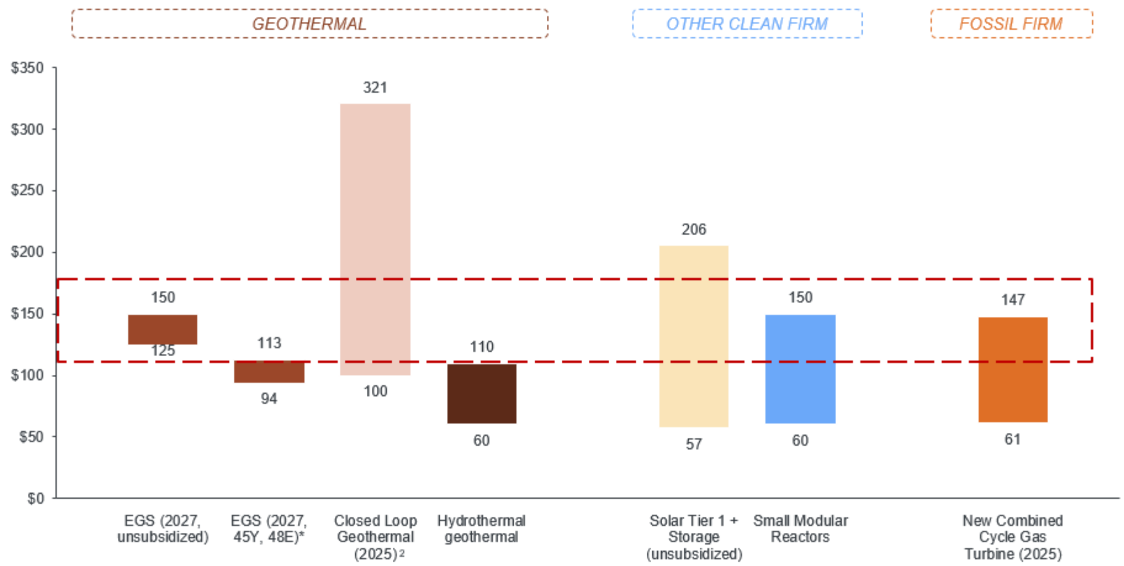
Source: JPMorganChase, adapted from U.S. Department of Energy (link)

Geothermal is increasingly being viewed as an energy resilience tool because it can provide reliable, around-the-clock electricity from a domestic resource.[37] Unlike solar and wind, which depend on weather conditions, geothermal taps into the Earth's constant heat, offering a source of power that is available 24/7 and largely insulated from fuel supply disruptions, import dependencies, and geopolitical shocks.

Geothermal also has a largely domestic supply chain in the U.S. There is a ready-made workforce with relevant, transferable skills from the oil and gas sector. Drilling machinery is produced domestically as is fracking fluid. Geological mapping and subsurface field development expertise are also robust domestic capabilities.[38]

Finally, geothermal costs are beginning to approach those of other technologies, aligning national security and financial considerations for deployment. If technological advancements continue to commercialize, they could transform geothermal from a niche resource dependent on a handful of geological "lucky sites" into a geographically widespread source of reliable, around-the-clock domestic power that supports grid resilience.

Figure 39: Grounds for optimism – Geothermal is becoming more cost competitive with other sources (levelized cost - USD/MWh)



Source: [1] Rystad, unless otherwise noted. Calculation used 8% cost of capital. Based on latest available estimates from NLR on learning curves; [2] BloombergNEF (link); [3] Carnegie Endowment (link)

Lessons learned

- By providing reliable 24/7 electricity from a resource beneath a nation's own soil, geothermal can reduce exposure to geopolitical shocks, strengthen grid resilience, and help power the AI, industrial, and defense infrastructure that increasingly underpin national competitiveness.
- **As energy becomes a strategic asset, geothermal offers a combination of traits few technologies can match: secure, domestic, baseload, low-carbon power at scale with no weapons proliferation risk.**

4. Strategic stockpiles

As discussed previously, a critical factor in our "Supply Your Own" framework lies in easy-to-access supplies when a global crisis hits. This has been a surprise element in the global response to the Iran conflict, most notably exemplified by China and America's deployment of crude stockpiles as discussed in Part I.

Strategic stockpiles

Since the oil shocks of the 1970s, strategic petroleum reserves have served as a form of national energy insurance, allowing governments to cushion markets during major supply disruptions. 2026 saw the largest emergency stockpile releases in modern history.[39]

In replacing disrupted Gulf supplies rapidly, these releases bought time for alternative trade routes and production increases to come online.

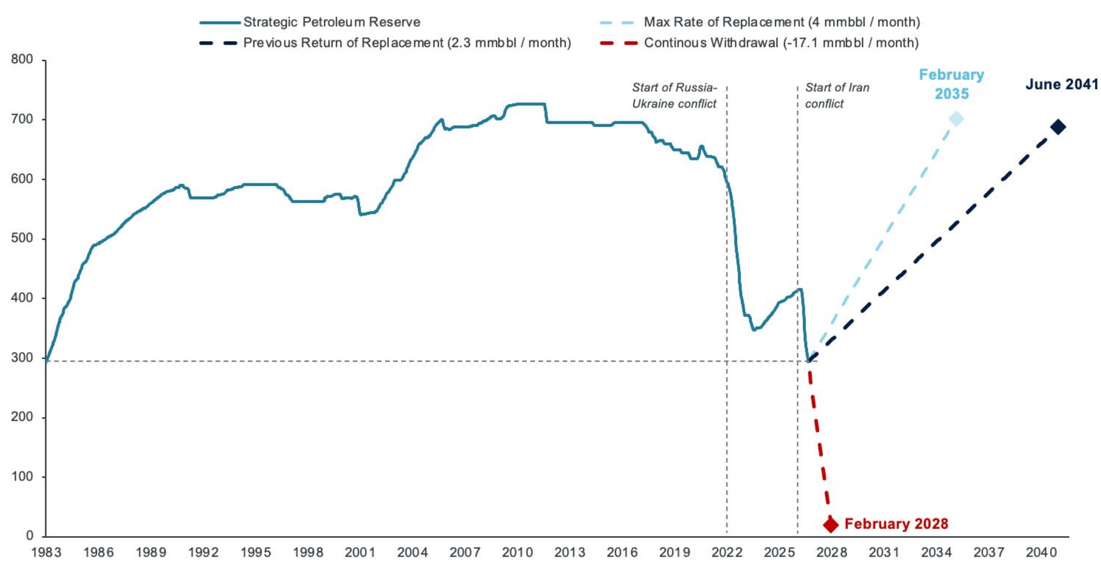
But the crisis also exposed the physical limits of this tool. By June 2026, the U.S. Strategic Petroleum Reserve had already been significantly depleted by earlier releases, leaving less room for another major intervention.

Some analysts also warned that continued drawdowns could complicate the management of the salt caverns used to store reserve oil, as removing mass further may cause them to collapse without the weight of oil to maintain their structural integrity.

Strategic stockpiles proved valuable in buying time during the crisis, but the war underscored a broader reality: **reserves are a finite buffer against short-term disruption, not a permanent substitute for secure supplies, diversified energy systems, or resilient infrastructure.**

Refilling strategic crude oil reserves will also come at a significant cost—and takes time. In the years ahead, expect governments dependent on petroleum[40] to re-enter crude oil markets as buyers, replenishing strategic stockpiles when crude prices fall to attractive levels. At a spot price of $80 a barrel, and a maximum potential refill rate of 4 mmbbl/month according to S&P Global, it will take the U.S. 8 years and $32 billion to reach previous multi-decade values of 700 million barrels.

Figure 40: Déjà crude – U.S. SPR is at a level not seen since the 1980s
US SPR total inventory over time and pathways back to prior levels (million bbl)



Sources: EIA U.S. Energy Information Administration (link) as of 8/14; S&P Global Energy, ©2026 by S&P Global Inc (link). Notes: Rate of replacement rates are based on the maximum estimate from S&P Global and previous return of replacement from 2023 to 2025

→ Those purchases could become an important source of demand during future periods of market weakness, creating a feedback loop in which governments not only respond to energy crises but also shape oil markets through their efforts to rebuild emergency reserves.

→ This also raises long-term investment questions. Significant usage of oil is needed for the transportation sector. The speed of EV adoption for scooters, automobiles, and long-range trucks will affect demand for strategic reserves in the coming decades in certain regions. If it takes decades to recover reserves, will they be as important in 2050? Or, do they become more important as oil usage concentrates further in difficult-to-substitute fuel sources?

Lessons learned

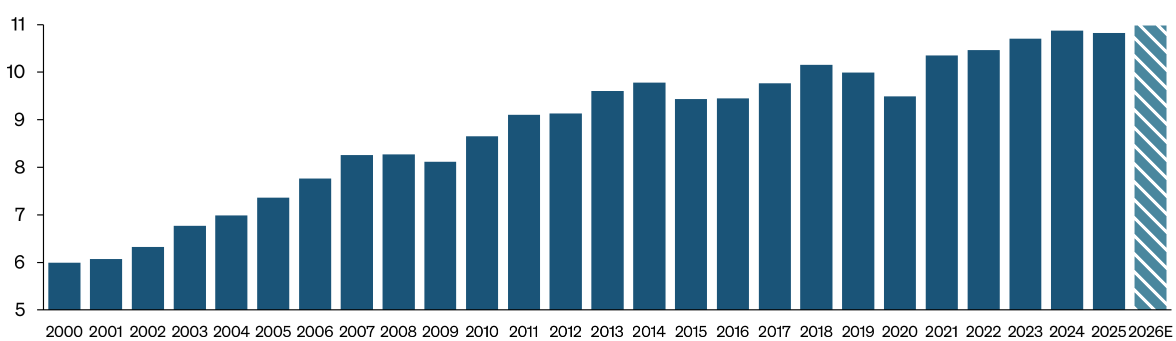
- Building the infrastructure for strategic stocks can be expensive and takes time.
- The value of a strategic reserve is correlated to how quickly it can be replenished.
- **Nations need to analyze which commodities will require strategic reserves in the future based on their specific energy system's trajectory and then develop policy and allocate funding accordingly.**

5. A return to local hydrocarbons – including coal

A wildcard of the Iran war was coal's strategic return—not as a long-term growth story, but as a short-term resilience tool when LNG became scarce and expensive. Faced with fuel shortages and surging gas prices, governments responded.

- **Domestically available hydrocarbons retain a strategic value during a crisis.** In moments of disruption, governments frequently prioritize reliability and affordability over longer-term energy system modernization goals. For a number of countries, that meant turning back to coal, or at least delaying closure of depreciated assets.
- **As a result, 2026 is expected to have record values of coal utilization for electricity.**

Figure 41: Coal's second wind – Global electricity generation from coal has increased, a trend expected to continue in 2026 (000's TWh)



Source: IEA Electricity Mid-Year Update 2026 (link). Note: 2026 is a forecast

Drilling down into individual countries, the largest coal energy producers reversed plans for retirement or increased utilization for below capacity plants.

Figure 42: Coal consumption is diverging across top global consumers

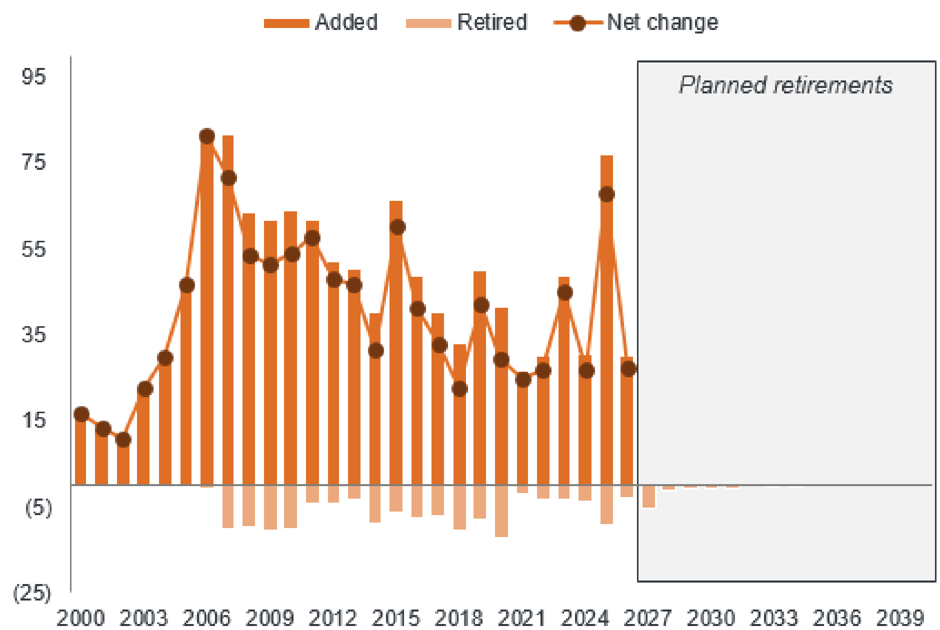
Coal Rank	Country	% of global consumption in 2025	% Change Jan-June 2025-2026 Coal Generation	Relevant coal-related policy changes post Iran conflict
1	China	56%	3%	Shift of coal from a primary baseload fuel to a flexible backup
2	India	14%	2% (Jan to May)	Instructed coal-fired plants to maximize output
3	U.S.	5%	-11%	Efforts to delay coal-fired retirements due to grid resilience concerns
4	Indonesia	3%	N/A, Not covered	Increased use of older, less-efficient coal units
5	Japan	3%	-1%	Relaxed rules temporarily to increase coal-fired generation
6	South Africa	2%	-9%	Coal plants granted five-year emissions standard exemptions
7	South Korea	2%	22%	Delayed coal-plant retirements and eased coal-generation limits
8	Vietnam	2%	2026 N/A	Increased reliance on coal-fired generation; operating existing plants at maximum capacity
9	Turkey	1%	-18%	Weighed reactivating mothballed coal units, and several governments revisited planned phaseout plans
10	Kazakhstan	1%	0% (Jan to March)	Announced target to increase coal production to 129 million tons for 2026 (11%)

Source: Energy Institute, Ember as of 8/14, news reports, JPMorganChase

In Asia, coal's resilience stems largely from geography and geology—and extends to both the power sector and industrial heat. Countries such as China, India, and Indonesia sit atop vast coal reserves, while recent years of investment have produced extensive mining, rail, port, and power-generation infrastructure. When imported Gulf fuels became scarce, they shifted to what was readily available.

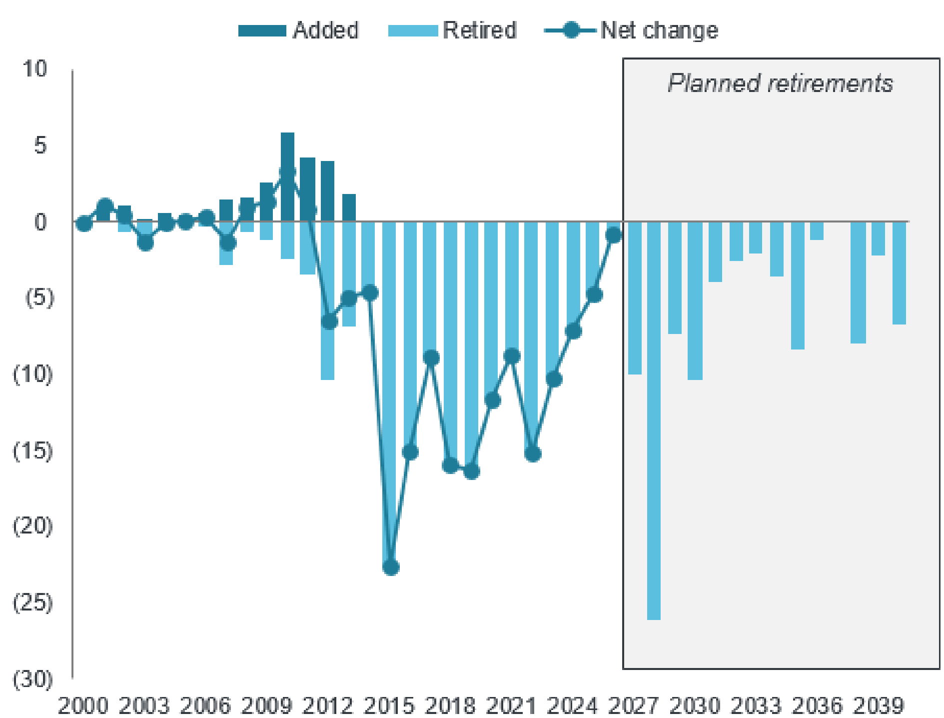
In the U.S., on the other hand, the structural decline of coal has been impacted by a combination of economic and policy forces: plummeting costs of natural gas and renewables and limited remaining useful life of assets built 40+ years ago. Despite the structural pressures, 2025 saw the lowest level of U.S. coal retirements in 15 years. Only 2.6 GW of capacity was retired out of an initially planned 8.5 GW as some retirements were delayed due to a focus on grid reliability and resource adequacy.[41]

Figure 43: Burning on – China is not expected to retire coal-fired generation in the future, in part due to significant remaining useful life of recently-built assets (GW)



Source: Global energy monitor (link) as of 8/14/2026

Figure 44: Aging Burn – Given the age of coal-fired generation units in the U.S. and low natural gas prices, coal plant retirements are expected in the coming years

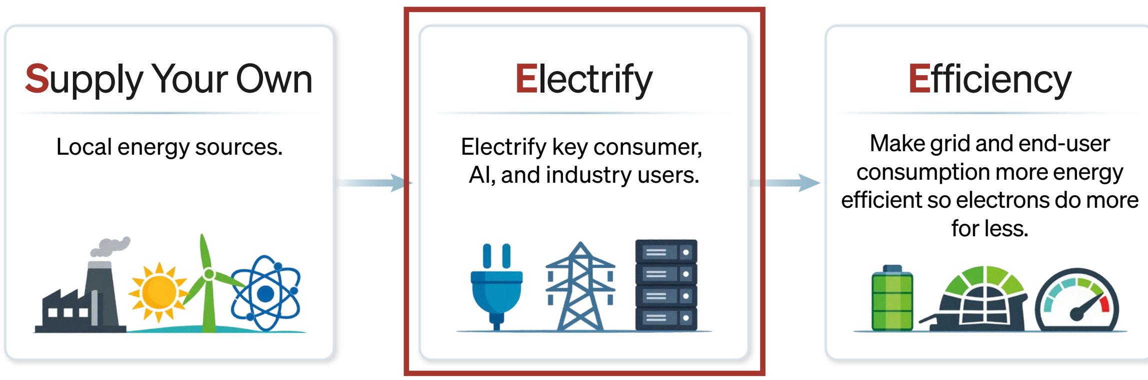


Source: Global energy monitor (link) as of 8/14/2026

Lessons learned

- The ability to ramp up idle coal-fired generation capacity can be a useful short-term backstop to supply disruptions of natural gas, but maintaining that infrastructure can be expensive.
- Building new coal-fired generation capacity in developed economies is likely challenging given the combination of economic competition with natural gas and renewables and policy competition, driven by a national security lens, with nuclear and geothermal.
- Given its emissions profile, new coal is also unlikely in the context of many countries Net Zero goals.
- Infrastructure that would otherwise be retired when approaching the end of its useful life may have added energy security value if it can be kept operational for "use in case of emergency" situations.

The First (E) in SEE – Electrify

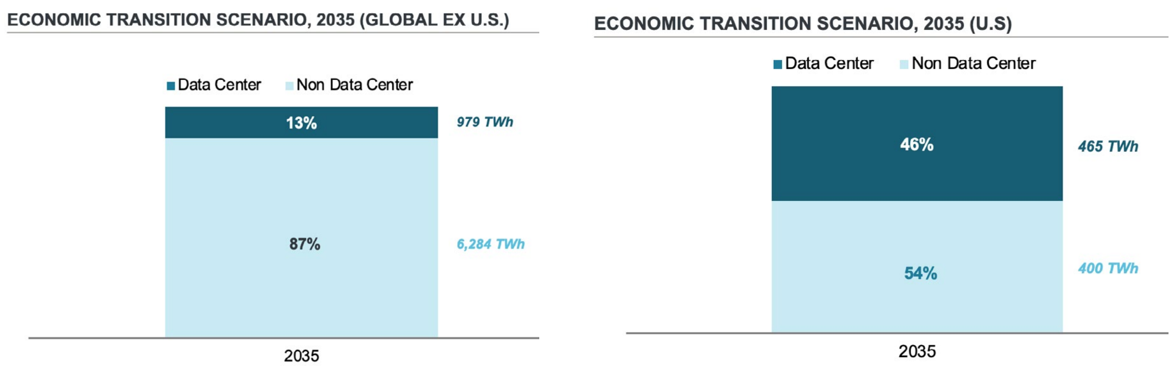


Source: JPMorganChase

The second part of the SEE framework is electrification. Electrification is more specific than simply adding renewables or selling more EVs. It is about rewiring the physical economy: expanding grids, connecting power markets, electrifying heat, and replacing historic fossil-fuel-fired industrial processes with modern electric alternatives. The more an economy runs on domestic electrons, the less exposed it is to the volatility of global molecules.

And more electrons are expected to be needed in every part of the world. But the drivers of growth are not the same across geographies. Globally, broad-based electrification dominates growth relative to data centers over the next decade (87% to 13%). In the U.S., data centers are expected to drive 46% of incremental power demand.

Figure 45: Different Drivers, Different Grids: While data centers are the core driver of power demand in the U.S., other sources are far greater globally
Drivers of electricity demand growth, 2025-2035

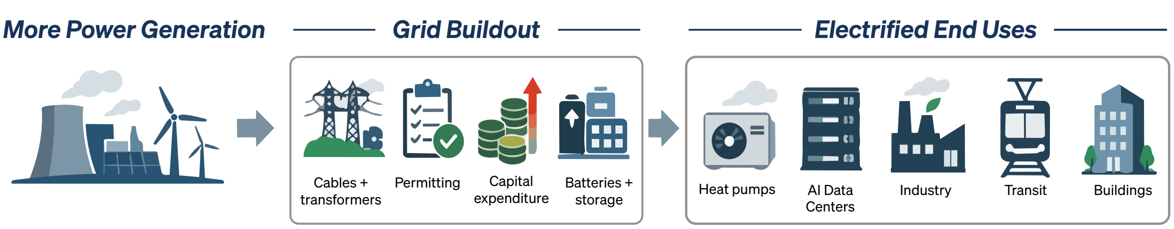


Sources: BloombergNEF, New Energy Outlook, ETS

The preeminent infrastructure requirement for electrification is the grid. As we highlighted in our definitions of energy security (see pages 7-10), **a resilient grid is crucial to meeting the needs of electrification and may become the constraint to growth given demand projections without proper policy design and investment levels.**

Generation without delivery does not solve energy security. A solar farm, offshore wind project, nuclear reactor, or gas plant only matters if the electricity it produces can reach the factory, data center, train line, heat pump, or household that needs it.

What electrification requires



Source: JPMorganChase

Grid buildout

Grid expansion is a necessity for any energy resilience pathway. This expansion is comprised of both a physical infrastructure endeavor and a modernization and optimization effort (the latter of which is discussed in the next section on Efficiency).

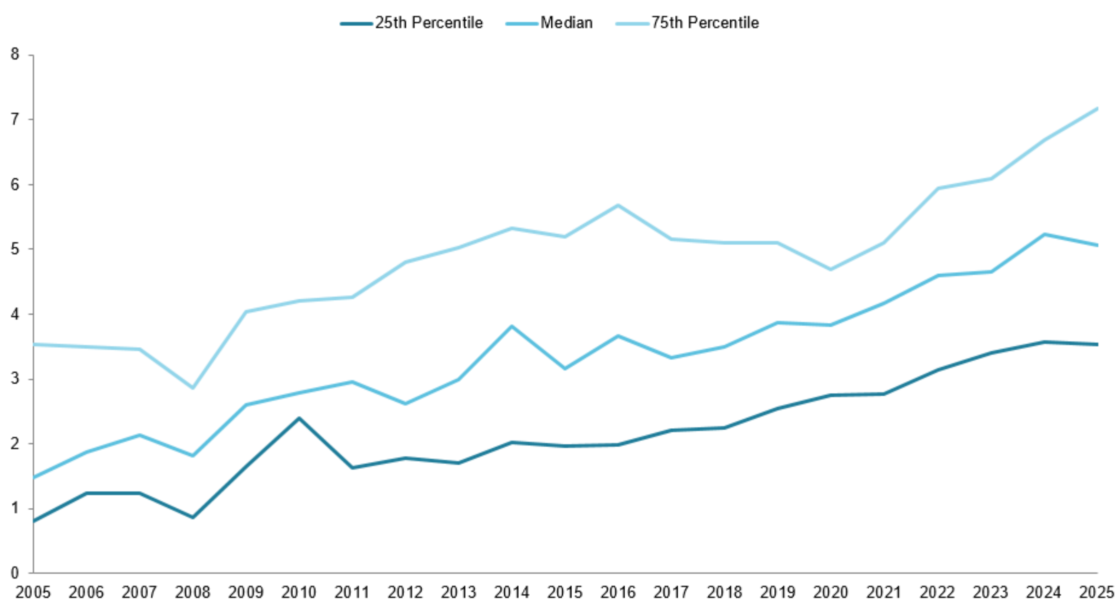
The physical dimension

The IEA estimates that **the world must add or replace more than 80 million kilometers of power lines by 2040—roughly equal to the entire existing global grid**—to keep up with national energy and climate goals.[42] Meeting global electricity demand will require annual grid investment to rise roughly 50%.[43]

But money alone is not enough. Permitting, grid congestion, and grid hardware are becoming major bottlenecks. In many developed countries, including the U.S., it is getting harder to build at speed and scale—slowing deployment relative to parts of the developing world.

Permitting velocity is ultimately a political choice, and one that is increasingly seen as a national security issue given its impact on economic security, energy security, innovation, and defense capabilities. Even if permitting is accelerated, physical construction still takes time, and the lead time for critical supplies and inputs may not keep pace. As has been well documented, the lead time for natural gas turbines has increased from ~1.5-2 years pre-2022 to up to 5-7 years today.[44] Similarly, lead times for geothermal ORC turbines are 12-18 months and companies like Ormat have reported product backlogs reaching their highest levels since 2015.[45]

Figure 46: Slower to switch on – America's slowing ability to build out new power generation
Time elapsed from interconnection request to commercial operation date (years)



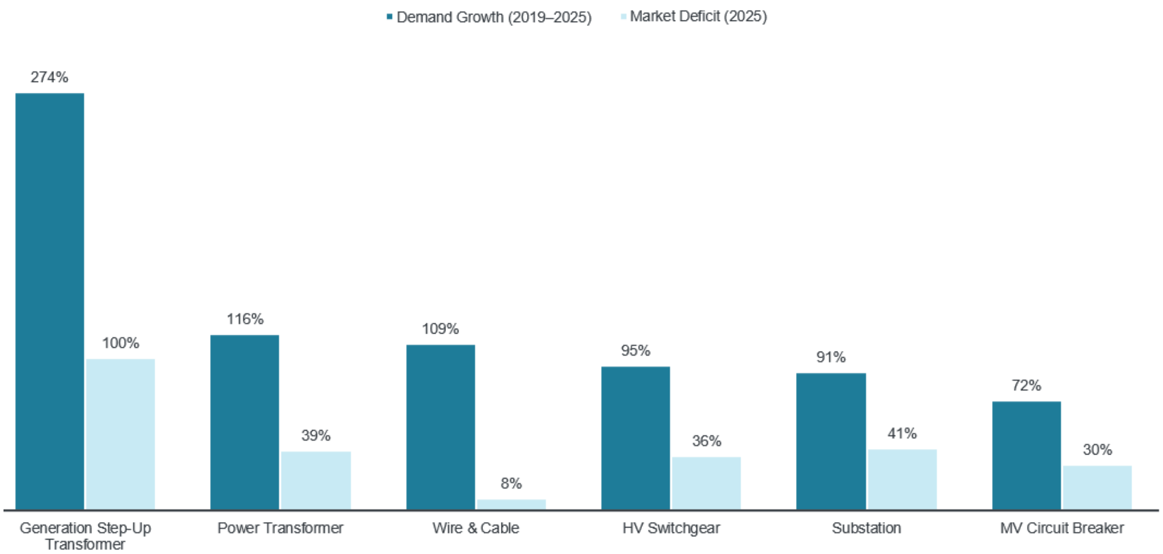
Source: Lawrence Berkeley National Laboratory, Queued Up, 2026 Edition (link); Note: Sample includes 3,310 projects from 6 ISOs and 19 non-ISO BAs that came online since 2005. Duration is calculated as the number of months from the queue entry date to the commercial operations date

Importantly, generation is not the only issue to be addressed. The physical components needed to expand electric grids—from transformers and substations to transmission equipment and high-voltage cables—are not being manufactured quickly enough.

→ Demand for transformers, substations, switchgear, and high-voltage cables is outpacing manufacturing capacity across advanced economies. **In the U.S., demand for power transformers has risen by more than 100% since 2019, while roughly 80% of large transformers are now imported to fill supply gaps**.[46] Europe faces similar pressures, with utilities reporting multi-year waiting periods for critical grid equipment even as the continent pursues hundreds of billions of euros in grid expansion.

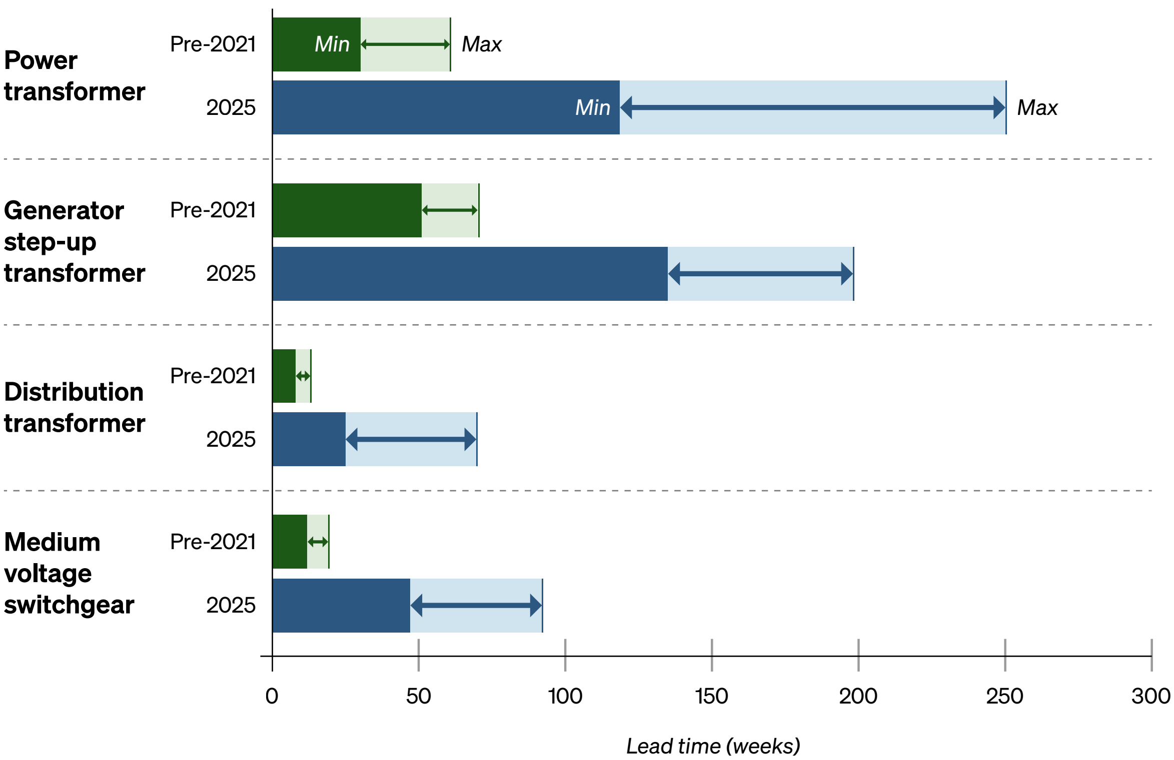
→ **These supply chain bottlenecks are slowing grid construction, delaying electrification projects, and creating new dependencies on foreign suppliers for critical infrastructure.**[47]

Figure 47: Gridlock at the grid factory – U.S. grid equipment demand has surged since 2019, contributing to market deficits



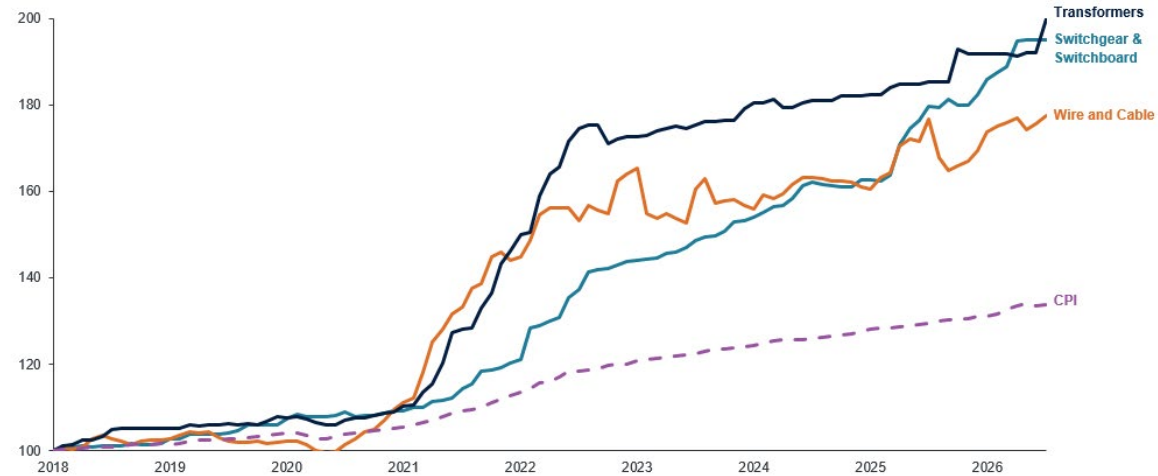
Source: Wood Mackenzie; Note: Market deficit indicates how much higher annual demand is than available supply

Figure 48: The hardware crunch – Electrical grid equipment lead times have increased in recent years



Source: Deloitte analysis based on: Sonal Patel, "The transformer crisis: An industry on the brink," *POWER Magazine*, June 26, 2024; US Senate Committee on Energy and Natural Resources, *Distribution Transformer Efficiency and Supply Chain Reliability Act of 2024*, Jan. 19, 2024; Anshuman Prakash, "Why the switchgear market is facing price & supply challenges," *GEP*, Jan. 7, 2025; Shannon Cuthrell, "Transformer supply chain woes persist as energy demand grows," *EE Power*, Aug. 27, 2025; David Reese and Matthew Stapf, "Considerations for selecting a spare GSU transformer," *Power Engineering*, Dec. 10, 2021; Swinerton, "Lead times," May 20, 2025; Sean Wolfe, "Can the US catch up to transformer demand?" *Renewable Energy World*, Aug. 14, 2025 (link)

Figure 49: Gridflation – Grid equipment price increases have outpaced broader inflation
Producer price index for grid equipment (2018 = 100)



Source: U.S. Bureau of Labor Statistics via FRED as of July; Federal Reserve Bank of St. Louis, Producer Price Indexes for Electric Power and Specialty Transformer Manufacturing (PCU335311335311) (link), Switchgear and Switchboard Apparatus Manufacturing (PCU335313335313) (link), and Communication and Energy Wire and Cable Manufacturing (PCU3359233592) (link); and Consumer Price Index for All Urban Consumers (CPIAUCSL) (link). Retrieved August 14, 2026

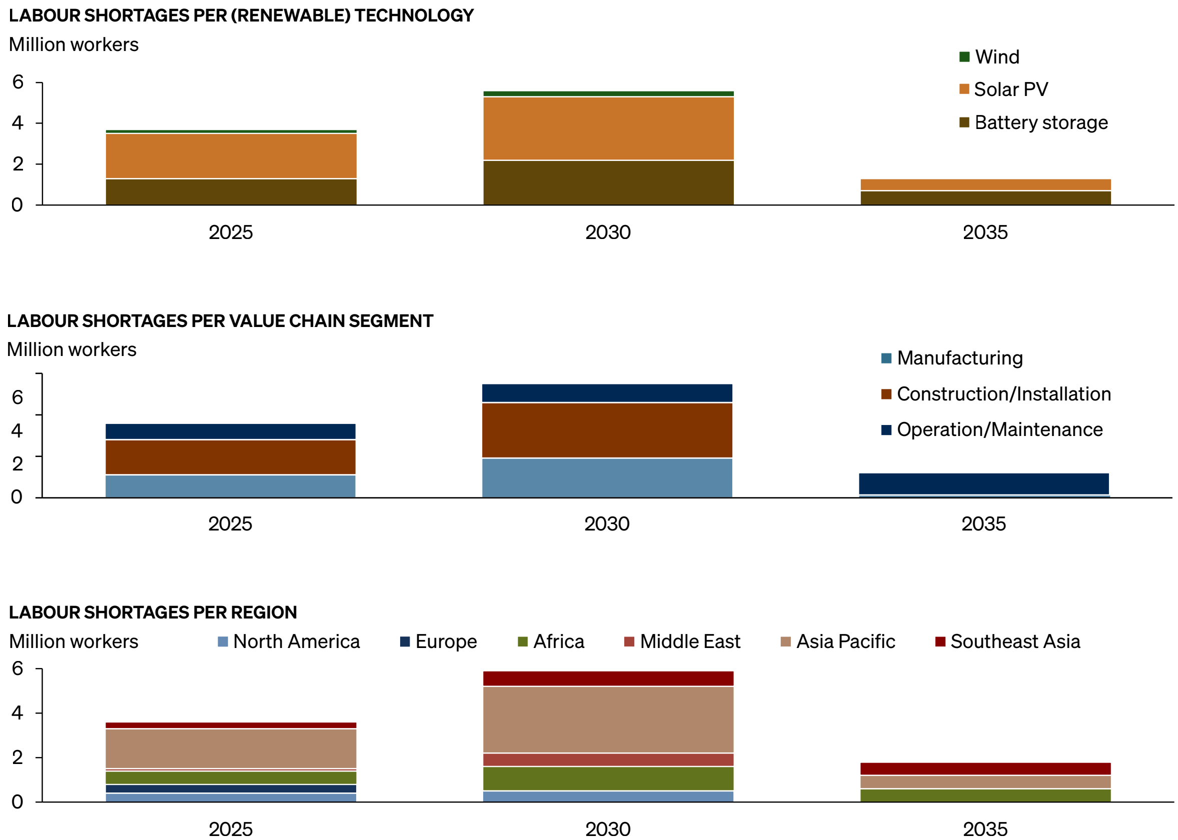
Finally, skilled labor is also a grid expansion constraint. Even if capital and materials are available, utilities will require tens of thousands of electricians, line workers, engineers, and construction workers to build the grid expansion necessary to support surging demand.

The energy sector faces a significant workforce shortage. A U.S. Department of Energy analysis found that 76% of energy sector employers experienced at least some difficulty hiring in 2023 as the workforce continued to grow.[48] Absent significant actions, this workforce shortage is estimated to be a persistent challenge.

→ This demand is exacerbated by retirements in the energy sector. Up to 400,000 U.S. energy sector employees are expected to retire by 2032[49], delaying critical projects and creating gaps in institutional knowledge.

→ Energy workforce retirements are outpacing new hires. In the nuclear sector, that gap is 1.7 retirements to every 1 new staff member. And in the grid sector, it's 1.4 retirements to every 1 new staff member.[50] These shortages can lead to project delays, safety risks, and cost overruns.

Figure 50: Short on hands – Skilled labor is a constraint to grid modernization efforts



Source: GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH), NewClimate Institute (link)

Looking across the key dimensions that impact physical grid expansion, a picture develops of which countries may be best positioned today to enhance the grid as a platform for energy resilience. But unlike domestic natural resource development, which is largely dependent on geology and geography, grid development is more tied to above-ground factors which provides more equal opportunity for leadership around the globe. A combination of policy reform, regulatory clarity, financial incentives, workforce development, and manufacturing capacity growth can help countries ensure the grid serves as a force multiplier for resilience in the future.

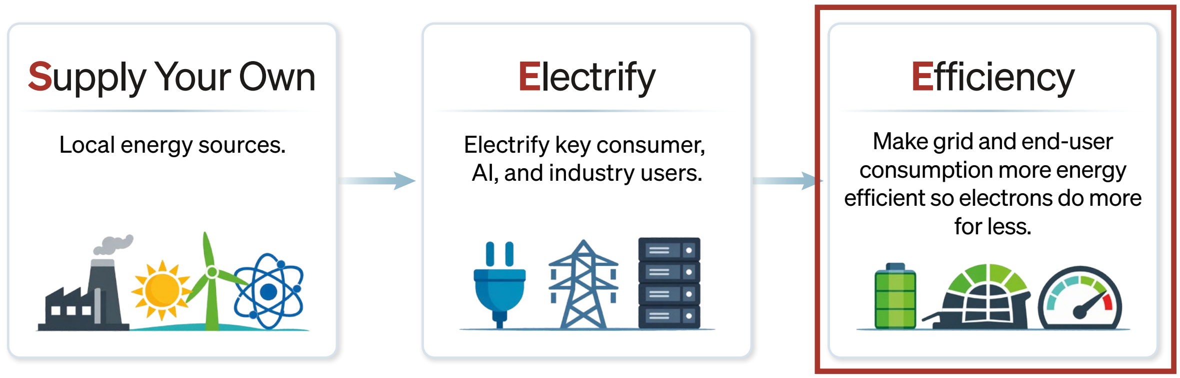
Figure 51: Power rankings – Global grid infrastructure policy RAG scale

Country / Region	Overall	Permitting Velocity	Financial Incentives	Workforce	Manufacturing capacity	Regulatory prioritization
China	**GREEN**	Faster	Moderate	Strong	Strong	Strong
Nordics (SE, DK, FI)	**AMBER**	Faster	Moderate	Moderate	Moderate	Strong
U.S.	**AMBER**	Slower	Strong	Moderate	Strong	Moderate
Germany	**AMBER**	Moderate	Moderate	Strong	Strong	Moderate
India	**AMBER**	Moderate	Strong	Moderate	Moderate	Strong
Australia	**AMBER**	Moderate	Strong	Moderate	Moderate	Moderate
United Kingdom	**RED**	Slower	Moderate	Moderate	Moderate	Moderate

Note: RAG scale is relative across countries shown, not comparable to all countries globally
Source: JPMorganChase

In the face of rising extreme weather-linked disruptions and replacement costs[51], resilience planning is also critical to retrofit existing infrastructure and build today's grid for the future. Planning for extreme weather disruptions is strategic for longer-term grid reliability and maintenance cost reduction over time. Over the long term, there is a return on investment in resilience.[52]

The last (E) in SEE – Efficiency



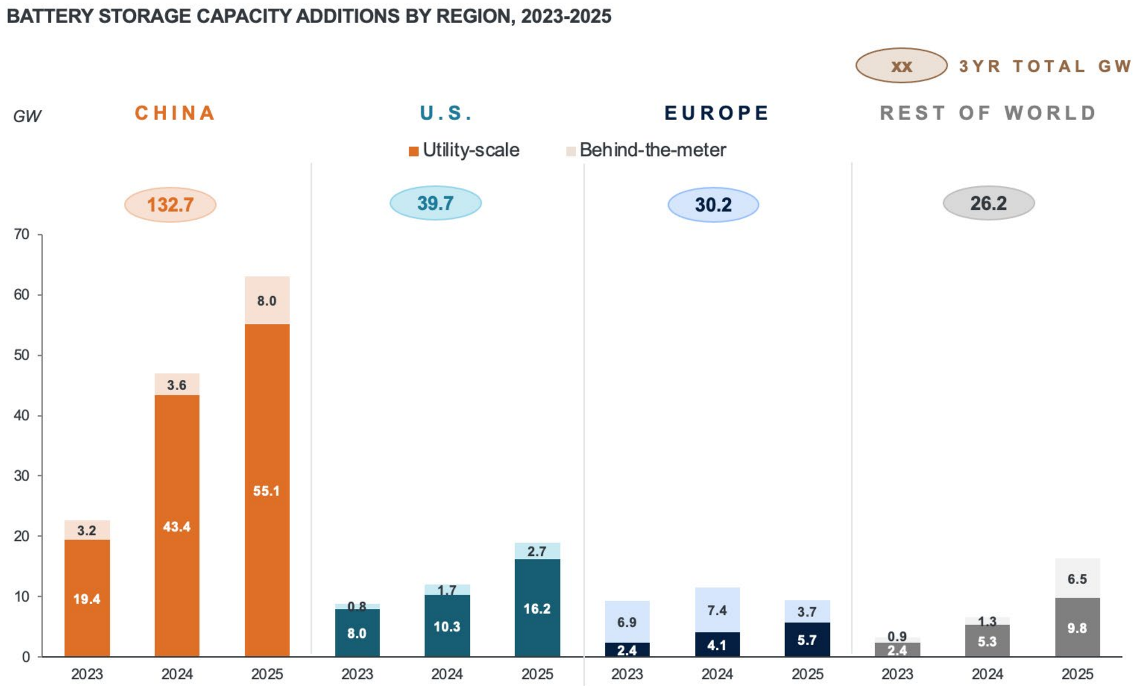
Source: JPMorganChase

Efficiency is often the least visible part of the resilience equation, but it is just as important. Countries can utilize both demand-side and supply-side efficiency measures to support energy resilience efforts.

Supply side

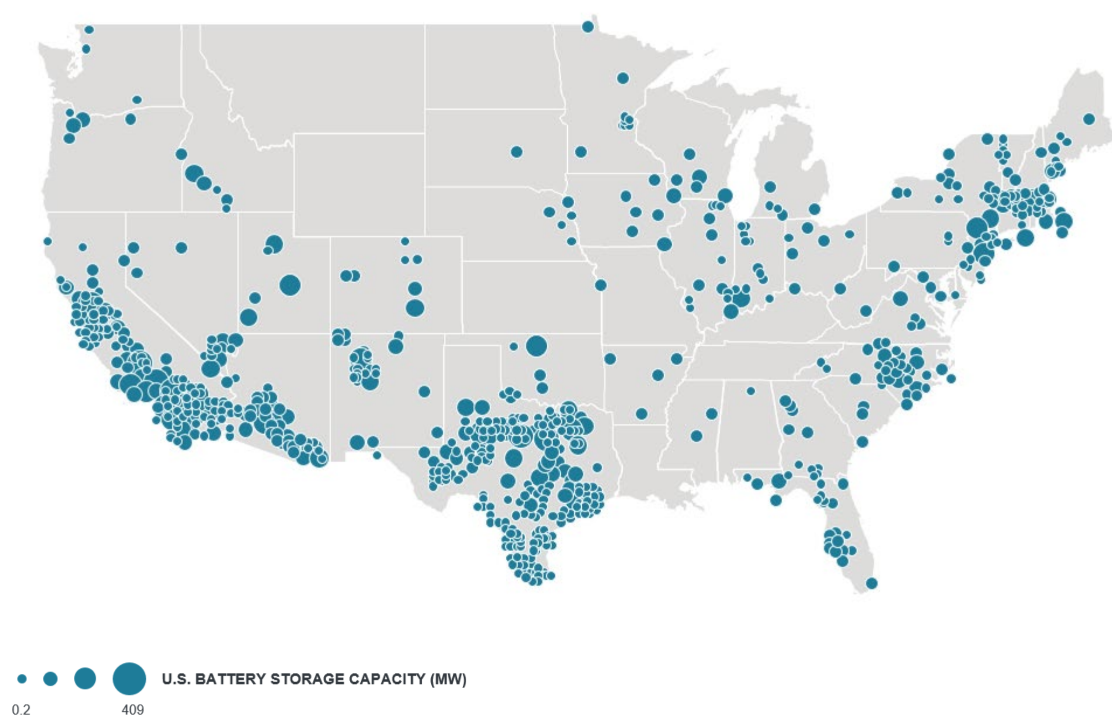
As supply and demand on the grid needs to be in constant balance, grids are built to handle periods of peak demand. This means that large parts of the grid are sitting idle at off-peak times, and then ramp up when needed. It also means that power generation from wind and solar projects can often be curtailed, or essentially wasted, when current demand doesn't meet supply. Batteries can help mitigate both of these issues. **Enhancing the flexibility of the grid to store more electricity at periods of low demand and discharge more power during peak periods can optimize power generation and deployment today while additional generation is built out in the coming decade.** This can help reduce the circumstances where the grid becomes a bottleneck to building a new data center or industrial plant. Globally, China is leading battery deployment at the utility scale. In the U.S., the majority of projects are concentrated in Texas, California, and the broader Sun Belt, although there are also a significant number of projects in the Northeast. The U.S. installed 9.7 GWh of battery energy storage in the first quarter of 2026, up 32% year over year and the largest volume ever.[53]

Figure 52: Charging Up – Where are grid storage batteries being built out? China.



Source: IEA Global Energy Review 2026, Energy Statistics Data Browser (link)

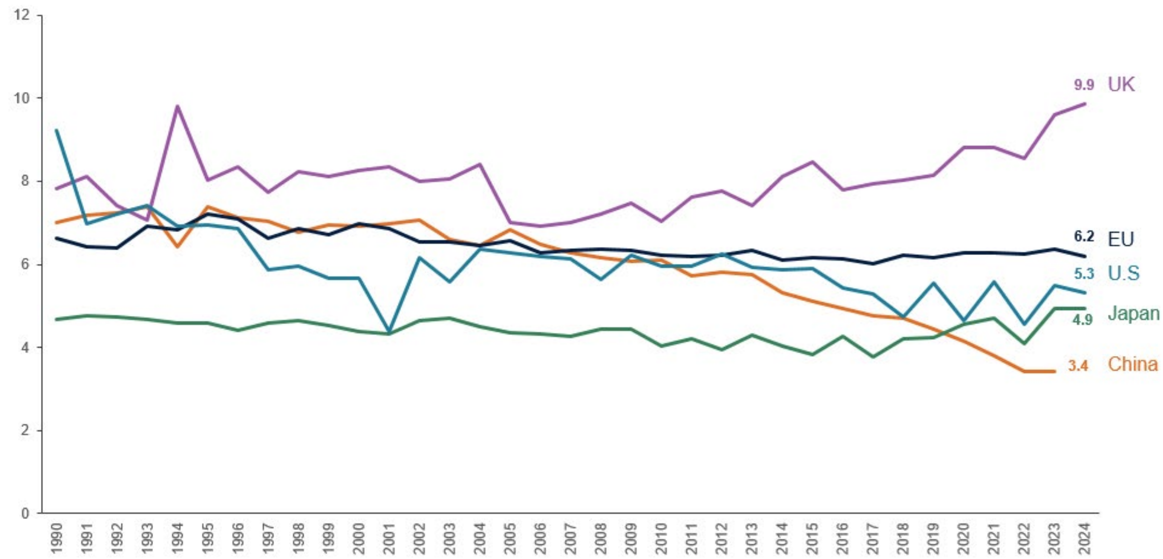
Figure 53: *The Battery Belt* – Map of battery projects in the U.S.



Source: U.S. Battery Storage Map, Cleanview (link). Note: Marker size reflects capacity — only facilities with reported capacity data are shown.

Another way to improve the efficiency of the existing grid is to lose less of its energy potential. The World Bank estimates that annual electricity transmission and distribution (T&D) losses averaged about 5% in the U.S. from 2018-2022, and the level has been relatively flat since 2000. For comparison, China is currently at 3.4% and has seen a steady improvement over the last 20 years.

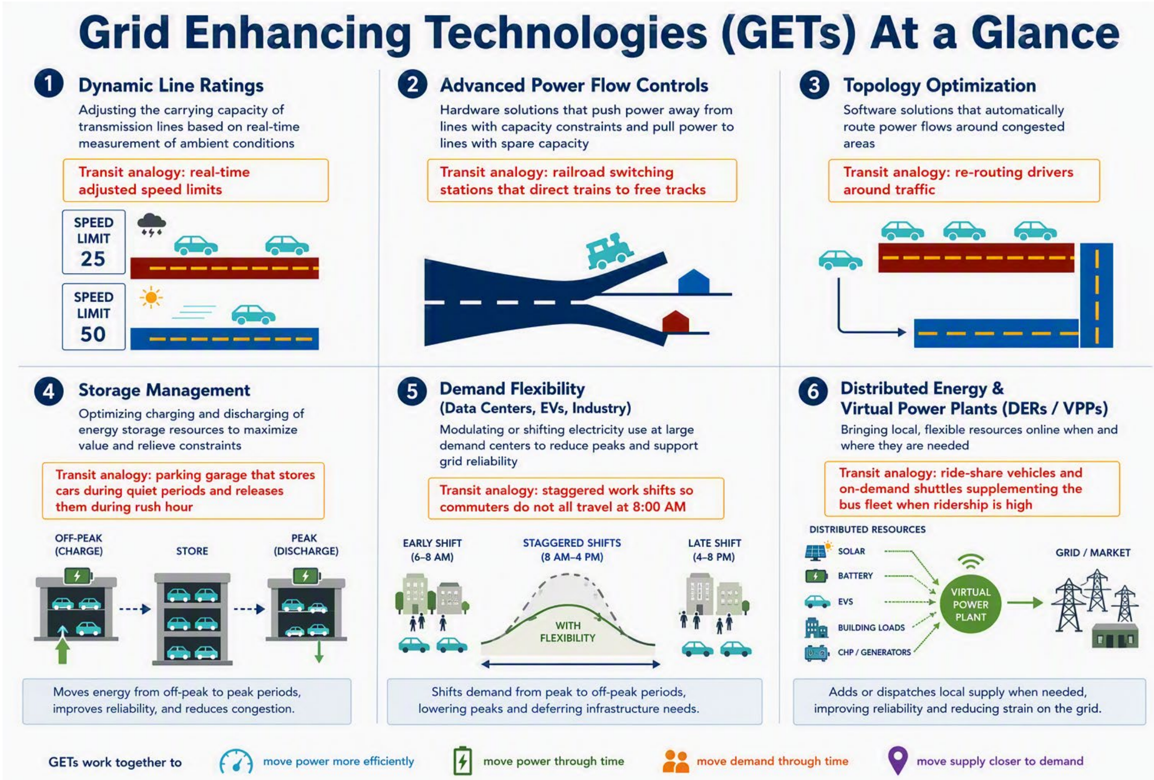
Figure 54: Lost in transmission – % of annual electricity transmission and distribution (T&D) losses across key countries



Source: World Bank (link), Electric power transmission and distribution losses (% of output)

Grid-enhancing technologies are a faster way to get more electricity out of the wires we already have. Investing in new high-voltage transmission lines is a critical part of that effort, but projects take 10 years to complete, on average.[54]

Grid-enhancing tools work by optimizing the grid: they ensure no area of the system becomes congested, rerouting supply to open capacity or reducing demand when flexible. These tools use historical data, real-time sensors, weather forecasts, and various software and AI tools to optimize the traffic of electrons moving on the grid to make full use of all idle or under-utilized assets. Deploying software can take months instead of a decade.[55]



Source: JPMorganChase; adapted from RMI.

This is both a near- and long-term solution for the grid: it boosts capacity today by using software while new infrastructure is still being built, and it also helps optimize the future grid as the network of transmission lines, storage, supply, and demand becomes more complex to meet ever-growing demand.

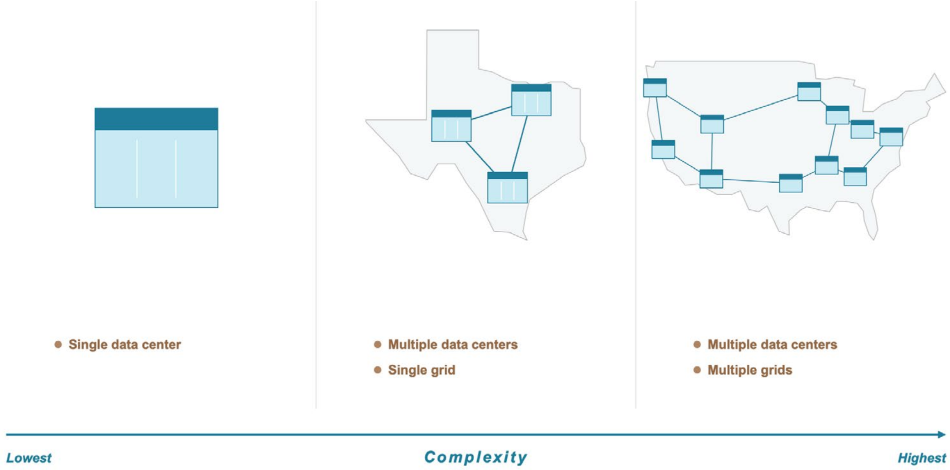
Demand side

Demand response programs (financial incentives offered to consumers for temporarily reducing or shifting their electricity use during periods of high demand or grid stress) are increasingly seen as a critical tool for grid reliability. By curtailing demand during peak periods, demand response programs decrease the frequency and duration of peaker plants, which are typically expensive and carbon-intensive. They can also help avoid costly upgrades to transmission and distribution infrastructure, which are facing permitting and cost constraints as discussed above.

Countries that can both (1) rapidly deploy technologies that can be aggregated into demand response programs and; (2) effectively operationalize the necessary regulatory frameworks, can maximize their grids today and moving forward.

New technological breakthroughs may also combine multiple optimization techniques together. For example, certain computations on data centers are flexible, they can be stopped, delayed, or rerouted to a different part of a grid or another grid within a data center network. This optimizes across space, time, and additional defined impacts (grid capacity, price, emissions, expected outages for maintenance or extreme weather).[56]

Figure 55: Compute Coordination – managing compute and energy resources together



Source: JPMorganChase

Figure 56: Load Flexibility - End uses, technologies, and program types that can support demand response

Category	Technology examples	Program types	Application
HVAC	Smart thermostats, advanced HVAC controls, HVAC/storage combined systems	Smart thermostat rebates, direct load control, time-of-use rates	Residential, commercial
Water heating	Connected/smart water heaters, load-shifting controls	Direct load control, dynamic pricing, bring your own device (BYOD), smart water heater incentives	Residential, commercial
Batteries	Distributed battery storage, commercial-scale storage	Installation incentives, virtual power plant (VPP) and battery aggregation programs	Residential, commercial
Electric vehicles	Grid-interactive charging (smart charging, V2G/V2B, networked charging stations, etc.)	Off-peak charging incentives, managed charging, and smart charging equipment incentives that support grid-responsive EV charging.	Residential, commercial
Large commercial and industrial demand response	Building management systems, automated DR platforms, onsite renewable generation/storage	Pay-for-performance, interruptibility agreements, time-varying rates, technology incentives	Commercial, industrial
Whole-building	Any behind-the-meter load	Voluntary behavioral demand response; customers encouraged to reduce load using whatever method they choose	Residential, commercial, industrial

Source: ACEEE 2026 (link), JPMorganChase

Part III

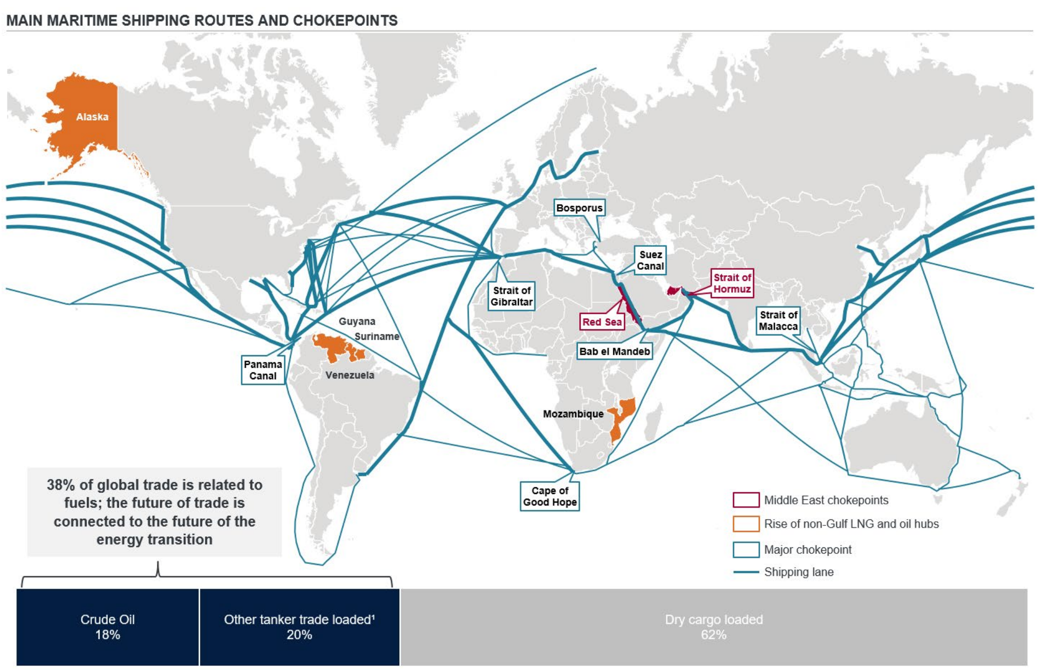
The future of energy — What we're watching

The adaptation spurred by the Iran war energy crisis is still in motion. In this section, we look at what the next phase of energy resilience may look like. While these options come with upfront costs today, they reduce vulnerabilities tomorrow, making them strategic national security plays for long term resilience.

Spotlight #1 The rise of non-Gulf LNG and oil hubs: Mozambique, Alaska, Venezuela

Several areas with LNG and Oil reserves could be developed to avoid Gulf trade routes to the global market.

Figure 57: New nodes – Development of non-Gulf LNG and oil hubs could further reduce exposure to Middle East supply risks



Sources: UNCTAD (link), CIA: "Map of the World Oceans" (link); Note: ¹ Includes refined petroleum products, liquefied natural gas (LNG), liquefied petroleum gas (LPG), and chemicals

Africa

Mozambique could become Africa's most important new LNG diversification story. Mozambique's LNG opportunity centers on the Rovuma Basin off Cabo Delgado, which holds more than 100 trillion cubic feet of proved gas reserves.[57] If developed, these reserves could make Mozambique sub-Saharan Africa's largest gas producer and one of the world's top five LNG suppliers, adding major new African gas volumes to global markets and giving buyers another supply option outside Russia and the Gulf. Sitting on Africa's eastern coast, it also has a direct trade route to Asia that can bypass major straits.

Latin America

- **Guyana and Suriname are emerging as two of the Western Hemisphere's most important non-Gulf oil hubs**. Both sit on the northeastern coast of South America, facing the Atlantic above Brazil, and their offshore waters form part of the same Guyana-Suriname Basin. Exports would readily serve European markets crossing the Atlantic or Asia by rounding Cape Horn. Guyana's rise has been extraordinary: before ExxonMobil's first major discovery in 2015, the country had no commercial oil production. **Production began only in 2019, but repeated discoveries in the Stabroek Block have since turned Guyana into one of the world's fastest-growing oil producers**. Eight planned developments could raise the country's total production capacity to around 1.7 million barrels per day by 2030.[58]
- Guyana's neighbor, Suriname, is now trying to follow the same geological path. Its offshore fields lie in the same basin and contain deepwater rock formations similar to those that produced Guyana's discoveries, raising expectations that the oil-bearing geology extends across the maritime border.[59]

Venezuela could return as a meaningful source of heavy crude, but speed matters. If sanctions policy shifts and U.S. refiners regain access, Venezuelan barrels could add another supply source to global markets.

- The constraint is execution: production recovery will depend on whether Venezuela can restore damaged infrastructure, attract outside capital, and stabilize control over production and export revenues. Its crude is also heavy and sour, which means it will require close coordination with U.S. Gulf Coast refiners who specialize in its oil type to ensure price competitiveness on the global market.

North America

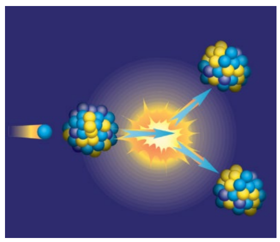
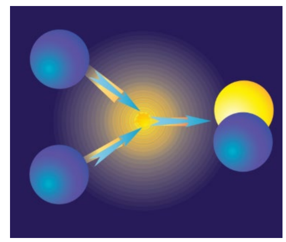
Alaska is becoming a U.S. test case for supply dominance through geography and permitting. The Trump administration is prioritizing Arctic and Alaskan energy development, including leasing and permitting in the National Petroleum Reserve–Alaska and offshore Alaska.

- The constraint carries political risk: it remains to be seen if investments will be made in a region that historically has political risk of reversal by the next administration, let alone challenges of building in this remote Arctic region.

Spotlight #2 Is this the decade fusion energy commercializes?

Unlike today's nuclear fission reactors, which generate electricity by splitting atoms, **fusion seeks to generate power by joining atoms together, replicating the process that powers the sun.**

Figure 58: Split or stick – Nuclear fission vs. fusion

Nuclear Fission	Process	Fusion
Splits atom into 2 or more smaller ones 	Definition	**Joins** 2 or more light atoms into a larger one 
Uranium, Plutonium, Thorium	Fuel Source	Hydrogen
Used nuclear fuel	Byproducts	Helium

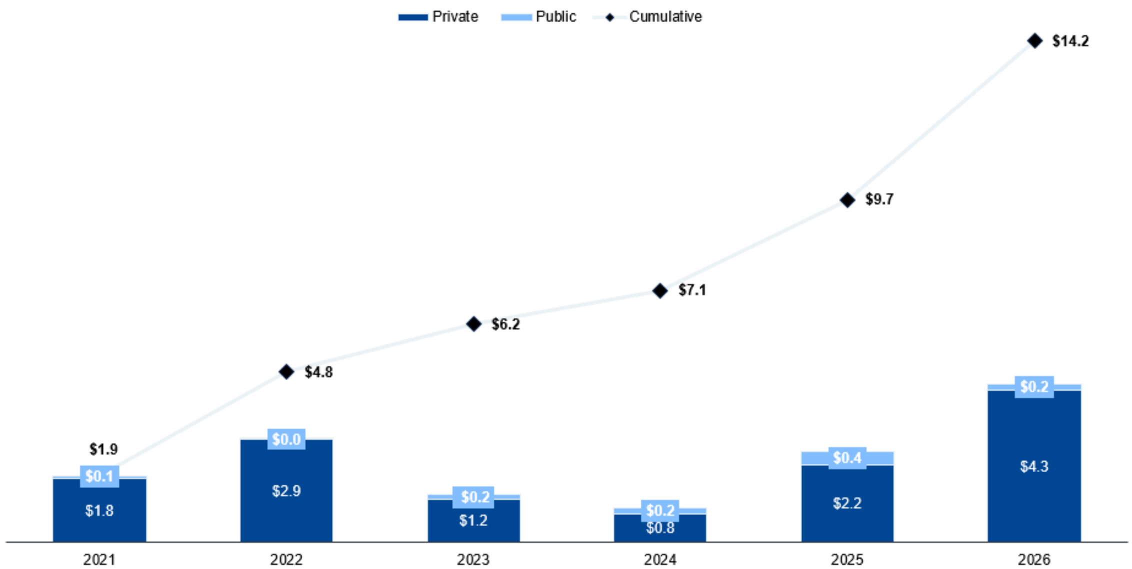
Source: U.S. Department of Energy, Office of Nuclear Energy, JPMorganChase

Fusion reactors do not require large volumes of mined uranium, do not produce long-lived radioactive waste[60], and cannot experience the same type of runaway reaction associated with conventional nuclear fission reactors. Break the conditions for fusion to occur, and the reaction turns off like a light switch. This assuages environmental concerns found in the previous generation of designs in the nuclear fission sector.

For decades, fusion remained primarily a scientific challenge. Today, advances in superconducting magnets, materials science, and computing power are increasingly turning it into an engineering and manufacturing challenge.

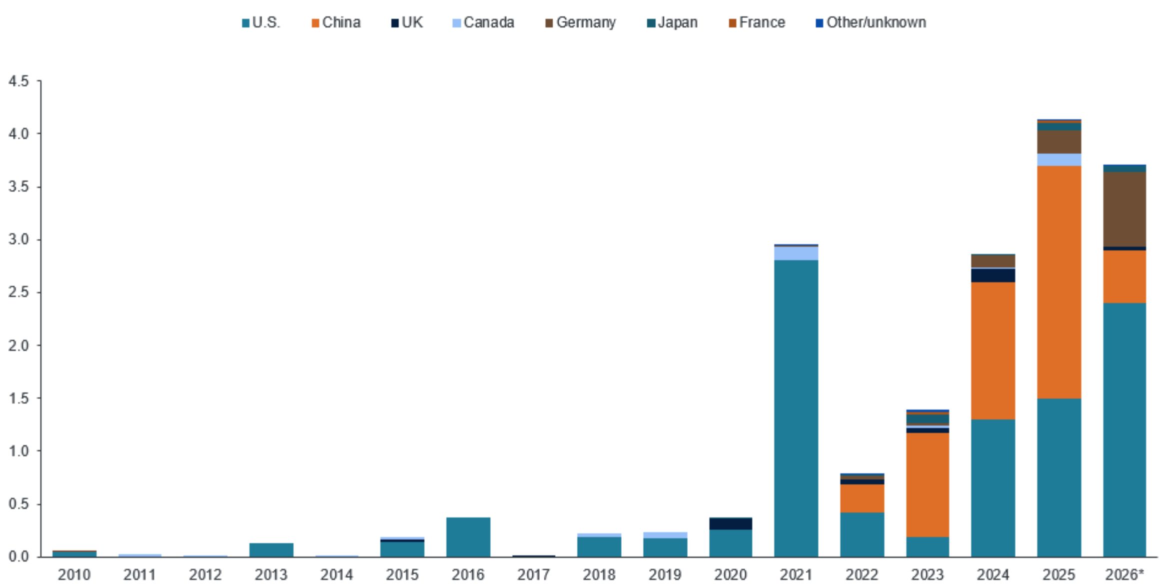
As a result, fusion is now transitioning from a decades-long physics experiment into a high-stakes engineering race with commercial deployment targets increasingly pulled forward into the coming decade. Private and public funding have risen significantly in the sector over the last 5 years. Significant investment has been made in the U.S., China, the U.K. and Germany.

Figure 59: Fusion gets funded – Public funding into fusion has increased as governments see its commercial potential as a pathway to improve energy resilience
Funding as declared to the Fusion Industry Association ($Bn)



Source: Fusion Industry Association, 2026 The Global Fusion Industry (link); Fusion Companies Survey by the Fusion Industry Association. Some reported figures have been converted to dollars/rounded. Figures do not represent calendar-year values; instead, each data point reflects the 12-month period from Q2 of one year to Q2 of the following year.

Figure 60: A red hot funding race – The U.S. and China have deployed the most capital into fusion companies to date
Equity investments into fusion energy companies, by FIA member state (2010-2026) ($Bn)

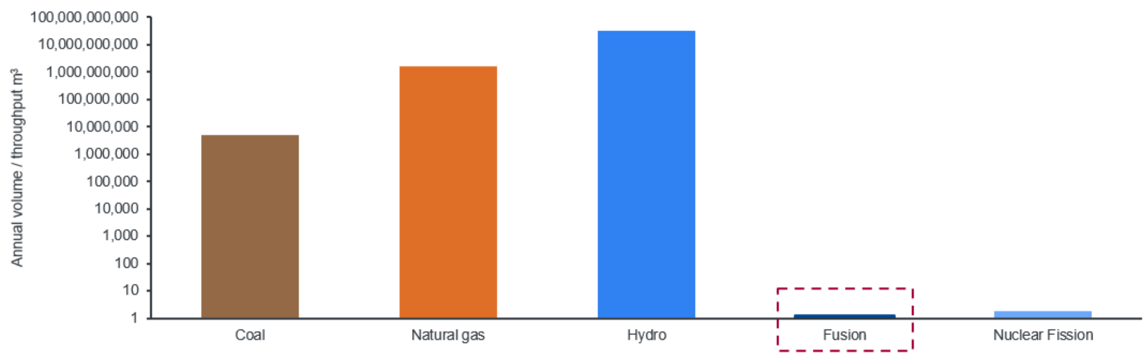


Source: Fusion Energy Base, Fusion Funding (link), *As of August 18, 2026

Technical and engineering limits to speed: The key question is whether recent advances in magnets and reactor design can be scaled into sustained reactions, and then continuously running commercial power plants. If that happens, **fusion could fundamentally change how countries think about energy security.** Because its fuel is abundant and widely available—much of it derived from seawater (deuterium)—it would reduce many of the supply concerns associated with oil, gas, and other energy commodities. Over 40% of today's trade by volume is for fossil fuels; scaling fusion would fundamentally transform shipping and port infrastructure if it replaces legacy fossil fuel energy sources.[61] The shipping and logistics impact would first be felt primarily for natural gas, and to a lesser extent coal, while the impacts for the oil market would be felt when and if the transportation sector became significantly more electrified.

To put this in perspective, we quantified estimates of the sheer annual volume throughput requirements of various energy sources to produce a 1,000 MW plant. Fusion requires dramatically less transportation of materials by volume annually to maintain a 1,000 MW plant than for fossil fuels (or even hydropower).[62]

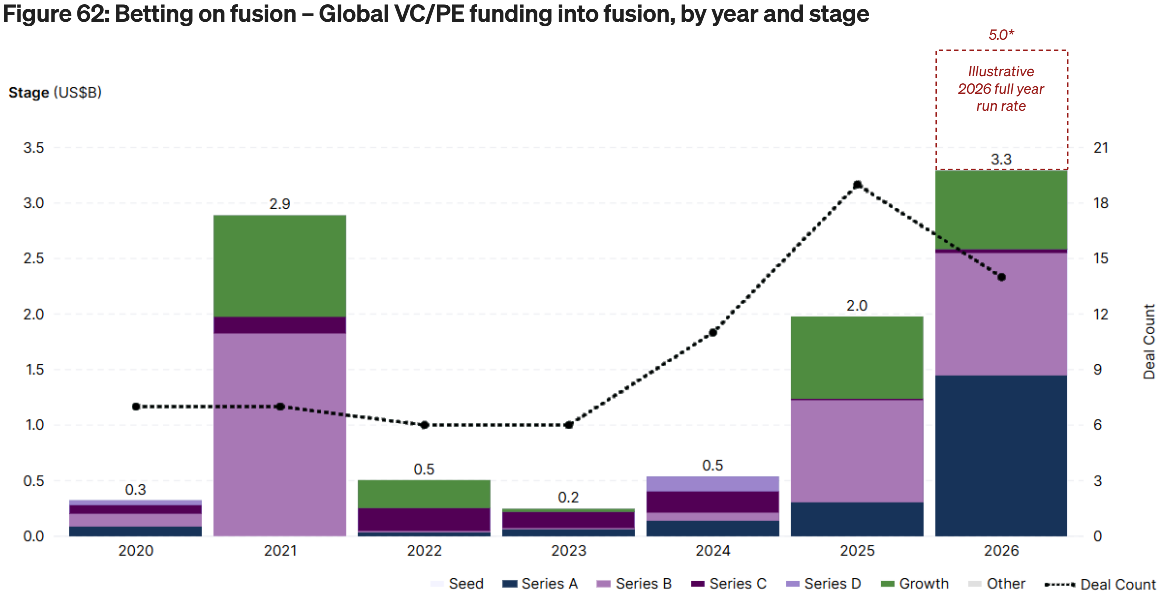
Figure 61: The density dividend – Both fusion and fission require significantly less volume of fuel compared to coal, gas or hydro plants
Annual volume / throughput of material needed to maintain a 1,000 MW plant for a year



Source: JPMorganChase analysis. See endnotes for assumptions

In that world, the focus would shift from securing access and transport of fuel toward building the factories, supply chains, and skilled workforce needed to deploy fusion at scale. The price of power shifts to the cost of construction and maintenance of the plant versus continuous fuel replenishment. **That shift is why fusion is attracting unprecedented attention from governments and long-horizon investors.**

Figure 62: Betting on fusion – Global VC/PE funding into fusion, by year and stage



Source: Currence. 2026 YTD as of 9/2/26. * Run rate annualized based on YTD data. Note: Funding stages include Series A-D and Growth

Venture capital funding for fusion has also expanded to include multiple types of fusion technologies in 2026.

FUSION TYPE	SCIENTIFIC DEFINITION	PLAIN LANGUAGE
Magnetic Confinement Fusion (MCF)	Uses very strong magnets to hold plasma (superhot gas like the sun) away from the walls long enough to fuse	Giant magnets hold a ball of superhot gas in the air, so it doesn't touch the sides, giving atoms time to smash together and fuse
MagnetoInertial Fusion (MIF)	Uses very strong magnets to hold plasma (superhot gas like the sun) away from the walls, then quickly squeezes/compresses it, so it gets hot and dense enough to fuse	Giant magnets hold a ball of superhot gas in the air, so it doesn't touch the sides, then squeezes the hot gas fast, so the atoms get pushed together and fuse
Inertial Confinement Fusion (ICF)	Uses a tiny fuel pellet and hits it with a very powerful, very quick burst of energy (often lasers) that crushes it inward (implodes) so it fuses for an instant before it flies apart	A quick, superstrong blast crushes a tiny fuel ball, so it fuses for a moment

Source: JPMorganChase

Spotlight #3 Long-duration storage

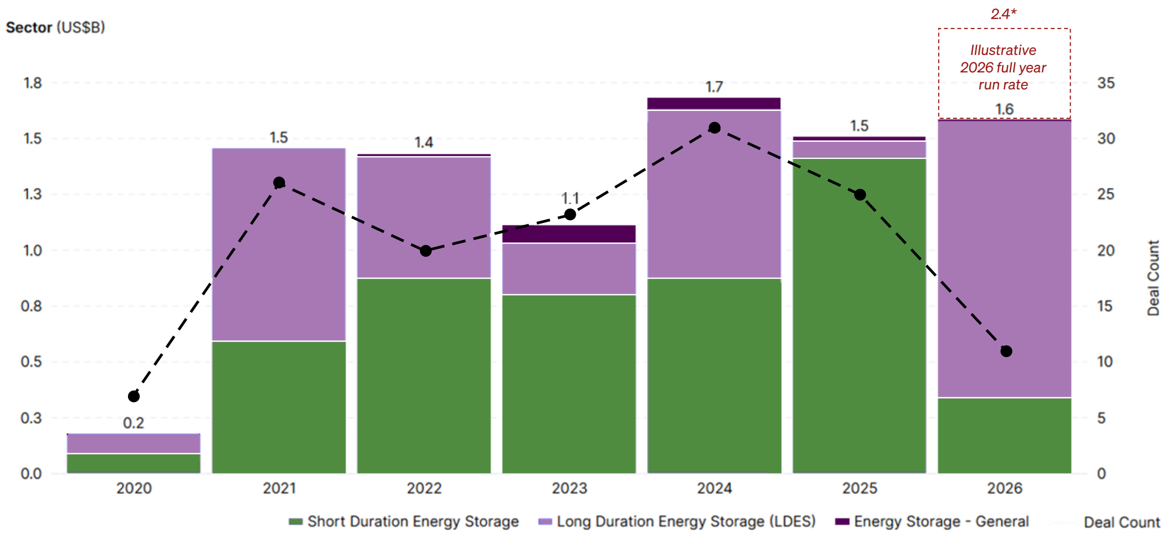
If the twentieth century's energy-security model was built around strategic petroleum reserves and fuel stockpiles, **the twenty-first century may increasingly rely on the ability to store electricity itself.**

→ The achievement of cost-effective 100-hour batteries would fundamentally reshape energy security by shifting power systems from a flow-based model—one dependent on the continuous delivery of fuels—to a stock-based model in which energy can be stored locally and deployed when needed.

→ **By storing power for days, rather than hours, these systems could help grids withstand prolonged periods of low wind and solar generation, reduce reliance on imported fuels, and improve resilience during extreme weather events or geopolitical shocks.**

→ This thesis has driven steady private capital support for storage.

Figure 63: Global VC/PE capital investment into all energy storage, by year and sector

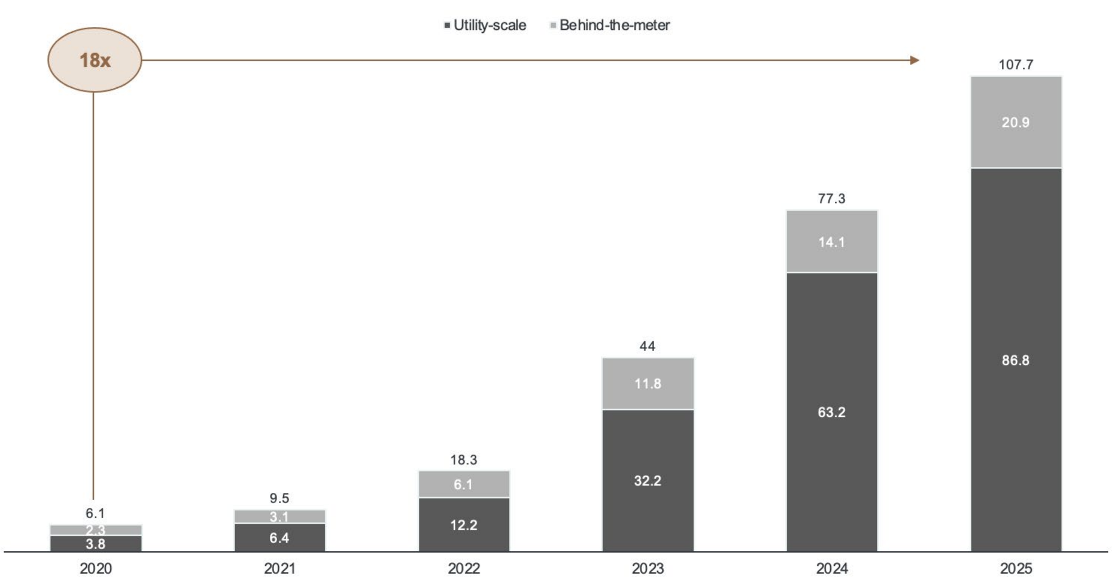


Source: Currence. 2026 YTD as of 9/2/26. * Run rate annualized based on YTD data

→ The International Energy Agency has called battery storage "the fastest-growing power technology today." In 2025, 108 GW of new battery storage capacity was deployed worldwide, 40% more than in 2024. According to its metrics, installed capacity is now 18 times higher than in 2020. Around 80% of new battery capacity in 2025 was utility-scale.

Figure 64: The battery boom – Global battery storage capacity is expanding rapidly, driven by utility-scale additions

Global battery storage capacity additions (2020-2025) (GW)



Source: IEA Global Energy Review 2026, Energy Statistics Data Browser (link)

The geopolitical implications are equally significant. Many emerging long-duration (24hr+)

storage technologies (e.g. sodium-ion, metals like iron, aluminum) rely on abundant materials broadly available over those with supply chains heavily concentrated in China (e.g. cobalt, manganese, nickel required for higher efficiency batteries with lithium). If successful, they would not only strengthen grid reliability but also reduce dependence on foreign energy and mineral supply chains.

- The future of battery technology is rapidly advancing. When we started writing this paper, most scientists predicted potential for sodium-ion commercialization at the earliest in 5 years. However, recently CATL has announced construction facilities to mass-produce sodium-ion by the end of 2026. BYD (the largest electric-car maker by global sales) has also announced major investments in sodium-ion, implying that large scale manufacturing and adoption could happen within the next two years.[63]
- Longer-duration non-lithium batteries would enhance grid reliability through generation fluctuations and extreme weather. Production with more widely available (cheaper) minerals would reduce supply chain vulnerabilities and reduce cost if they can scale to be mass-produced relative to rarer mineral (pricier) feedstocks.

→ Finland is also piloting long-duration energy storage through large-scale "sand batteries," which store excess renewable electricity as heat for later use in district heating networks.[64] By utilizing abundant, low-cost materials instead of critical minerals, these systems offer a potentially scalable and lower-cost solution for addressing renewable intermittency while reducing dependence on imported fuels and fossil-fuel-based heating.

→ **Longer duration storage has strategic potential if it can commercialize and scale. We'll be watching technological and manufacturing breakthroughs as this commercializes (or not).**

Conclusion

Energy security depends on doing several things at once, not just finding a single silver bullet. The Iran war showed that resilience is not just the ability to absorb an immediate shock. It is the ability to recover fast enough to be ready for the next one.

→ In practice, short-term fixes such as drawing down reserves, rerouting supply, paying up for cargoes, or shifting fuels often do not eliminate risk. They reshape it, delay it, or move it elsewhere in the system.

→ **The most resilient systems are those that (1) work to minimize and compartmentalize risk exposure, (2) recalibrate quickly, repeatedly, and at scale when disruptions do occur.**

→ Such systems combine robust contingency planning with long-term investments in domestic supply, electrification, grid modernization, storage, efficiency, infrastructure hardening, and workforce development.

That is why the competitive frame is changing. Energy competition is moving from who can produce the most to who can keep energy flowing under stress. **Since our 2025 report, the core challenge has compounded: resilience is now the differentiator, not just abundant supply**.

→ The next energy order will belong to flexible systems builders—those who can assemble, integrate, and sustain full stacks across supply, grids, storage, software modernization, critical infrastructure, and supply chains.

→ Frontier and improved energy technologies, from small modular nuclear reactors to hydropower upgrades and enhanced geothermal systems, are expanding the menu of options available to energy systems at a time when demand is rising and physical risk is intensifying. **But turning that optionality into resilience will require significant capital to advance research, scale production, and deploy these technologies, especially those that are not at cost parity today.**

→ **Equally important will be building an energy workforce capable of installing, operating, and maintaining the physical systems that the next energy order will depend on.**

The real test is our energy systems achieving both optionality and resilience. Shocks will not hit evenly, and the countries best positioned for the next disruption will be those with the most ways to respond: reserves to buy time, alternative routes to move supply, diversified partners to reduce concentration, flexible power systems to balance demand, and technologies that reduce dependence on vulnerable fuels and supply chains.

→ At the same time, the changing nature of conflict means energy infrastructure must be both physically and technologically resilient against threats ranging from kinetic warfare to extreme weather to cyberattacks. Resilience is no longer only about securing supply and transit routes. It is also about hardening the physical and digital systems that keep energy flowing under stress.

The sources of energy supply that serve as building blocks for resilient systems all have different considerations, risk exposures, and limiting constraints. **In a world where volatility is structural, the winners will not simply be those with the most barrels in the ground. They will be the systems with the most ways to keep economies competitive when the ground shifts.**

Figure 65: No silver bullets – Global considerations of resilience across sources of energy supply

Energy source	Operational production security[1]	Cost competitive today	Low emissions impact	Workforce readiness	Major physical risk exposure	Limiting constraints	Trade / supply chain security
Next-gen geothermal	✓ Stronger	✗ Weaker	✓ Stronger	✓ Okay	• Water scarcity • Seismic events	• Geology • Scaling tech	✓ Stronger
Nuclear SMR	✓ Stronger	✗ Weaker	✓ Stronger	✓ Okay	• Increasing ambient air temperature	• Environmental and security concerns • Social acceptance	✓ Okay
Nuclear Fusion	✓ Stronger	✗ Weaker	✓ Stronger	✗ Weaker	• Increasing water temperatures	• Theoretical to operational transition	✓ Stronger
Grid	✓ Okay	✓ Okay	*NA*	✓ Okay	• Severe convective storms • Wildfires • Winter storms	• Permitting	**World ex-China** ✗ Weaker 🇨🇳 ✓ Stronger
Renewables	✓ Stronger	✓ Stronger	✓ Stronger	✓ Stronger	• Severe convective storms	• Critical minerals • Domestic manufacturing capacity	**World ex-China** ✗ Weaker 🇨🇳 ✓ Stronger
Oil/Gas	✓ Stronger	✓ Stronger	✗ Weaker	✓ Stronger	• Severe convective storms • Sea level rise	• Geology • Geopolitical conflict	**Middle East?** ✗ Weaker **Other** ✓ Stronger
Thermal Coal	✓ Stronger	✓ Okay	✗ Weaker	✓ Okay	• Water scarcity	• Economics	✓ Stronger

Source: JPMorganChase; [1] Defined as when a facility is up and running, how secure is the production

Endnotes

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37 At its core, geothermal works by accessing the natural heat stored beneath the Earth's surface. Wells are drilled into deep layers of hot rock, where circulating water absorbs heat and carries it back to the surface. That heat is then used to generate electricity before the cooled water is reinjected underground, creating a continuous cycle.

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Sweden, Switzerland, The Netherlands, Türkiye, United Kingdom, and U.S. China, an associated country, also drew on its own strategic reserves.

40 The top 10 countries by oil consumption: U.S., China, India, Russia, Japan, South Korea, Germany, Canada, Brazil and Saudi Arabia. They represent ~60% of global oil demand. <https://energynow.ca/2025/09/ranked-the-worlds-top-25-countries-by-oil-consumption/>

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to host Nuclear Lifecycle Innovation Campuses — Energy Department-backed facilities that would support the full nuclear fuel cycle, from enriching uranium and fabricating fuel to reprocessing and disposing of waste (EE News)

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62 Note: The following analysis is predicated on a standardized 1,000 MW (1 GW) capacity plant operating under continuous load (24 hours/day, 365 days/year) to produce a calculated annual electricity output of 8.76 TWh (8,760,000,000 kWh). Fossil fuel assumptions utilize an EIA average operating heat rate of 10,777 Btu/kWh for coal (with a heat content of 19.167 MMBtu/short ton and a 1.2 m^3/metric tonne stowage factor) and 7,754 Btu/kWh for natural gas (at 1,034 Btu/cf and a density of 0.84 kg/m^3). Hydropower modeling assumes 90.0% system efficiency at a 100-meter head height, utilizing standard gravity of 9.81 m/s^2 and water density of 1,000 kg/m^3. Advanced nuclear assumptions include a 250 kg/year D-T fuel requirement for fusion (50% deuterium share by mass) and 200 million kWh of productivity per 500 kg UO2 fuel assembly for fission

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