The Energy Transition's Next Chapter

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The Center for Energy Impact (CEI) shines light on the energy transition, focusing on the actions required to achieve global transformation. CEI applies a holistic perspective to understanding and shaping bold responses to one of the most critical and complex challenges of our time.

Our deep expertise spans markets and economics, carbon and technology, capital and investors, the macrodynamics of geopolitics and resilience, and the microdynamics of politics and specific policies. We offer nuanced, constructive ideas and solutions covering the future availability, economics, and sustainability of the world's energy sources—and the implications for energy companies, industries, investors, consumers,and governments. The CEI team is committed to facilitating informed, innovative discussions to make our world sustainable.

Preface

The energy transition has entered a new phase. Over the past 36 months, the global energy landscape has evolved significantly.

Among the most notable developments is the increasing emphasis on energy security and affordability. This reflects the fact that access to energy underpins economic vitality and human prosperity. Yet the increased carbon emissions associated with meeting the world's energy needs risk undermining those very gains. Failing to price in the externalities of CO_2 emissions doesn't make them disappear.

That said, the energy transition remains a fundamental secular shift. It is, however, unlikely to be a linear one—with the road ahead marked by uneven progress and occasional setbacks. It is also important to note that there is no single transition, but multiple country and regional transitions unfolding with differences in pace and technology choices. Still, the evolving and complex environment we observe today does not signal a retreat from the energy transition overall: in many cases, energy security and affordability can be aligned with decarbonization goals.

The question now is not whether these transitions will continue, but how and at what pace. Accelerating progress remains essential. The world is on track to reach a level of warming that significantly exceeds 2°C above preindustrial levels, and momentum on climate action is weakening in some countries. Multilateral alignment is proving harder, even as strong business cases for action persist. Moving forward at pace therefore requires three reinforcing efforts: accelerated deployment of commercially viable decarbonization technologies (which can address approximately 65% of energy-related emissions), encouragement of collective policy and public support, and preparation for a warmer world through smarter adaptation.

This publication, developed by BCG's Center for Energy Impact as a follow-up to **our 2023 report**, is intended to help stakeholders make sense of the profound shifts underway in the global energy system and navigate its ongoing transition. In an environment filled with conflicting signals and information, our fact-based analysis seeks to bring greater clarity to the path forward.

Our report is structured in three parts. The first section takes stock of where we stand by exploring seven shifts that are reshaping the transition. Some of these changes create headwinds for the transition, while others produce tailwinds. Our assessment is based not on subjective judgments, but on observations of current trajectories. The second section explores four major implications of these shifts. The third section offers targeted recommendations for different stakeholder groups.

This report aims to cut through the noise with realism—providing a clear-eyed view of the path ahead based on fact and action.

RICH LESSER
Global Chair, BCG

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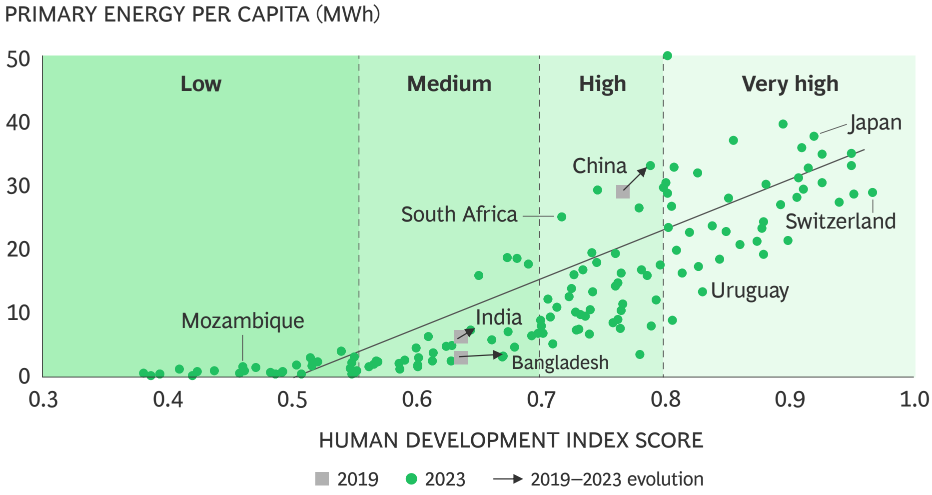
Energy access is essential for societal prosperity

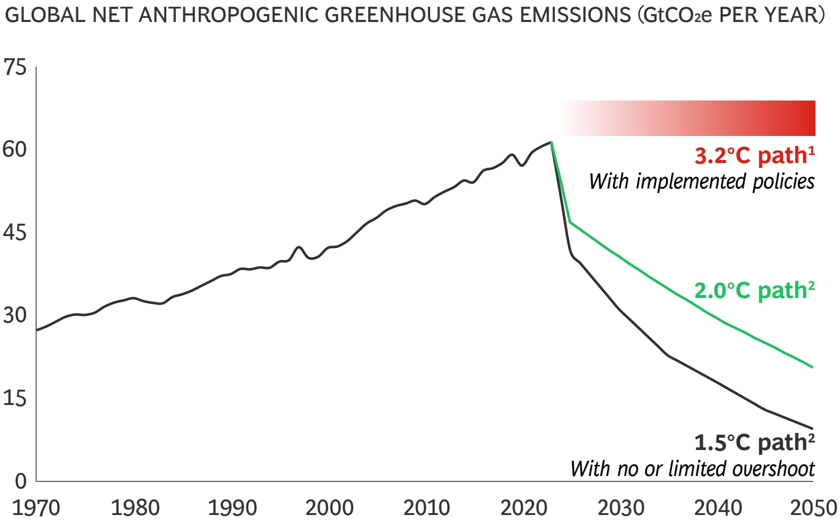
Primary energy per capita in 2023—and in 2019 for selected countries—and Human Development Index score, by country



- High Human Development Index countries typically have high primary energy use per capita
- Some countries (e.g., UK, Sweden, Germany, Switzerland) have successfully decoupled energy use from economic growth
- ~700 million people, mostly in Asia and Africa, still lack electricity access; billions of others face supply constraints and will require more energy in the decades ahead
- The carbon intensity associated with meeting that additional demand risks undermining development gains

Sources: UNDP; EIA; WHO; World Bank; BCG analysis.
Note: The Human Development Index (HDI) measures a country's performance in terms of life expectancy at birth, average years of schooling, and gross national income. The trendline is based on correlation measured until 0.88 HDI and 40 MWh primary energy per capita and is shown for illustrative purposes. Countries/regions with energy consumption above 60MWh per capita and 0.8 HDI (Middle East, US, Nordics, Benelux, Australia, Canada) are not shown on the graph. MWh = megawatt-hour.

Current warming is on a path toward roughly 3°C; accelerating proven solutions and adaptation is essential



Moving forward requires three reinforcing efforts:

1. **Deploy proven technologies.** With sufficient policy support, commercially viable and soon-to-be viable technologies can address ~65% of emissions.
2. **Encourage collective policy and public support.** Collaboration among countries and institutions can help address emissions in harder-to-abate sectors and scale nascent solutions; such action can be focused in areas such as carbon pricing, climate finance, technology transfers, and alignment of regulation.
3. **Invest in adaptation and resilience.** As extreme weather becomes more frequent, investments in resilience (e.g., infrastructure and coastal protection, food security) grow in importance.

Sources: World Bank; IMF; IPCC; EDGAR; WEF; BCG analysis.
Note: $GtCO_2e$ = gigatons of carbon dioxide equivalent.
[1]IPCC AR6 WG III (April 2022) median projection, 5th to 95th percentile range: 2.2–3.5°C by 2100, medium confidence.
[2]IPCC median projection.

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Seven Shifts Reshaping the Energy Transition

Multiple forces have altered the path of the transition:

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4. Natural gas and nuclear power are back in the plans, strongly
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6. Demand trajectory for oil and gas is higher than expected, but also increasingly uncertain
7. Technology cost trajectories are diverging—some falling fast, others proving persistently more expensive

SHIFT 1

Energy security has emerged as the driving force globally

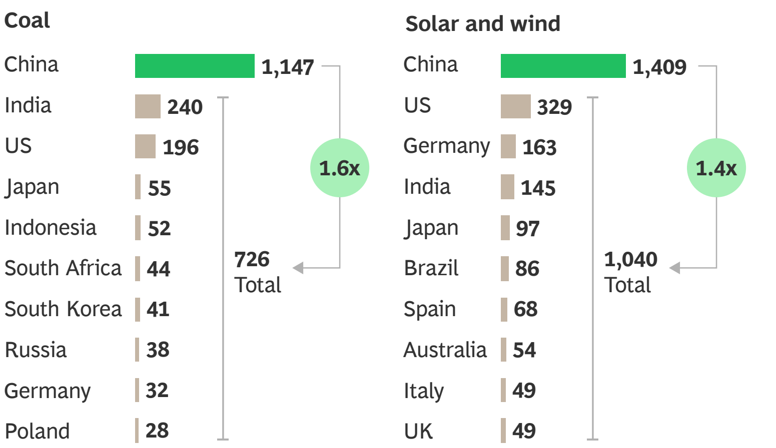
Energy security, energy affordability, and economic resilience and competitiveness are tightly linked. As the geopolitical landscape becomes more fragmented, altering the economic dynamics in many countries, energy security has taken on even greater urgency. This development has profound implications for the energy transition. Increasingly, countries are focusing on expanding the share of their energy that comes from indigenous sources.

For example, the US is incentivizing development of domestic oil and gas resources while also supporting alternative energy sources such as nuclear, geothermal, and hydro. China has emerged as a dominant force in global low-carbon energy, both in deployment and across manufacturing and technology value chains, leveraging its substantial coal reserves while rapidly scaling up its solar and wind capacity. The EU, meanwhile, has explicitly tied decarbonization to energy security, reducing its reliance on Russian gas.

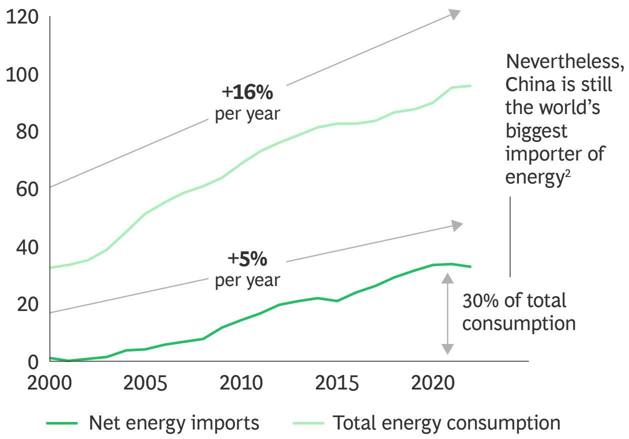
Many countries are also seeking to build localized value chains for critical low-carbon technologies, often through trade protections and industrial policy. For now, though, many clean energy value chains remain global. As an example, most of the value chain for batteries used in the US is located outside the country. However, the renewed commitment to domestic energy development doesn't necessarily signal a slowdown in the transition. History shows that high energy prices and a focus on energy security can be a tailwind for the transition, particularly in countries with renewables potential.

China invests heavily in energy security; its renewables capacity and coal capacity are larger than those of the next nine countries combined

2024 INSTALLED GENERATION CAPACITY IN CHINA AND IN OTHER TOP 10 COUNTRIES GLOBALLY FOR THE SPECIFIED ENERGY SOURCE (GW)[1]



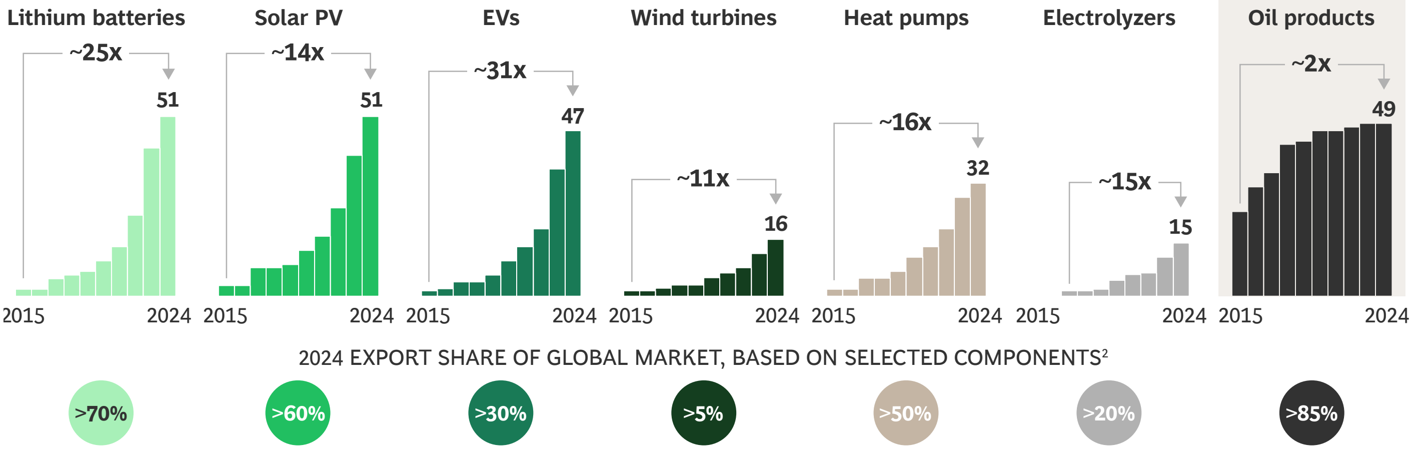
CHINA'S ANNUAL NET ENERGY IMPORTS AND TOTAL ENERGY CONSUMPTION (EJ)



Sources: IRENA; Global Energy Monitor; IEA; BCG analysis.
Note: EJ = exajoule; GW = gigawatt.
[1]Based on end-of-year 2024 figures.
[2]In 2023, China's oil, natural gas, and coal imports represented, respectively, 32%, 26%, and 33% of global trade for these commodities.

Even before 2025 tariffs, trade barriers on green tech were increasing more than those on oil products; some are now reaching similar levels

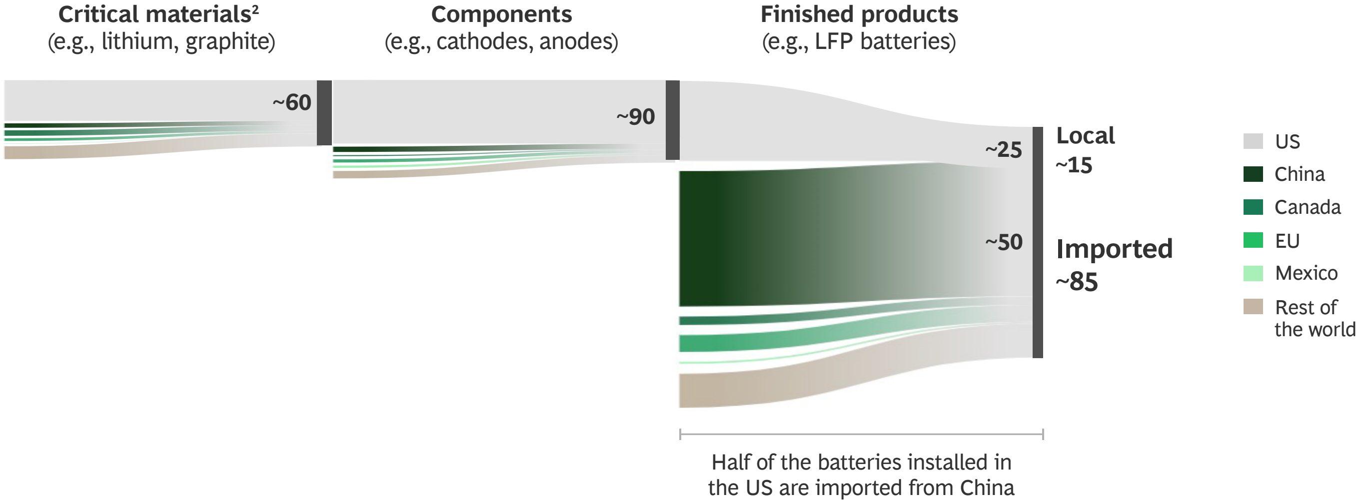
GLOBAL TRADE RESTRICTIONS BY SECTOR (NUMBER)[1]



Sources: UN Comtrade; IEA; BloombergNEF; BCG analysis.
Note: Excludes data from 2025 tariff changes. EVs = electric vehicles; PV = photovoltaics.
[1]The trade policies considered as barriers include changes in import or export tariffs, anti-dumping duties and countervailing measures, import or export control and bans, and other nontariff measures such as import or export licensing and quotas.
[2]Export shares reflect the share of international trade (by value, 2024) based on Harmonized System codes representing the following selected components: lithium batteries, PV modules, passenger EVs, wind-powered electricity generating sets, heat pumps, electrolyzers, and crude oil products.

Many clean technologies are highly exposed to global supply chains

RELATIVE DOLLAR VALUE CONTRIBUTION OF GOODS TO US BATTERY SUPPLY CHAIN (%)[1]



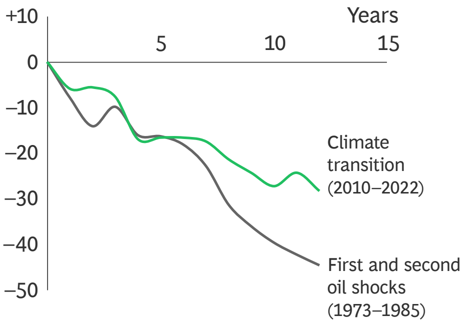
Sources: UN COMTRADE; BCG SWITCH-GT; BCG analysis.
Note: Excludes 2025 tariff impact. LFP = lithium iron phosphate.
[1]Averages across clean technologies.
[2]Metals for anodes, cathodes, and electrolytes.

High energy prices and security concerns can drive decarbonization, sometimes faster than climate policies

France’s response to oil crisis

The first and second oil shocks in the 1970s and 1980s triggered state-led energy planning in France and rapid expansion of national nuclear power

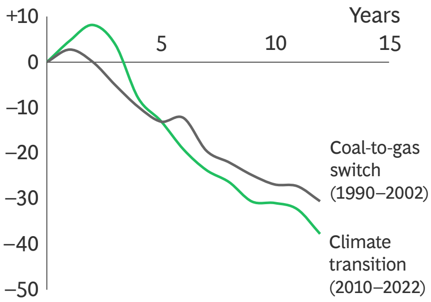
CHANGE IN CO_2 EMISSIONS INTENSITY (%)[1]



UK’s switch from coal to gas

In the 1990s, declining coal reserves and the availability of cheap natural gas from deposits beneath the North Sea drove a switch from coal to gas in the UK

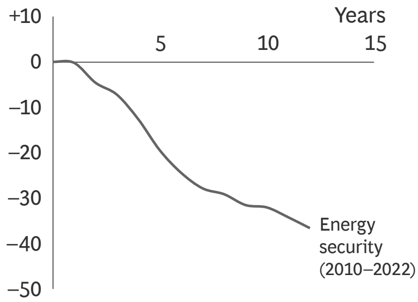
CHANGE IN CO_2 EMISSIONS INTENSITY (%)[1]



China’s push for energy security

Facing energy shortages and geopolitical risks, China invested heavily in renewables and storage starting in 2010 to boost energy security

CHANGE IN CO_2 EMISSIONS INTENSITY (%)[1]



Sources: EDGAR; World Bank; Energy Institute; BCG analysis.
Note: Each chart tracks change since the start date of the specified event.
[1]Percentage change in CO_2 emitted per unit of energy consumed.

SHIFT 2

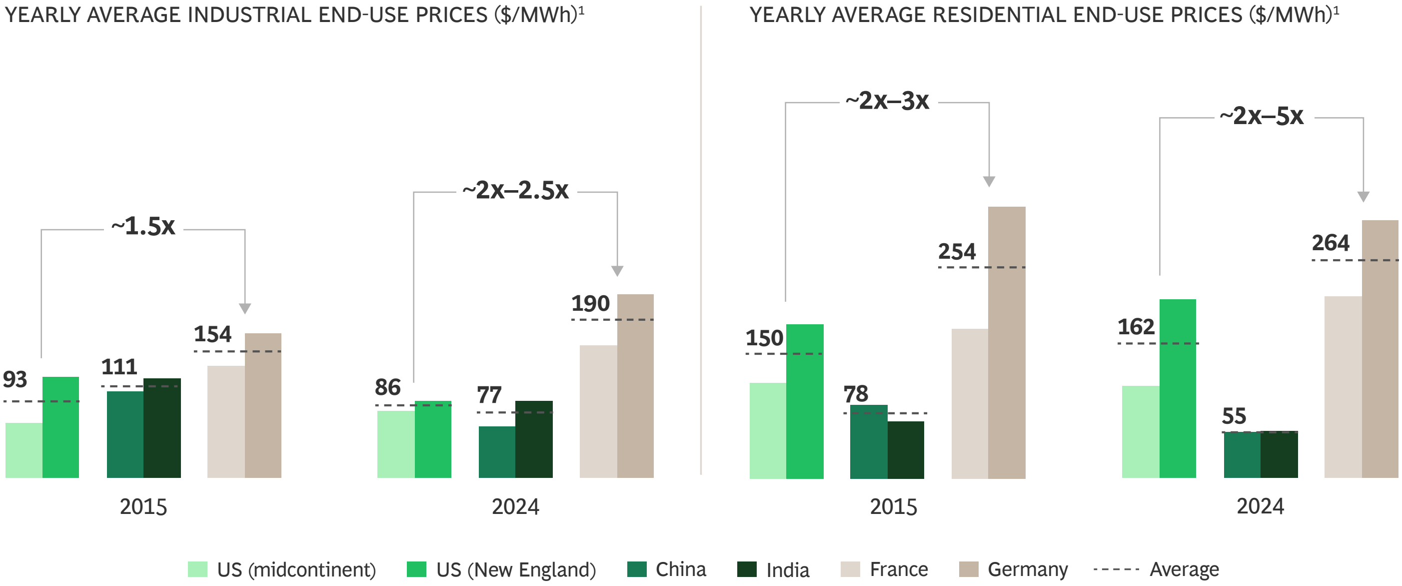
Public support for the energy transition is being challenged, driven in part by high energy prices

Energy affordability, especially for the poorest households, has deteriorated over the past 25 years, especially in recent years. In France and Germany, for example, industrial and residential users pay roughly 2.5 times as much for power as users in more competitive regions such as the US, China, and India do.

The repercussions are twofold. For consumers, concerns about energy affordability can erode public support for the transition: since 2020, public prioritization of sustainability has declined across the EU, and concern about climate mitigation has weakened. For business users, higher prices in one market than in another can limit growth and trigger a flight of capital and jobs.

Already, growth in investments in energy-intensive industries in countries such as the US and China outstrip the increases in countries such as Germany, where end users pay more for energy. That said, high energy prices can also fuel innovation that drives energy efficiency or other accelerating improvements.

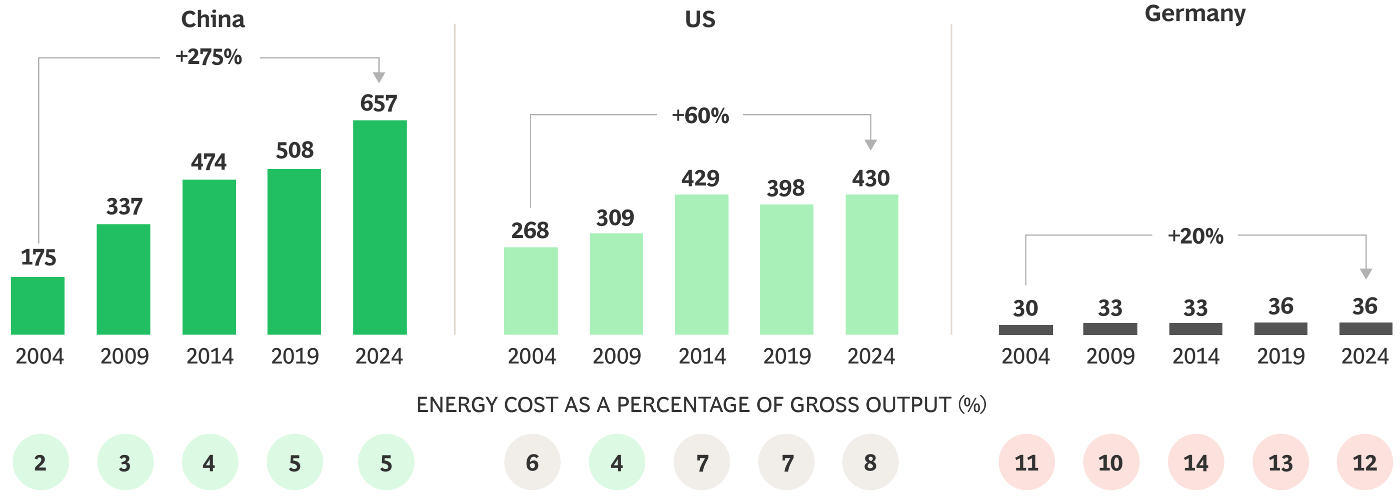
Electricity is more expensive in Europe than in other regions



Sources: OECD; US Energy Information Administration; IEA; Eurostat; Statista; BCG analysis.
Note: US electricity prices vary considerably by region; midcontinent and New England prices are shown to reflect the range of prices nationally.
MWh = megawatt-hour.
[1]All prices are expressed in constant 2015 dollars.

China and the US are outpacing Europe in investments in energy-intensive industries

INVESTMENTS IN ENERGY-INTENSIVE INDUSTRIES ($BILLIONS)[1]

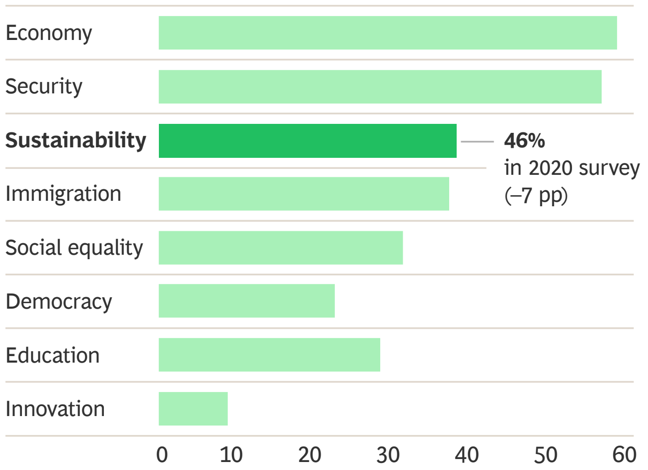


Sources: Bureau of Economic Analysis; China National Bureau of Statistics; World Bank; Federal Statistics Office Germany; Haver Analytics; IEA; Oxford Economics; BCG analysis.
Note: Energy-intensive industries include chemicals and pharmaceuticals, metals and minerals, coke and refined petroleum products, mining, and paper and printing. “Gross output” refers to the total value of sales by domestic industries. Beyond energy cost, other important drivers include labor productivity, carbon markets, and broader government and fiscal policies.
[1]All prices are expressed in constant 2015 dollars.

Support for the energy transition in the EU is decreasing but remains strong

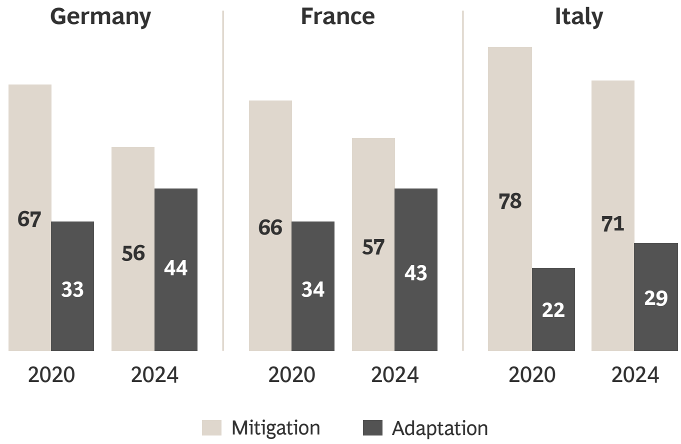
Sustainability is declining as a political priority

EU RESPONDENTS WHO RANKED THE TOPIC AS A TOP 3 PRIORITY FOR THE REGION IN 2024 (%)



Public focus is shifting from mitigation to adaptation

EU RESPONDENTS WHO CHOSE MITIGATION VS. ADAPTATION (%)[1]



Sources: Bruegel; European Commission; BCG analysis.
Note: Results based on Standard Eurobarometer Survey of 7,819 people conducted in April 2024 in Germany, France, Italy, Poland, and Sweden.
[1]Respondents were asked to choose between “do everything we can to stop climate change” and “should adapt to climate change, so that we can live well with a changed climate.”

SHIFT 3

Electricity demand has entered a structural supercycle

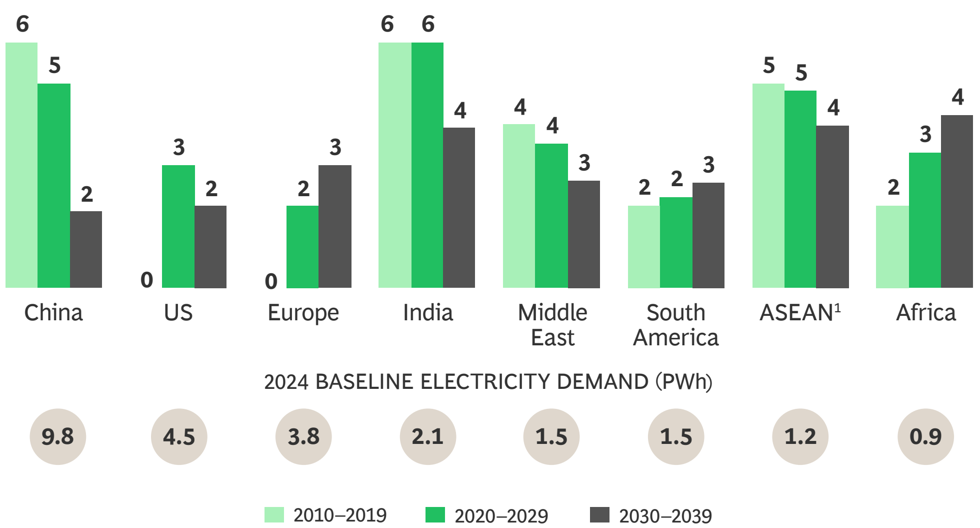
The rapid build-out of data centers (fueled in part by the AI boom), rising demand for cooling, and growing electrification of transport, buildings, and industry have pushed electricity demand into a structural supercycle.

The Global South is leading this shift. China and India alone are expected to drive 30% to 50% growth in national consumption by 2030, with many ASEAN and African economies on similar trajectories. This reflects strong economic expansion, expanding populations (with the exception of China), and rising access to modern energy. Advanced economies, meanwhile, are experiencing a more structural inflection.

After decades of stagnant electricity demand, new uses are driving a surge in generation. The switch from fossil fuels to electricity has been slower than anticipated but is now gaining momentum. Paired with new sources of demand, such as data centers, this trend marks a notable shift after many years during which efficiency gains offset consumption growth. In the US alone, demand is projected to rise by roughly 800 TWh from 2024 to 2030—the equivalent of 1.5 times Germany's current power consumption—representing 4% growth annually, driven by strong uptake from data centers. Europe is on a similar path. Around the world, the projected structural increase in electricity demand is likely to require significant additional supply, in the absence of which prices are likely to see upward pressure.

Power generation is set to rise to meet surging demand

ELECTRICITY GENERATION CAGR PER 10-YEAR PERIOD (%)



Total absolute increase in global power generation by decade

2010–2019

+5.3 PWh

2020–2029

+7.1 PWh

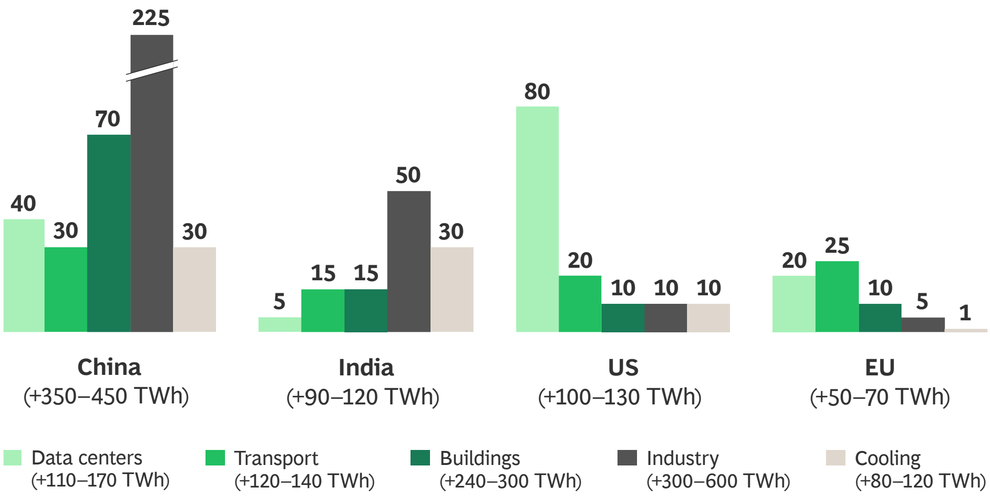
2030–2039

+7.4 PWh

Sources: Energy Institute; Enerdata; EIA; IEA; BCG analysis.
Note: Based on Enerfuture Base Case scenario, EIA Reference Case, IEA Stated Policies (STEPS). All decade intervals run from January 1 of the start year through December 31 of the end year. CAGR = compound annual growth rate; PWh = petawatt-hour.
[1]Includes data from Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam.

Structural demand drivers fuel electricity growth across major economies

PROJECTED ANNUAL ELECTRICITY GROWTH BY DRIVER, 2025–2030 (TWh)[1]



- In China and India, industry and cooling drive most of the increase, underscoring the structural nature of demand growth
- AI-driven data center load is projected to be a key driver of demand, accounting for about 60% of US growth

Sources: Energy Policy Simulator; Energy Institute; EIA; IEA; TSE Research; Vasudha (2024); BCG analysis.
Note: Sectoral global split follows the IEA and BCG data center model. TWh = terawatt-hours.
[1]Data is for the EPS BAU and IEA STEPS scenario.

SHIFT 4

Natural gas and nuclear power are back in the plans, strongly

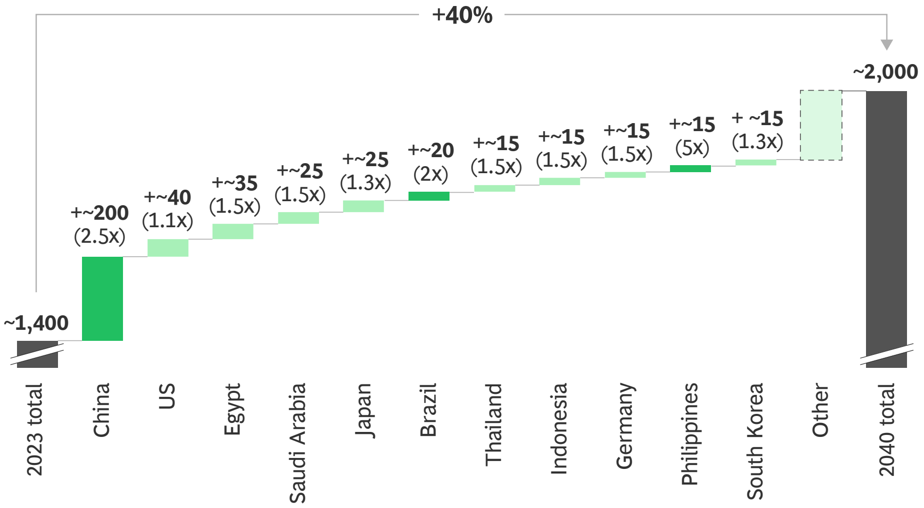
As renewables expand, the need will persist for firm, dispatchable power—electricity generation that can be dialed up or down to balance supply and demand. The growth of energy-hungry data centers is amplifying the demand for reliable firm power sources. Natural gas, a well-established and flexible energy source, is seeing renewed energy investment globally. (Of course, rising supply chain costs, such as those recently seen in new builds of combined-cycle gas turbines, could dampen that momentum.)

Meanwhile, nuclear power, a zero-carbon firm supply option, is experiencing a strong revival, with projections of 2040 capacity rising sharply in recent years. Both large-scale reactors and small modular reactors (SMRs) are gaining traction. SMRs are especially attractive because of their potential to lower the risk of cost overruns and avoid bet-the-company decisions. Ultimately, the pace and scale of the nuclear resurgence will depend on factors such as the speed of permitting, access to a skilled workforce, the evolution of public support, and, above all, the industry's ability to deliver on-cost and on-budget and avoid the high-profile overruns witnessed in recent years.

Other firm supply options are gaining momentum as well: geothermal is receiving renewed interest, and investment in long-duration energy storage is accelerating. These technologies will play a critical role alongside gas and nuclear in shaping future energy systems.

Global gas generation capacity is expected to increase by roughly 40% through 2040 as demand increases

ADDITIONAL GAS-FIRED POWER GENERATION CAPACITY BY COUNTRY UNTIL 2040 (GW)

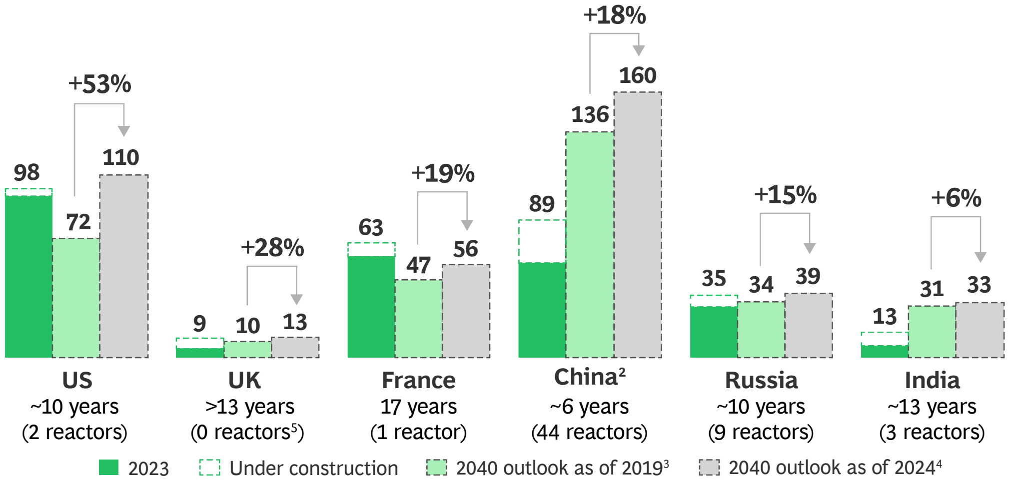


- Demand for natural gas has risen sharply. One driver is its role as a flexible, lower-carbon alternative to coal for power generation
- Natural gas can also serve as a dispatchable, flexible power source for hyperscalers and industrial users seeking a degree of reliability that renewables alone can't guarantee
- However, for many countries, including those that rely on coal today, imported LNG carries a cost disadvantage, limiting broad adoption
- In the short term, gas power is constrained by supply chain delays and rising costs (e.g., lead times now exceed five years in certain geographies)

Sources: Enerdata; EMBER; Bloomberg; GlobalData; Reuters; GE Vernova; BCG analysis.
Note: GW = gigawatts; LNG = liquefied natural gas.

A nuclear renaissance is underway in key markets

NUCLEAR INSTALLED CAPACITY AND OUTLOOK (GW) AND BUILD TIME (YEARS) FOR NEW REACTORS[1]



- Public sentiment— including among environmentalists— has shifted in many regions, with growing support for nuclear as a reliable low-carbon energy source
- The time it takes to build new reactors varies significantly across countries, with timelines north of 10 years in many markets and cost overruns frequently pushing actual project costs well above initial forecasts

Sources: IAEA ARIS (2022); UBS; National Grid ESO; CRE France; IEA; BCG Global Nuclear Capacity Model (July 2024), base case scenario; BCG analysis.
Note: "Capacity" refers to total net electrical capacity (subtracting internal consumption). Build times and new reactor numbers include reactors actually built since 2005 and operational, but do not include reactors currently under construction or projected to be built.
[1]Figures for build time are averages for reactors that are now operational and for which construction started after 2005.
[2]China's domestic model depends on long-term state financing, centralized planning, and workforce pipelines not easily mirrored in liberalized energy markets.
[3]IEA New Policies Scenario for the US, China, Russia, and India; UK National Grid's FES Steady Progression Scenario; calculations for France based on nuclear generation mix to 50% by 2035.
[4]IEA Stated Policies Scenario, UK FES 2024 Electric Engagement, CRE assumptions.
[5]Construction for Hinkley Point C has been ongoing since 2016, and current estimates put its earliest probable completion date at 2029.

SHIFT 5

We have moved from “sweat the assets” to “build the assets” in the energy system

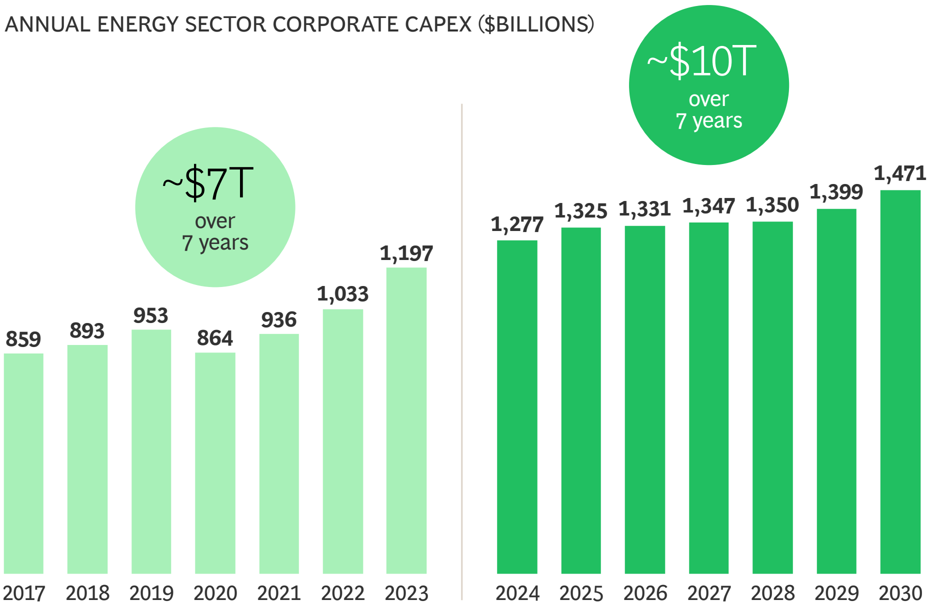
After decades of focusing on maintaining or upgrading existing energy infrastructure, we are moving into a new era characterized by large-scale capital build-out. Global annual corporate energy capex is expected to rise by roughly 50%, from about $7 trillion to about $10 trillion from 2024 to 2030 (equivalent to approximately 1.5% of global GDP). This marks a structural shift, especially for advanced economies such as the US and Europe.

Much of the investment is in grids and renewables, which require more upfront investment and have lower operating costs than fossil fuel-based systems. In addition, with greater penetration of solar and wind in our electricity systems, the hours during which gas-fired plants operate will be lower. That reduced utilization rate will make dispatchable fossil assets even more capital-intensive relative to their operating expenditures. As a result, cost of capital (including payments to debt holders and equity investors) is becoming the single largest driver of system economics. But companies and supply chains are not yet configured for this capital-intensive build-the-assets phase.

Meanwhile, governments—which have historically played an important role in energy infrastructure construction and funding—face rising budget pressure and competing priorities, with significant variations by country.

The energy sector is in a “build the assets” phase

ANNUAL ENERGY SECTOR CORPORATE CAPEX ($BILLIONS)

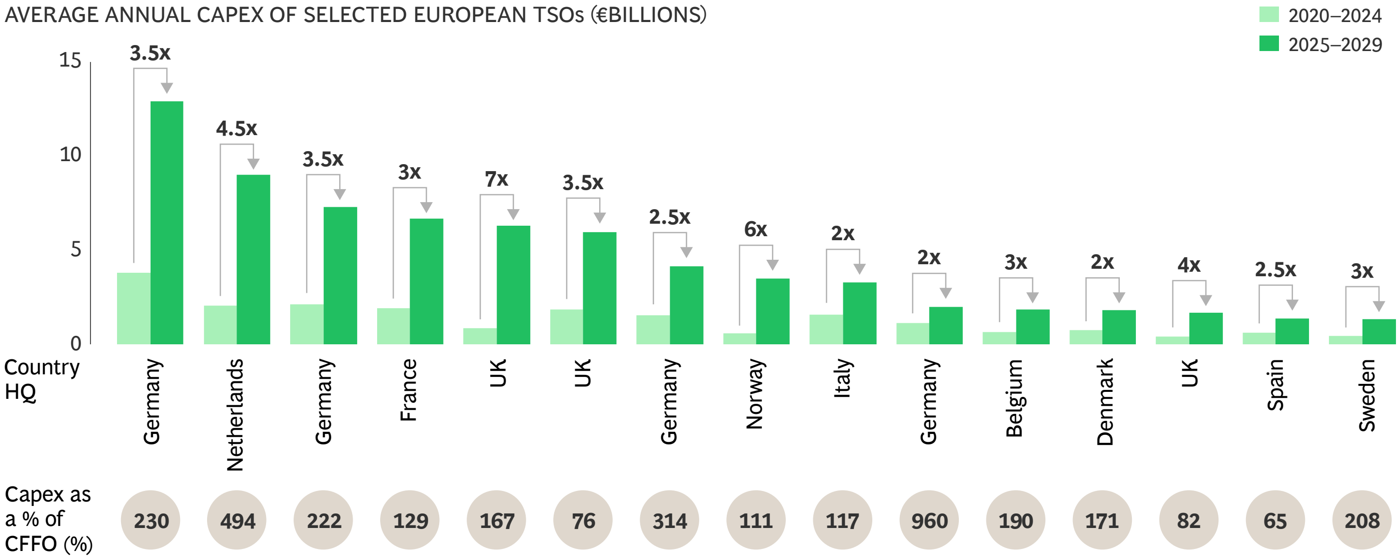


- The energy system is shifting from a “sweat the assets” era into a “build the assets” phase that will focus on a rapid build-out of renewables, grids, firm power, and storage
- Power and utilities will outpace oil and gas in capital deployment, moving from a 47%/53% split to a 52%/48% split
- Public investment is under pressure from competing demands, including defense, demographics, and infrastructure

Sources: Company filings; S&P Capital IQ; BCG CEI analysis.
Note: Data is for the 262 largest energy companies worldwide across sectors (e.g., oil and gas, utilities, grids). T = trillion.

European network operators plan record investments, strongly exceeding cash flow from operations

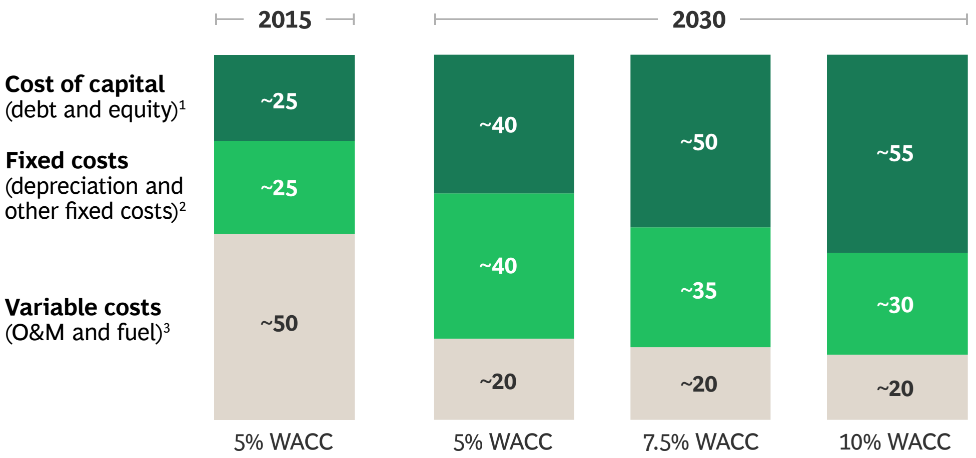
AVERAGE ANNUAL CAPEX OF SELECTED EUROPEAN TSOs (€BILLIONS)



Sources: S&P; company annual report; company investors presentation; BCG analysis.
Note: A high capex-to-CFFO ratio means that more operational cash is being reinvested in capital assets. CFFO = cash flow from operations; TSO = transmission system operators.

Cost of capital is becoming single largest cost driver in our energy system

BREAKDOWN OF UK ELECTRICITY SYSTEM COSTS AT DIFFERENT WEIGHTED AVERAGE COSTS OF CAPITAL (%)



- Renewables and grids are 50% more sensitive to capital costs than fossil-based generation assets are
- The transition is shifting the system toward a higher share of fixed costs
- Rising macroeconomic volatility, interest rates, and regulatory uncertainty are adding further pressure

Sources: Aurora; Ofgem; NESO; IEA; BCG XVector Model; BCG analysis.
Note: All cost figures were calculated in dollars per kilowatt-hour. O&M = operations and maintenance; WACC = weighted average cost of capital. Because of rounding, not all bar segment approximations add up to 100%.
[1]Reflects the annual returns that equity and debt holders earn and is based on WACC.
[2]Depreciation for generation and networks, plus fixed O&M such as routine inspection.
[3]Fuel costs for uranium, coal, and gas, plus daily running cost of generation and networks, along with maintenance and labor expenditures such as preventive maintenance, which can vary depending on the plant's production level.

SHIFT 6

Demand trajectory for oil and gas is higher than expected, but also increasingly uncertain

Oil and gas will very likely continue to play a significant role in the global energy mix for longer than many previous estimates had predicted. Even in accelerated transition scenarios, sectors such as aviation, heavy transport, and petrochemicals lack scalable alternatives, keeping oil demand structurally resilient.

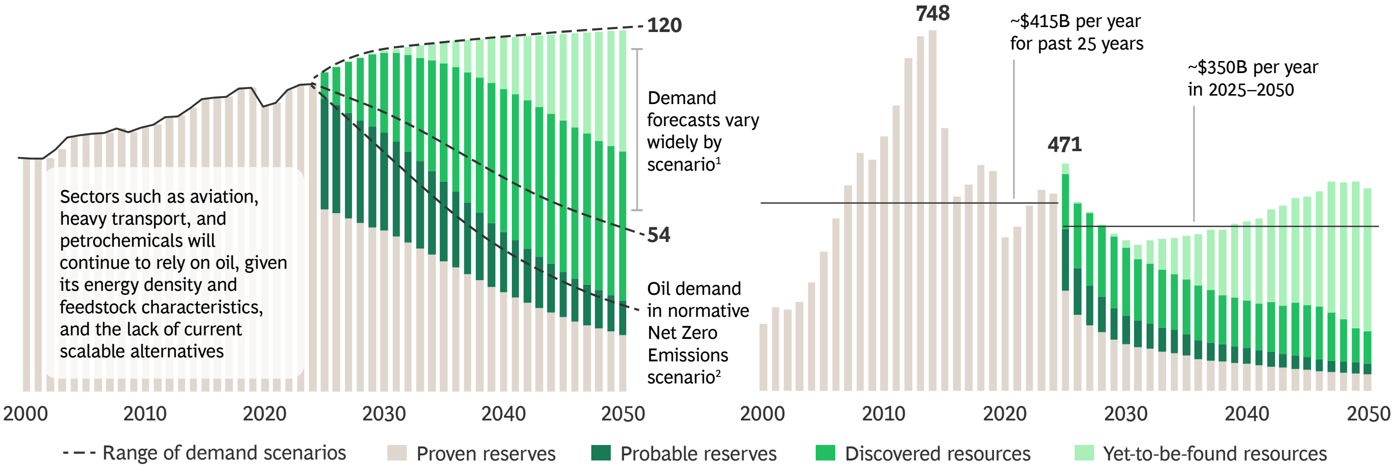
For example, the 2024 IEA World Energy Outlook projects that oil production in 2040 will remain at 96% of 2023 levels under the Stated Policies Scenario (STEPS) and at 71% under the Announced Pledges Scenario (APS). Projections of peak oil demand continue to be pushed out further in time. Meeting this demand will require sustained upstream investment of, on average, $350 billion per year through 2050, with new resource development needed under most scenarios. Only under the normative Net Zero Emissions scenario would discovered and economically viable resources be sufficient to meet projected oil demand through 2050.

Meanwhile, gas—particularly LNG—is seeing a more robust and strategic expansion. Global LNG demand is expected to rise 80% by 2040, with 38 new importing countries projected joining the market. LNG is now seen as a geopolitical fuel, with flows increasingly shaped by national alliances. The US has emerged as the leading exporter, overtaking legacy suppliers. Continued gas reliance makes addressing methane emissions critical, given that its short-term warming potential is 80 times greater than CO_2.

Today's proven and probable reserves are insufficient under most scenarios

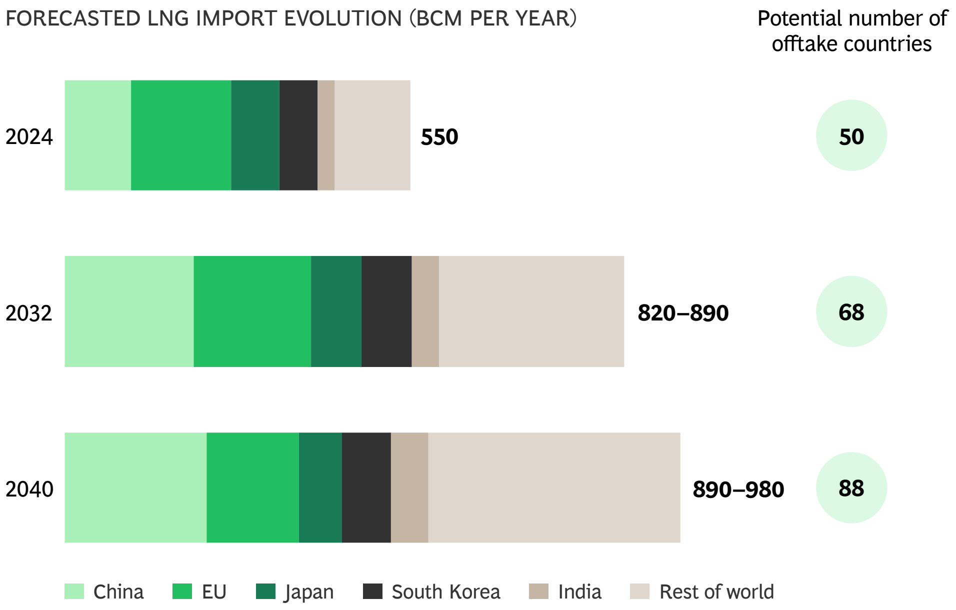
OIL RESERVES AND DEMAND PROJECTIONS (MILLIONS OF BARRELS PER DAY)

OIL DEVELOPMENT AND PRODUCTION CAPEX NEEDS ($BILLIONS)[3]



Sources: Rystad Energy; OPEC; IEA; IEF; BCG analysis.
Note: "Proven reserves" are 1P reserves, which are recoverable with reasonable certainty under existing economic and operating conditions. "Probable reserves" are the increment in 2P reserves, which are less certain but still likely to be technically and economically recoverable. B = billions.
[1] Demand scenario range is based on non-Paris-aligned climate policy, including OPEC Reference (upper) and IEA APS (lower) and all other reference demand scenarios (e.g., Shell, ExxonMobil, bp).
[2] Based on IEA NZE scenario as per WEO 2024.
[3] Supply scenarios and capex needs are based on Rystad Energy Base Case Scenario, using development capex per barrel of oil equivalent and resources under different stages of maturity. All prices are expressed in constant 2025 dollars.

Global demand for LNG imports is expected to nearly double by 2040



- LNG has become the new strategic fuel for its flexibility, tradability, and firm power backup role
- Import demand is likely to nearly double, reflecting demand not only from core markets but increasingly from new offtakers across the Global South
- Trade patterns are becoming geopolitical, with long-term contracts aligning with national alliances
- The US is the world's largest LNG exporter, having overtaken Qatar and Australia in 2023 with its abundant low-cost gas

Source: BCG analysis.
Note: bcm = billion cubic meters; LNG = liquefied natural gas.

SHIFT 7

Technology cost trajectories are diverging—some falling fast, others proving persistently more expensive

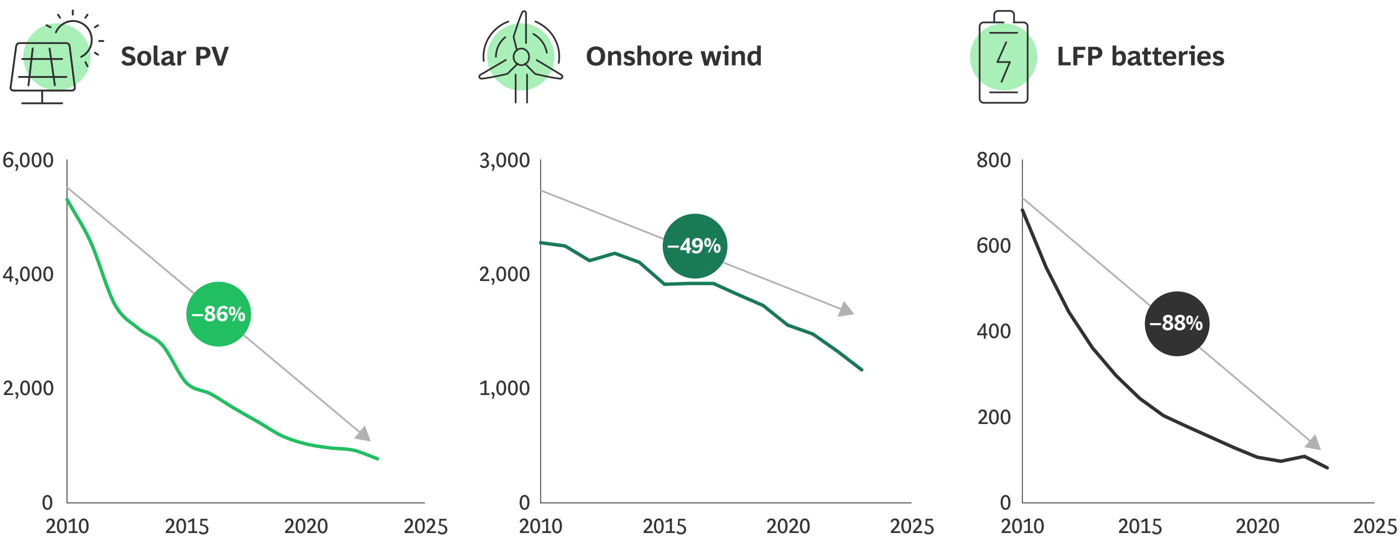
A two-speed reality is emerging in low-carbon energy economics. Although technologies like solar, onshore wind, and batteries have achieved cost reductions of up to 90% since 2010 and continue to benefit from rapid progress up their respective learning curves, the challenge lies in delivering firm, 24-7 low-carbon energy.

Several critical strategic solutions, such as green hydrogen, carbon capture, utilization, and storage (CCUS), and long-duration storage, remain more expensive than anticipated. The variation in cost-competitiveness reflects differences in maturity, with wind and solar benefiting from decades of R&D and scale effects, while solutions like hydrogen and CCUS remain tied to energy input costs, infrastructure complexity, and slower learning curves. Even core grid infrastructure, which requires significant expansion to enable renewable growth and to manage an intermittent system, is under strain. High-voltage direct-current substations and cable prices increased by more than 65% over the past five years due to demand spikes and constrained supply.

Furthermore, unlike firm and centralized systems such as fossil fuel plants, variable renewables are modular and distributed, which makes them easier to scale but harder to coordinate. This leads to a divergence in investment priorities between variable renewables and firm low-carbon capacity. Technologies essential for deep decarbonization—particularly in hard-to-abate industrial sectors—and for delivery of continuous power are struggling to scale, as costs have been slow to decline, limiting capital flows and deployment.

Solar, wind, and battery costs have decreased significantly

GLOBAL AVERAGE CAPEX FOR SELECTED ENERGY TECHNOLOGIES, 2010–2023 ($/kW)[1]



Sources: IRENA (2024); IEA; BNEF; BCG analysis.
Note: Note: kW = kilowatt; LFP = lithium iron phosphate; PV = photovoltaics.
[1]All prices are expressed in constant 2023 dollars.

Some key technologies are expected to be more expensive than previously forecast

More expensive than expected

FORECASTED 2030 GREEN H_2 COSTS IN CENTRAL EUROPE AS OF 2021 AND 2025 (€/kg)[1]

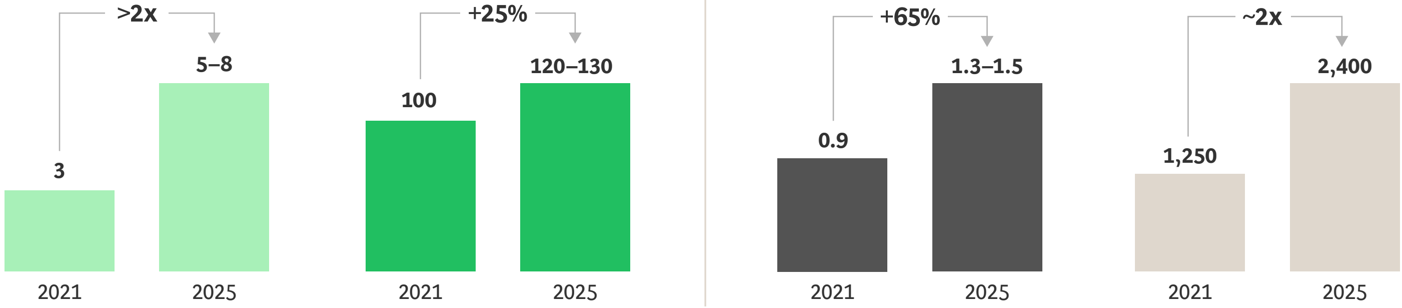
FORECASTED 2030 CCUS COSTS IN TEXAS AS OF 2021 AND 2025 ($/t$CO_2$)[2]

Increased demand and constrained supply

Could be temporary

FORECASTED 2030 PRICES FOR HVDC SUBSTATIONS AS OF 2021 AND 2025 (€B/GW)[3]

FORECASTED 2030 PRICES FOR CCGT TURNKEY EPC AS OF 2021 AND 2025 ($/kW)



Sources: IRENA; BloombergNEF; IEA; TenneT; Amprion; 50 Hertz; Reuters; Dragados; OE Digital; GE Vernova; National Grid; Offshore Wind; Enerdata; 4C; SSEN Transmission; NeuConnect; Terna; EIB; Sumitomo Electric; Renewables Snow; EIA; S&P Global; BCG Hydrogen Cost Model; BCG CCUS Cost Model; BCG analysis.
Note: B = billion; CCGT = combined cycle gas turbine; CCUS = carbon capture and storage; EPC = engineering, procurement, and construction; GW = gigawatt; HVDC = high-voltage direct-current; kg = kilogram; kW = kilowatt; tCO_2 = tons of carbon dioxide.
[1]All prices are expressed in constant 2025 euros.
[2]All prices are expressed in constant 2025 dollars.
[3]Projects with one offshore substation and one onshore substation.

Implications of the Seven Shifts

The seven shifts outlined above have four critical implications:

1. We need to reduce the overall cost and accelerate the build-out of enabling infrastructure
2. We can accelerate progress by doubling down on proven technologies and placing strategic bets
3. Energy affordability and customer agency are essential to sustain public support for the transition
4. The transition will vary across countries and regions—and strategies must follow suit

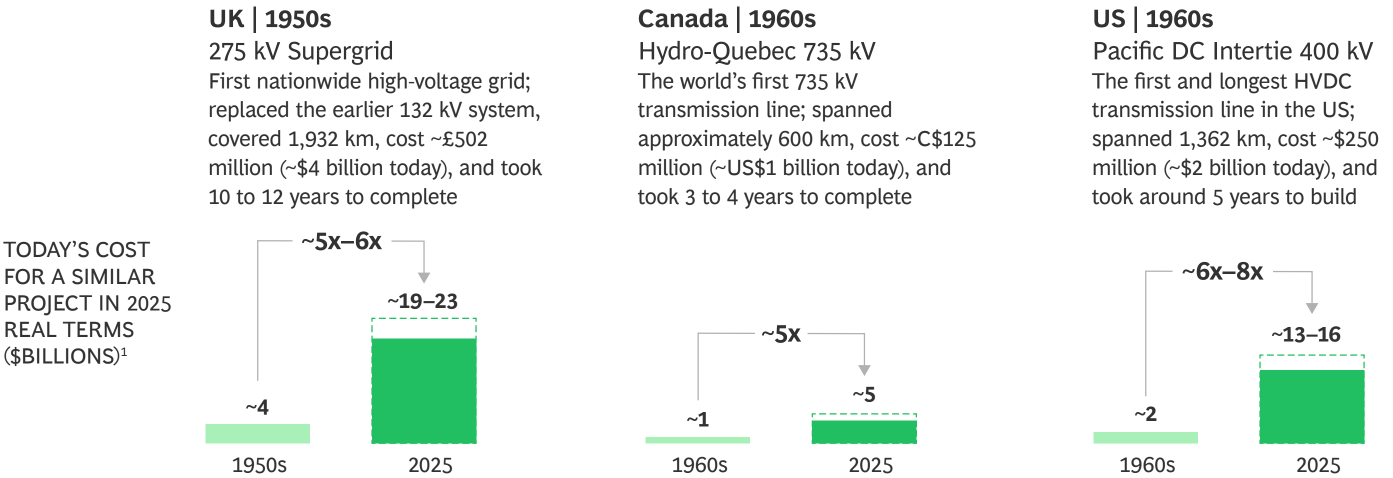
IMPLICATION 1

We need to reduce the overall cost and accelerate the build-out of enabling infrastructure

The cost of delivering large-scale grid infrastructure has increased about sixfold since the last major build-out, driven primarily by permitting delays, labor constraints, rising technical complexity, and supply chain bottlenecks. This is the case not only for electricity grids, but more broadly across all energy infrastructure. These pressures now risk slowing the energy transition and raising end-user costs. Reducing cost and accelerating delivery will require a combination of five levers:

1. Stress-test current demand and supply scenarios to ensure that we build the infrastructure truly needed in a changing energy landscape.
2. Unlock more capacity from existing assets by applying advanced analytics, modernized risk frameworks, and dynamic operations, while making smart tradeoffs between performing targeted upgrades and deferring large-scale overhauls.
3. Urgently accelerate permitting to help lower risk premiums while ensuring robust public engagement and environmental safeguards.
4. Improve capital project execution through more standardized design, tighter project controls, and greater strategic engagement between customers and suppliers to scale reliable supply chains for items with long lead times.
5. Reevaluate prior design choices (such as underground cable versus overhead line, and DC versus AC configurations) in light of recent cost escalations, to ensure that legacy decisions still make economic and operational sense.

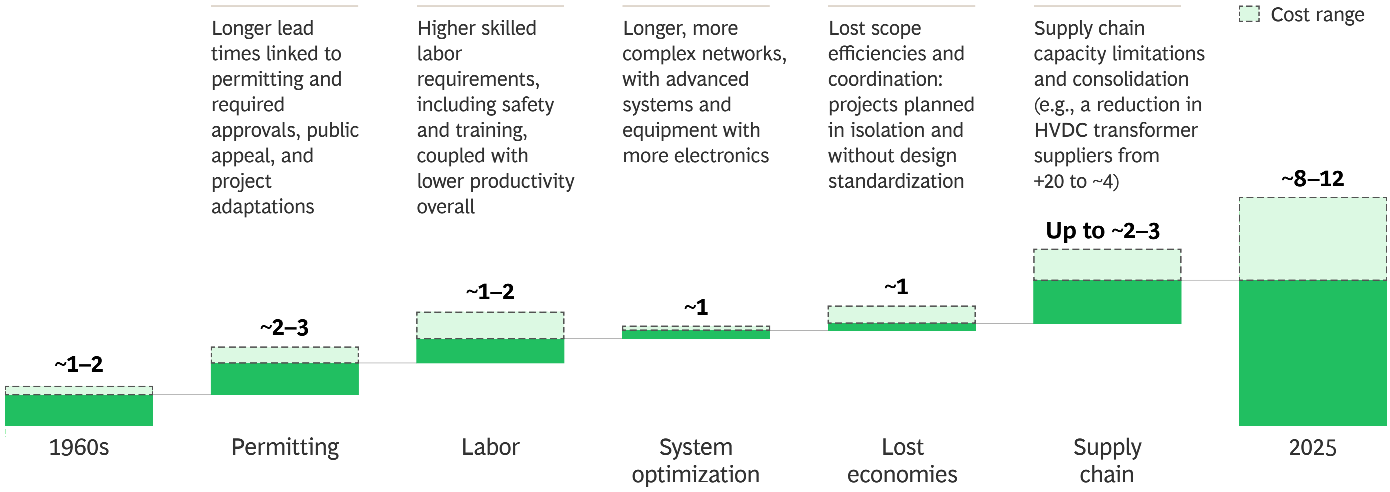
Grid build costs have increased about sixfold since the previous great infrastructure build-out



Sources: CHPE; D. Morton, "A Survey History of Electric Power Technology Since 1945"; J. Lewis & E. Severnini, "Short- and Long-Run Impacts of Rural Electrification: Evidence from the Historical Rollout of the US Power Grid"; Bonneville Power Administration; IEEE Power Engineering Society; US Department of Energy; Bank of Canada; US Federal Reserve; Bank of England; Prysmian; National Grid; Hydro-Québec; Ofgem; Oregon Historical Society; BCG Transmission Project Costing Tool; BCG analysis.
Note: HVDC = high-voltage direct-current; kV = kilovolts.
[1]Nominal costs rose from ~$0.1 million/km in 1953 to ~$10 million to –$12 million/km today (UK), from ~$0.2 million/km in 1965 to ~$7 million to $9 million/km today (Canada), and from ~$0.2M million/km in 1970 to ~$10 million to –$12 million/km today (US), considering the range of project costs based on actual projects to be completed between 2025 and 2035 and assuming a 1953 £/$ exchange rate of 2.81, a 2025 £/$ exchange rate of 1.20, a 1965 C$/US$ exchange rate of 0.93, and a 2025 C$/US$ exchange rate of 0.70. 2025 dollars.

Permitting, labor, technology, coordination, and supply chain are driving the surge in costs versus the 1960s

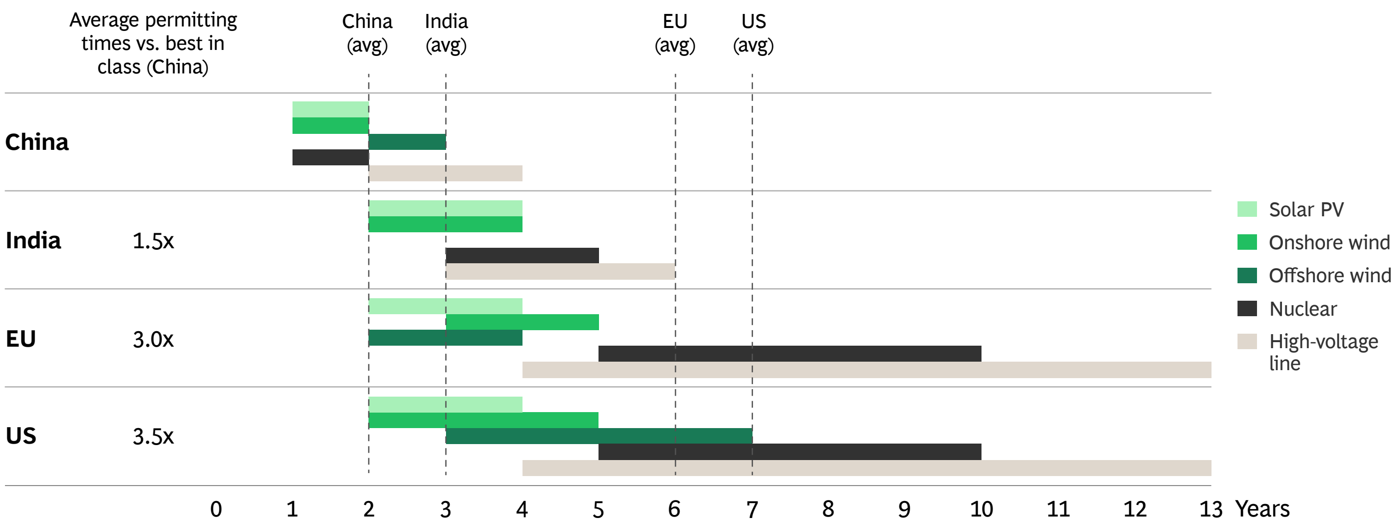
RELEVANT DRIVERS OF INCREASED COSTS ($MILLIONS/km)[1]



Sources: US National Bureau of Economic Research; expert interviews; TEN-E; BCG project experience; BCG analysis.
Note: Factors such as higher population density, reduced land availability, and increased demand for decarbonization and for greater power reliability are indirectly included in other categories such as permitting and supply chain. HVDC = high-voltage direct-current; km = kilometers.
[1]All prices are expressed in constant 2023 dollars.

Permitting times in the EU and the US are about three times as long as those in China

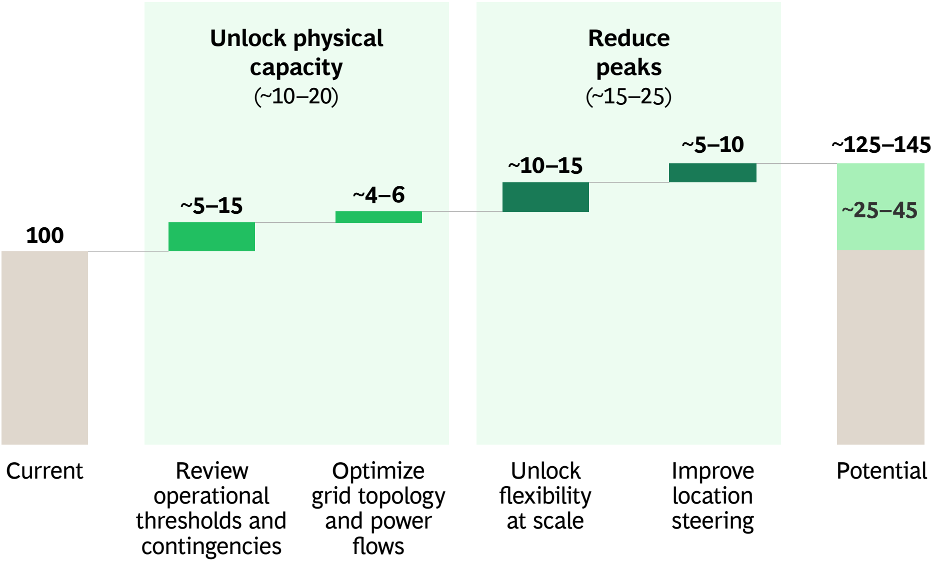
TYPICAL PERMITTING TIME FOR CRITICAL PROJECTS FOR THE ENERGY TRANSITION (YEARS)



Sources: US Permitting Dashboard; IEA WEO 2022; IAEA; NEA; BCG analysis.
Note: As yet, there are no offshore wind projects in operation in India. Times listed are average times across all project types. PV = photovoltaics.

We could get more out of our existing grids

GRID CAPACITY BREAKDOWN AND ESTIMATED IMPROVEMENT POTENTIAL (%)



- Up to 45% greater grid capacity can be unlocked without new cabling
- **Physical headroom** comes from dynamic line rating, thermal efficiency, redesigned flows, and smarter grid planning
- **Peak load** can be flattened via behind-the-meter flexibility, enabled by the right incentives (such as dynamic tariffs)
- Optimization requires risk-informed, digital, dynamic grids, with AI-driven analytics and scenario-based design

Sources: Netbeheer Nederland (IBO); Federal Energy Regulatory Commission; National Grid; ABB; NREL; ERCOT; Brattle Group; Nicholas Institute at Duke; BCG analysis.

IMPLICATION 2

We can accelerate progress by doubling down on proven technologies and placing strategic bets

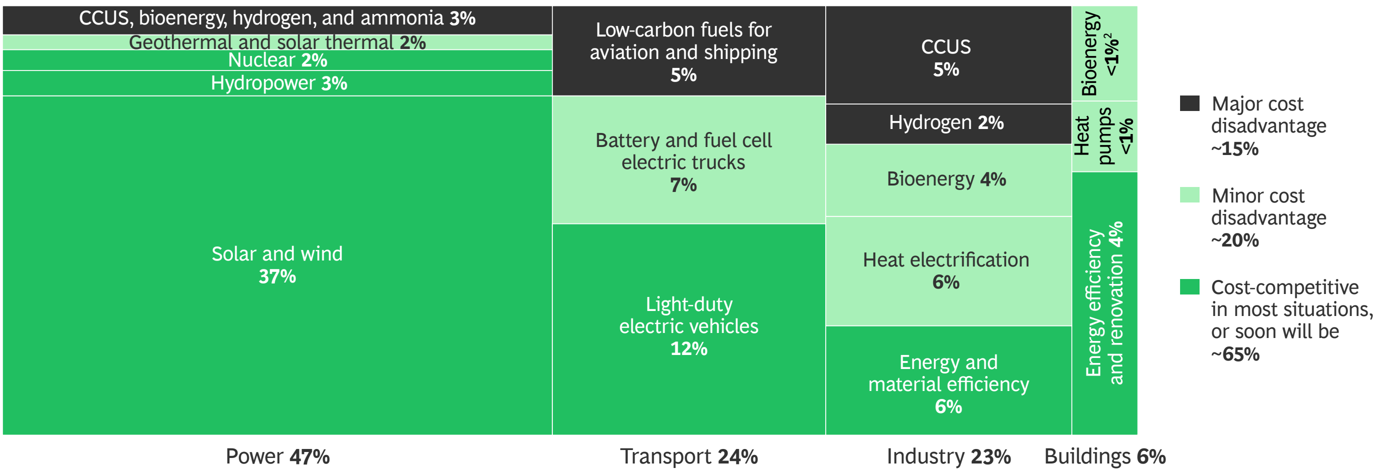
Roughly two-thirds of energy-related emissions can be addressed using commercially available technologies, especially in parts of power generation and in electrifying certain end uses. In many cases, deployment still depends on structural support—whether through contracts for difference, tax credits, or policy mandates. The transition's success will hinge on what is already "in the money" and on which business cases that are not yet "in the money" can be strengthened through clear and stable policy frameworks. Technologies like wind, solar, and EVs have benefited from this kind of support for decades, and largely still do.

The impact can be material: gasoline demand falls by 19,000 barrels/day (or diesel demand by 24,000 barrels/day) for every one million EVs that take to the road. BCG modeling shows that as the EV market expands, CO_2 emissions from light-duty vehicles could drop by nearly one-third by 2035. There is a similar opportunity to facilitate the development of solutions for harder-to-abate parts of our emissions. Gas power with CCUS, for instance, is projected to be economically viable by 2035 under a carbon price of $125/ton, a gap that can be closed today through carbon contracts for difference.

First CCUS projects, from gas turbines to cement kilns, are being sanctioned across power and industry. These are not moonshots, but bankable with the right underwriting. Rather than separating technologies by cost alone, we must differentiate by system role, substitutability, and maturity, and design support accordingly. A strong deployment pipeline depends on treating cost-effective scaling and strategic bets as part of the same strategy.

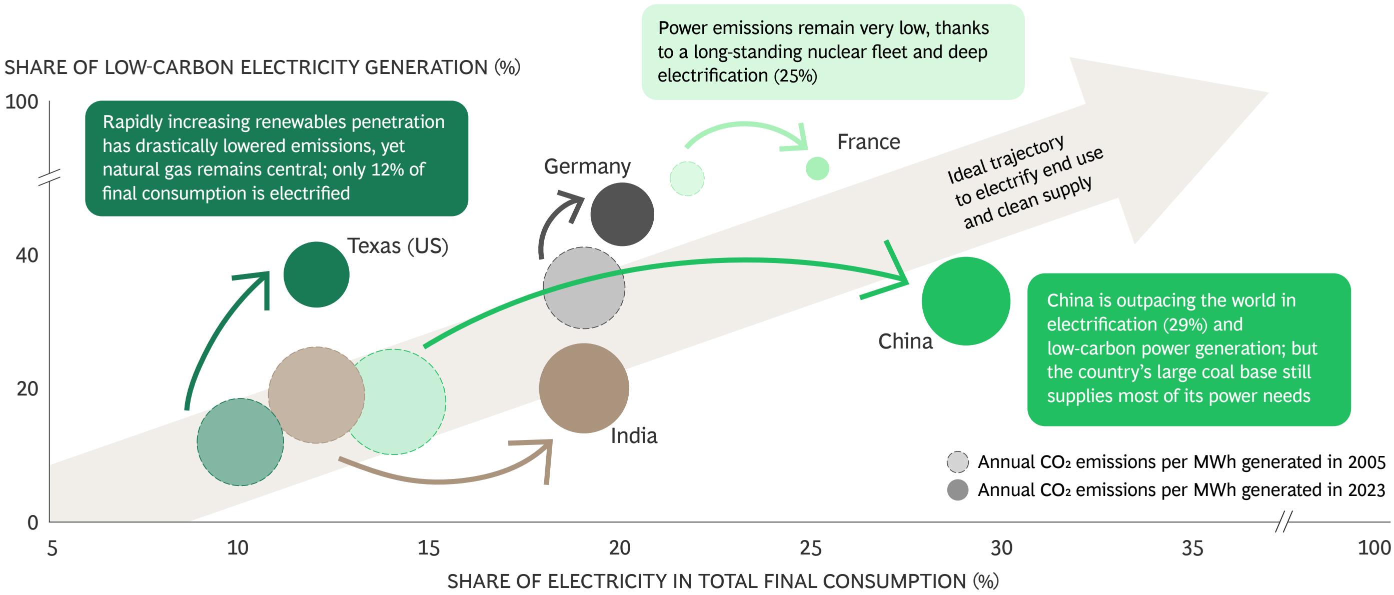
Two-thirds of energy-related emissions can be abated with positive business cases for the asset owners today

GLOBAL ENERGY-RELATED GREENHOUSE GAS MITIGATION REQUIRED BY 2050 TO REACH 1.5°C, AS A PERCENTAGE OF NET GT CO_2e PER YEAR[1]



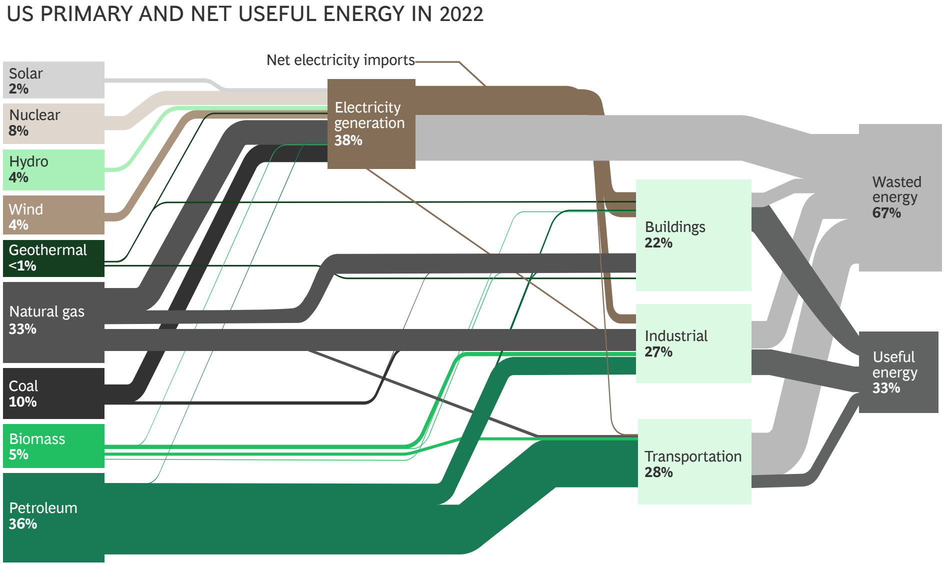
Sources: IEA; IPCC; Höglund-Isaksson et al. (2021); BCG analysis.
Note: Cost-competitiveness is defined in comparison to today's higher-GHG reference, including capex and opex, and is measured from the perspective of the business case for an individual asset owner (i.e., does not present a full system view). CCUS = carbon capture, utilization, and storage. Because of rounding, not all bar segments add up to 100%.
[1]Annual emissions at projected 2050 level; current cost-competitiveness.
[2]For heating only.

To decarbonize, countries can electrify end uses and clean the supply; accelerated progress is possible



Sources: EDGAR; IEA; EIA; BCG analysis.
Note: Texas was chosen as example for the US because of strong availability of relevant data and extensive renewables penetration in the state. MWh = megawatt-hour.

Roughly two-thirds of primary energy is wasted, making electrification and efficiency powerful opportunities



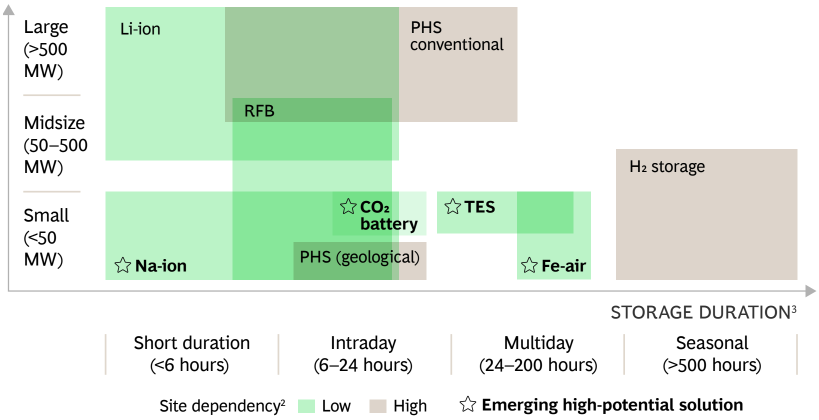
- The majority of energy losses stem from thermal inefficiency in fossil-based systems. Even modern combined cycle gas turbine (CCGT) plants lose ~30% of input energy as heat, while coal plants lose ~60%. By contrast, solar and wind convert primary energy to electricity directly, with no combustion loss.
- Reducing these losses requires shifting electricity generation from combustion to renewables (e.g., CCGTs to solar) and shifting end use from thermal to electric (e.g., replacing blast furnaces with electric arc furnaces or ICE vehicles with EVs).
- Companies that improve their energy efficiency—and pass savings onto customers—can strengthen customer loyalty and enhance their license to operate.

Sources: Lawrence Livermore National Laboratory; DOE; EIA; BCG analysis.

Only a few storage technologies reach multiday scale with low constraints, but breakthroughs are coming

Achieved storage capacity and duration across technologies

DEMONSTRATED PROJECT SCALE[1]

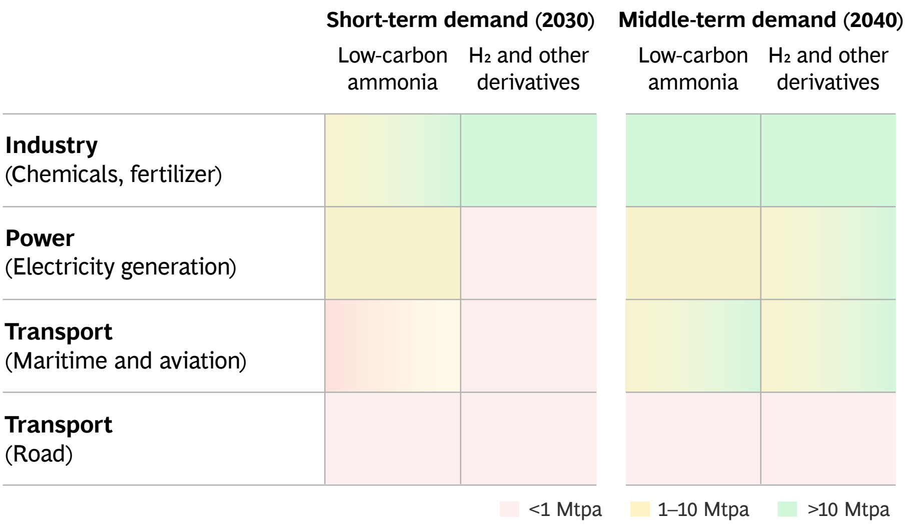


- As variable renewables scale, closing long-duration storage gaps becomes essential for renewables integration and system reliability
- Most mature technologies (including Li-ion, NaS, RFB, and PHS) are limited to short or intraday durations, and they are often site dependent
- Li-ion dominates current deployment (200 GWh by 2025), targeting durations of up to 8 hours. Early 24-7 solar+BESS can be seen in operation in the Middle East
- Emerging options like Na-ion, CO_2 batteries, TES, and Fe-air show multiday traction but are immature; seasonal storage remains largely limited to hydrogen (site dependent)
- Falling costs could unlock broader deployment of some storage technologies across use cases

Source: BCG analysis.
Note: BESS = battery energy storage system; Fe-air = iron-air battery; FID = final investment decision; GWh = gigawatt-hour; Li-Ion = lithium-ion battery; MW = megawatt; Na-Ion = sodium-ion battery; NaS = sodium-sulfur battery; PHS = pumped hydro storage; RFB = redox flow battery; TES = thermal energy storage.
[1]Includes projects post-FID.
[2]"Site dependency" refers to the degree to which local geographic, geological, or infrastructure conditions constrain a storage technology's deployment.
[3]"Storage duration" refers to the number of hours a storage system can discharge at rated power before depletion.

Hydrogen has fallen short of previous expectations, but it still holds value—especially for ammonia

POTENTIAL FOR LOW-CARBON HYDROGEN AND DERIVATIVES ACROSS FOUR VERTICALS

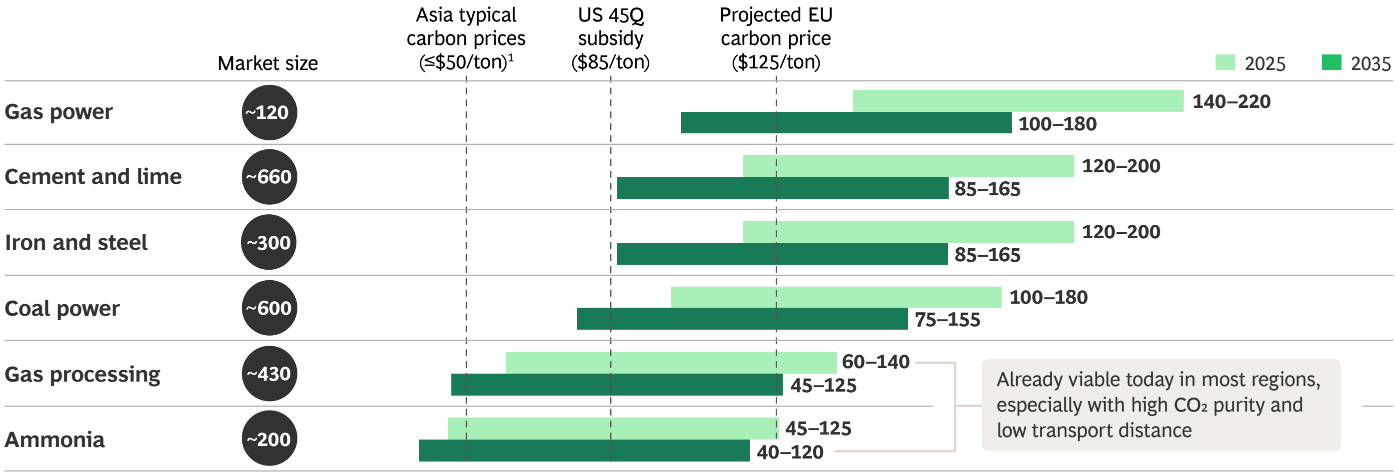


- Global demand projections for low-carbon H_2 in 2030 have fallen by ~50% in the past three years, driven by rising costs, slow infrastructure progress, and weak offtake certainty
- Ammonia is leading early uptake, backed by mature infrastructure and a large existing fertilizer market
- Industrial sectors are moving first, where low-carbon hydrogen can replace gray H_2 with minimal system changes and policy-driven pull
- Power sector demand is region-specific, with Japan and South Korea advancing ammonia-based generation under strong policy support

Source: BCG analysis.
Note: Mtpa = million metric tons per year.

CCUS can be cost-competitive with strong policy support, but gaps with unabated options remain across sectors

GLOBAL 2050 ESTIMATED MARKET SIZE (Mtpa) AND INTEGRATED 2025–2035 CCUS COSTS ($/$tCO_2$)



Sources: EPA; IEA; GlobalData; BCG CCUS Model; BCG analysis.
Note: Market size is based on IEA APS 2050 scenario. Capture cost (depending on plant size): ammonia 1.2 Mtpa, natural gas processing 0.14 Mtpa, iron and steel 0.55 Mtpa, coal power 3.2 Mtpa, gas power 0.7 Mtpa, cement 0.7 Mtpa. Energy prices: $100/MWh for electricity and $4.51/MBtu for natural gas; 12% learning rate and deployed according to IEA APS scenario. CO_2 concentration: ammonia and gas processing (~100%), iron and steel (17–35%), coal power (12–15%), gas power (3–4%), cement (14–33%). Transport and storage: $20–$100/ton, with lower end representing pipeline to onshore storage and upper-end shipping to offshore storage. CCUS = carbon capture and storage; Mbtu = million British thermal units; MWh = megawatt-hour; Mtpa = million metric tons per year; tCO_2 = tons of carbon dioxide.
[1]Typical carbon prices in Asia range from $0 per ton to $50 per ton, depending on the country.

IMPLICATION 3

Energy affordability and customer agency are essential to sustain public support for the transition

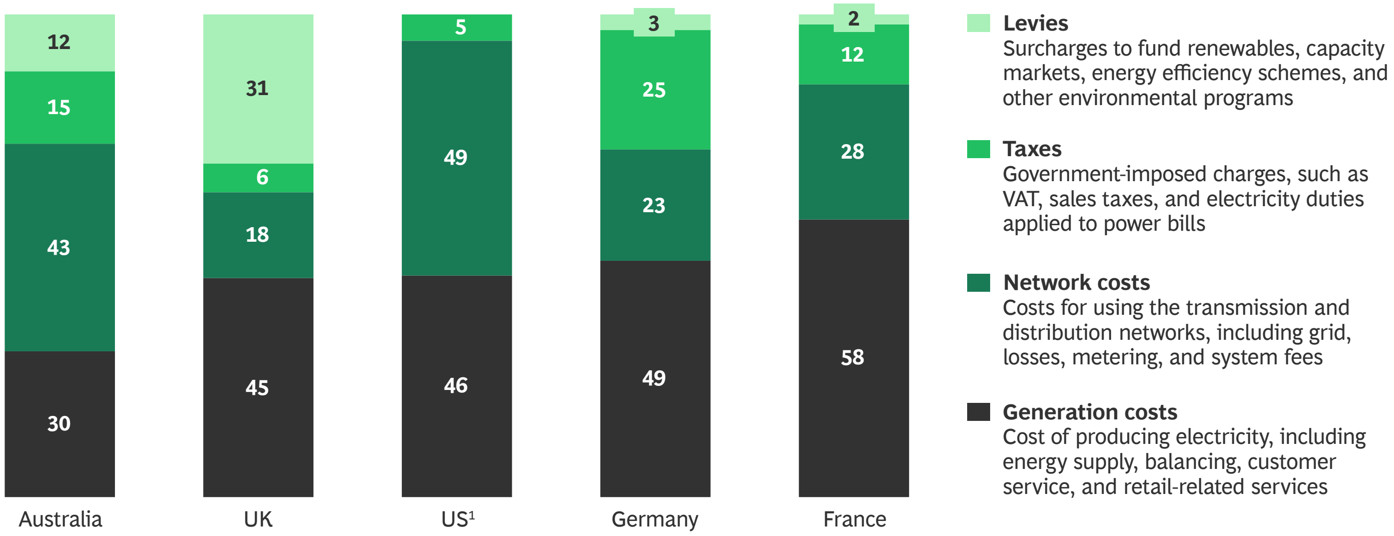
The credibility of the energy transition depends not only on cost reductions, but also on who pays, and how. In many countries, nongeneration costs such as grid charges, levies, and taxes make up more than half of residential electricity bills. When these costs are passed through via flat-rate or regressive structures, they disproportionately burden lower-income households and small businesses. That erodes political support and fuels resistance.

But affordability isn't just a constraint to manage, it's also a lever for change. When consumers are empowered to shape their energy use—through flexible pricing, rooftop solar, community energy, or participation in demand-side markets—they become **allies in the transition**. This is even more likely in a process of change that carries other consumer benefits such as reduced air pollution. Demand-side activation is not an optional add-on, but core infrastructure for transition success.

A new generation of customer-facing energy models is emerging: communal storage platforms, public utilities that reduce pass-through costs, and digital tools that allow households to optimize consumption in real time. These are not just ways to lower bills; they are ways to build enduring support for the transition.

Nongeneration costs make up the majority of power bills

BREAKDOWN OF ELECTRICITY BILL COMPONENTS FOR RESIDENTIAL CONSUMERS IN 2023 AS A PERCENTAGE OF THE TOTAL BILL (%)



Sources: Eurostat; UK Office of Gas and Electricity Markets; US Energy Information Administration; Australian Energy Market Commission; BCG analysis.
Note: VAT = value-added tax.
[1]New England data, chosen as electricity prices close to national average, balanced energy mix, relatively average tax structures, and moderate policies are representative of the broader US.

IMPLICATION 4

The transition will vary across countries and regions—and strategies must follow suit

The core pillars of the energy transition are universal: maximize energy efficiency; scale renewables; deploy low-carbon firm power; build grids; decarbonize industry through electrification, CCUS, and low-carbon fuels; and capture or offset residual emissions.

But the sequence, pace, and mechanisms for delivering these goals will vary widely—shaped by each country's starting point, resource endowment, industrial base, institutional capacity, and market structure. Consequently, strategies must be tailored—not just at the national level, but in many cases regionally and locally. What works in Germany may not work in Indonesia or Texas. For policymakers, this means designing systems that are feasible for the specific context, not the conceptually perfect system.

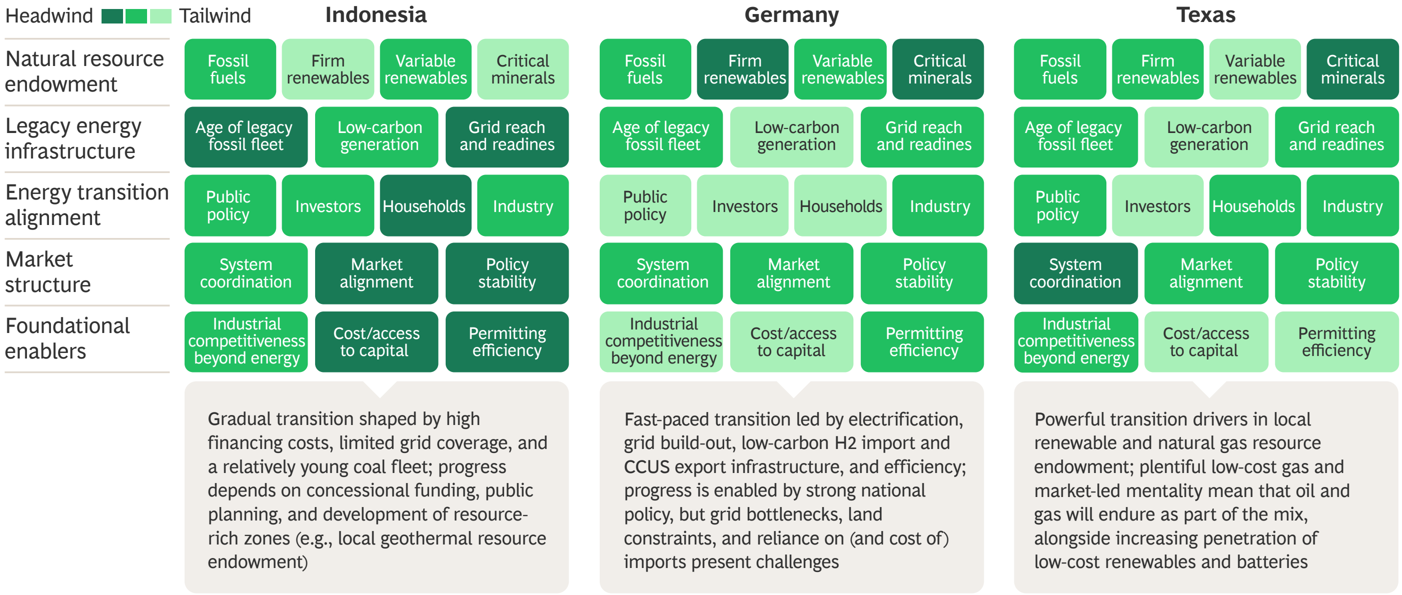
For companies and investors, it means segmenting markets by technology fit, policy maturity, and bankability—and timing bets accordingly. For multilateral actors, it means focusing on alignment where it matters most: industrialization of common technologies, shared standards, finance mechanisms, and interoperable infrastructure.

Taking a systems perspective: Starting point, momentum, and enablers shape each country's transition

SUPPLY	**Natural resource endowment**	Fossil fuels (e.g., coal, gas, oil)	Firm renewables (e.g., geothermal, hydro)	Variable renewables (e.g., potential for solar, wind)	Critical minerals (e.g., copper, lithium)
SUPPLY	**Legacy energy infrastructure**	Age of existing fossil fleet	Share of low-carbon generation	Current grid reach and readiness	
DEMAND	**Energy transition alignment**	Public policy	Investors	Households	Energy-intensive industry
ENABLERS	**Market structure**	System coordination (degree of centralized transition planning and execution management)	Market alignment (how well investment and pricing signals reinforce the plan)	Policy stability (ability to maintain long-term direction across political and market cycles)	
ENABLERS	**Foundational enablers**	Industrial competitiveness beyond energy (e.g., low-cost manufacturing, innovation)	Cost and access to capital (e.g., credit rating)	Permitting efficiency (e.g., speed, predictability, and simplicity)	

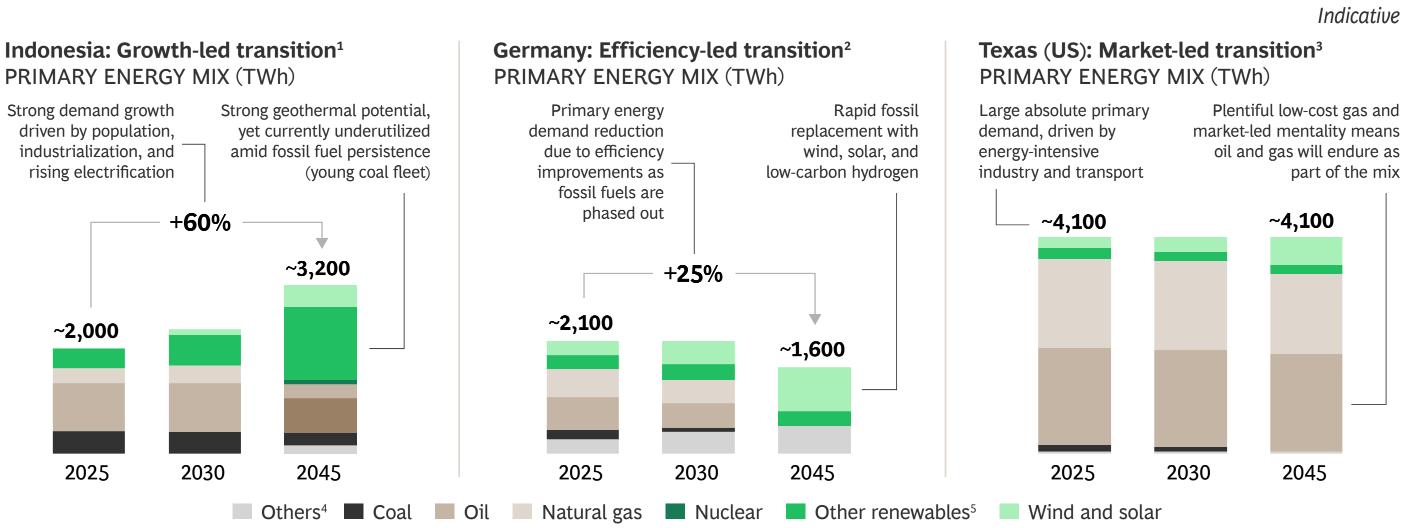
Source: BCG analysis.

The transition will take different paths across countries and regions



Source: BCG analysis.
Note: Texas was chosen as example for the US because of strong availability of relevant data and extensive renewables penetration in the state. Color indicates impact on the energy transition, not necessarily the country's or region's strength on the dimension; for example, Texas fossil fuels shown as orange, given the availability of abundant low-cost gas, but access to gas also supports the transition (although it emits CO2 without CCUS). CCUS = carbon capture, utilization, and storage.

Evolution of its energy mix reflects a country's starting point and position



Sources: JETP Secretariat and Working Groups (2023); IEA; IESR; IRENA; Enerdata; BDI (2025); ERCOT; EIA; BNEF; BCG analysis.
Note: For Indonesia's nonpower energy use, 2018–2030 and 2030–2050 were interpolated based on the IRENA 1.5°C scenario; Texas was chosen as example for the US because of strong availability of relevant data and extensive renewables penetration in the state. TWh = terawatt-hours.
[1]Based on JETP scenario as described by JETP Secretariat and Working Groups.
[2]Based on BDI x BCG report of Net Zero by 2045 scenario, 2025.
[3]Based on US EIA Reference Case for West South Central, extrapolated based on Texas share in 2023 (66%).
[4]Includes hydrogen, distributed heat, and others.
[5]Includes hydropower, geothermal, and bioenergy.

Recommendations

Different key players can take role-specific actions to advance the energy transition:

1. Recommendations for grid owners and operators
2. Recommendations for large consumers
3. Recommendations for energy producers and suppliers
4. Options for policymakers as they navigate the transition

RECOMMENDATION 1

Recommendations for grid owners and operators

1 **Stress-test future demand and supply scenarios.** Ensure that we build the infrastructure truly needed in a changing energy landscape.

2 **Get more out of existing assets. Conduct detailed asset reviews to understand true limits.** Unlock latent headroom through advanced analytics, modernized risk frameworks, and dynamic operating practices. Consider smaller replacement works instead of major overhauls to push some projects a few years out.

3 **Accelerate permitting as a nonnegotiable delivery lever.** Treat permitting as a mission-critical path item. Work with stakeholders to streamline processes, pre-identify environmental hurdles, and advocate for fast-track pathways to prevent delays in delivery timelines.

4 **Strengthen capital project execution and supply chain resilience.** Scale standardized design practices, reliable supply chains based on strategic engagement between customers and suppliers, delivery coordination, and project controls.

5 **Reform grid connection processes to deal with connection queues.** Demand for new grid connections is accelerating, but connection processes were not designed for this scale or level of complexity. Grid operators must investigate levers comprehensively to address structural bottlenecks in both connection studies and connection delivery.

6 **Reassess legacy design standards in light of today's costs.** Re-evaluate infrastructure design assumptions—such as underground vs. overhead cabling or DC vs. AC—to ensure that legacy choices still make sense amid rising costs and supply chain bottlenecks.

7 **Actively shape and price flexibility to reduce peak demand.** To smooth load curves and reduce expensive grid reinforcement needs, design and scale demand-side products such as interruptible load contracts, local flexibility auctions, or behind-the-meter storage.

8 **Explore innovative financing models to unlock constrained capital.** In the context of of many grid companies' stretched balance sheets, consider nontraditional financing sources to enable much-needed continued investment in electricity grids. These might include new equity raises, minority stake sales, divestment of noncore assets, or even direct government funding of grid.

RECOMMENDATION 2

Recommendations for large consumers

1 **Assume that clean energy will be constrained, and compete accordingly.** Lock in clean energy—electrons and molecules—early, via long-term contracts with flexible delivery models (power purchase agreements, virtual power plants, heat-as-a-service) before supply tightens, to avoid risking exposure to price volatility and policy-driven rationing.

2 **Become a prosumer.** Invest in onsite generation, demand shaping, and storage to increase autonomy and manage volatility.

3 **Build infrastructure in coordinated clusters, not as stand-alone assets.** Hydrogen, CCUS, and high-voltage grids work only with scale and coordination. Initiate joint infrastructure development—including shared financing and demand aggregation with peers—and stake equity to unlock solutions for harder-to-abate emissions.

4 **Make flexibility a revenue stream, not just a contingency plan.** Treat demand-side flexibility and controllability as products, not as risk mitigation, and build capabilities to participate in capacity balancing and ancillary services markets.

5 **Design capex for adaptability, not just for cost efficiency.** Prioritize investments in equipment and infrastructure that can be retrofitted, co-located, or fuel-switched, and carefully consider long payback investments that assume static market conditions. Modularize build-outs in situations where uncertainty is high.

RECOMMENDATION 3

Recommendations for energy producers and suppliers

1 **Selectively invest in oil and gas, focusing on low-carbon, low-methane reserves.** Secure long-term reserves by prioritizing exploration and development of low-carbon resources, while aggressively reducing methane leakage and operational emission from proven reserves. Invest in resilient LNG infrastructure to serve both domestic and global needs.

2 **Reshape asset portfolios aligned to core capabilities to stay ahead of demand shifts and asset risk.** Proactively downsize or repurpose legacy assets ahead of market declines, reducing exposure to stranded assets in long-cycle infrastructure. At the same time, invest in proven low-carbon drop-in solutions like biofuels and biomethane.

3 **Innovate to reduce cost structures, managing down costs over time.** To drive down cost structures over time—especially in an inflationary environment—embed digital tools and predictive and generative AI into core workflows, rethink outdated business processes and decision cycles, and realign organizational models to these innovations.

4 **Integrate demand-side assets to avoid diminishing returns.** Maximize system value by co-locating and integrating demand-side assets (such as electrolyzers, batteries, or dispatchable load), to reduce curtailment and unlock grid-constrained growth.

5 **Differentiate through customer-facing decarbonization with energy service models.** Move beyond commodity sales by offering decarbonization-as-a-service bundles—such as heat-as-a-service—or behind-the-meter battery optimization to help customers navigate policy, permitting, and technology complexity.

6 **Help manage volatility for end users, and monetize it.** Design product offerings that soak up risk instead of passing it on, such as flexible tariffs, hedging-as-a-service, or demand response aggregation to secure a premium for volatility management.

RECOMMENDATION 4

Options for policymakers as they navigate the transition

Policymakers can consider a variety of possible moves; the right mix of actions will depend on the country's context and starting point

1 **Prioritize total system cost and value in market design.** Today's market designs often reward lowest marginal cost instead of long-term system value. Move toward capacity mechanisms, contracts for firm power, and efficient integration of electricity and molecules. Focus on a balance of full-system outcomes: cost, reliability, resilience, and sustainability.

2 **Accelerate deployment of "in the money" technologies, and electrify where feasible.** Scale proven technologies such as wind, solar, EVs, batteries, and heat pumps; in many cases, they already outcompete conventional energies. Expand enabling infrastructure, including grids and flexibility mechanisms, to support widespread electrification of transport, heat, and industry.

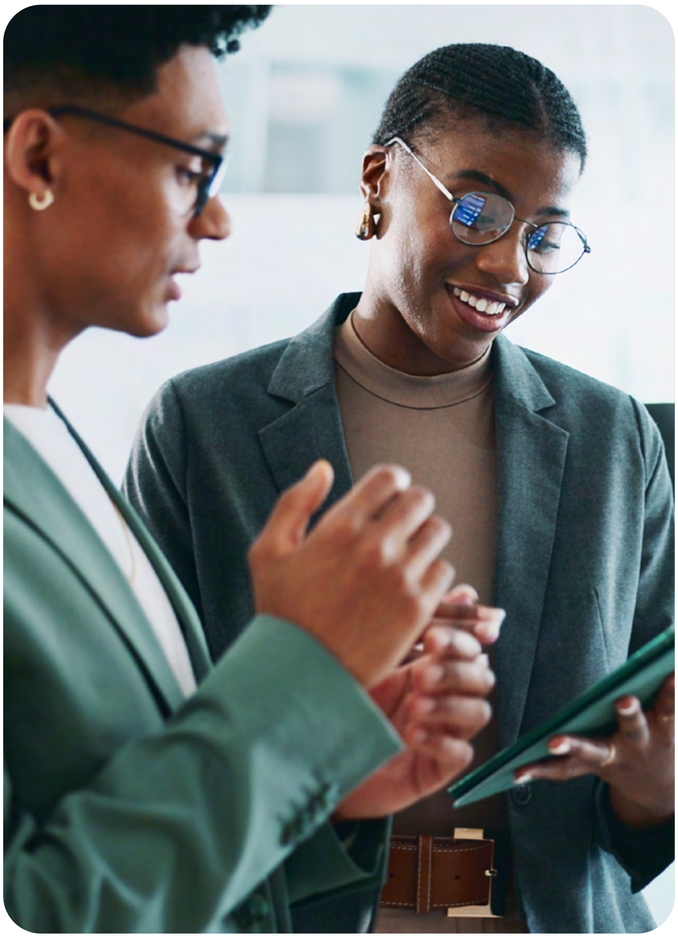
3 **Convert permitting from a bottleneck to strategic advantage.** Treat permitting reform as national (and in the US, for example, regional) infrastructure policy. Build fast-track channels for key energy transition projects, backed by pre-approved zoned corridors, develop digital one-stop permitting hubs, and set permitting time limits by statute.

4 **Aim for stable and enduring policy, with clear benefits communicated to the public.** Policy consistency lowers financing costs and enables private investment, including in developing, deploying, and lowering the cost of advanced technologies. Define longer-term energy system pathways with clear targets, incentives, and governance stability. Prioritize public financing that draws in private capital at significant leverage. And invest in explaining to the broader public the rationale for and benefits of the changes.

5 **Recognize energy security and affordability as national strategic priority and fund accordingly.** Define, track, and publish national energy independence indicators such as domestic supply share, import concentration, and storage adequacy. Use these to actively guide investment and policy choices, prioritizing infrastructure that improves resilience even when it is not the lowest-cost option.

6 **Differentiate short-term technology risk from long-term commodity exposure.** Technology risk is one-off and declines with deployment. Commodity risk is persistent and systemic, and it often materializes cyclically. Use targeted support mechanisms—such as upfront innovation grants and indexed fuels pricing—that reflect this asymmetry.

7 **Enhance and build further on carbon markets; broaden to carbon accounting over time in hard-to-abate sectors.** Carbon markets remain the most efficient way to internalize climate externalities. Protect their integrity, expand their coverage, and provide long-term price guidance to investors even amid short-term volatility.



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