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# PREFACE



> Our energy system has transformed before, but not like this, and not this fast … We're trying to rewire the global economy to meet an urgent environmental imperative.

We wanted to open this report with a powerful anecdote to illustrate the huge size, scope and speed of the energy transition.

The truth is, we couldn't choose just one from the many examples of innovation unfolding across the world. A pipeline to pump green hydrogen more than 5,000 kilometers from West Africa to Morocco and eventually Europe. The world's biggest copper mine switching to 100% renewable energy three years ahead of schedule. Investment banks pouring billions into battery recycling. Even a Californian collaboration between a fuel cell company and a carmaker that will turn biogas and sludge into clean electricity, hydrogen and water.

Across industries and governments, and in our own homes, both big and small changes are together driving a global energy revolution. Electric vehicles (EVs) fill more driveways. Boards are focused on performance against sustainability metrics. Nanogrids are bringing power to villages for the first time. Our energy system has transformed before, but not like this, and not this fast. Previous transitions have been driven by new technologies and achieved through market forces. These play a part in this change too, as well as a changing consumer, but our primary aim this time is far more ambitious. We're trying to rewire the global economy to meet an urgent environmental imperative.

The bad news is that we're simply not moving fast enough. The target to limit global warming to 1.5 degrees Celsius is unlikely to be met. The good news is that progress is accelerating. The new EY Energy and Resources Transition Acceleration model, combined with deep industry knowledge and experience, confirms that the energy transition has reached critical momentum and is accelerating. Our model also highlights that this journey to the new energy future will not be linear, or singular. In fact, we believe that talking of one energy transition denies the complexity of the change ahead. Multiple transitions will unfold at varying paces and in many ways.

> We believe that talking of one energy transition denies the complexity of the change ahead. Multiple transitions will unfold at varying paces and in many ways.

These transitions will proceed at different speeds, depending on individual markets' motivations and resources, but all will now move ahead at pace. We're entering a decade of disruption, shaped by new technology and underpinned by government policy. The build-out of renewables to date has been relatively simple compared with what comes next. Decarbonizing a largely hydrocarbon-powered industrial sector is the far more difficult challenge – and our ability to tackle it will determine the ultimate success of the world's transition to clean energy. Making it happen will involve governments facing tough choices, balancing economic and environmental priorities to set policy that sends the right signals to the market and, ultimately, all of us. Energy transitions in every country will only succeed if they deliver more value to industrial consumers and end users – you and me – and this requires clean energy solutions that are genuinely better and cheaper.

Accelerating change will have eight major implications for our energy system, and for the energy and resources companies at its heart. These implications indicate a volatile transition. Technologies will reach tipping points and be adopted in overlapping waves. Capital portfolios must shift to both sustain legacy assets and incentivize investment in the new. Supply chains will evolve to meet demand for different minerals and materials. For power and utilities, mining and metals, and oil and gas companies, the road ahead will be challenging and often uncertain. Reshaping operations, culture and customer relationships will be complex, requiring huge investment, new capabilities and different skills. The sectors will need to make various trade-offs, keeping energy security, sustainability and supply in balance. And each company will face its own dilemmas – determining which changes to make and when, amid ongoing uncertainty and, for multinationals, inconsistency across different markets.

> "Organizations that commit to the right choices now can secure their own future and amplify our collective impact in accelerating the journey to a new energy system.

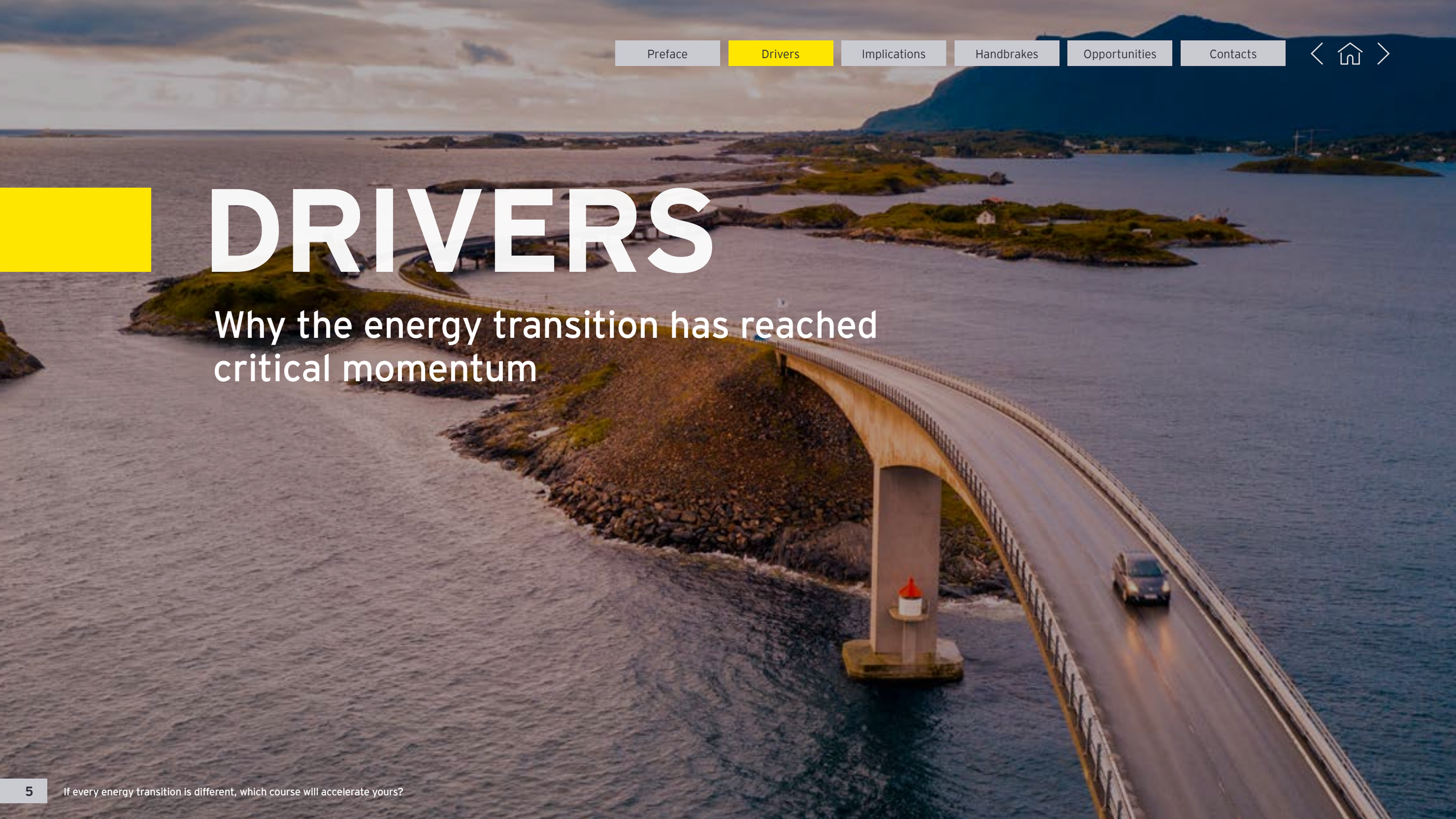
Making these changes will inevitably create new risks for the energy and resources industry. But the greatest risk comes from inaction – companies that don't adapt will see revenues decrease, access to capital become harder and competitors steal market share. We believe that enormous commercial opportunities are on offer for those organizations that act now to play their role in the shift to a cleaner, more resilient, integrated and affordable energy system. In this report, we outline a series of no-regret actions that companies in each sector can take now to capture value from our changing energy system. They are a starting point, because every organization will need to consider their own path across multiple energy transitions. None are easy. But we're confident they are possible – this is an industry that knows how to do hard things. Organizations that commit to the right choices now can secure their own future and amplify our collective impact in accelerating the journey to a new energy system.

## The EY Energy and Resources Transition Acceleration model

The Energy and Resources Transition Acceleration model – an EY proprietary tool – leverages over 50,000 data points to identify the timelines by which conventional energy assets are likely to be partially or fully replaced by the widespread adoption and integration of new energy technologies. It assesses 13 regions and considers 52 generation and end-use technologies, analyzing the impact of four key levers on the future energy mix:

1. Technology advancement, considering current and emerging trends, speed of scaling and impact on cost
2. Commodity supply, considering forecast demand and possible bottlenecks
3. Consumer engagement, including adoption of technology such as EVs
4. Government policy, including current regulation and potential changes

The model's in-depth analysis is designed to help organizations understand and explore the likely energy transition scenarios. It provides a platform for strategic discussions about the different energy transition strategies available to them and the resulting implications, opportunities and no regret actions for their organizations.



# DRIVERS

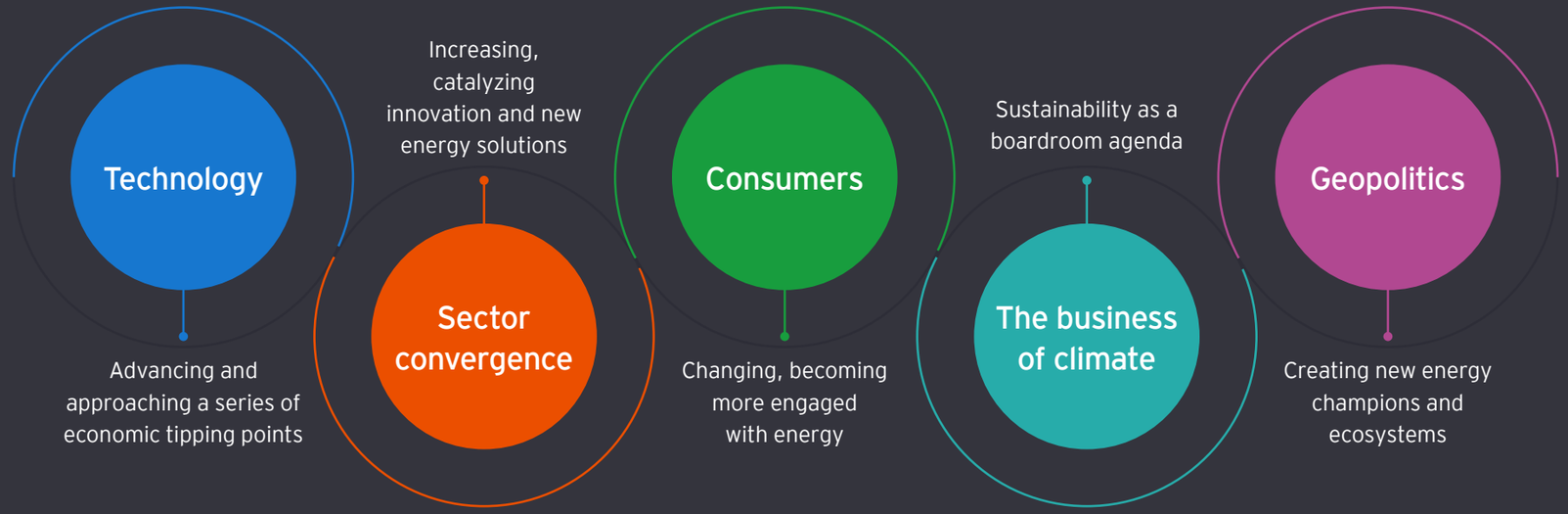
## Why the energy transition has reached critical momentum

"Double down and triple up." In September 2023, EY joined the Global Renewables Alliance and more than 250 other organizations to call on world leaders to agree to a target of tripling renewable electricity capacity to at least 11,000 gigawatts (GW) by 2030 at COP28.

It's an ambitious target, but one we believe is critical if we are to secure a livable future for all of us. Keeping global warming to the 1.5 degrees target set in Paris would require a 45% reduction in greenhouse gas emissions by 2030 – the UN predicts they will instead rise by 10%.

But while progress toward a new energy system has not been fast enough, it has rapidly picked up speed over the past couple of years. Renewables build-out and adoption of energy technologies have outpaced most forecasts, but our model (see page 4), which considers a greater array of factors than most others, reveals that change is accelerating faster than even the most optimistic predictions. In fact, we believe that, around the world, change has reached an unstoppable momentum due to the combination of several key drivers.

## The combination of key drivers means energy transitions around the world are progressing at pace



## Technology is advancing

Technologies are advancing and rapidly approaching a series of economic tipping points – underpinning affordable clean energy solutions that are powerful, efficient and scalable, and help bolster security of supply. In 2022, around 86%, or 187GW, of newly commissioned, utility-scale renewable power generation produced electricity at a lower cost than the average cost of fossil fuel generation. Solar is now the cheapest source of new-build electricity in many markets, even amid recent inflation and price rises. The global weighted average levelized cost of electricity (LCOE)[1] for solar photovoltaic (PV) is 29% lower than the cheapest fossil fuel alternative. Large-scale energy storage – critical to an energy system dominated by renewables – is also quickly becoming more cost-competitive and sophisticated.

**48%**

The EY survey of 70,000 global consumers across 18 markets revealed that nearly half (48%) will likely buy an EV as their next vehicle.

## Renewable power generation costs

LCOE (US$/MWh), 2010–22


Source: EY analysis of IRENA data.

[1] The LCOE is the minimum constant price at which electricity must be sold to break even over the lifetime of a project.

## Sectors are converging

Sector convergence is increasing as digitalization blurs boundaries between sectors. When companies, including competitors, join forces, they can amplify their collective knowledge and skills, and accelerate innovation. For example, the world's first offshore solar energy platform, launched in the North Sea in August 2023, is the result of several offshore wind and engineering companies coming together to form a consortium (SeaVolt) with common goals.

## Consumers are changing

Consumers' attitudes and demographics are changing. Gen Z and millennials are now the majority. There is still a gap between intent and action, but sustainability is more important to many people – the EY survey of 70,000 global consumers across 18 markets revealed that nearly half (48%) will likely buy an EV as their next vehicle. Indications suggest that EVs will outstrip sales of all other vehicles by 2030. Our survey also found that 62% of people have bought, or are thinking about buying, solar panels, and 50% are considering buying, or have already bought, battery storage.

## Climate is a business issue

Sustainability is key to boardroom agendas in many regions, as pressure increases from investors and customers, regulations get tougher and capital begins to flow to sustainable investments. More than 3,000 businesses and financial institutions are working with the Science-Based Targets initiative to reduce their emissions in line with climate science.

## Geopolitics are more volatile

Geopolitics, particularly the war in Ukraine, have redefined the importance of energy security, triggering a renewed focus on renewables in markets that import energy. In 2022, investment in low-carbon technologies surpassed US$1t for the first time, triggered by turbocharged clean energy policy in the world's biggest economies, including US$369b earmarked for greentech under the US Inflation Reduction Act, and a US$270b provision from the European Commission for cleantech companies.

Conflict and other geopolitical factors have also seen some nations embark on a quest to become energy superpowers, taking advantage of location and availability of natural resources. For example, the US, Australia, Saudi Arabia and Chile are attempting to take back control of energy supply chains from China, the world's current cleantech superpower.

## Multiple energy transitions will move at different paces

The pace of change will continue to pick up over the next decade and beyond, creating fundamental shifts in how the world produces, consumes and trades energy. Our model indicates that global renewable energy capacity will rise by 2,000GW by the end of the decade, an amount equivalent to China and Europe's entire renewable capacity today. But our modeling of the impact of four key levers – technology advancement, commodity supply, consumer engagement and government policy – and their impact on 52 technologies, reveals that the speed and nature of this change will vary widely across countries, markets and sectors. There is not one energy transition, but many.

Our model indicates that global renewable energy capacity will rise by

**2,000GW**

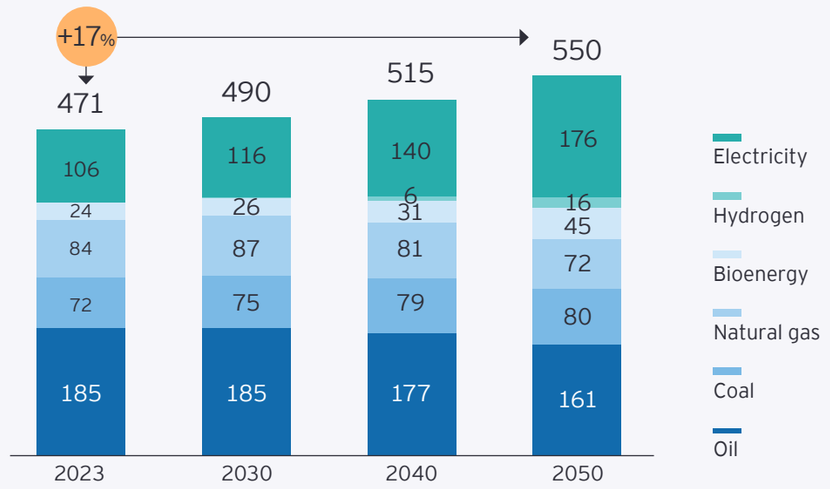
by the end of the decade, an amount equivalent to China and Europe's entire renewable capacity today.

## Global final energy demand by fuel type and region

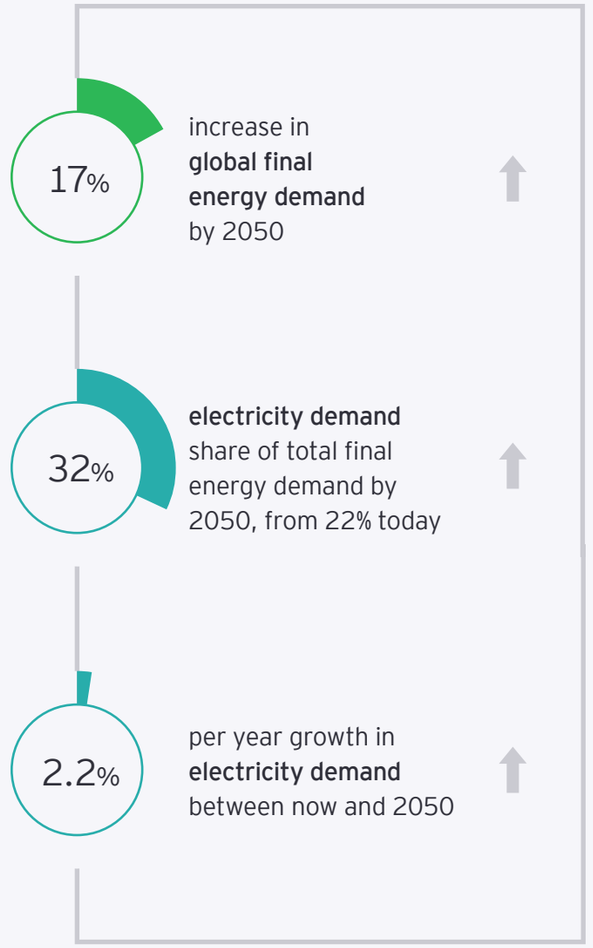
Global final energy demand is projected to increase by 17% by 2050, as growth engines China and South Asia offset energy demand stability in the US and Europe.

The global energy mix is projected to shift toward power, with the share of electricity in final consumption expected to grow to 24% by 2030 and 32% by 2050. The corresponding doubling of electricity consumption, combined with uptake of hydrogen, is projected to offset fossil fuel consumption, which is forecast to meet 57% of final energy demand, compared with 72% today.

**Global final energy demand by fuel type (exajoule)**




Source: EY analysis of ERTA model data.



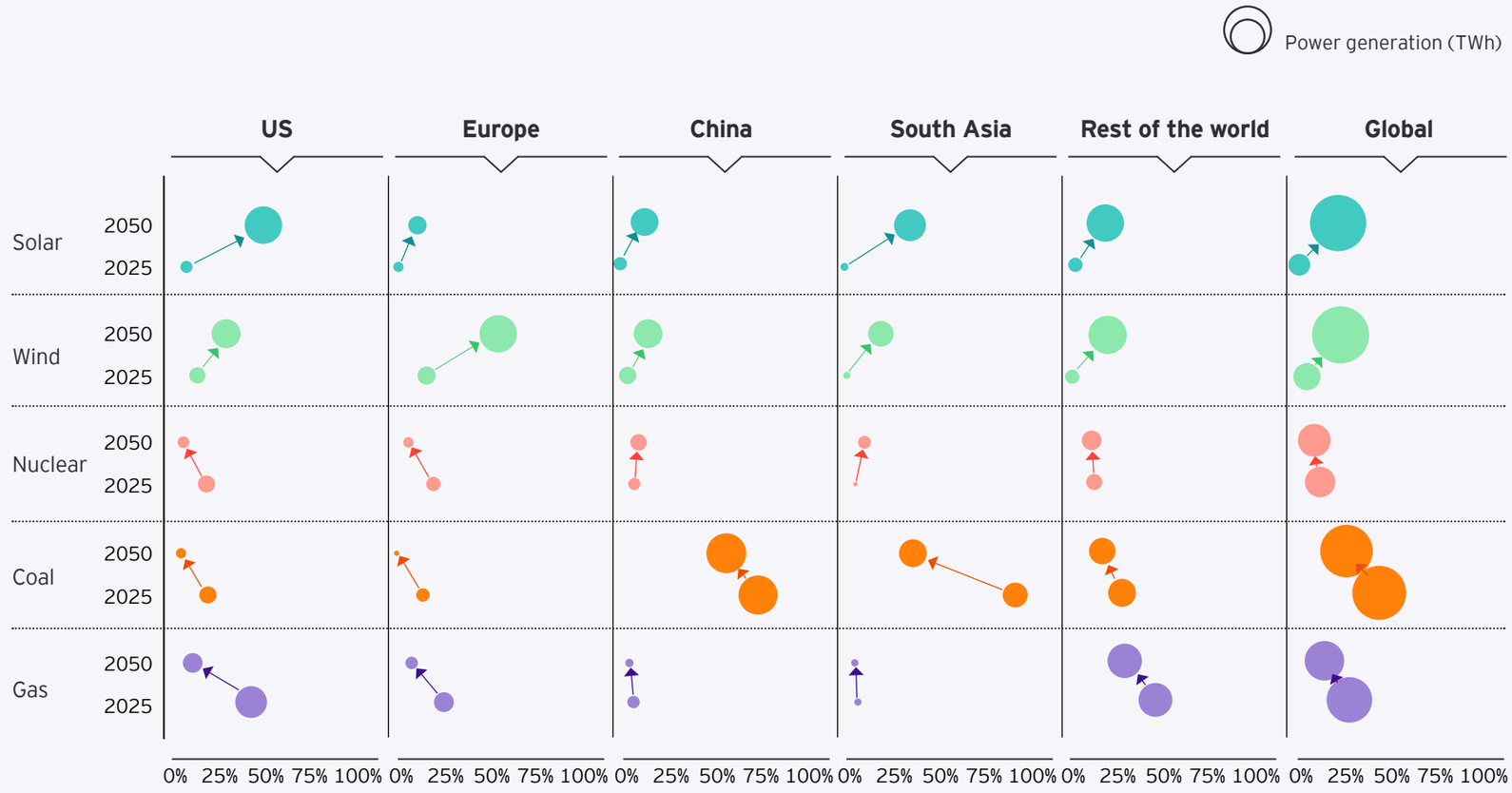
The speed of transition will vary based on multiple factors, including the motives for change. Around the world, governments face different, sometimes competing, priorities – economic prosperity, geopolitical pressures, environmental goals and the need to provide secure access to affordable energy. These motives will drive different policy decisions that will determine progress. Every market will need to activate a range of accelerators to overcome the inertia of the status quo, keep up the momentum of change and meet climate targets.

> “Every market will need to activate a range of accelerators to overcome the inertia of the status quo, keep up the momentum of change and meet climate targets.

These should include everything from carbon pricing to investment in technology, faster connections of new capacity, embedding intelligence into a digital, bidirectional grid and strengthening supply of critical minerals. These accelerators should send the right signals – to investors, the industry and consumers – to speed up the shift away from traditional generation and toward renewables. If they don't do this fast enough, markets will need to consider other options, including large-scale carbon capture, usage and storage (CCUS) and even expanded nuclear programs.

## Technology adoption rates

The transformation to a new energy system will vary across regions.




Source: EY analysis of ERTA model data.

# The complexity of change will require tough trade-offs and huge investment

For energy and resources companies, multiple transitions will make for a volatile landscape. Different markets will require different strategies, create different risks and present different trade-offs — all at different times.

Besides the huge cost and complexity of transitioning legacy assets, our model indicates the task at hand is more challenging, and multifaceted, than many anticipated. Energy and resources companies will take on the challenge while also planning for downstream disruption and keeping investors onside.

For the power and utilities sector, challenges include a need to significantly expand and upgrade the grid, and also reset relationships with customers. Miners must find more access to capital and secure license to operate (LTO) if they are to build supply chains that keep up with evolving demand — no energy transition can take place without mining. For oil and gas companies, decarbonizing the molecules that much of the world's industry will continue to rely on will become a priority — and critical to the ultimate success of climate ambitions.

Multinationals will navigate the complexity of operating across different environments, taking care that actions in one region don't negatively impact operations in others (especially around the social agenda). Every sector will need new talent and technology to make change happen. And, critically, they will need to collaborate across multiple sectors, working together to help mobilize governments, reshape and achieve consensus on regulation, shift consumer and corporate behavior, and make sure our emerging new energy system is also a fair and equitable one.

We know this will be challenging, but we also believe that evidence of accelerating change is reason for optimism. This is a critical decade. The right decisions made now can speed up our transition to the new energy system and bend the emissions curve in our favor. For government and regulators, this means deciding how to convert objectives into the economic signals that nudge consumers and markets in the right direction at the right time. An estimated US$4.1t of annual investment in low-carbon transition technologies and enabling energy infrastructure will be needed by 2050 (that's a quadrupling of current levels).

And for energy and resources companies, making smart, no-regret actions now can mitigate risk and capture the value of change. This won't be easy, particularly as every company will be on their own path, facing risks unique to their own market and geography. But those that can identify and commit to the right strategic choices now can realize significant commercial opportunities and, collectively, hasten our journey to a sustainable, resilient energy future.

# IMPLICATIONS

## How our energy system will change

As the energy transition accelerates, the pace of change will have major implications for our energy system and for energy and resource companies. We discuss these implications separately but, in reality, they are interconnected, driving and impacting each other.

Rising electrification will accelerate the evolution of the molecule. Mainstream adoption of EVs will shift supply chains. Localized energy will reconfigure the grid. Considering the cumulative impact of these implications can help companies assess their impact – and identify emerging risks. Every energy and resources company will need to reassess investment decisions in line with different risk-return profiles.

## The eight implications of the energy transition

Changes to our energy system have reached critical momentum, driven by technology advancement, commodity supply, consumer engagement and government policy.

### Implication 1

**Renewables dominate energy generation**

**2038**

When renewables will replace fossil fuels and become the dominant power generation source.

### Implication 2

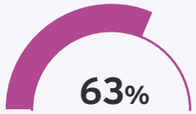
**(Almost) everything is electrified**

**2x**

Global electricity demand rise by 2050.

### Implication 3

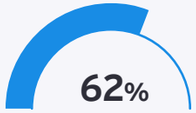
**Oil and gas go green**




of the crude oil demand drop beyond 2030 will be from transport.

### Implication 4

**Energy systems are localized**




of power will come from local renewable sources by 2050.

### Implication 5

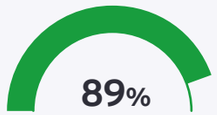
**The urgent quest to build a hyper-intelligent, flexible grid**

**10x**

more grid flexibility required in Europe by 2050.

### Implication 6

**Consumers take the lead**




of global consumers surveyed across 18 markets are interested in renewables and self-generation to reduce reliance on fossil fuels.

### Implication 7

**Supply chains are redefined**

**910%**

increase in demand for lithium by 2050 from 2022 levels.

### Implication 8

**Integration of old and new energy systems**

**300%**

increased annual investment in low-carbon technologies required to 2050.

Source: EY analysis of ERTA model data.

# Renewables dominate energy generation

Change in the power sector will be swift but not linear. By mid-century, the global power market will be double the size it is today, driven by electrification of industrial and end-use applications. It's easy to see how proliferating wind and solar will come to dominate, but our modeling suggests this will happen faster than previous indications.

We forecast renewable generation, mainly wind and solar, will become the new baseload – accounting for 38% of the power mix by 2030 and 62% by 2050. Globally, renewables will become the dominant power generation by 2038.

A global solar boom will power more than half of this, but adoption will vary across markets. Solar-generated power will become the biggest source of energy in countries such as the US, and those in Oceania and South Asia, driven by technologies around solar PV modules advancing at rapid pace. The price of crystalline silicon PV modules has reduced by more than 80% since 2010.

But in Europe, the clean energy story will center around wind. We anticipate that a mix of offshore and onshore wind will become the region's leading source of power generation by as early as 2027. In the UK, wind power capacity had already surpassed gas power capacity by June 2023.

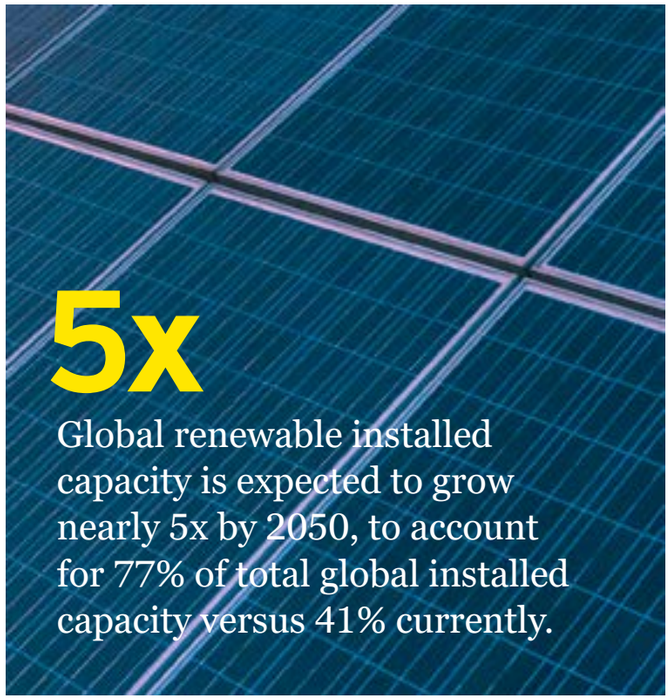
The positive impact of accelerated renewables build-out is huge – helping reduce carbon emissions, enhance energy security and create economic opportunities. However, they will also pose challenges, particularly around the need to integrate renewables into the grid, fund infrastructure upgrades and ensure regulation keeps up with change. Overcoming these will require a collaborative effort across the public and private sector, bringing together policy, investments, innovative partnerships and technological advancements.

# Implication 1 2 3 4 5 6 7 8

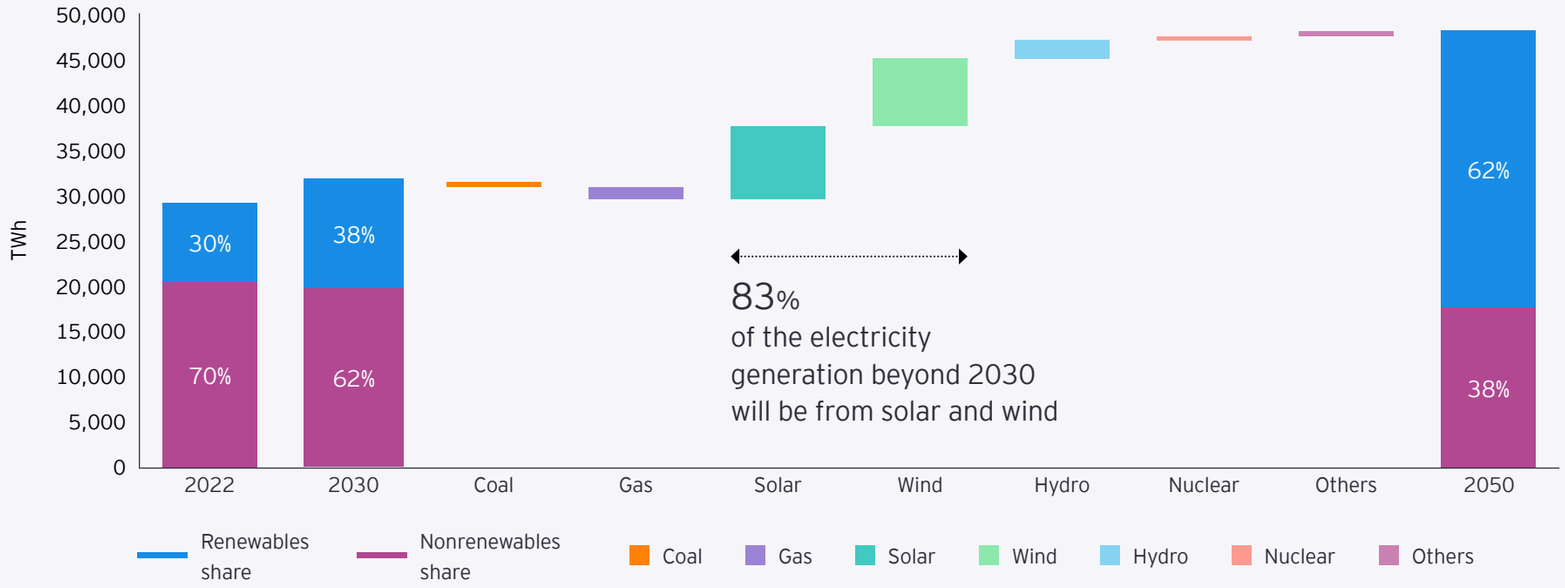
## Renewables dominate energy generation

### Share of nonrenewables and renewables in global power generation

We forecast renewables will become the new baseload – accounting for 38% of the power mix by 2030 and 62% by 2050. Fossil fuel generation will peak before the end of the decade.




### Change in global electricity generation mix (TWh), 2022–50



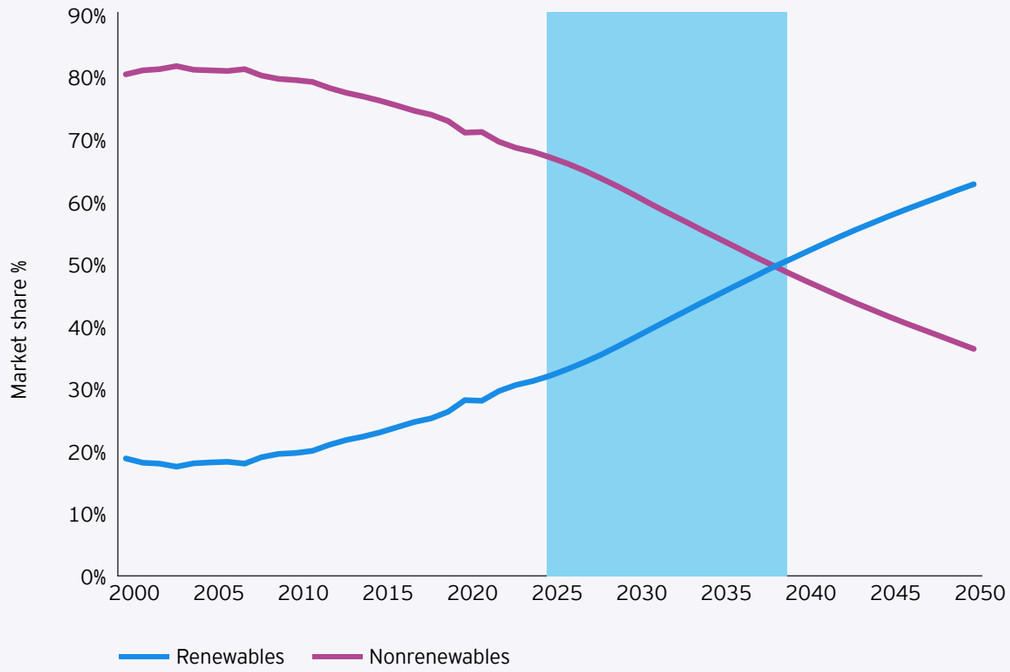

Others: biomass, combustion turbine, hydrogen turbine and CCUS.

Source: EY analysis of ERTA model data.

## Renewables dominate energy generation

Globally, renewables will become the dominant power generation by 2038. China, Europe and the US will drive a 53% increase in solar and wind generation, producing over 57% of global solar and wind output by 2050.


### Share of nonrenewables and renewables in global power generation (%), 2000–50




**Accelerators**

- Carbon price
- Technology breakthroughs
- Faster connections
- Digital grid
- Availability of resources

**Risks**

- Access to capital
- Regulatory uncertainty
- Insufficient returns
- Supply chain
- Consumer confidence

Note: Fossil fuels include coal, gas and other fossil fuels.

Source: EY analysis of ERTA model data, data from IRENA Renewable Energy Capacity Statistics 2023, Ember Electricity Data Explorer 2023.

# (Almost) everything is electrified

The build-out in renewable generation will pave the way for rapid electrification of end-use applications. Our modeling suggests final electricity demand will double by 2050 from current figures.

Economic growth, particularly in China and India, will fuel much of the increase in global consumption. In some markets, people will access electricity for the first time. In others, rapid proliferation of consumer technologies will push up demand as they become mainstream.

But electrification of industries may be the biggest driver of change. Today, industry is the biggest energy-consuming sector, accounting for around 37% of final energy demand. Of that, electricity demand is relatively modest – about 22% – most of which is used in mechanical processes. Our model forecasts industrial electricity demand to grow 159% by 2050, as technologies such as electric heat pumps for low- and medium-temperature applications, and electric furnaces for high-temperature uses, are adopted. Capturing the value of surging industrial demand isn't a given for power and utilities companies, which will need to contend with competition from independent power producers and a growing trend toward self-generation. Oil and gas companies will face dual impacts – declining demand from some sectors and increasing pressure to decarbonize the molecules that will remain integral to others.

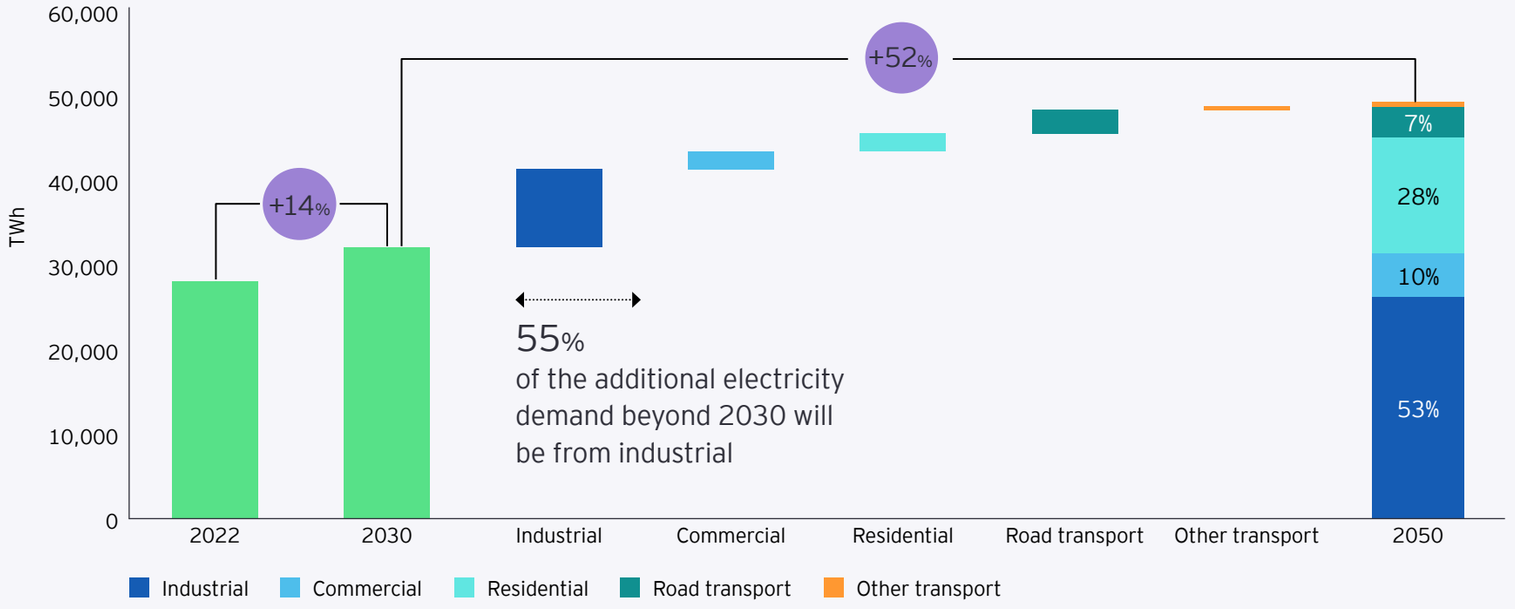
## (Almost) everything is electrified

### Power demand will double by 2050

Final electricity demand will increase nearly twofold by 2050, driven by electrification of industrial and end-use consumer applications, with demand growth set to accelerate post-2030.

Industrial electricity demand will increase to 36% of total energy demand, driven by technology innovation that enables the decarbonization of previously hard-to-abate industries. In residential buildings, increasing living standards are projected to push up demand for electric appliances and space cooling or heating. And transport is projected to see one of the fastest transitions to electricity, with EVs reaching cost parity with internal combustion vehicles by the mid-2020s.

### Electricity demand growth by end-use technologies (TWh)




Source: EY analysis of ERTA model data.

# (Almost) everything is electrified

## Steel demand is soaring. Could hydrogen turn it green?

Traditional means of producing steel are carbon-intensive, accounting for about 7% of global carbon emissions. With demand for steel set to increase by 30% by 2050, efforts to green its production are growing.

Hydrogen may offer the most potential to reduce emissions. Replacing coal or gas with green hydrogen, based on the carbon intensity of global grid power, in direct reduced iron or electric arc furnaces (EAF) could cut greenhouse gases produced by as much as 20% to 40%. The cost of production is higher, but producers can charge a premium to consumers keen for more sustainable options. Several steelmakers are taking advantage of this demand — ArcelorMittal is using hydrogen in its EAF steelmaking operations, where it reduces iron oxide in scrap metal feedstock. The company is also investing, with partners including BHP, in carbon capture storage (CCS) technology that could help decarbonize legacy blast furnaces. It's a particularly difficult challenge due to the differing levels of contaminants in the gas, but ArcelorMittal hopes its trials across its Belgian and North American plants could pave the way to roll out CCS across the world's steel plants.

# Implication 1 2 3 4 5 6 7 8

## Oil and gas go green

Even as electrification increases, hydrocarbons will remain part of the energy mix for longer than anticipated. Demand for gas will stay strong, partly because of its role as an interim fuel, but also because it powers so much existing infrastructure and is used as a feedstock in industrial applications.

Transitioning from old to new assets will take time, and the impact of change will differ across the sector and global businesses. Upstream oil and liquefied natural gas (LNG) businesses will be driven by global trends that are less volatile and somewhat insulated from local policies. Downstream and midstream oil and gas assets, highly exposed to local market dynamics such as EV adoption, will have to adapt much more quickly.

# Implication 1 2 3 4 5 6 7 8

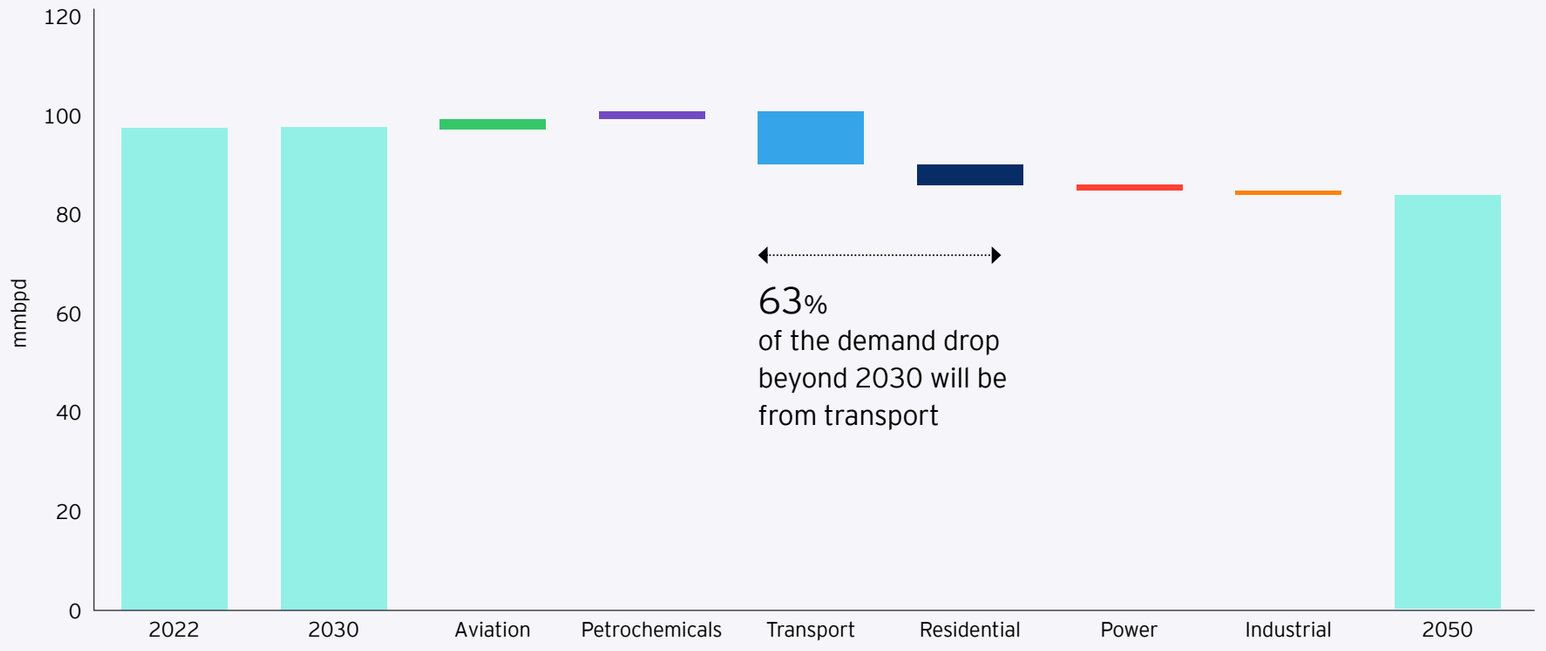
## Oil and gas go green

### The changing dynamics of oil and gas demand

Dynamics of molecule to green molecule to electron competition will play out at a global level for upstream, and at local levels for midstream and downstream. Some crude oil current end markets are easily electrified with current state technologies. Some markets, more difficult to electrify or bound to molecules, will be subject to competition from non-carbon molecules or hydrocarbons with abatement.

We see a significant market for oil and gas over the next 25 years, even with energy transitions accelerating in multiple geographies. A 15% reduction in global crude demand is estimated by 2050, due to the slow attrition of existing energy use assets. Aviation and petrochemicals demand will increase, but the electrification of road transport will be behind a large declining demand. Today, the transport sector uses around 45 million barrels of oil every day, of which about one-third is consumed in the commercial sector. But from 2030, electrification of transportation will be behind 63% of the demand drop for global crude oil.

### Global crude oil demand (mmbpd), 2022–50




Note: Transport includes rail, water, cargo and passenger transport data, commercial is combined with residential demand.

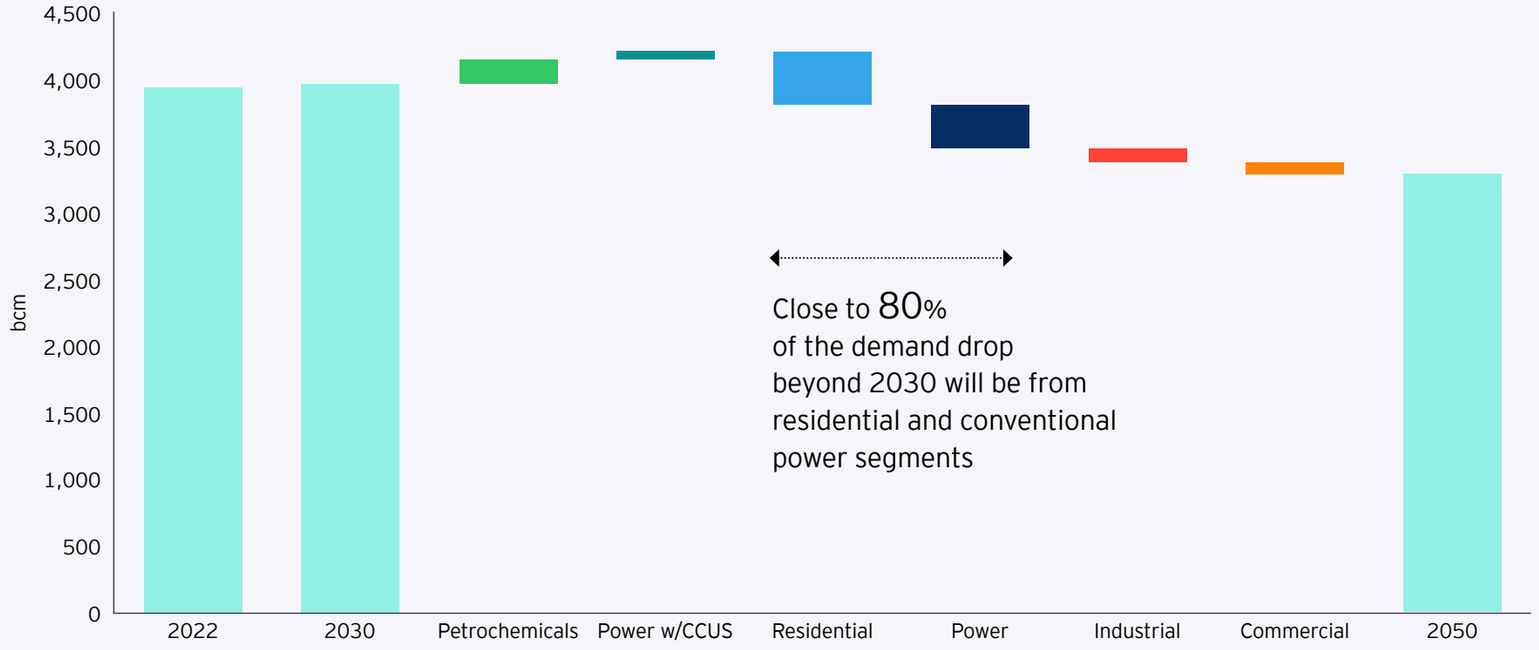
Source: EY analysis of ERTA model data.

## Oil and gas go green

Gas demand will stabilize this decade, with decline set to accelerate past 2030. The pace of decline will depend on attrition of existing energy uses and competition from new ones. More than 80% of the demand drop beyond 2030 will be from residential and conventional power segments. Demand for natural gas in conventional power and heating applications will decline fast, but other end uses will grow, with green and alternative molecules preferred to electrons. CCUS will enable growth in decarbonized power and blue hydrogen and ammonia production.

With molecular energy around for longer, it will be essential to decarbonize it. Get ready for a race to "green the molecule," through a mix of CCUS, synthetic and bio-hydrocarbons, and alternative molecules such as hydrogen and ammonia. Urgency will catalyze innovation, with technology, including CCUS, maturing and scaling at pace. We forecast that consumer demand and regulatory support should see returns for green molecules outpace gray by the early 2040s.

### Global natural gas demand (bcm), 2022–50




Note: Industrial segment includes water and other transport data.

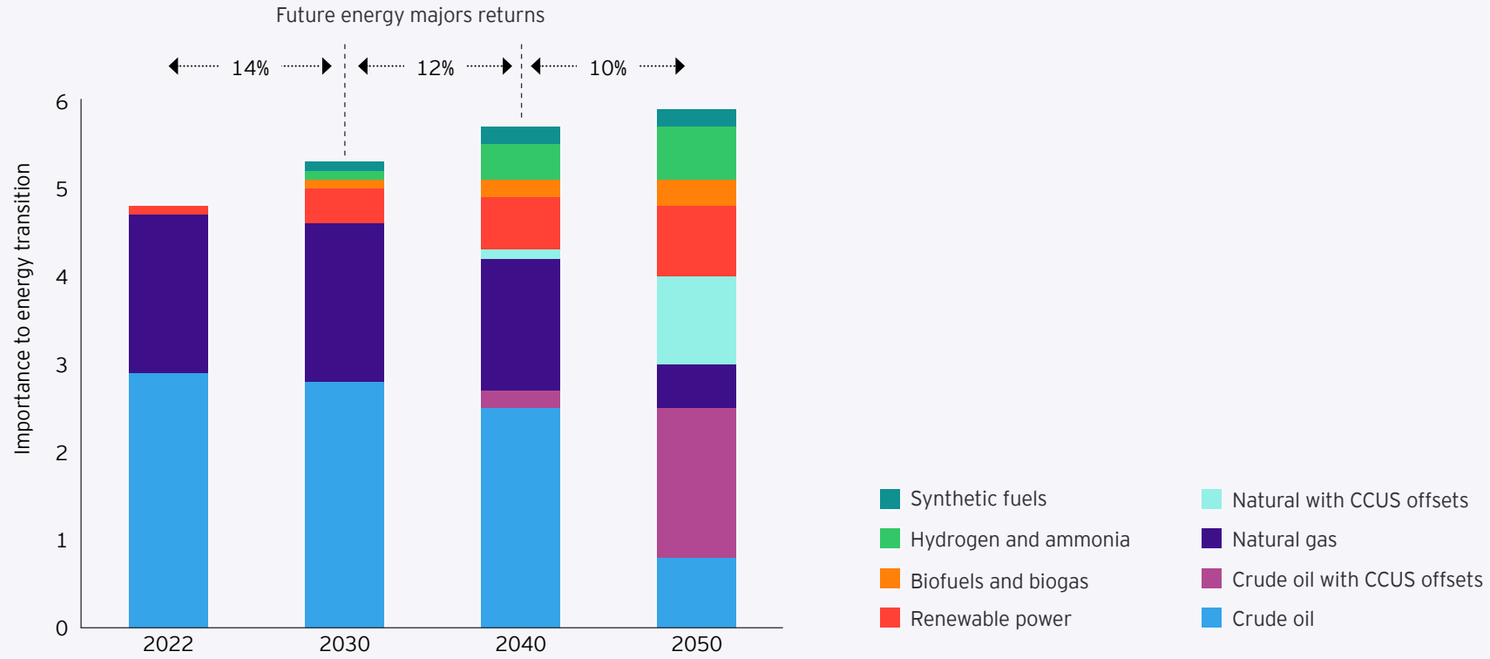
Source: EY analysis of ERTA model data.

## Oil and gas go green

We anticipate returns from conventional oil and gas operations to decline after 2030, as carbon costs increase and electrification in some sectors reduces demand.

In the short term, oil and gas companies will adapt by improving operational efficiency and focusing on shorter-cycle assets. But success over the longer term will require companies to rethink portfolio strategies, moving away from a pure focus on oil and gas to a mix of conventional and decarbonized oil and gas molecules, synthetic and bio-based fuels, renewable power, and alternative energy carriers such as hydrogen and ammonia. Returns for green molecules will begin to rise as technologies mature and commercialization scales, leading to a significant expansion of market opportunities for oil and gas companies. These companies are particularly well positioned to develop and deploy CCUS technologies, both to decarbonize their own conventional molecules through offsets and to support decarbonization of other hard-to-abate industries.

### Oil and gas portfolio evolution (illustrative)




Source: EY analysis of ERTA model data and O&G majors strategies.

# Implication 1 2 3 4 5 6 7 8

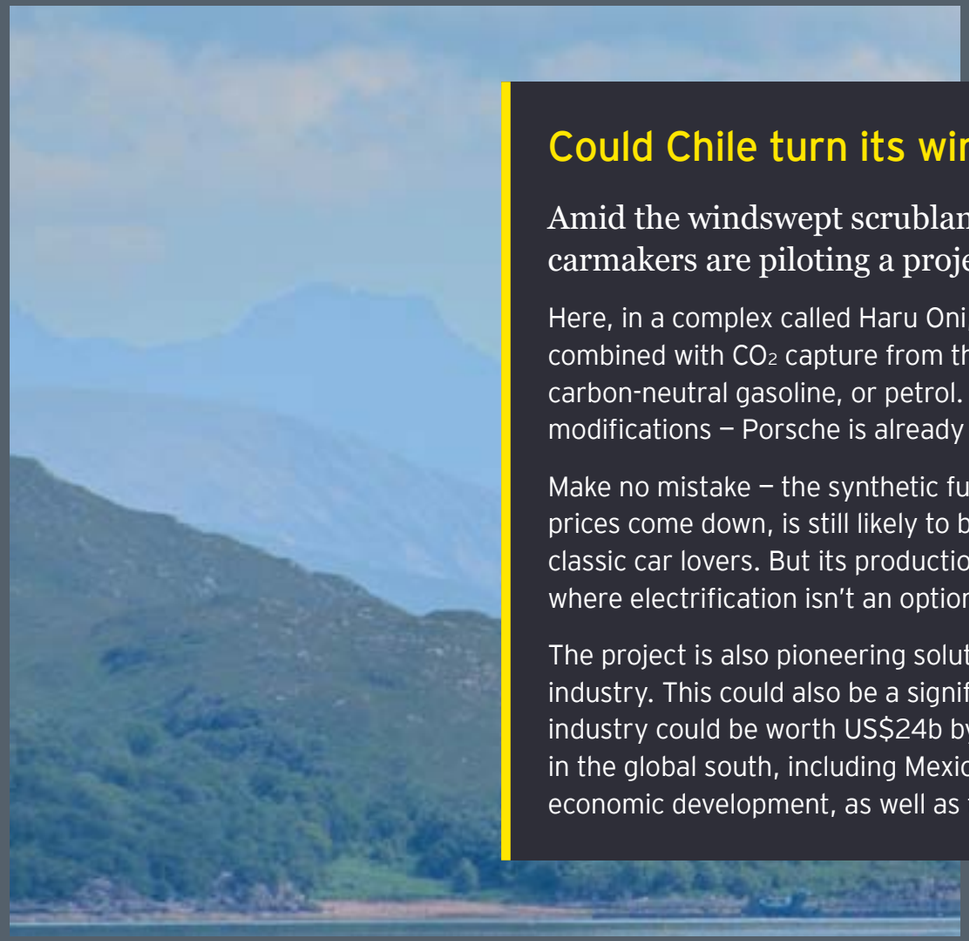
## Oil and gas go green

### How the Netherlands is burying its carbon

The Netherlands will reduce its carbon emissions by burying some of them under the North Sea. In early 2024, production is set to begin on Porthos, a massive carbon capture and storage project that will see $CO_2$ produced in refineries and chemical plants owned by Shell, ExxonMobil, Air Liquide and Air Products transported through the Rotterdam port to empty gas fields under the North Sea. Once operational in 2026, the project is forecast to reduce the Netherlands' carbon emissions by 2% annually for 15 years, as well as 10% of the Port of Rotterdam's overall emissions.

It's an ambitious plan – set to be Europe's biggest ever carbon capture project – but, in some ways, deeply practical. Porthos is making fresh use of old oil and gas fields and leveraging expertise honed in the production of hydrocarbons to pioneer new decarbonization solutions. It also highlights the advantage of an open access approach. Multiple companies across industries are sharing knowledge and costs to ensure best practice is applied and reduce overall cost. Innovation here is likely to be deployed in other countries exploring undersea carbon capture. The UK has already granted licenses to multiple oil companies, anticipating that 10% of the UK's carbon emissions could be buried under the North Sea by 2030.

# Oil and gas go green



## Could Chile turn its wind into synthetic fuel – and economic advantage?

Amid the windswept scrublands of Chile's Patagonia, a collaboration of energy companies, miners, engineering firms and carmakers are piloting a project that could significantly advance the world's journey to carbon-free fuels.

Here, in a complex called Haru Oni, a 3.4-megawatt (MW) wind turbine is pumping out electricity that is used to produce hydrogen, which is then combined with $CO_2$ capture from the air to form a syngas. This syngas is used to make green methanol, which is transformed into a synthetic carbon-neutral gasoline, or petrol. This fuel is set to be used in internal combustion engine (ICE) vehicles, without the need for any engine modifications – Porsche is already using it in race cars. It could help reduce emissions from transport faster than EV adoption alone.

Make no mistake – the synthetic fuel produced at Haru Oni is currently about 100 times more expensive than traditional gasoline and, even when prices come down, is still likely to be a far more expensive way to power cars than batteries or hydrogen. It will probably find its market among classic car lovers. But its production is an exciting step forward in the development of synthetic fuels that will be critical to power those industries where electrification isn't an option, such as aviation and transoceanic shipping.

The project is also pioneering solutions to store and transport renewable energy, which could speed up decarbonization of the world's heavy industry. This could also be a significant economic opportunity for Chile, with the government forecasting that the country's hydrogen export industry could be worth US$24b by 2050. Could it be a sign of how global economic power may shift as renewables accelerate? If more countries in the global south, including Mexico, India and some African countries, leverage abundant wind and solar, they could accelerate their own economic development, as well as the world's transition to cleaner power.

# Energy systems are localized

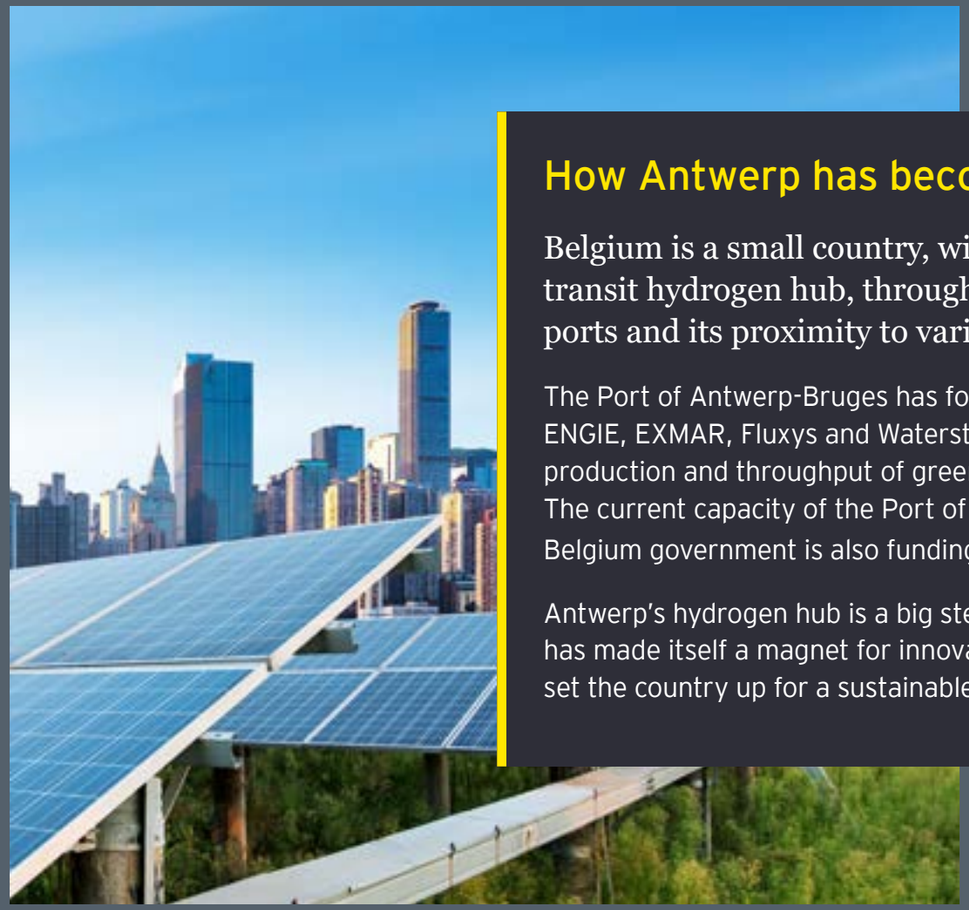
The electrification of industrial, residential and transport sectors will be a key driver of a more localized energy system. As renewables and clean energy infrastructure are built out at scale, energy will become localized for all consumer segments — residential, commercial and industry.

Regions with plentiful, cheap energy sources, particularly solar and wind, will attract new generation assets, and demand will follow, where it makes sense. In regions where localized energy supply isn't possible, we'll see more projects to supply green electrons by transmission connection or interconnection, such as the ambitious proposed project to import Moroccan clean energy to the UK, or transport decarbonized green molecules via pipe or ship.

The colocation of supply and demand will create ecosystems of industries, with new jobs, economic opportunities and cheaper power for communities. We already see the emergence of localized hydrogen hubs that take advantage of green energy. Overcoming infrastructure challenges (hydrogen is expensive to store and transport) could expand opportunities beyond current industrial clusters and localized offtakers.

A localized energy system will bring new grid challenges, particularly as distributed energy resources (DERs), EVs and heat pumps scale at speed. Clever solutions to flatten local peaks – flexibility technologies, interconnections and energy sharing platforms – can manage intermittency and minimize network losses.

# Energy systems are localized



## How Antwerp has become Europe's clean hydrogen hub

Belgium is a small country, with not much space, sun, wind or coastline. But it's fast becoming Europe's clean import and transit hydrogen hub, through an ambitious strategy that takes advantage of Antwerp's position as one of the world's busiest ports and its proximity to various significant industrial clusters.

The Port of Antwerp-Bruges has formed a hydrogen import coalition that includes a mix of major industrial players and public stakeholders: DEME, ENGIE, EXMAR, Fluxys and WaterstofNet. Together, they have built a shared industrial hydrogen ecosystem – a one-stop shop for the importation, production and throughput of green hydrogen and hydrogen carriers (for example, ammonia and methanol) throughout the country and beyond. The current capacity of the Port of Antwerp-Bruges will be expanded from 2026 onward, to receive the first green hydrogen molecules. The Belgium government is also funding a network of hydrogen pipelines that will connect the port to Belgian industrial areas and Germany by 2028.

Antwerp's hydrogen hub is a big step forward in meeting Belgium's energy transition goals, but it's delivering huge economic benefits too. Belgium has made itself a magnet for innovation – attracting the world's most innovative companies, leading researchers and building infrastructure that will set the country up for a sustainable future.

# The urgent quest to build a hyper-intelligent, flexible grid

**The widespread adoption of solar, wind, hydrogen and distributed generation will drive fundamental energy system transformation.**

The grid will come under extreme pressure, demanding urgent solutions to both expand the network and embed flexibility capabilities that enable a balanced, reliable system.

The impacts to the grid will hit different markets at different times. In Europe, flexibility requirements will increase 10 times by 2050, according to our forecasts. This will amount to 26% of the total regional electricity demand. Orchestrating flexibility solutions within a more localized energy system with millions of "invisible" connections will require an approach that includes diverse options.

Technologies, both mature and emerging, will be key, including batteries and longer duration storage. But they won't solve the problem by themselves. Strategies that involve consumers as active grid participants, supported by new tariffs, will be critical levers to manage intermittency, particularly as adoption of consumer technologies, such as EVs, picks up. Collaboration across the consumer ecosystem to enhance the energy experience and introduce new services can not only help capture the value of grid investment but also drive behavioral changes.

Unless solutions are found to shorten the interconnection queues holding up new capacity, much of the investment in grid flexibility will fail to realize its potential. We'll need to rapidly speed up connection of renewables or risk outages as traditional generation retires. Regulatory changes and speedier permitting processes won't be enough to clear the bottlenecks – robust supply of materials and minerals, and a healthy pipeline of talent with digital skills, will also be required to build the grid of the future.

# Implication 1 2 3 4 5 6 7 8

## The urgent quest to build a hyper-intelligent, flexible grid

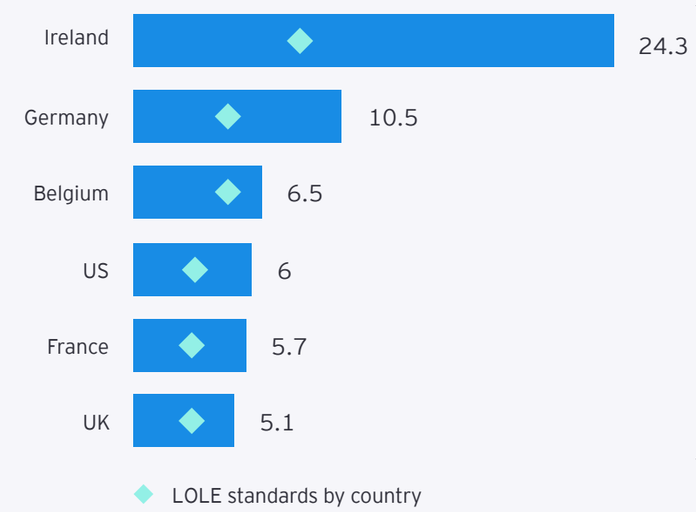
### Supply adequacy challenges will hit within a decade

The rapid growth of renewables and DERs will drive high levels of network intermittency and bidirectional flow that the grid was not built to withstand.

As dispatchable capacity gets replaced by intermittent renewables, system adequacy challenges are expected to impact major regions within the coming decade.


### System adequacy – loss of load expectations (LOLE) comparison

**Expected LOLE for 2025, in hours/year**



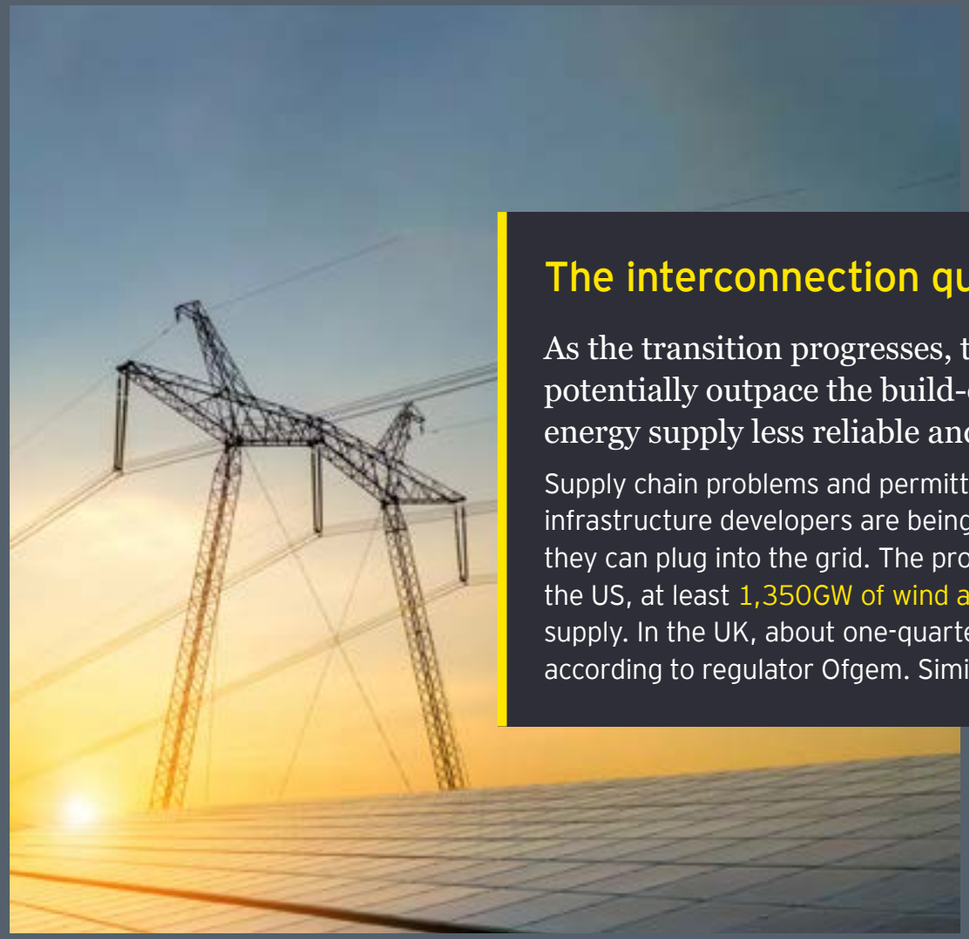

=

- Falling reserve capacity
- Loss of load more than reliability standard
- Reduced plant availability
- High incidents of forced outages

Source: EY analysis of ENTSO-E reports, EIA.

LOLE: the number of hours in a period (typically a year) during which the available generation plant will be inadequate to meet the instantaneous demand.

# The urgent quest to build a hyper-intelligent, flexible grid



## The interconnection queue that is holding up new capacity

As the transition progresses, the risk of reliability challenges increases as the retirement of old assets and demand growth potentially outpace the build-out of new generation. This could see the world face a huge capacity shortfall — making our energy supply less reliable and shaking confidence in the energy transition.

Supply chain problems and permitting delays are slowing down construction and installation of new assets. Around the world, renewable energy infrastructure developers are being told they must wait anywhere from between a couple of years (in the US) to up to 15 years (in the UK) before they can plug into the grid. The problem is known as the "interconnection queue," and it could be a major bottleneck in the energy transition. In the US, at least 1,350GW of wind and solar capacity and 680GW of storage is waiting to be connected – enough to double the country's electricity supply. In the UK, about one-quarter of connection applications approved in 2022 have been offered connection dates of 2030 or beyond, according to regulator Ofgem. Similar problems are seen in Spain and Italy.

# Consumers take the lead

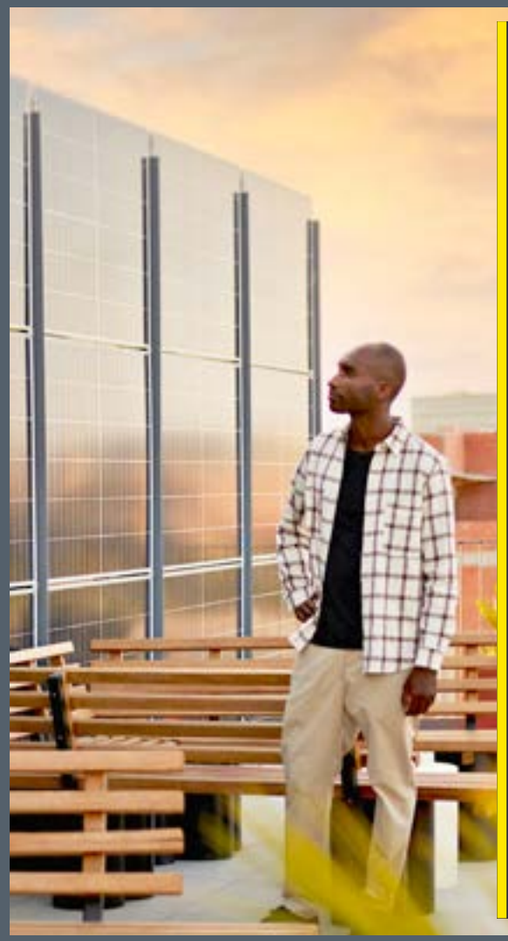
Consumers — both industrial and residential — will take the lead in the shift to a new energy system, ultimately determining its success. The reality is that we cannot expect people or business to change their behavior because of sustainability motivations alone.

Clean energy solutions must be easy, cheaper and genuinely better to drive the switch. Energy companies that can give consumers what they want can also capture the inherent value they offer, which will support investment in grid flexibility and intelligence.

How to achieve this will vary by market and consumer group. Each company will need to determine its own strategy, considering a range of products, services and experiences. And the success of these strategies will depend on a company's ability to meet the needs of a changing energy consumer.

Industrial customers want more sophisticated, personalized options, such as rewards for shifting demand. Residential consumers in many markets are more engaged, keen to take control of their energy experience. The proliferation of EVs, rooftop solar, batteries and smart hometech means consumers produce, store, and buy and sell energy in different places across their daily lives. They interact with many different providers and demand personalized, convenient energy options that align with their values, according to an EY survey of around 70,000 residential consumers across 18 markets. Eighty-nine percent are interested in renewables and self-generation to reduce reliance on other markets, fossil fuels and energy providers.

# Consumers take the lead



## Closing the gap between consumer intent and action

EY research find residential consumers are inspired and committed to playing their part in building a clean energy future. Forty percent are considering purchasing energy-efficient appliances, and about half are considering an EV. But there's a gap between intention and action. Consumers say making changes is too difficult, too expensive or just confusing. How can we close the gap between intent and action — and accelerate the adoption of sustainable energy behaviors and new energy technologies? These actions can help:

Collaborate to create consumer-centric ecosystems: Have you installed rooftop solar or a heat pump? How many companies and government agencies did you interact with along the way? Collaboration across industries and government could reinvent the experience into one that's effortless and more affordable.

Target lifestyles and individual actions: Decisions about how we use energy are part of bigger lifestyle choices driven by personal values and priorities, including sustainability, convenience and the desire to save money. Tailoring energy solutions to meet these different needs can accelerate their adoption.

Value the energy intangibles: Showing how renewables and greener solutions can deliver other important consumer intangibles, including community and social impact, choice, convenience and comfort, could strengthen consumer confidence in a changing energy system.

Master behavioral science: According to EY research, about half of us think it's okay to offset our positive energy actions with negative ones. Focusing purely on sustainability messaging or price isn't enough to drive consumer changes. Understanding behavioral science – why we do what we do – helps tap into values to influence energy investments and actions.

You can read more about the EY Energy Consumer Confidence Index here.

# Consumers take the lead

## How the surge in EVs and heat pump sales will vary across regions

In core markets, EVs are entering the mainstream; sales in the US, China and Europe will outstrip all other engine sales by 2032. Uptake is being driven by pledges to phase out sales of ICE vehicles, commitment from automakers to an electric future, and greater choice of vehicles at price points that are comparable with, or lower than, their ICE equivalents.

Heat pump sales are also on the rise, as technology advances and some governments mandate their adoption to help cut emissions. Our modeling suggests heat pump uptake will increase faster than some predict, outpacing fuel-based heating systems as early as 2028, largely because of trends across Europe, the US and China.

### Consumer uptake of technology

EV adoption (% of sales)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| Global | 28% | 53% | 74% | 86% | 92% | 94% |
| Europe | 36% | 74% | 99% | 100% | | |
| US | 17% | 43% | 70% | 92% | 100% | |
| China | 36% | 51% | 77% | 85% | 90% | 94% |

Heat pump adoption (% of sales)

| | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| Global | 42% | 63% | 77% | 89% | 96% | 98% |
| Europe | 39% | 59% | 78% | 94% | 99% | 100% |
| US | 48% | 63% | 78% | 91% | 98% | 100% |
| China | 46% | 60% | 73% | 84% | 91% | 96% |

Source: EY analysis of ERTA model data.

# Supply chains are redefined

**Localized, renewable energy, as well as the proliferation of energy solutions such as EVs and offshore wind farms, will also redefine value chains. Demand for minerals and metals used in new energy technology will soar.**

Meeting demand will require miners to overcome the growing bottlenecks around finding, extracting, processing and transporting these minerals and materials. Building stronger relationships with government could see permits issued faster, and shorten the timeline from discovery to processing, but solving the problem will require miners to develop a sophisticated level of understanding of individual markets. Geopolitical tensions are increasing in many regions, and resource nationalism is likely to rise further, leading to more royalties and restrictions. Miners may need to consider partnerships with local businesses as a response to protectionism. And strategic alliances with other industries, such as automakers, can create integrated value chains that reduce costs and friction, open up access to new sources of capital, and speed up the build of new energy technologies.

Funding exploration and development will require investment in mining and metals to significantly increase from current levels. Our survey of global mining and metals leaders revealed access to capital is considered the sector's second-highest risk. Environmental, social and governance (ESG) issues were number one and highlight how improving the sector's reputation can form part of the solution to help increase supply (winning over communities, investors, regulators and talent). The role of mining and metals companies in supporting countries' energy transitions is seriously undervalued — changing the energy system simply cannot happen without miners.

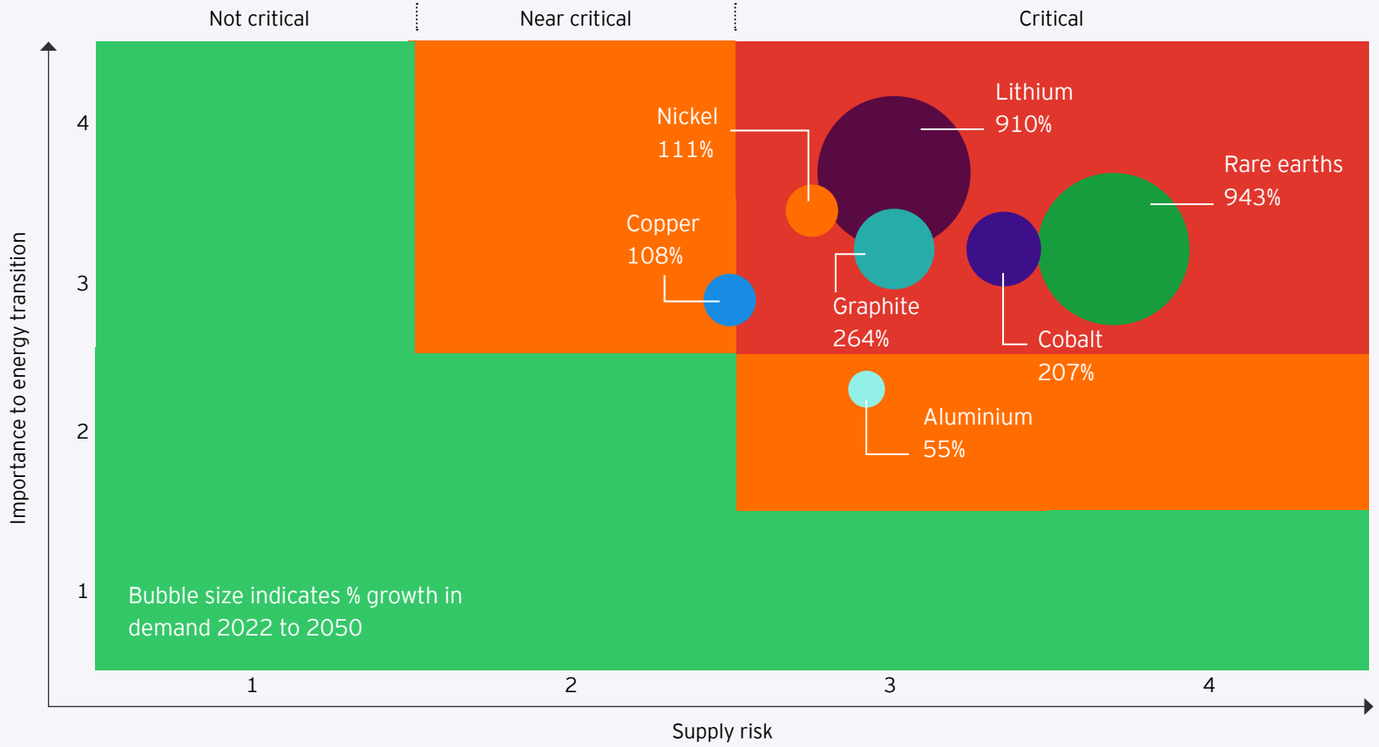
# Implication

## Supply chains are redefined

### Which minerals and metals are most critical to our new energy system?

Demand is set to soar for minerals and metals critical to building new energy assets and infrastructure. We considered multiple challenges and factors impacting the supply of these minerals and metals – including ESG pressures, geopolitics, access to capital, regulation and potential threat of substitutes – to develop a criticality matrix.

### Minerals and metals criticality matrix




Source: US Department of Energy; Argus Direct; S&P Global; IEA (NZE); Credit Suisse: European Aluminium; EU Joint Resource Centre.

Criticality of mineral and metals is based on the US Department of Energy assessment of importance to energy and supply risk over 2025–35.
Supply risk is calculated on the basis of availability, competing technology, ESG and geopolitics and co-dependence on other markets as well as extent of producer diversity.

# Supply chains are redefined

## Solving the copper conundrum

**Almost every new energy technology contains copper. One wind turbine includes three tonnes of it, and building an EV requires six times as much as a conventional car. But supply is struggling to keep up with demand, which is forecast to almost double by 2035.**

How can miners solve the problem? It's complicated. New mines are part of the answer, but they take decades to come online. In the meantime, some companies are expanding brownfield sites, while others are reopening closed mines. But boosting supply at speed will depend on more novel approaches, including innovation that helps miners get more copper from existing reserves, and unexpected sources. Acid leaching to extract copper from waste rock is not new, but Rio Tinto and partners have developed a secondary bacteria-based leaching process capable of extracting copper at far lower concentrations (<0.5% compared with the typical grade of around 0.6% to 1.0%). A US chemical company has developed a similar technique using yeast. Leaching requires low capital to set up and run, produces no carbon emissions and usually doesn't need regulatory approval. Rio Tinto and others say that there could be as much as 100 million tonnes of copper sitting in waste rock at mines around the world.

Recycling will also be part of the answer. Recycled copper accounted for about 32% of copper demand during the last decade, according to the International Copper Association, and will only grow as more EVs, batteries and other energy components reach the end of their life.

Of course, the problem is not only mining's to solve. Engineering advances across other industries can reduce the need for copper in EVs, batteries and other energy technologies and assets. For example, the use of aluminium in underground and subsea cables is likely to reduce demand for copper by more than one-third from current levels. But this may further complicate the issue – shifting demand away from copper will impact its investability. And this may be the biggest hurdle of all. To meet forecast demand, investment in copper mining will need to increase to more than US$250b a year by 2030, up from around US$105b today. Securing capital will be critical to securing supply – and the world's transition to a new energy system.

# Implication 1 2 3 4 5 6 7 8

## Integration of old and new energy systems

Underpinning everything will be the need to bring a new energy system online while retiring and repurposing legacy assets. This complex balancing act requires consideration of multiple, sometimes contradictory, issues, including maintaining secure supply, reducing carbon emissions, minimizing job losses, and ensuring energy and resources companies stay investable.

It will also require huge investment. We forecast that energy transition annual investments need to increase by 300% by 2050 and will require a significant scaling up of financial resources and investment flows into low-carbon technology. Decisions about long-term investments will be made as companies grapple with more immediate dilemmas – how to balance the threat of obsolete assets impairment with other risks that arise when old assets operate for longer.

Shifting capital portfolios will be helped along by carbon pricing, but it won't be the whole solution. Government intervention may be needed to incentivize investment in renewables that deliver lower rates of return than hydrocarbons.

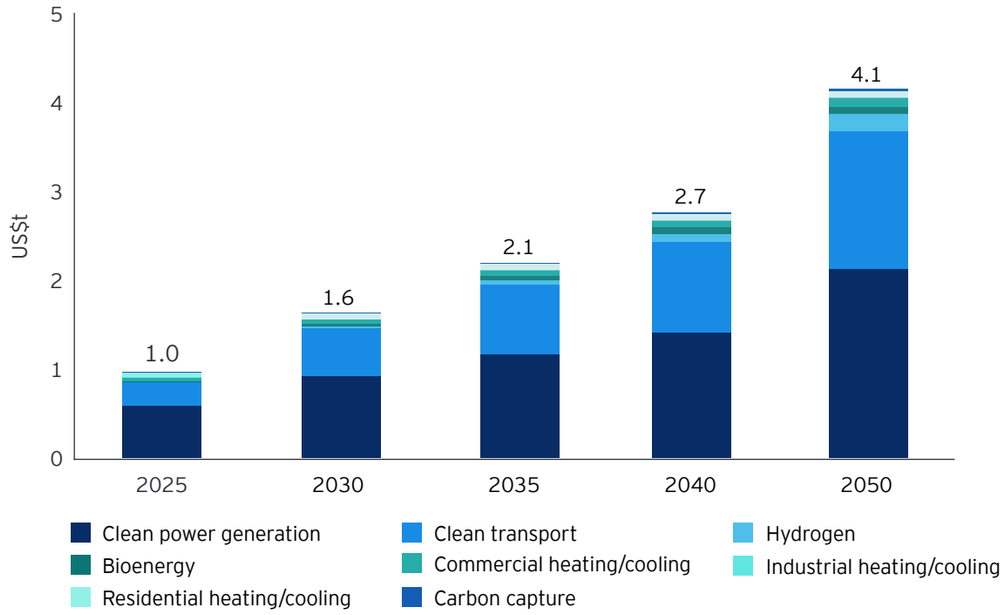
# Implication 1 2 3 4 5 6 7 8

## Integration of old and new energy systems

### How investment in low-carbon technology will increase

A new energy system is emerging, but it will require annual investment in low-carbon technologies to increase fourfold by 2050. Closing the gap between investments required and the current levels will involve a significant scaling up of financial resources and investment flows into renewable energy and related infrastructure.


### Global annual capital expenditure by low-carbon technology (US$t)




Growth in clean power generation investments from **US$0.6t** in 2025 to **US$2.1t** by 2050

Growth in electric mobility investments from **US$0.3t** in 2025 to **US$1.5t** by 2050

Source: EY analysis of ERTA model data.

# HANDBRAKES

## Why we need to address risks to progress

# Releasing the handbrakes

The speed of the energy transition will vary as technology advances, policies evolve and societal attitudes shift. But several issues pose a serious risk to progress — releasing these "handbrakes" through collaboration across companies, governments and consumers could fast-track change.

**Supply chain constraints could halt the build-out of new energy assets**

The world has enough of the commodities and critical minerals needed to build new energy assets, but they are concentrated within a handful of countries. The risk is that rising resource nationalism and geopolitical tensions could disrupt supply, push up costs and increase market volatility. China dominates processing of almost all critical minerals.

**Inconsistent regulatory environments could disincentivize investment**

Across the world, regulatory frameworks around clean energy differ according to government priorities, societal attitudes and energy needs. This creates inconsistent investment conditions for energy and resources companies and could slow progress.

**Short-termism may hinder capital raising**

Making the energy transition happen will require investment of a size and scale never seen before. But current returns don't incentivize investment where it's needed, which may make it tough for energy and resources companies to secure the capital they need. Meeting short-term shareholder demands and juggling the risks of keeping old assets operational could hinder companies' investment in the future.

**Renewables don't (yet) deliver sufficient returns**

Without the right incentives, subsidies and carbon pricing, returns on renewables and other low-carbon technology investments won't be enough to accelerate change at the pace we need. Current returns on clean energy are around 6%, compared with double that or more for upstream oil and gas.

# Releasing the handbrakes

**Decreasing demand for oil and gas risks deterring investors**

Oil and gas will play an important role in the energy mix for some time, but decreasing demand and carbon pricing will almost certainly impact revenues eventually. Continuing to attract investment despite the risk of lower returns will be critical if companies are to fund decarbonization and digital technologies.

**Innovation depends on faster adoption of still unproven technology**

We'll need a mix of mature and early-stage technologies to drive the energy transition. Adopting new technology can bring higher costs and risks for energy and resources companies, but waiting until costs come down could slow the innovation needed to solve challenges such as intermittency. Intelligent incentives from government could go a long way in bridging this gap.

**Talent shortage may deprive the sector of critical skills**

Across energy and resources, a skills crisis is looming. An aging workforce is part of the problem – about 50% of mining engineers will retire in the next decade – but perhaps more concerning is a dearth of young recruits and difficulty in competing for talent with new, in-demand skills. Ninety percent of power and utilities executives say they have very few workers with the digital skills they need. Closing the skills gap will require companies to think beyond the obvious – the industry already offers healthy salaries – and identify a winning employee value proposition.

**Consumers could lose confidence in a changing energy system**

Our research suggests that consumers' dissatisfaction with the energy experience is already undermining their confidence in the energy system. This is important because confident consumers are more likely to invest in new energy solutions, adopt sustainable behavior, and influence corporate sustainability and government policy. Creating energy solutions that give consumers what they want, beyond the basics, can boost confidence and mobilize sustainability actions.

# OPPORTUNITIES

## How energy and resources companies can create value

The implications of a changing energy system create uncertain operating conditions for energy and resources companies. Adapting to change will expose organizations to new risks – big operational shifts always do – but we believe the risk of not changing will be far greater.

Declining revenue. Shrinking market share. Difficulty accessing capital. And a scarcity of talent. These consequences may hit different sectors and companies at different times but are the inevitable outcome for every energy and resources company that doesn't embrace change.

Alternatively, organizations that act now can seize a huge prize. The opportunities unfolding as the energy system transitions are huge, and will only increase as the pace of change intensifies. Making the most of these opportunities, while mitigating risks, will depend on identifying and committing to appropriate no-regret actions for the years ahead.

## Opportunities for energy and resources companies

A changing energy system has created unprecedented complexity and uncertainty. Organizations will need to strategically manage dual challenges — strengthening the current system while developing for the future.

### Mining and metals

**Build trust to compete for capital and labor**

- Focus ESG efforts to build the brand.
- Build a portfolio that caters for future demand.
- Balance new business models with core activities.
- Get closer to governments to combat resource nationalism.
- Invest in innovation to reduce emissions along the supply chain.

### Oil and gas

**Seize and scale the growing green molecule market**

- Safely reduce the cost of operations and your carbon footprint.
- Get your alternative molecule offering right.
- Plan for downstream market disruption.

### Power and utilities

**Unlock the grid and create a flexible platform for innovation**

- Continue to build out renewables at pace – where it makes sense.
- Invest in grid flexibility and intermittency management.
- Reset your relationship with the customer.
- Reshape your operating model to fit.

# Mining and metals

## Build trust to compete for capital and labor

There is no energy transition without mining and metals. Demonstrating the sector's value is now an urgent priority. Securing capital LTO is the priority for miners, and largely achieved by building trust. Miners that shift their focus from purely short-term profits to longer-term value can win over investors, enable the development of new mines, attract talent and mitigate geopolitical volatility.

These no-regret actions can help guide the way:

- **Focus ESG efforts to build the brand.** Identify your ESG focus. Some miners are prioritizing local community engagement; others are committing to net positive biodiversity impact or water stewardship. Determine where value lies for you and adopt a long-term strategy to achieve it. Invest in the digital and data capabilities needed to monitor, measure and report on progress.
- **Build a portfolio that caters to future demand**. Plan for possible alternative futures by considering a mix of strategies. These may include building out reserves, and divesting or investing in different minerals and metals, and new technologies. Consider how innovation, including in batteries, might displace projected mineral demand.
- **Balance new business models with core activities**. The challenge for miners is addressing the need to invest in new business models while maintaining discipline and returns. EY analysis shows most companies are focusing investment in traditional or core activities such as exploration, mining and processing to ensure returns remain strong, and can fund investments in sustainability, technology and new business models such as vertical integration, investing in adjacencies (renewables and infrastructure) and the circular economy.
- **Get closer to government to combat resource nationalism**. Forging stronger relationships with government can help weather inevitable regulatory volatility.
- **Invest in innovation to reduce emissions along the supply chain**. Demand from customers for more sustainable supply chains creates opportunities for miners that invest in decarbonizing operations, as well as solutions, such as blockchain, that track and trace emissions from mine to market and beyond. Abating Scope 3 emissions is now an imperative, or miners will lose competitive advantage.

Depending on a miner's market, the road ahead will look very different. Knowing which bets to place will depend on a deeper understanding of the trajectory of technology adoption across multiple markets, as well as insight into potential geopolitical impacts. We see evidence of how different companies are approaching these issues in varying ways. For example, some organizations are spinning off parts of the business that deal with critical minerals into separate entities, to attract a broader investor base. Others are exploring how partnering with companies in adjacent industries, such as automakers, could help boost investment into exploration and production, and tap into government incentives, including the US Inflation Reduction Act.

# Oil and gas

## Seize and scale the growing green molecule market

For oil and gas companies, the challenge will be balancing a need to invest in new technologies, while keeping core assets operating for longer. Upstream, midstream and downstream companies face different operating environments, but all should consider how to decarbonize, diversify, digitalize and even disrupt themselves.

These no-regret actions can help companies get started now:

- **Safely reduce the cost of operations and your carbon footprint**. Declining demand will eventually pressure margins, requiring a laser focus on cost and efficiency. Stakeholder pressure and increasing carbon costs will make decarbonization a priority. Focus on cutting emissions in the short term by removing methane, addressing routine flaring, electrifying drilling and processing operations and recycling $CO_2$ into enhanced lift.
- **Get your alternative molecule offering right**. Markets will emerge for new molecules, but understanding how and when (and if) these markets work from an economic and technical standpoint will be critical. Focusing on molecules closest to current capabilities (including decarbonizing fossil fuels with CCUS) and leveraging government incentives can hedge risk. Before deciding to invest, be sure to understand whether the economics make sense to the end user (i.e., beyond relative costs of production).
- **Plan for downstream market disruption**. Understand where changing dynamics, such as EV adoption, will hit the business hardest, and be ready for a new kind of energy customer. Review current retail and B2B portfolios, and create a plan to evolve them. Develop a series of more attractive value propositions for different customers.

Beyond this, strategic choices will differ by company. Even organizations that appear very similar and operate in the same markets may take very different paths, depending on their current strengths and future ambitions. For example, international oil companies (IOCs) based in Europe are becoming integrated energy companies, with portfolios that mix hydrocarbons and new energies. By contrast, US IOCs and Middle Eastern national oil companies are continuing to focus on oil and gas, prioritizing cost, operational and carbon resilience.

# Power and utilities

## Unlock the grid and create a flexible platform for innovation

Fundamental shifts in how energy is produced, distributed and consumed will change everything for power and utilities companies. Challenges around the risk of stranded assets and grid modernization must be overcome at the same time as companies consider which new technologies and consumer solutions offer the best opportunities for growth. Treating the grid as a flexible intelligent platform can help power and utilities companies capture value through innovation, new services and alternative business models.

These no-regret actions can help companies get started now:

- **Continue to build out renewables at pace – where it makes sense.** Consider the speed of the transition in your market, understand the impact of regulatory frameworks, make sure timely grid connection is feasible – and check the economics work.
- **Invest in grid flexibility and intermittency management.** Adopt digital solutions that support active network management systems, local energy markets and flexibility platforms. Consider the feasibility of regional interconnections.
- **Reset your relationship with the customer.** Put consumers at the heart of the business, identifying what motivates them, what they value, gaps in current energy solutions and, crucially, the common thread across all of these. Invest in the technology and business models that overcome business silos and allow you to offer a holistic, integrated customer experience that better meets needs and captures more value.
- **Reshape your operating model to fit.** Identify your core competencies and invest in strengthening these. Adopt a digital-first approach, investing in digitalizing and streamlining operations, products, services and experiences.

Developing a successful strategy will largely depend on making the right choices at the right time. This requires a deep understanding of how, when and to what extent different implications will affect multiple energy transitions, as well as the impact of policy and technology across markets. For example, an energy retailer in a competitive market may decide to harness the potential of growing EV adoption. Offering personalized energy solutions that bundle charging services, batteries and demand management can create differentiation, and also help embed flexibility into the grid. On the other hand, transmission system operators in regulated markets might prioritize investment in technologies, such as dynamic voltage control, that can better balance supply and demand – and articulating the value of such investment to regulators and government.

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