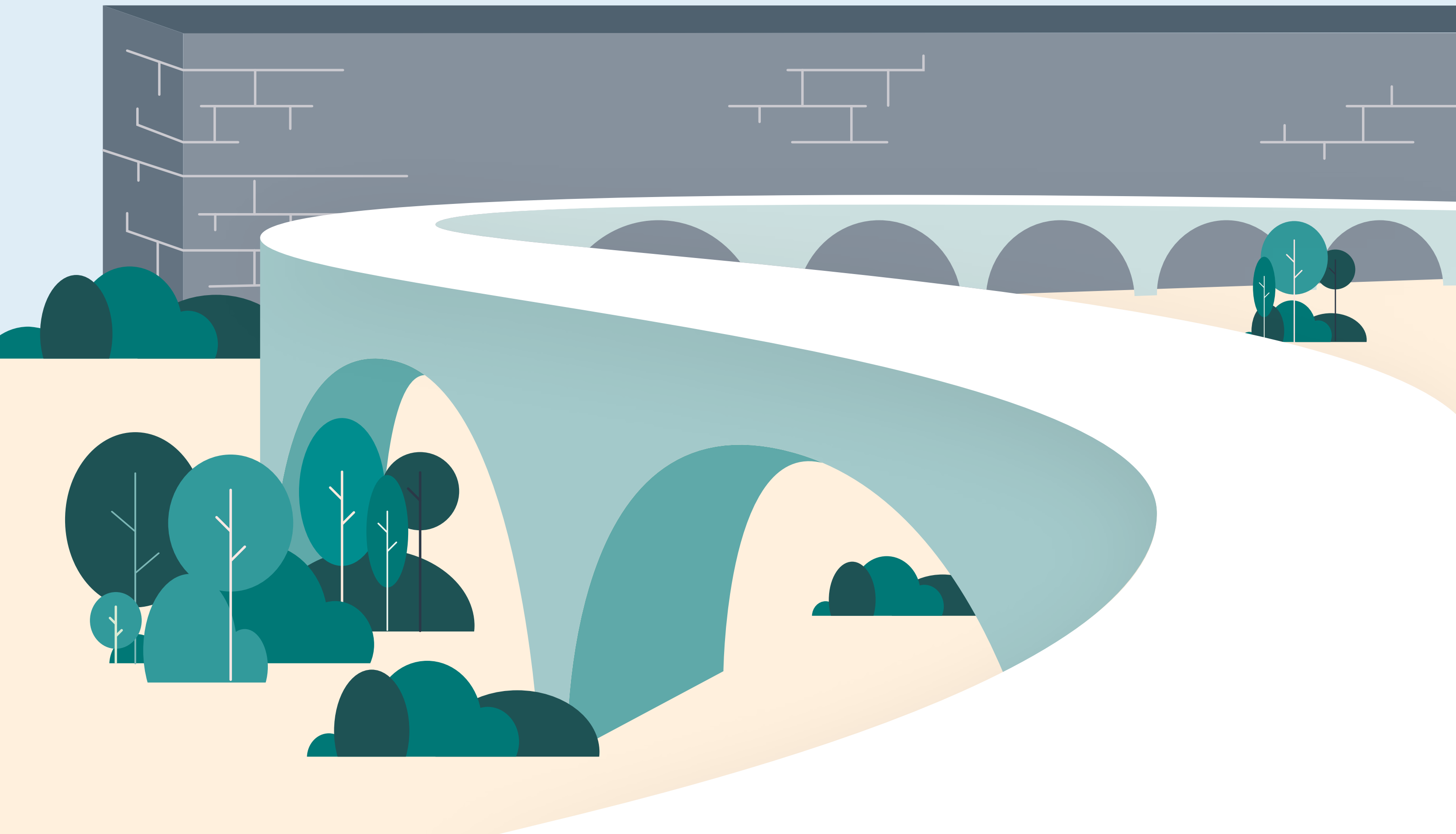
equinor

2022

Energy Perspectives

Global macroeconomic and energy market outlook



WE BUILD
TOO MANY
WALLS
AND
NOT ENOUGH
BRIDGES

Sir Isaac Newton

Welcome to Equinor's Energy Perspectives 2022

Meeting global climate goals through an energy transition is an immense challenge that requires commitment from governments, industry and individuals alike. Russia's invasion of Ukraine earlier this year has not only tragically impacted the lives and livelihoods of those directly affected, but the associated geopolitical tensions have also further deteriorated global cooperation and trade and supply flows on which a sustainable energy transition is completely dependent. Security of energy supply has come to the forefront of the energy policy agenda, with rising energy prices and unprecedented overall cost of living, keeping energy affordability firmly on the agenda as well.

In order to bring the world on track to address long-term sustainability challenges in a balanced manner, trust, cooperation, and burden-sharing must be established. This will take time and is by no means guaranteed. As long as short-termism and local priorities dominate policy making, the necessary global changes in the direction of sustainable development will be delayed.

Energy Perspectives presents two distinct scenarios for the future world economy, international energy markets and energy-related greenhouse gas emissions. The scenarios are not predictions, but possible contrasting pathways, providing a platform for debate and decision making.

The two scenarios, *Walls* and *Bridges*, illustrate very different future pathways driven by a variety of factors, ranging from economic growth and technological development to climate policy and geopolitics. The scenarios aim to highlight the immense challenges that must be overcome to make the move from the slow, incremental changes that characterise the energy transition today (*Walls*), to the radical changes needed to move the world onto a path aligned with the 1.5°C ambition of the Paris Agreement (*Bridges*).

We are committed to being a leader in the energy transition. Energy Perspectives provides me and my colleagues with crucial insight about the outcome space within which we have to balance our strategic priorities.

Anders Opedal
President and CEO

Walls divide and bridges connect. Our new scenarios paint a large outcome space for what the long-term energy future might look like based on choices made today and going forward.

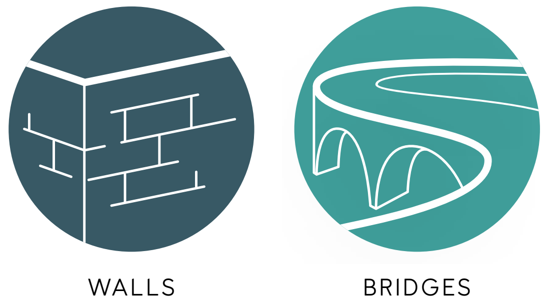
Eirik Wærness
Senior vice president and Chief economist

Key insights from Energy Perspectives 2022

Energy Perspectives 2022 presents two scenarios for economic and energy market development, *Walls* and *Bridges*.

Walls builds on current energy market trends and energy and climate policies, assuming climate action to progress at a slowly accelerating pace in the future.

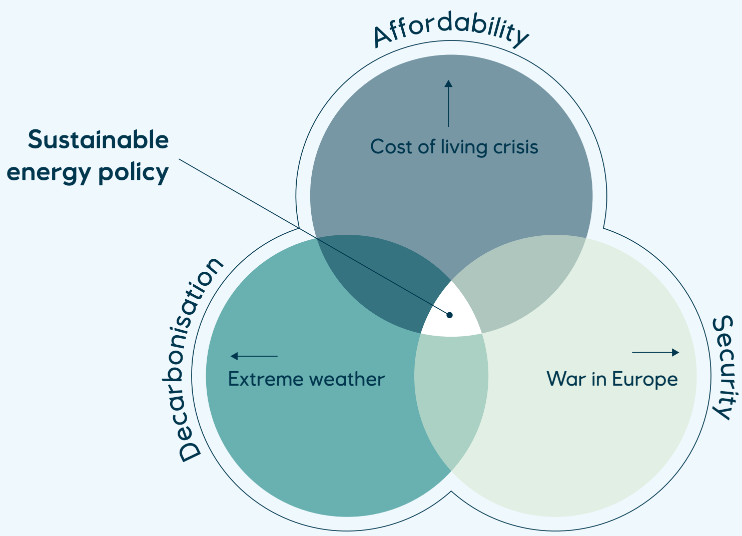
Bridges is a normative back-cast complying with the 1.5°C carbon budget, demonstrating the enormous and sustained efforts required to reach this target.



Policy-makers' focus has shifted repeatedly over the last 18 months

This is due to the cost-of-living crisis, the Russian invasion of Ukraine, and extreme weather events.

Sustainable energy policy requires maintaining between these competing priorities to be maintained.



Peak demand for fossil fuels arrives before 2030

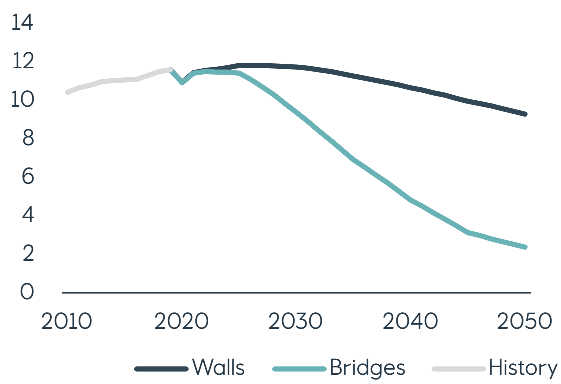
In *Walls*, the peak occurs in 2026, followed by a gentle downward trajectory.

In *Bridges*, fossil fuel demand declines at a rapid pace after 2025. By 2050, all remaining fossil fuel use is either fully abated or compensated by carbon removal.

IEA (history), Equinor (projections) →

Global fossil fuel demand

Gtoe



Gas demand will continue to grow in *Walls*, but declines sharply in *Bridges*

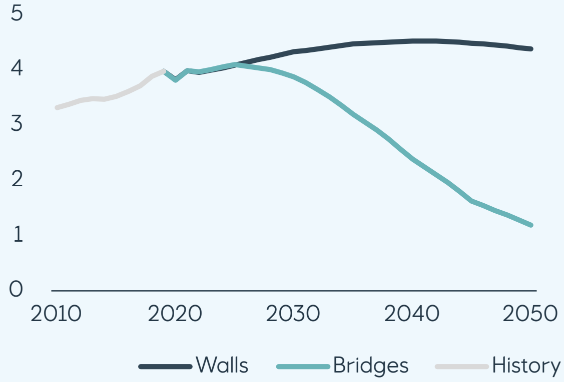
In *Walls*, gas demand peaks in 2041 and is around 10% higher than today's level in 2050.

In *Bridges*, gas demand peaks in 2025 and falls to around a quarter of today's level in 2050.

IEA (history), Equinor (projections) →

Global gas demand

Thousand Bcm



Energy consumption shifts towards electricity

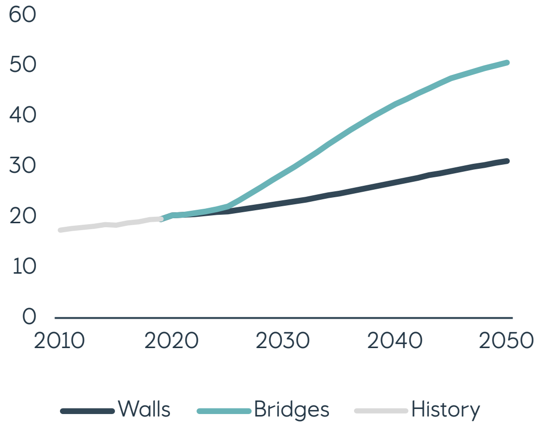
In *Walls*, electrification accelerates steadily towards 2050, increasing its share by half.

In *Bridges*, a massive acceleration happens before 2030. By 2050, the share exceeds 50%, two and a half times as large as today.

IEA (history), Equinor (projections) →

Electricity share of energy consumption

%



The growth of wind & solar photovoltaics (PV) capacity outruns all previous trends

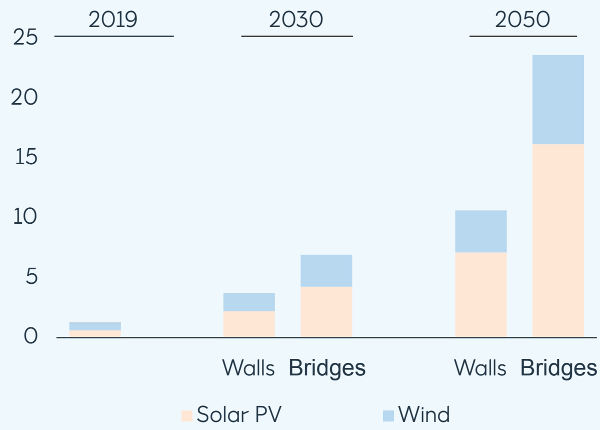
In *Walls*, wind capacity is six times greater, and solar PV capacity 12 times greater in 2050 compared with today.

In *Bridges*, wind capacity is 12 times greater, and solar PV capacity 27 times greater in 2050 compared with today.

IEA (history), Equinor (projections) →

Wind & solar PV capacity

Thousand GW



Electrification and hydrogen-based fuels will contribute to the decarbonisation of transport

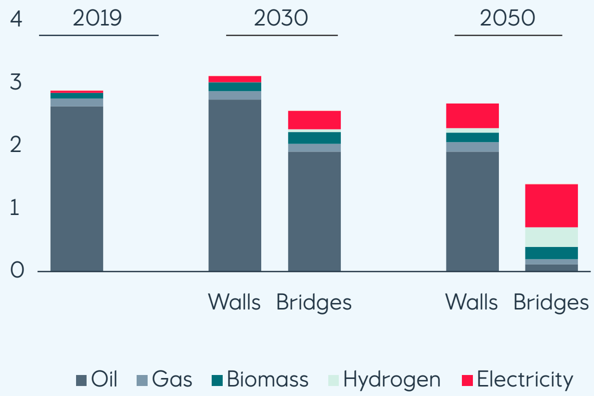
In both scenarios, electric vehicles replace internal combustion engines in road transport.

In *Bridges*, further decarbonisation is achieved by increasing the use of hydrogen-based fuels in marine and air transport.

Source: IEA (history) Equinor (projections)

Transport fuel mix

Gtoe



Carbon capture, utilisation and storage (CCUS) will play an essential role in the decarbonisation of the power and industry sectors

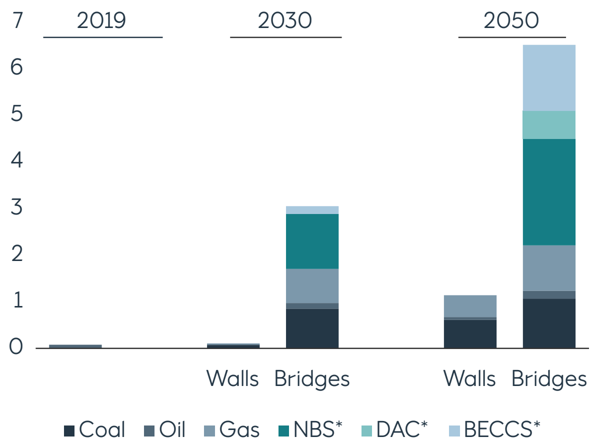
In *Walls*, CCUS on both coal and gas starts to accelerate after 2030.

In *Bridges*, there is massive growth in CCUS even before 2030, and no unabated fossil fuel use remains in 2050.

Source: IEA (history) Equinor (projections)

Carbon captured and stored annually

Gt CO_2



* NBS/DAC/BECCS – definitions are on page 9

Current net zero commitments are not enough to avoid global warming above 1.5°C

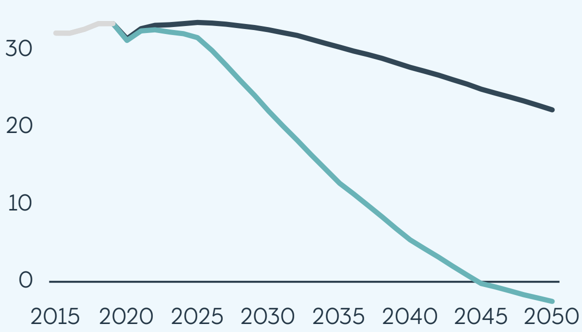
In *Walls*, the 1.5°C budget is exhausted by 2032.

In *Bridges*, current commitments are met, and further commitments are made that enable emissions to remain within the 1.5°C carbon budget with the help of carbon removal technologies.

Source: IEA (history) Equinor (projections)

Global energy-related CO_2 emissions, after carbon removal

Gt CO_2



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INTRODUCTION

The energy transition

The energy transition is defined by an ongoing process of restructuring the energy system through energy efficiency and substituting away from fossil fuels towards sustainable low-carbon energy sources, in order to deliver sufficient energy, reduce CO_2 emissions and limit global warming.

As the threats posed by global warming have become progressively more evident, the concept of energy transition has become coupled with the ambition to reduce net greenhouse gas emissions to zero by the middle of the century, and preferably cap global warming at 1.5°C above pre-industrial levels. Massive transformative measures and structural changes in the global energy system are needed to support the energy transition. The key enablers to this transition can be categorised as follows:

ENERGY INTENSITY

Decoupling economic activity and energy use

- Structural changes to the economy
- Technological improvements
- Behavioural changes

CARBON INTENSITY

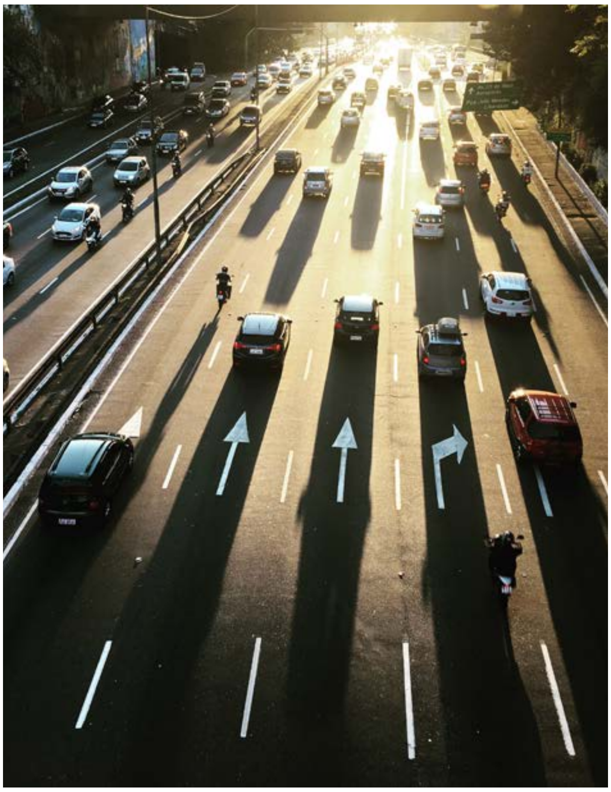
Decarbonising energy use

- Fuel-switching, including electrification
- Renewable energy sources
- Carbon capture, utilisation and storage

CARBON REMOVAL

Removing carbon from the atmosphere

- Nature-based solutions (NBS)
- Bioenergy with carbon capture and storage (BECCS)
- Direct air capture (DAC)



Rapid growth in the shares of wind and solar photovoltaic (PV) generation in the power sector, and electric vehicle (EV) sales, demonstrate that the energy transition is under way in some sectors.

However, while power generation accounts for some 40% of global CO_2 emissions, and passenger car use for another 9%, complete decarbonisation of these two sectors would, all else being equal, leave the world with emissions at about half of today's level. This would reduce global warming but not come close to delivering on the 1.5°C target. Furthermore, emissions remaining in other sectors are proving more challenging to eliminate, for example high-temperature industrial process heating and non-road transportation.

The energy transition needs to consider the growth aspirations of poorer countries and, more generally, the affordability of electricity and fuels to consumers. Climbing out of poverty may come into at least temporary conflict with emission reduction targets, suggesting difficult trade-offs. In addition, the energy transition, as highlighted by events this winter, needs to be aligned with the requirement for supply security.

Facilitating an energy transition that delivers on the 1.5°C target is an enormous challenge. Meeting the 1.5°C target in a just and sustainable manner for all adds additional levels of complexity.

Net zero and 1.5°C targets

Around seventy countries have already committed to reducing their CO_2 emissions to net zero by the middle of the 21st century, comprising around three-quarters of current global emissions. Many corporations have also announced net zero targets and put forward strategies to achieve these ambitions.

It is a common misperception that achieving net zero will deliver on the 1.5°C cap on global warming.

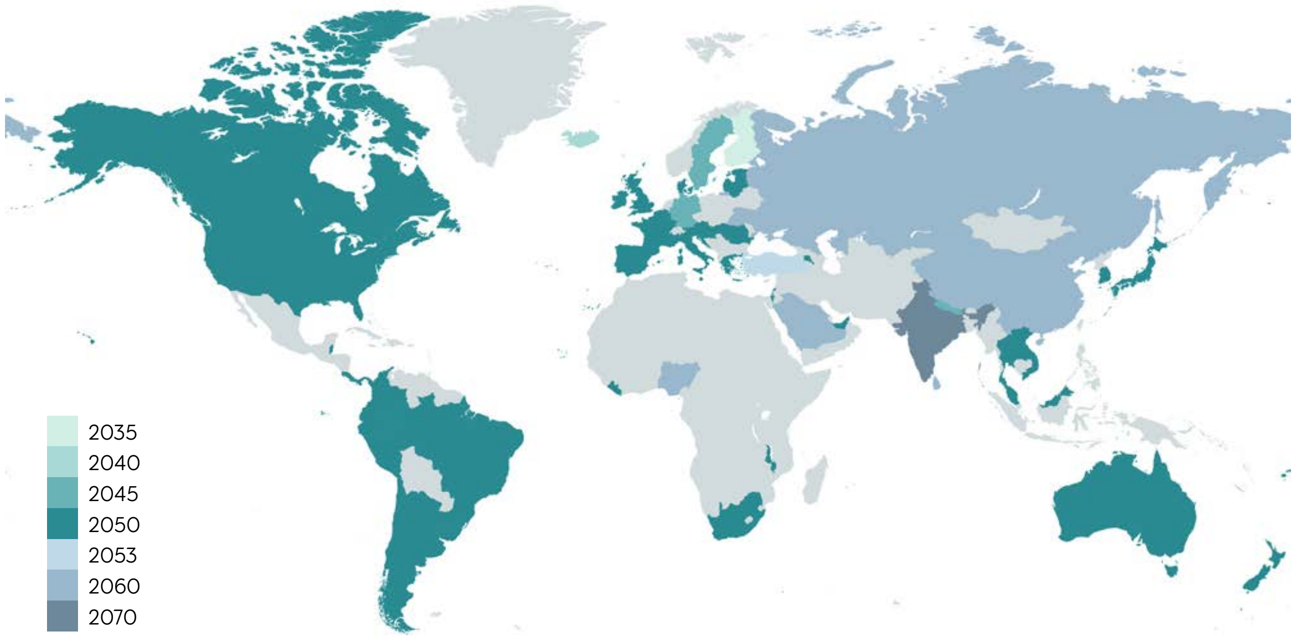
Capping global warming at 1.5°C above pre-industrial levels was agreed upon as an ambition in Paris in 2015 at the United Nations Climate Change Conference. It became the dominant target after the Intergovernmental Panel on Climate Change (IPCC) published a report on global warming of 1.5°C in 2018. The 1.5°C target corresponds to a specific remaining carbon emissions budget. The IPCC AR6 report of 2021 estimated this budget to be 500 Gt CO_2 for the period 2020-50, which covers emissions in the energy system as well as other uses*. This implies that the world has less than ten years at current emissions levels before the budget is exhausted.

Net zero, sometimes called carbon neutrality, refers to the equilibrium between the number of anthropogenic greenhouse gases released into the atmosphere and the amount removed and stored by carbon sinks. A commitment to net zero entails a commitment to achieving this equilibrium at a specific future point in time and sustaining this balance indefinitely.

In short, the 1.5°C target requires cumulative net carbon emissions to remain under a finite level, whilst net zero requires only that emissions are balanced by an equivalent amount of carbon removal after some specific point in the future.

It follows that the 1.5°C target is the more onerous constraint: of the many pathways that lead to net zero by mid-century, the vast majority will not meet the 1.5°C target.

Countries with net zero targets set either in law, policy documents or pledges



Source: Energy & Climate Intelligence Unit, MapChart

** The IPCC's 6th Assessment Report puts the CO_2 budget for the 2020-50 period at 500 Gt. This budget is to be shared between emissions in energy, industrial uses like cement, and agriculture. In this analysis a budget of 445 Gt is allocated to emissions for energy purposes.*

The 1.5°C target can be achieved only through a radical and unprecedented reduction in emissions as a result of an accelerated phase-out of fossil fuels in the short-to-medium term, as demonstrated in *Bridges*, a scenario which not only achieves net zero by 2050 but also complies with the required carbon budget.

Postponing the phase-out of fossil fuels and maintaining, or increasing, emissions in the short-to-medium term will only exacerbate the challenge and will require even more radical and challenging emission reductions in later years.

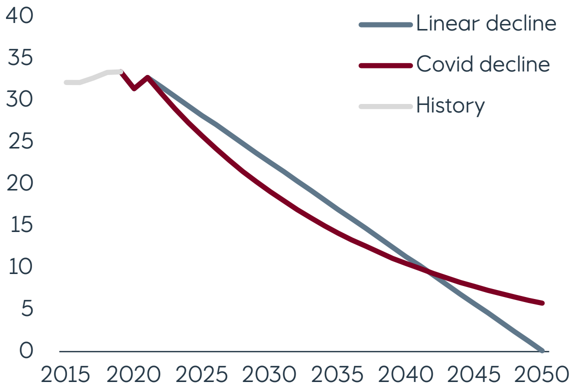
To try to put into context the unprecedented emissions reductions required to achieve the 1.5°C target, consider the two following possible futures, illustrated in the charts below:

- **Linear decline:** A linear decline in emissions of approximately 1.1 Gt per year, reaching net zero in 2050, which will overshoot the emissions budget in the year 2038.
- **Covid decline:** An annual reduction in emissions of 5.8% per year until 2050, a similar level of decline to that observed in 2020 in response to reduced activity levels during the Covid-19 lockdowns, which will overshoot the emissions budget in the year 2043.

Neither of these extreme alternatives avoids overshooting the emission budget compatible with a 1.5°C temperature increase, meaning that in both cases negative emissions at a future date would be required to reduce the aggregate carbon emissions and comply with the budget.

Annual energy-related emissions

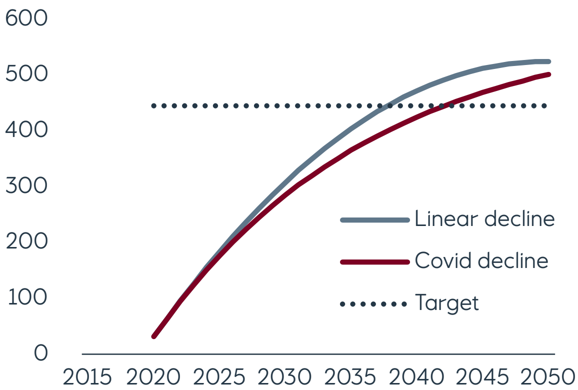
Gt CO_2



Source: IEA (history), Equinor (projections)

Cumulative energy-related emissions

Gt CO_2



Source: Equinor

The energy trilemma

The purpose of energy policymaking is to use the tools of government including national legislation, international treaties, investment incentives, taxation and other public policy elements, to find an acceptable and sustainable compromise between a myriad of competing priorities. This compromise is commonly simplified and referred to as the 'Energy Trilemma', a trade-off between three criteria:

- **Energy affordability:** that consumers' needs for heating, cooling and other energy services can be met without compromising their ability to meet other basic needs
- **Energy security:** that energy supply is always available in adequate amounts, robust against geopolitical instability and/or natural disasters
- **Energy decarbonisation:** that energy services are provided and consumed in ways that do not endanger future supply or negatively impact the climate, disadvantaging future generations

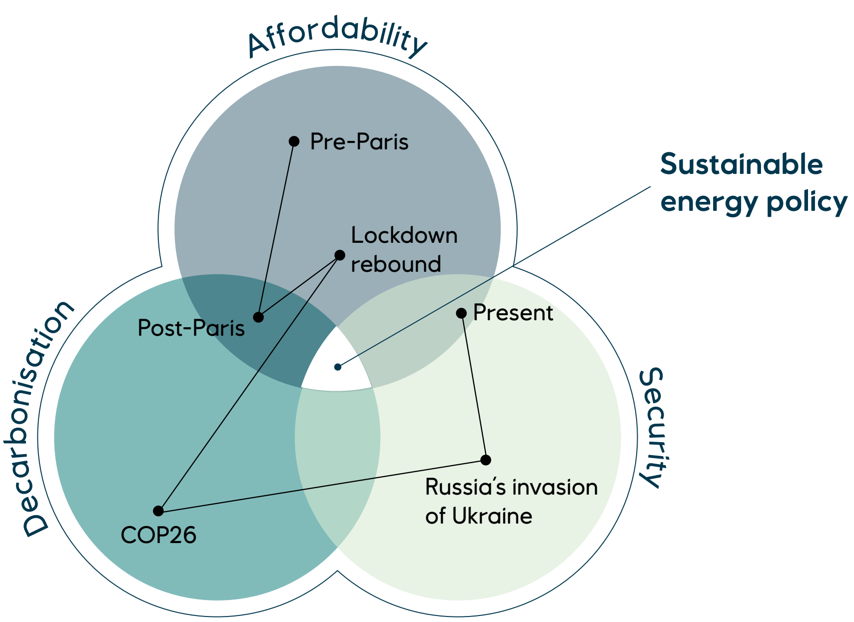
Policymakers' concerns about individual criteria have ebbed and flowed, and policy priorities have shifted accordingly. The diagram below is a simplified illustration of the changing focus of global energy policy over the past decade, with the last eighteen months exhibiting a particularly erratic trajectory.

Prior to the Paris Agreement, energy policy was predominantly efficiency-driven and directed mainly at securing energy supply as cheaply as possible, although there were reminders in periods of oil market turbulence that energy affordability depended very much on energy supply security. Local pollution was a factor in energy policy making, but wider environmental issues, with the notable exception of the hole in the ozone layer, received limited attention.

The Paris Agreement brought climate change to the forefront of energy policy, and subsequent IPCC reports and Conferences of the Parties (COPs) have reinforced this prioritisation. Although the costs of pursuing decarbonisation targets were not altogether ignored, energy affordability was often relegated to a secondary concern, and potential supply security challenges were typically discounted.

Although the economic recovery from Covid-19 drove a sharp rebound in fossil fuel demand and made energy affordability a high-profile issue in the summer of 2021, COP26 in Glasgow in late 2021 seemed to have maintained the focus on decarbonisation. However, the invasion of Ukraine by Russian forces in February of this year brought the issue of security back to the forefront of energy policy. Further rises in energy prices and the overall cost of living kept energy affordability at the top of the agenda in many countries.

A schematic illustration of the changing focus of global energy policy since the Paris Agreement was negotiated and adopted in 2015



Source: Equinor

It is highly uncertain now where the focus of energy policy will move next.

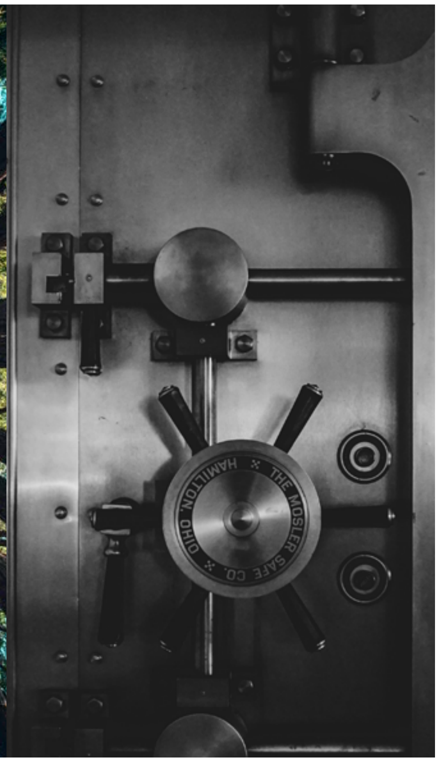
- Will decarbonisation regain its momentum and its position on the political agenda? Will the increasing frequency of extreme weather events impacting natural habitats, destroying people's homes, and disrupting infrastructure, provoke policymakers to focus more on climate change mitigation or adaptation?
- Will the cost-of-living crisis lead to increased energy poverty and food shortages? Will the ongoing situation in Ukraine exacerbate the crisis, and food security become a global issue?
- As emerging economies strive to raise the living standards of their populations and inevitably consume more energy, will that energy be supplied sustainably? Should the economic rise of these regions be limited by the emission legacy of the industrialised regions?
- Will bottlenecks in the supply of minerals critical to the energy transition, including lithium and cobalt (for batteries), silicon (for solar panels), rare earth elements (for permanent magnets) and steel, copper, aluminium and nickel (for practically everything), impose limits to the rate of electrification of road transport and decarbonisation of regional power systems? Will the reliance on a small number of countries for many of these minerals, and reliance on China for refinement, give further reasons for concern? Will the exclusion of Russia from global trade exacerbate critical bottlenecks?

The energy supply security and energy decarbonisation criteria call for many of the same long-term solutions, namely the prioritisation of energy efficiency measures and an accelerated shift from imported fossil fuels to indigenous renewable energy sources, meaning in most cases wind and solar power.

Moreover, climate change will likely provide a steady stream of reminders of its existence, as it has this summer, with heat waves, forest fires, floods and droughts affecting large parts of Europe, North America and Asia.

At the same time, the issue of energy affordability is not expected to diminish in importance in the short term. These conflicting demands should ensure that the focus of actual policymaking will be near the sweetspot where the conflicting demands of energy security, affordability and decarbonisation are adequately balanced.

The aim of energy policymakers is to find a pathway to the sweetspot. Any such pathway will meet barriers, and the test will be in how efficiently obstructions can be surmounted, circumvented or dismantled.



Energy intensity

The energy intensity of an economy, be it the world, a region, a country or an industry, denotes the amount of energy required to produce a unit of the economy's output. Changes in this amount are not only driven by changes in energy efficiency, but by many other factors as well. Energy intensity is thus a wider concept than energy efficiency.

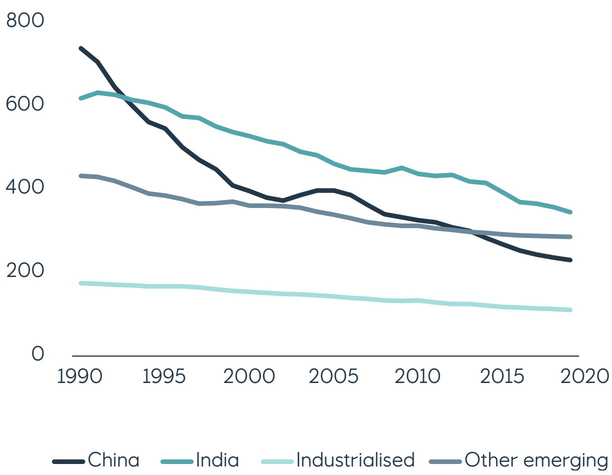
Energy intensity is a useful metric for energy scenario builders because it is possible to see trends in past changes, indicating the scope for future changes. Energy intensity projections together with economic output projections enable analysts to develop energy demand outlooks which are essential components of energy scenario analysis.

Technological changes are the main driver of energy intensity improvements, encompassing the development of technology capable of delivering the same amounts of output with less energy input along with the deployment of this technology via the turnover of capital stock, and the subsequent changes to the energy mix that result from this. The most prominent example of the latter is electrification. Electric engines waste less energy than combustion engines, and thus the ongoing gradual replacement of conventional cars with EVs lowers the energy intensity of road transport.

Normally, the profit motive would stimulate progress in the development and deployment of more energy-efficient technology in order to reduce input costs.

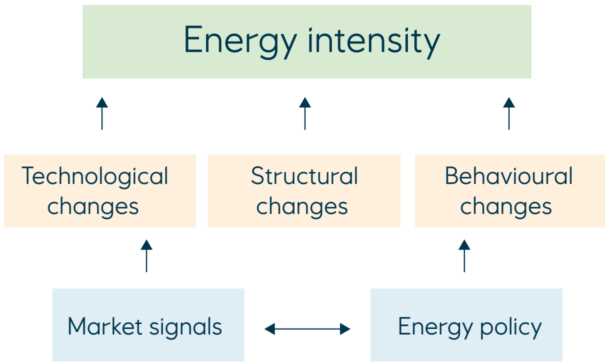
Energy intensity

toe per million USD



Source: IEA © Oxford Economics Limited 2022

Drivers of energy intensity



Source: Equinor

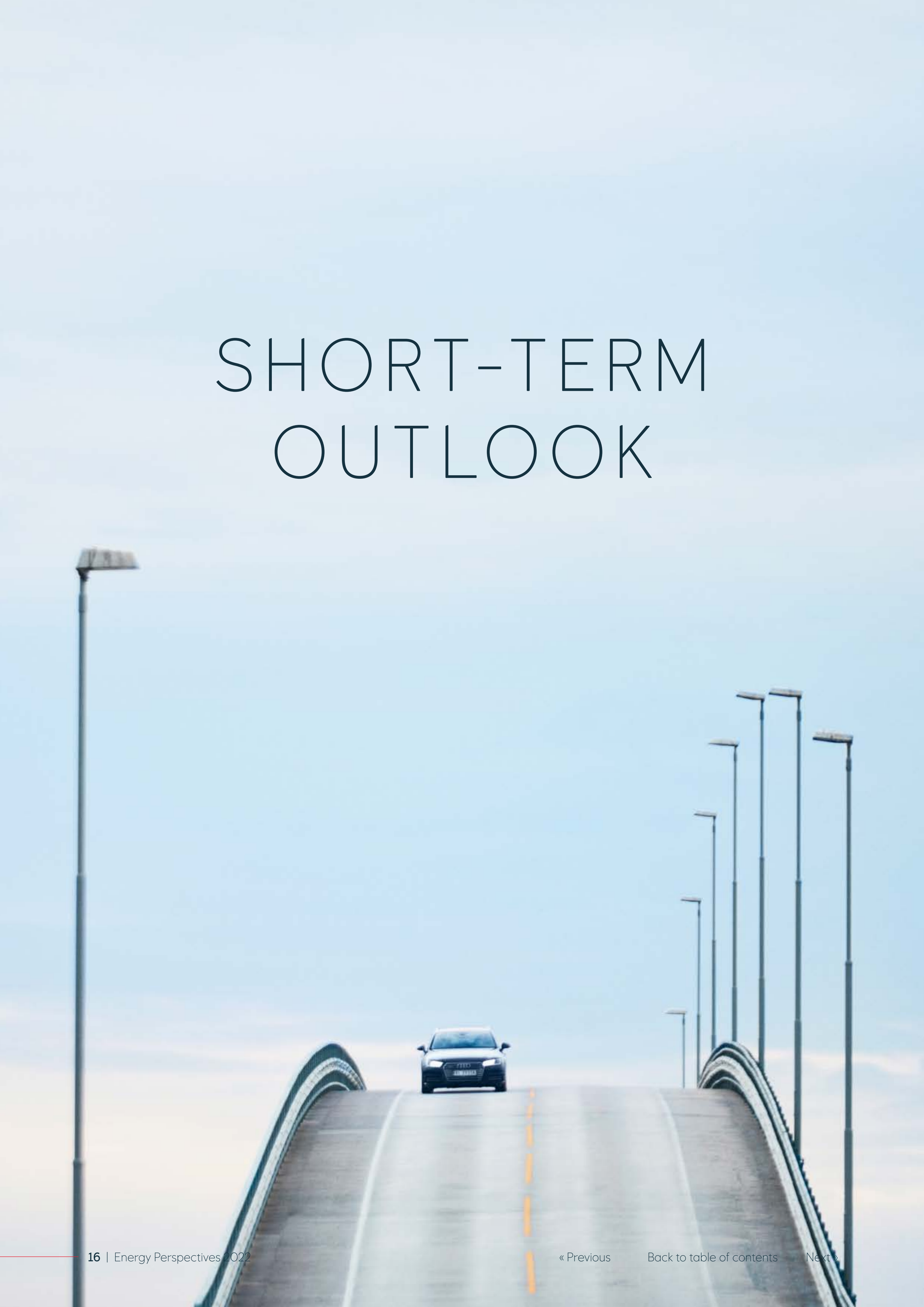
It may be, however, that the market does not deliver improvements at the pace required by environmental or supply security concerns. If so, policymakers may intervene with targets and incentives to accelerate progress.

The second driver of energy intensity improvements is structural changes to the economy, i.e. changes in the sector composition of its output. Economies typically evolve in stages, with the first stage characterised by agrarian production, the second by industrialisation and the third by rapid growth in the provision of services. A recurrent pattern is that the migration of resources between sectors first leads to an increase and then to a decline in energy intensity.

The third driver is changes in behaviour. Given incentives, people may be willing to make do with smaller amounts of energy services. They may accept to travel less, turn down their radiators and even adjust their eating habits towards food produced with a smaller energy and emission footprint. This has happened before, at least over short periods, and may happen again.

Annual changes in energy intensities fluctuate as the weather plays a part. While cold winters and hot summers push up the demand for heating and cooling, mild winters and summers do the opposite, with sharp deviations from the trend as a result. However, clear trends exist, and they are mostly down. Between 1990 and 2019, the energy intensities of North America, the EU27 area, China and India declined by averages of 1.8%, 1.8%, 3.9% and 1.9% per year respectively, according to IEA data. Globally, there was a levelling out in the early 2000s reflecting China's rapid industrialisation and build-out of infrastructure, but since around 2010 the downward trend has reasserted itself.

SHORT-TERM OUTLOOK



Geopolitical drivers

Russia's invasion of Ukraine will drive broad global change. The core conflict will not be resolved in the short-to-medium term, and the war will continue to last for months if not years. The liberal world order will remain under pressure from Russia's challenge, and the outcome in Ukraine will reverberate around the world. Nato will spend more on defence and tension in Europe will grow. Russia will muddle through economically despite sanctions, increasingly relying on a war economy approach. The war will impact the global economy negatively far beyond original expectations, which may in turn lead to increased political volatility.

With energy weaponised, energy security will be a key policy priority. There is little to suggest a return to normalcy any time soon. The EU has committed to shutting out Russian hydrocarbons. Before Russian gas becomes obsolete, Moscow will do what it can to make sure gas shortages make the next couple of winters in Europe economically and politically challenging. The EU will not abandon their energy transition and climate goals, but they will be more painful than anticipated to achieve. Opec+ will seek to continue to wield its market power and sustain high oil prices. Cooperation and unity on addressing climate change could be in jeopardy.

The divide between developed and emerging economies will deepen. First, the post-pandemic economic downturn will affect poor countries and poor people disproportionately. Second, the aftermath of the Covid-19 pandemic and the perceived unfairness in vaccine distribution will linger. Third, climate policy and the energy transition will increasingly be seen by the global South as a North-western responsibility, and there will be fear that climate policies can entrench developed-economy dominance. All of this will reduce the world's ability to tackle main issues together.

Reglobalisation is globalisation that recognises the importance of national security, supply chain resilience, and climate change, which in turn adds new risks. After 30 years of globalisation with vast gains for business and consumers, Chinese-US rivalry and Russia's invasion of Ukraine are changing the global economy. Commodities, logistics, technology, and finance will be the most vulnerable sectors, and supply chains could be selectively decoupled for political purposes. In a world with less trust, autarky and protectionism will be politically fashionable. Businesses will have different risks to consider. However, this will not be the end of global trade and supply chains; rather globalisation with a new ruleset: reglobalisation.

WILD CARD:

Even with the positive momentum of the Inflation Reduction Act, the election of a US republican president in 2024 could fast overturn Biden's policies on climate, energy, trade, and security (Nato). In the short term, US global leadership will also be hampered by internal divisions and isolationist impulses.

Global economy

In 2021, the global economy rebounded following the Covid-19 pandemic economic downturn. Global economic growth in 2021 was 5.9% compared to the 3.4% contraction in 2020. Growth was strong among most economies. The Eurozone economy expanded by 5.3%, the US economy by 5.7%, and the Chinese economy by 8.1%. Globally, GDP recovered to the pre-pandemic level in the first quarter of 2021.

As Russia invaded Ukraine in February 2022 global growth expectations for the year were significantly reduced. Russia and Ukraine account for a relatively small part of the global economy, but they are important suppliers of energy, food commodities, fertilisers, and certain metals. The war has led to the destruction of Ukrainian production capacity, disruption of supply chains and economic sanctions on Russia. These developments have contributed to supply shortages and increased price levels for the goods mentioned above. As a consequence, the global economy has slowed during the first half of 2022.

Europe is the region most significantly hit by the war in Ukraine. Prior to the war, Russia was the EU's main energy provider, supplying almost 40% of gas and significant amounts of oil and coal. While the EU is working towards reducing its dependence on Russian energy, any shortages will have major economic consequences for the region. Governments are expected to seek to shield households, in which case shortages could mean significant contractions in industry. Germany, Italy and other central European countries are most at risk.

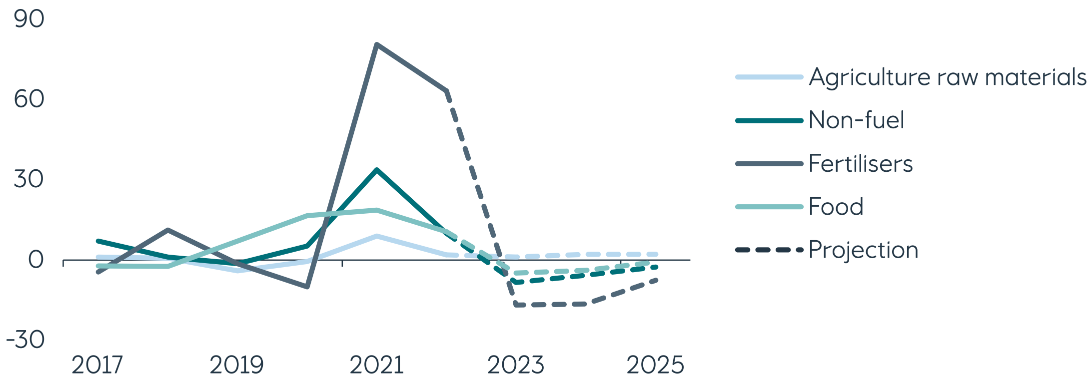
High global food prices will hit emerging markets the hardest. As global food price increases are exacerbated by the war, emerging markets are particularly vulnerable to food price inflation or potential food shortages. Several African and Middle East countries are dependent on wheat imports from Russia and Ukraine. Following a period of significant export disruptions, grain exports by ship have tentatively started again. High costs of fertilisers could also cause disruption of domestic food production in many countries, including in advanced economies. While Latin America and Asia are less dependent on Russian and Ukrainian food commodities, high global food and fertilizer prices could put significant strains on these regions.

China's Covid-19 restrictions continue to be a key risk factor in the global economy. The lockdown in Shanghai and other Chinese cities during the second quarter of 2022 exacerbated existing global supply chain disruptions following the pandemic as it disrupts Chinese goods manufacturing and export. While it is expected that potential future lockdowns will be less severe as China has moved towards "societal zero-Covid", any major lockdown will have negative consequences for the global economy.

The US economy has shown resilience and is expected to gain economically from the war in the short term. US energy exports will be key for Europe as it reduces reliance on Russian fossil fuels. However, surging US inflation followed by monetary tightening will restrain growth. Two consecutive quarterly declines in GDP during spring/summer 2022 raised recession fears. Inflation is set to remain high in the near term, before easing. A tight labour market and high consumer spending have caused concerns about a price-wage upward spiral fuelling inflation.

World commodity prices

% change y/y



Source: © Oxford Economics Limited 2022

Outlook to 2025

Two extraordinary events, the Covid-19 pandemic and Russia's invasion of Ukraine, have dominated the headlines in the past couple of years and have left their mark on energy markets and the short-term commodity demand forecast.

Covid-19 had a shock effect on energy demand in 2020 with the oil market being hardest hit. Oil demand fell due to a significant drop in the transport sector, as people refrained from travelling to work and using air transport for holidays and business appointments. Gas demand proved resilient to the impact of Covid-19 in the western world but suffered in Asia due to dampened industrial activity. Electricity demand in the residential sector increased during the peak of the pandemic as people were forced to spend more time at home, but this was by far outweighed by the decline in demand from the commercial and industrial sectors during the same period.

Whilst Covid-19 is still very much present, the implications for energy markets have proven to be short-lived. All markets made a strong recovery during 2021 and 2022 as activity returned to pre-Covid levels. The less severe health implications of the more recent variants, combined with impressive vaccine rollouts in large parts of the world, mean that the Covid-19 virus has become part of a new normal way of life.

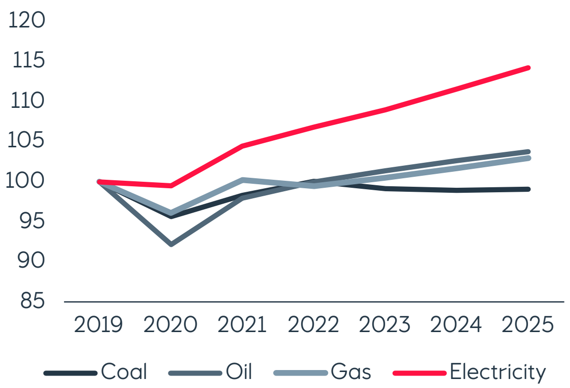
With Covid-19 posing less of a threat the focus has shifted, and the need for sustained economic growth now outweighs the risk posed by the virus. Recent whole-city lockdowns in China bear witness to a more drawn-out return to normal in Asia, leading to some lingering impacts on energy demand rebound and continued disruptions to global supply chains.

Russia's invasion of Ukraine will have a significant impact on energy markets in the next decade. Geopolitical tensions and the weaponisation of commodities will force a change in the energy mix and trade flows. Outside Russia, the impact of the war will be most severely felt in Europe, as declining, if not non-existent, gas flows from Russia are replaced by other energy sources and energy efficiencies in addition to LNG (Liquefied natural gas) and alternative pipeline imports. Build out of renewable capacity will be accelerated as part of the REPowerEU ambition, with lifetime extensions of coal and nuclear power plants helping to fill the supply gap in the short term. Russian oil and gas will find other outlets than Europe, with increased supply available to the domestic markets and export to Asia.

Demand destruction may be seen across all commodities and regions as a result of limited or lack of supply and high prices. Global LNG supply is likely to prove insufficient to meet demand, as Russian flows are reduced and potentially switched off altogether, with the supply deficit and higher prices leading to demand destruction. Russian oil supply is unlikely to return to pre-war levels.

Coal, oil, gas and electricity demand

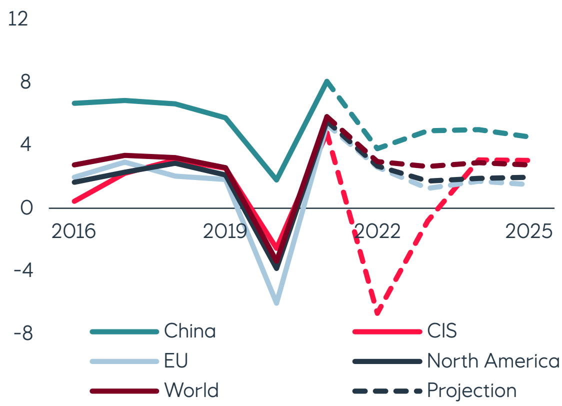
Indexed 2019 = 100



Source: IEA (history), Equinor (projections)

GDP growth

% change y/y



Source: © Oxford Economics Limited 2022 (history), Equinor (forecast from June 2022)

Commodities

Oil

Oil markets remain volatile, driven by supply and demand uncertainty.

Sanctions on Russian oil following the invasion of Ukraine, Opec+ failing to deliver on their agreed production as well as supply disruptions in other regions, have led to fears of supply shortages. A downward revision of global economic growth, continued lockdowns in China and high prices lead to decreased demand. Market volatility is expected to remain high in the short term, with considerable upside and downside risk, dependent on how events unfold.

Gas

Short-term outlooks offer little respite to stressed global gas markets.

The Nord Stream 2 gas pipeline between Russia and Germany would have provided some supply relief, but the project has been halted indefinitely. This has been replaced by increased tightness and reduced flexibility, as rising hostilities between the East and the West disrupt gas flows with global consequences. With very limited options to increase short-term gas supply, global gas markets are volatile and highly sensitive to disruptions in supply and seasonal variations in demand. US liquefied natural gas can buffer but not cure short-term global tightness, and infrastructure bottlenecks, policies and regulations prevent further loosening. The short-term focus is therefore on efficiencies and alternatives to ease the burden of tight balances.

Power

Power prices will remain stretched between the need for security of supply and the volatility of underlying commodities.

Both will be dependent upon political changes emerging from the ongoing crisis and weather patterns until 2025. A combination of heightened political tension, a higher share of intermittent generation and lack of investment in dispatchable capacity over the past decade has resulted in the delay of around 10 GW of coal capacity retirements in Europe and a shift towards nuclear for reliability. Russia's invasion of Ukraine has taken Europe from being the market of last resort for LNG and coal to a prime location. This in turn has substantially increased the fuel cost for power generation across the world. Power prices will be strongly affected by a worldwide surge in fuel prices and the current market design. The sector is expected to lean heavily towards market reforms to provide corrective measures and accelerate the energy transition.

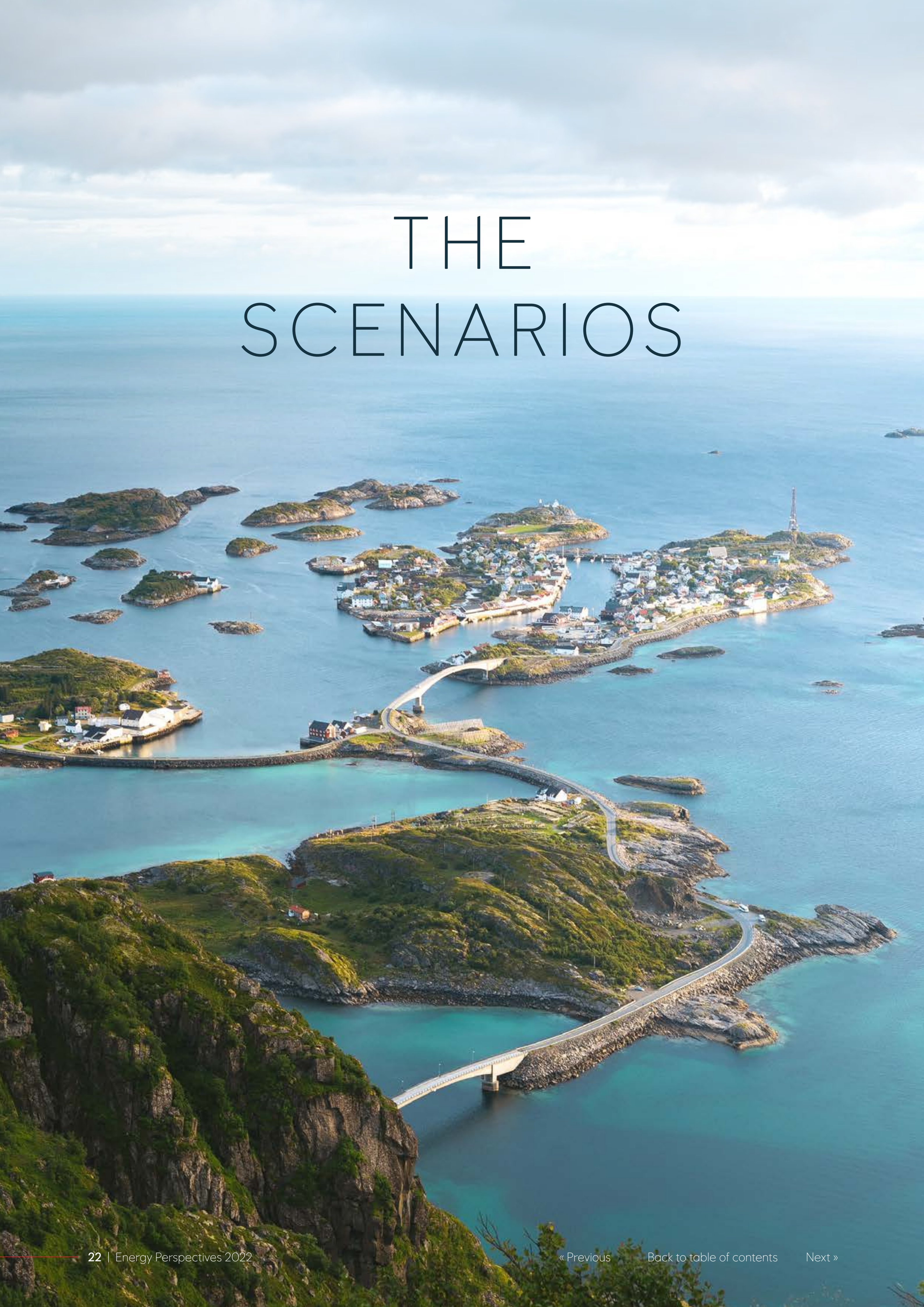
H_2

Hydrogen*

Hydrogen demand in the energy sector is looking to grow.

Current geopolitical and energy market turmoil encumbers the development of a hydrogen market. In an uncertain context, governments could delay their decarbonisation strategies, making it harder for companies to justify investments in emerging low-carbon technologies. While hydrogen is a relevant part of the decarbonisation narrative, short-term market effects will likely postpone its uptake.

**This report does not consider grey hydrogen, i.e. hydrogen produced by reforming natural gas without carbon capture and storage since hydrogen produced in this way is not used for energy-related purposes.*



THE SCENARIOS

The scenarios

Energy Perspectives 2022 breaks with tradition and presents two scenarios for global development and future global energy markets: *Walls* and *Bridges*.

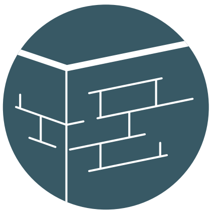
Two scenarios are presented, not because the world has become simpler, quite the opposite. A sharp dichotomy is emerging between the slow, incremental change that characterises the energy transition seen today, and the acceleration necessary to achieve the radical changes required to move the world onto a truly sustainable path. The two scenarios encapsulate this dichotomy.

The future of energy markets is difficult to predict. Recent events have shown it is not only the long-term development of macroeconomics and energy markets that are uncertain. Covid-19 has only a short-term impact in both scenarios, with no significant lasting impact expected in the medium and long term. However, the Russian invasion of Ukraine and the associated geopolitical tensions have given rise to the reappearance of obstacles to cooperation and existing trade and supply flows which may have long-lasting effects on economic development, government policy and corporate decision-making in some regions. The scenarios consider these key uncertainties.

The scenarios start from the world as it is today, where the energy transition has begun but has yet to accelerate to the speed required to achieve the goals of the Paris Agreement. They share near-identical paths up until 2025, at which point they start to diverge. *Walls* shows a pathway of where the world could go if it continues to broadly follow current trends, whilst *Bridges* illustrates a pathway the world would need to follow to reach the 1.5°C target.

Both scenarios consider the same set of drivers, ranging from economic growth and technological development to climate policy and geopolitics, and both scenarios recognise the profound systemic change required to put the energy system on a more sustainable track. The difference between the two scenarios is the relative force of these drivers and the extent to which they influence the future path of the global energy system after 2025. In short, *Walls* fails to make this transition to a sustainable pathway, whilst *Bridges* succeeds.

Energy Perspectives does not try to predict the future but shows possible future paths for the global energy system based on the choices the world makes, providing a platform for debate and informed decision-making.



Walls

Walls signify the abundance of barriers blocking fundamental and accelerated change in the global energy system.

Throughout human history, walls have been built to protect us from the things that we fear: intruders, plagues, viruses, the weather, and wild animals. Inadvertently, walls exclude us, cut off options and place obstacles in our path. Walls shield us, but also form barriers to transition and movement.

Walls protect, but they also divide.

The *Walls* scenario builds on current trends in market, technology and policy, assuming them to continue developing at a slowly accelerating pace in the future. Economic growth remains the key driver for growing energy demand, and national governments continue to prioritise short-term economic growth over long-term climate goals. Geopolitical tensions in the wake of the Russian invasion of Ukraine lead to long-lasting effects on economic development and government policy, especially in the Commonwealth of Independent States (CIS), the EU and China.

The energy transition is hampered by a lack of cooperation and trust, and although climate policies continue to tighten, with momentum-driven mainly by the industrialised regions, the scenario does not meet all stated targets and does not move fast enough to satisfy the goals of the Paris Agreement. Change is simply not happening fast enough.

Walls is a story about an energy transition that is slowly accelerating, but that does not reach climate targets. However, it is important to note that the changes to the global energy system outlined in *Walls* are not a given. They will still require enormous changes to the foundations of the global energy system, but this will not be sufficient.

Bridges

If Walls signify the barriers to change, Bridges represent the overcoming of these barriers and the impetus towards accelerated change.

Bridges help us to connect, allowing people to reach places they would not otherwise have been able to reach and achieve things they would not otherwise have been able to achieve. Bridges are open-ended and facilitate transition, movement, trade and communication.

Bridges connect and enable.

The *Bridges* scenario is a normative back-cast constrained by an energy-related CO_2 emissions budget of 445 Gt CO_2 compliant with a 50% probability of no more than a 1.5°C temperature rise*.

A benign geopolitical landscape is re-established, supporting renewed cooperation and friendly competition among nations. Energy markets become more integrated and technological advancements are shared more readily. Climate action remains the key driver, and all regions are under pressure to rapidly phase out fossil fuels, build renewable capacity, improve energy efficiency and make drastic behavioural changes. The accelerated transition brings significant changes to the energy system even before 2030.

This ambitious scenario serves to illustrate the enormous challenge the world is faced with. It is technically within reach, but whether it is also practically and economically achievable, and saleable to voters once all the implications are clear, is open to debate. The scenario is not anchored in detailed analytical convictions but rather aims to stimulate discussions around the feasibility of the changes required to limit global warming to 1.5°C by the end of the century.

* *See footnote on page 10*

Walls

The *Walls* scenario builds on current trends in energy markets, technology and policy.

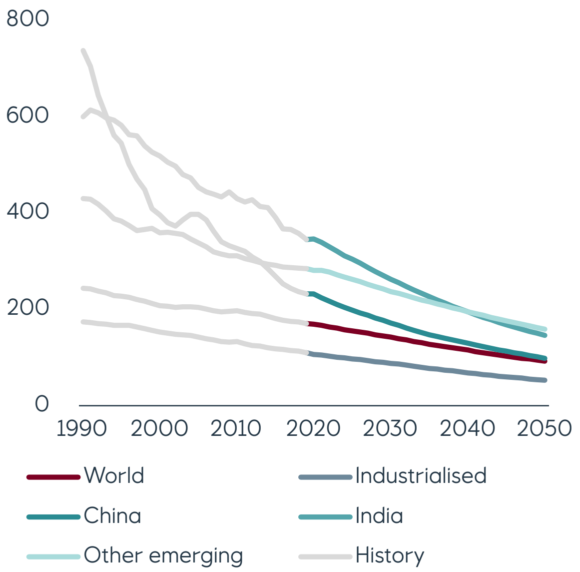
Energy intensity

In *Walls*, the energy intensity of the global economy improves by 2% per year between 2020 and 2050. The pace of improvement is significantly higher than the average of 1.2% per year for the 1990-2019 period, driven by a strong focus on energy efficiency. Some regions accomplish even more impressive improvements than the average: the European Union and parts of Asia drop their energy intensities by between 2.5% and 3% per year.

Though *Walls* is not a sustainable scenario from a climate perspective, people become more keenly aware of the global warming threat and its link to energy consumption, and a large share of the low-hanging fruit is harvested. Energy intensity decline rates are significantly improved as a result of the electrification of road transport and, to lesser degrees, the industry and the buildings sectors. However, as a rule, high-emitting industrial assets are not retired ahead of their normal economic lifetimes, constraining the turnover of capital stock and the deployment of the most efficient technologies.

Walls – Energy intensity

toe per million USD



Source: IEA, © Oxford Economics International 2022 (history), Equinor (projections)

Decarbonisation

Decarbonisation occurs in both the energy end-use and transformation sectors at a slowly accelerating pace compared with recent history. Fossil fuels do remain a part of the fuel mix where alternatives result in significantly higher costs, and where abatement via CCUS offers an economic option for decarbonisation.

The share of fossil fuels in total primary energy is around 80% today and has been so for the last thirty years at least. In *Walls*, this share steadily decreases to 62% in 2050. Fossil fuel use only begins to fall in the 2030s and is 20% lower in 2050 compared with 2019. Coal sees the biggest reduction, halving over the period to 2050. The transport sector continues to see increasing electrification, contributing to a reduction in the oil share of total primary energy from around 30% today to 25% in 2050. Gas maintains a share of around a quarter of total primary energy demand throughout the projection (2019-2050) period.

Fossil fuels comprise around two-thirds of end-use energy consumption today, and this has been the case for the last thirty years at least. In *Walls*, this share steadily decreases to around half in 2050. In addition, CCUS in the industrial sector contributes around 0.2 Gt CO_2 of direct abatement in 2050.

Electrification

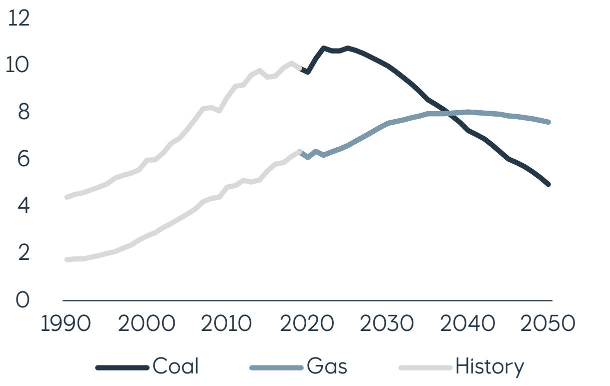
Electrification, measured by both the amount of electricity used and the share of electricity in energy consumption, has increased steadily over the last thirty years. Consumption increased at a rate of 2.9% per year across the period 1990-2019, and the electricity share increased from 13% in 1990 to 20% in 2019.

This increase is mainly the result of massive electrification in China since the turn of the millennium, contributing to an increase in total electricity demand of 130% between 1990 and today. However, China's growth rate cannot be maintained indefinitely, and this will lead to a decline in the global growth rate over the next three decades.

In *Walls*, electricity demand grows by two-thirds over the projection period, with an annual average growth rate of 1.6%. The share of electricity in final consumption increases from 20% today to around 30% in 2050.

Walls – Global coal and gas power generation

Thousand TWh



Source: IEA (history), Equinor (projections)

Power generation from coal grew by an average of 2.8% per year over the period 1990-2019. In *Walls*, this growth ends immediately, and power from coal decreases by 2.2% per year across the projection period, a drop of 50% by 2050.

Gas power generation grew by an average of 2.4% per year over the period 1990-2019. In *Walls*, this growth continues in the 2020s, and reaches a plateau soon after 2030. Gas power grows by an annual average of 0.6% per year across the projection period, an increase of 20% overall. Coal power peaks in 2024, and gas overtakes coal in 2039. Gas-to-power achieves a peak in 2041.

In *Walls*, CCUS on fossil fuel use in the power sector contributes around 0.3 Gt CO_2 of abatement in 2050.

Wind power capacity grows at an annual rate of 5.6% over the projection period, making wind generation roughly five times greater in 2050 than it is today. Even more impressively, solar power capacity grows at an annual rate of over 8% over the same period, making solar generation in 2050 around 16 times greater than today. Together, wind and solar constitute 45% of the global power generation mix in 2050, up from 8% today. By 2050, wind and solar power both exceed gas, and hydro power is greater than coal.

Nuclear power capacity grows at a rate of 1% per year across the projection period, compared with the 1990-2019 rate of 0.7%, making nuclear generation 50% higher in 2050 than today's level.

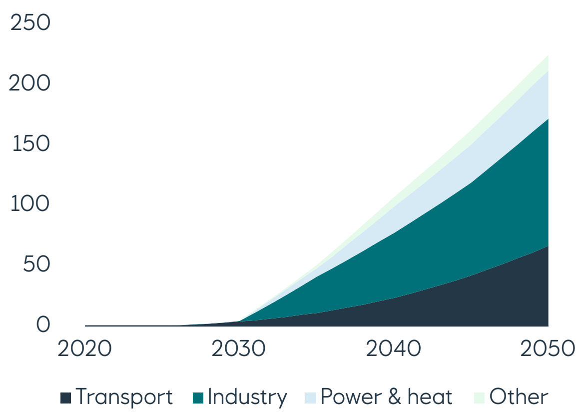
The share of total zero-carbon generation in the global power mix increases from around 40% today to nearly three-quarters in 2050. Potential bottlenecks, such as insufficient electricity grids or land space for new renewables, are addressed and adequately solved, with suitable regulatory frameworks and market design structures implemented to harness the efficiency of market forces where possible.

Hydrogen-based fuels

In *Walls*, both blue and green hydrogen are introduced into the energy mix from 2025 onwards and scaled up in the 2030s. Hydrogen, and its derivatives, such as ammonia and other e-fuels, are slowly introduced in sectors that cannot easily electrify, such as heavy industry, marine transport and aviation. However, there remains very limited penetration in all sectors, with costs remaining too high compared with competing decarbonisation technologies and carbon emission allowances. CCUS required for blue hydrogen production is approximately 0.6 Gt CO_2 in 2050.

Walls – Global hydrogen demand

Mtoe



Source: Equinor

Carbon removal

Although research and development into carbon removal technologies proceeds, there remains very limited penetration, and in *Walls*, negligible carbon is removed from the atmosphere in 2050 via carbon removal methods.

Bridges

In *Bridges*, changes beyond 2025 need to happen at an astonishing rate, supported and driven by policy throughout.

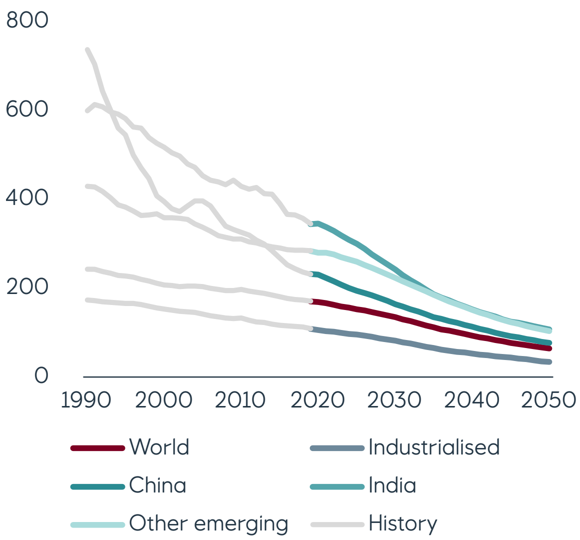
Energy Intensity

In *Bridges*, the energy intensity of the global economy improves by an average of 3.1% per year between 2020 and 2050, with all regions making significant contributions. The pace of change is much higher than the 2% per year improvement in *Walls*, relying on energy efficiency increases far beyond anything experienced in recent history. Technologies that make this possible are conceivable but would require significant and sustained policy support and financing to make them a reality, and in *Bridges* this is forthcoming.

After 2025, an absolute decoupling of economic growth from energy demand occurs at a global level, something never seen before in modern history, enabling global economic growth to continue whilst total primary energy demand peaks and then declines. This decline in primary energy demand is present to a greater or lesser extent in almost all regions, India being the prominent exception, where primary energy demand continues to grow towards 2050 by a further 20% compared to the 2025 level.

Bridges – Energy intensity

toe per million USD



Source: IEA, © Oxford Economics International 2022 (history), Equinor (projections)

However, India's per capita energy use, although rising across the period, remains lower than all but the very poorest regions of Asia and Africa.

Decarbonisation

In *Bridges*, the impetus towards decarbonisation is immediate and unrelenting. Fossil fuel use decreases by more than 5% per year across the period to 2050, compared to less than 1% in *Walls*, and significant change is already observable by 2030.

Bridges sees the share of fossil fuels in total primary energy fall to 67% in 2030 (compared to 76% in *Walls*) and to 22% in 2050 (62% in *Walls*). Fossil fuel use in 2050 is a fifth of its current level. Coal is by far the hardest hit, with its share of primary energy demand shrinking from a quarter today to around 3%. Oil and gas fare a little better, their shares being reduced by approximately two-thirds by 2050.

In addition, CCUS on industrial fossil fuel use contributes around 0.4 Gt CO_2 of direct abatement in 2050.

Electrification

In *Bridges*, electrification happens everywhere possible, and it happens fast. Electricity currently supplies around a fifth of the total end-use energy demand. By 2030, this share increases to nearly 30%, and by 2050 electricity makes up the largest share of total final consumption.

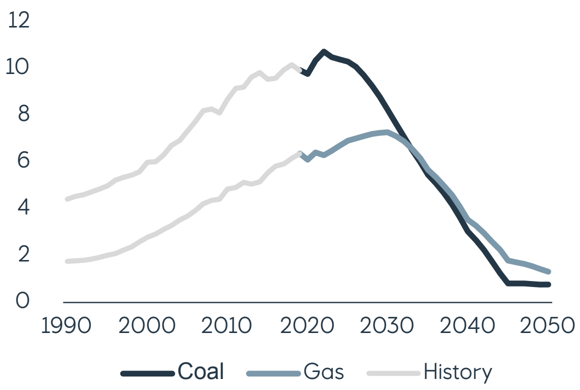
Electricity demand increases 2% per year across the projection period, which looks reasonable compared to growth observed in the last two decades, which was driven by China's electrification. However, this masks the fact that the increase to 2030 is 3.1% per year, falling to 2.3% in the following decade to 2040, and only 0.5% in the decade after that. It is the speed of electrification in the early part of the projection period that is key to differentiating *Bridges* from *Walls*.

The road transport sector undergoes the largest transformation, with nearly three-quarters of global demand supplied by electricity in 2050, compared to around a fifth in *Walls*. Electricity demand in the road transport sector in 2050 is around 35 times the level today.

In *Bridges*, electricity demand in the industrial sector grows at a rate of 1.3% per year, with an increase of nearly 50% in 2050 compared with today. Residential electricity demand increases by 2.2% per year, and by 2050 is almost double today's level and a third larger than that in *Walls*, driven by accelerating demand for electrical heating, particularly in the decade after 2025.

Bridges – Coal and gas power generation

Thousand TWh



Source: IEA (history), Equinor (projections)

In *Bridges*, the utilisation of existing coal and gas power plants is reduced as quickly as possible, with emissions from remaining plants captured and stored. This requires around 1 Gt CO_2 of abatement in 2050 split evenly between coal and gas.

Power generation from coal peaks in 2022 and thereafter shrinks at an average rate of more than 10% per year until 2045. Power generation from gas grows until 2030, peaks and then declines at a similar rate to coal. By 2050, no unabated coal or gas power generation capacity remains. Coal and gas with CCUS contribute approximately 1,250 GW of dispatchable, zero-carbon power generation capacity in 2050.

Zero-carbon power

Rapidly increasing electricity demand in *Bridges* makes it imperative that electricity supply is decarbonised quickly and completely.

Wind and solar power bear most of the burden, supported by varying amounts of dispatchable renewables such as hydro and biomass depending on regional conditions and political feasibility. Wind capacity grows at around 7% per year over the period, resulting in wind generation eleven times higher in 2050 than today. Solar capacity grows at nearly 10% per year, resulting in solar generation 25 times higher in 2050 than today.

Nuclear power capacity increases at nearly 2% per year over the period, resulting in nuclear generation 50% higher in 2050 than today.

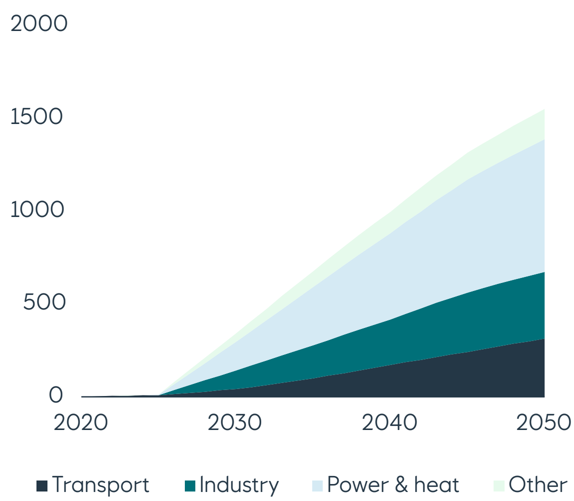
Already by 2030, nearly 60% of electricity comes from zero-carbon sources (compared to 47% in *Walls*), with half of this provided by intermittent generation. Zero-carbon power generation accounts for 96% of all electricity supply in 2050, with two-thirds of this power coming from intermittent sources. This requires extensive upgrades and extensions to existing power grids, and the widespread deployment of electricity storage technologies across all timescales.

Hydrogen-based fuels

In *Bridges*, hydrogen is introduced into the energy mix from 2025 onwards and scaled up rapidly. Demand for hydrogen in 2050 is approximately 466 Mt, approximately seven times the level seen in *Walls*.

Bridges – Global hydrogen demand

Mtoe



Source: Equinor

The industrial and transport sectors see significant increases compared to *Walls*, but it is the energy transformation sectors that really differentiate the scenarios, with demand in the power & heat sector nearly 20 times greater in 2050 in *Bridges* than in *Walls*, driven by the critical necessity to drive out remaining emissions from gas power generation.

The vast majority of the additional hydrogen in *Bridges* is green hydrogen. CCUS required for blue hydrogen production is around 0.8 Gt CO_2 in 2050, an increase of approximately a third compared with *Walls*.

Carbon removal

In *Bridges*, carbon removal technologies make a critical contribution to achieving the goal of remaining within the carbon budget required for 1.5°C.

In 2050, nature-based solutions for carbon removal, which include forestry, wetland, agricultural and ocean-based practices, are responsible for removing 2.3 Gt CO_2 from the atmosphere. Bioenergy with carbon capture and storage, and direct air capture, are responsible for removing a further 1.4 Gt CO_2 and 0.6 Gt CO_2, respectively.

Policy & behaviour

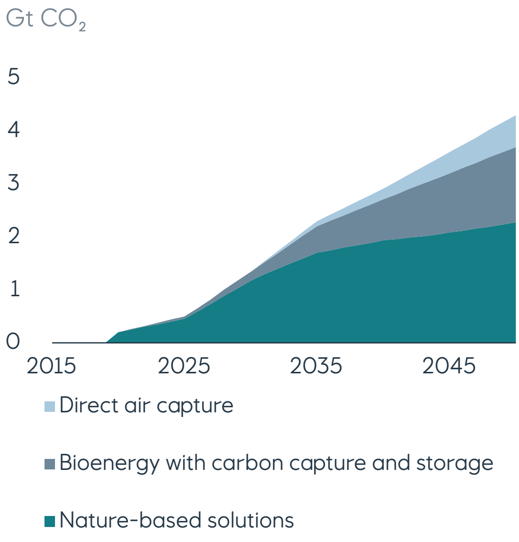
To ensure that the systemic changes and technological improvements outlined above actually achieve their potential, a firm and targeted energy policy is required.

A significant shift in human behaviour and expectations is absolutely critical to success in *Bridges*, incentivising consumers to choose more ecological goods and services, and investors to provide finance for research, development and deployment of low carbon technologies. Changes in home heating, travel and dietary habits will also play an important role.

A higher carbon price is essential, since carbon pricing is a proven, cost-effective way to incentivise a reduction in CO_2 emissions. This will encourage consumers and companies to find solutions with lower emissions.

There is currently limited evidence to support the idea that voters in democracies are inclined to delegate personal investment, dietary and other lifestyle choices to the authorities. Raising the level of acceptance for the energy transition, and the enormous lifestyle changes that it requires, will be essential to its success, and in *Bridges*, it is assumed that this is accepted and promptly established.

Bridges - Annual carbon removal



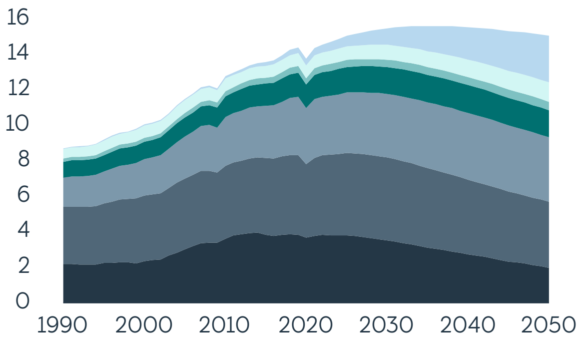
Source: Equinor

LONG-TERM OUTLOOK

The energy world: Two scenarios

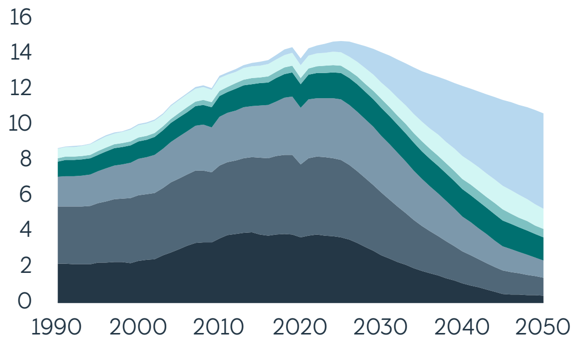
Walls – Total primary energy demand

Gtoe



Bridges – Total primary energy demand

Gtoe



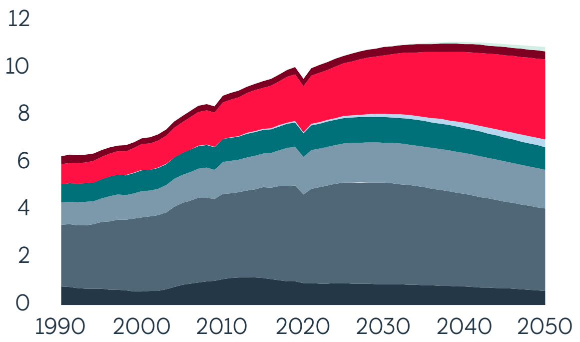
■ Coal ■ Oil ■ Gas ■ Biomass ■ Hydro ■ Nuclear ■ New renewables

Source: IEA (history), Equinor (projections)

Source: IEA (history), Equinor (projections)

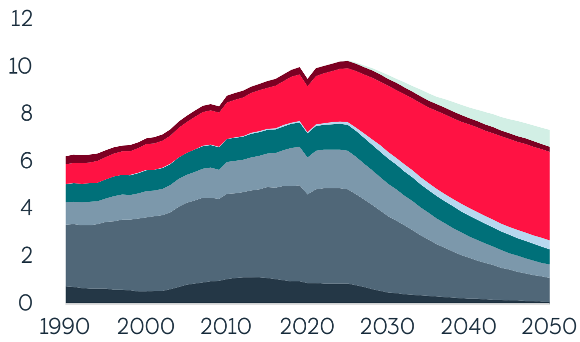
Walls – Total final energy consumption

Gtoe



Bridges – Total final energy consumption

Gtoe



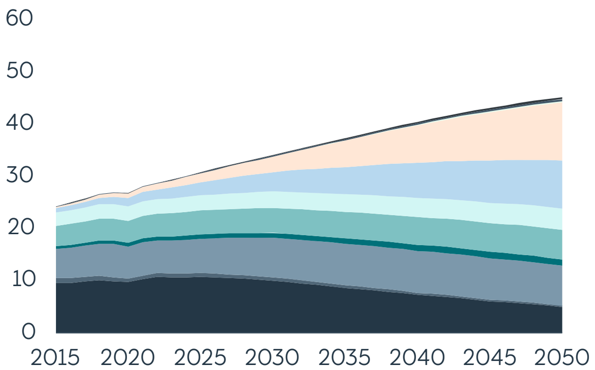
■ Coal ■ Oil ■ Gas ■ Biomass ■ New renewables ■ Electricity ■ Heat ■ Hydrogen

Source: IEA (history), Equinor (projections)

Source: IEA (history), Equinor (projections)

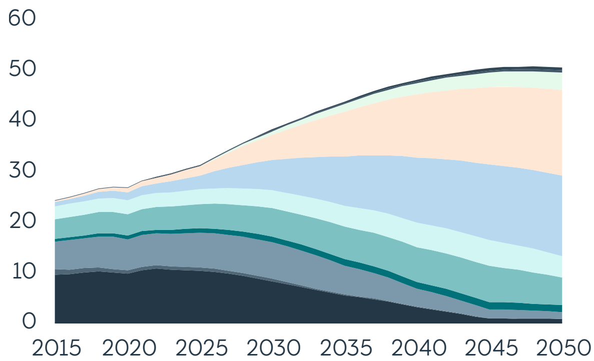
Walls – Power generation

Thousand TWh



Bridges – Power generation

Thousand TWh



■ Coal ■ Oil ■ Gas ■ Biomass ■ Hydro ■ Nuclear ■ Wind ■ Solar ■ Hydrogen ■ Geothermal ■ Other

Source: IEA (history), Equinor (projections)

Source: IEA (history), Equinor (projections)

Global energy demand

Total primary energy demand

Total primary energy demand (TPED) is the sum of demand for coal, oil, gas, nuclear energy, hydro energy, wind, solar and other renewable energy sources. It includes the energy lost in transmission, transportation and conversion of energy. Electricity and heat are not included in the primary energy definition, but the energy inputs used to generate electricity and heat are.

In *Walls*, total primary energy demand peaks in the late 2030s as rapidly declining demand in industrialised regions outweighs a continued increase in demand in most emerging regions. Despite growth in the global population and GDP, the demand in 2050 is only 5% higher than that seen in 2019. Curtailment is aided by electrification, efficiency gains and a degree of behavioural changes as politicians, investors and consumers all look to support a more sustainable future.

Total primary energy demand in *Bridges* peaks much sooner than in *Walls*, in 2025, before going into a sharp decline and ending up at a global demand level in 2050 that is 25% lower than that observed in 2019.

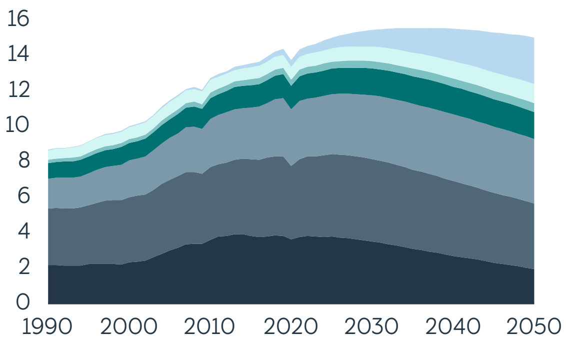
Fossil fuels in primary energy demand

In *Walls*, coal demand peaked in 2018. Following a drop during the Covid-19 pandemic, coal demand recovers to 2019 levels in 2022 before going into a steady decline towards 2050. Oil demand also sees a rapid return to pre-Covid levels and starts to drop after 2028. Gas fulfils the role of a transition fuel and continues to grow until 2040, with demand increasing by 14% relative to the 2019 level, before gently decreasing towards 2050. Despite a drop in the share of fossil fuels in the total primary energy demand from a 2019 level of 81%, the share of fossil fuels in *Walls* remains high at 62% in 2050.

In *Bridges*, gas is not given the opportunity to act as a transition fuel with all fossil fuels declining rapidly from 2025 onwards. By 2050 the share of fossil fuels in the total primary energy demand is 22%. As in *Walls*, coal demand peaked in 2018 and declines from 2022 following a short-lived demand rebound post Covid-19. Oil and gas demand has to decline rapidly to align with climate targets with oil declining from 2019 and gas from 2025.

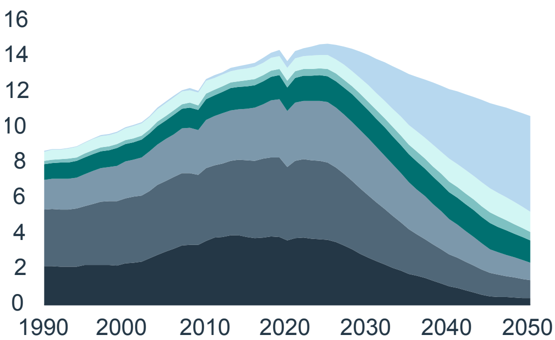
Walls – Total primary energy demand

Gtoe



Bridges – Total primary energy demand

Gtoe



■ Coal ■ Oil ■ Gas ■ Biomass ■ Hydro ■ Nuclear ■ New renewables

Source: IEA (history), Equinor (projections)

Source: IEA (history), Equinor (projections)

Global energy consumption: Fuel mix

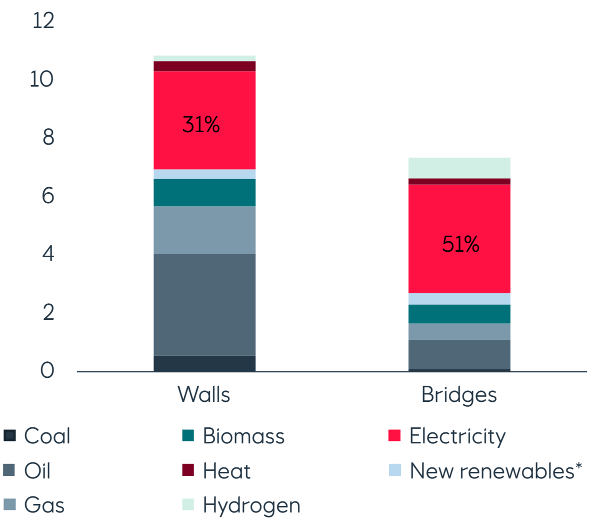
Total final consumption (TFC) is the amount of energy used in the end-use sectors.

The global fuel mix in total final consumption will change significantly over the next decades as energy efficiency improvement brings TFC down and electrification is set to accelerate and reduce the reliance on fossil fuels. However, the fuel mix and the role of fossil fuels in *Bridges* is radically different to that represented in *Walls*. In *Bridges*, total electricity demand is only slightly higher in 2050 compared to *Walls*, but the increase in electricity demand starts earlier and the build-up is faster. Total final consumption is significantly lower in 2050 in *Bridges*, due to the massive, assumed efficiency gains. This, combined with only a slightly higher electricity demand, results in a higher electricity share of the total final consumption. The electricity share in TFC is 31% in *Walls* and 51% in *Bridges* in 2050. For comparison, the 2019 share is 20%.

In *Walls*, the demand for electricity is increasing in line with the historic trend and makes up just over half of global consumption in 2050. In 2019, oil had the largest share of energy consumption at 40%, driven by the transport sector. As sectors increasingly electrify, especially transport, oil loses some market share, but remains an important part of the fuel mix, with electricity and oil having equal shares at just over 30% in 2050. Gas consumption maintains a constant share of the fuel mix towards 2050. A slight decline is seen beyond 2040, driven by solar and wind replacing gas in the power sector, and new renewables and hydrogen gaining market share in the industry sector.

Total final energy consumption in 2050

Gtoe

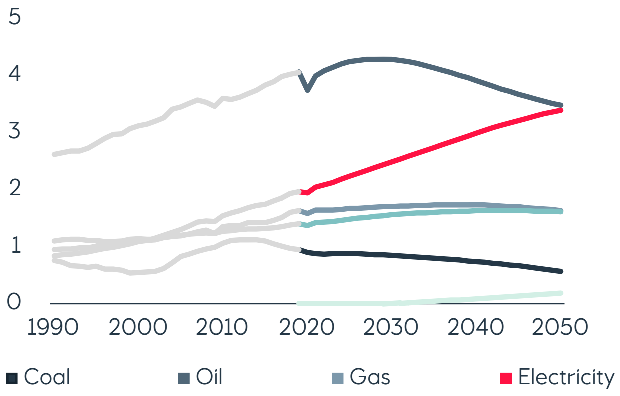


Source: Equinor

Driven by climate ambitions, electricity consumption increases rapidly in *Bridges*, replacing fossil fuels. Fossil fuel consumption is reduced to 23% of the fuel mix in 2050 and all remaining emissions from fossil fuels are removed by CCUS or compensated for by carbon removal technologies. Oil consumption drops 75% from its peak in 2019 to 2050, with electricity consumption nearly doubling over the same period. Electricity consumption surpasses oil as the main fuel in the early 2030s, as the transport sector undergoes a radical transformation. Hydrogen also sees a rapid uptake in market share as expanding renewable capacity paves the way for hydrogen in the industry and transport sectors.

Walls – Total final energy consumption by fuel type

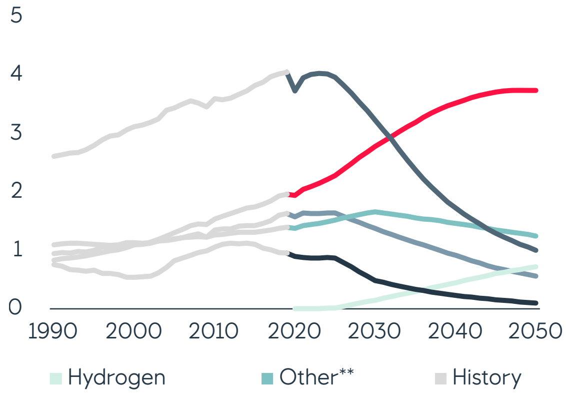
Gtoe



Source: IEA (history), Equinor (projections)

Bridges – Total final energy consumption by fuel type

Gtoe



Source: IEA (history), Equinor (projections)

** Includes wind. solar PV, concentrated solar power, tidal, geothermal*
*** Includes biomass, new renewable and heat*

Global energy consumption: Regional perspectives

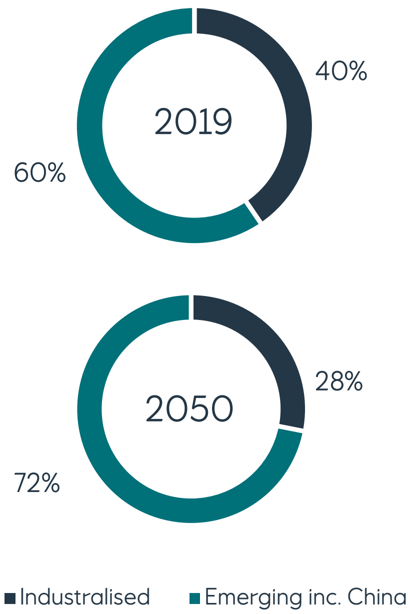
Total energy consumption will peak later in emerging than in industrialised regions. Global energy consumption peaks in 2039 and 2025 in *Walls* and *Bridges*, respectively. In *Walls*, the industrialised economies saw peak consumption in 2018, whilst the emerging economies continue to increase their energy consumption towards 2050. In *Bridges*, the emerging economies do not increase their consumption beyond 2025.

Emerging regions will claim an increasing share of global energy consumption from 60% today to 72% in 2050. The delayed peak and increasing share in consumption in the emerging regions are being driven by growing populations, urbanisation and the expanding middle class, demanding more goods and services. This growth is led by China, India and Africa.

China is the largest energy consumer globally today and remains so throughout the scenario period in both *Walls* and *Bridges*. In *Walls*, China's consumption grows by 1.3% per year until 2038 before experiencing a very gentle decline towards 2050. The consumption is driven by the industrial sector, which remains steadily above 40% of consumption until 2050.

North America, followed by Industrial Asia Pacific, exhibits the highest per capita energy consumption, currently consuming up to ten times more energy per capita than emerging regions such as India, Africa and Other Asia Pacific. Per capita, energy demand does not increase significantly in most emerging regions in either scenario as the demand increase from economic and population growth are countered by electrification and efficiency developments.

Walls – Total final energy consumption

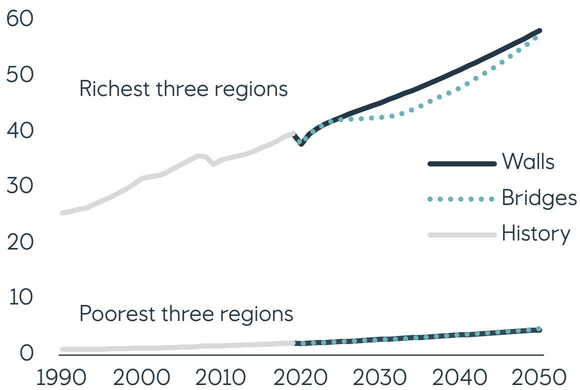


Source: IEA (history), Equinor (projections)

Per capita energy consumption is down in the industrialised regions, with electrification boosting energy efficiency in the transport and residential sectors. In *Bridges*, these effects are significantly amplified by tougher efficiency standards, taxation, subsidies, and changes in behaviour and consumption habits, resulting in a per capita energy consumption in the industrialised region of less than half of today's level in 2050.

GDP per capita in the richest and poorest regions

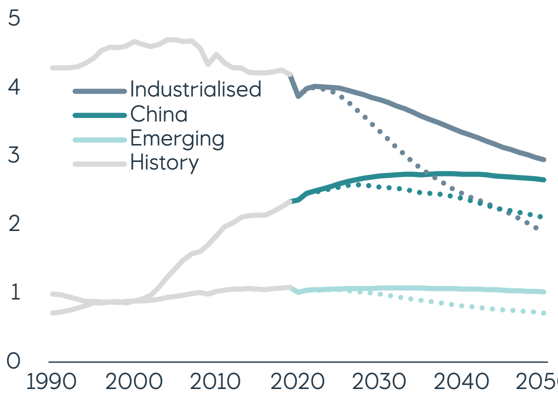
Real thousand USD at market exchange rates



Source: © Oxford Economics International 2022 (history), Equinor (projections), UN (population)

Energy demand per capita

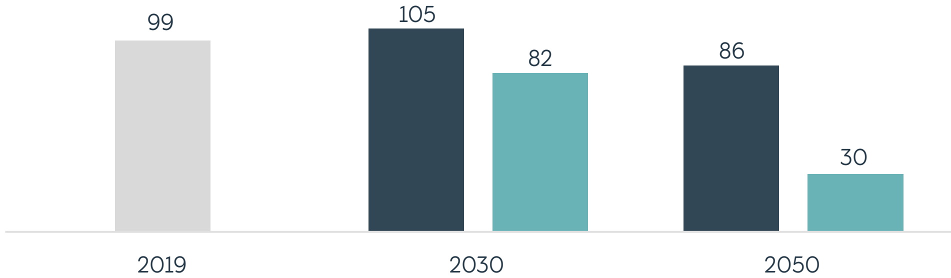
toe per capita



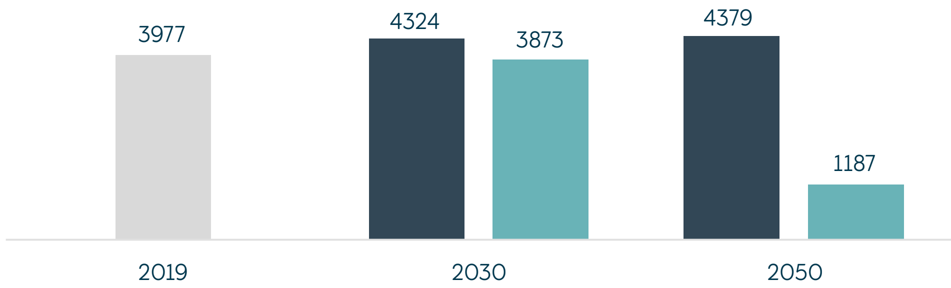
Source: IEA (history), Equinor (projections), UN (population)

The energy world in 2030 and 2050

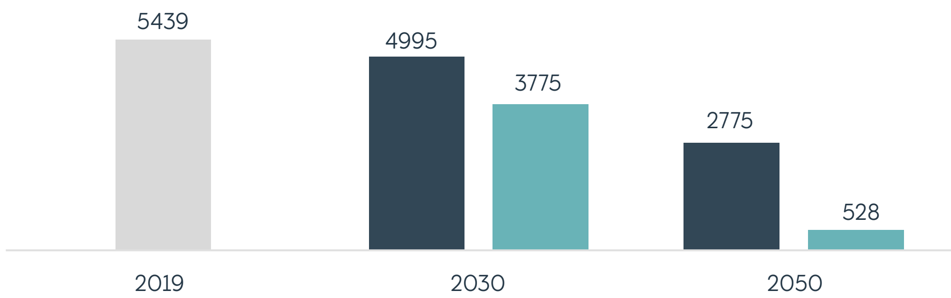
Global Oil Demand
mbd



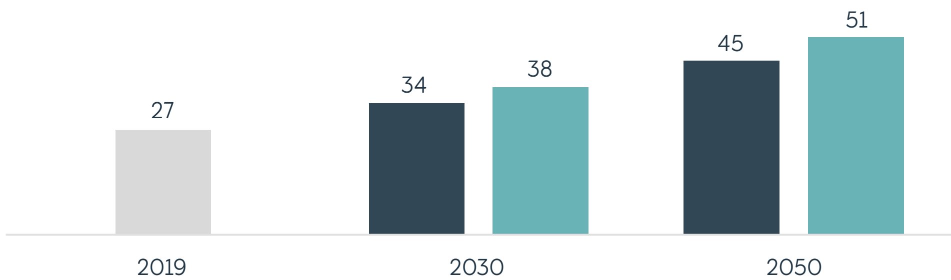
Global Gas Demand
Bcm



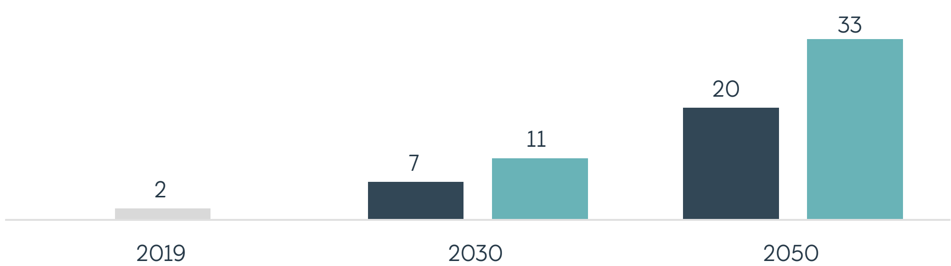
Global Coal Demand
Btce



Global Electricity Demand
PWh



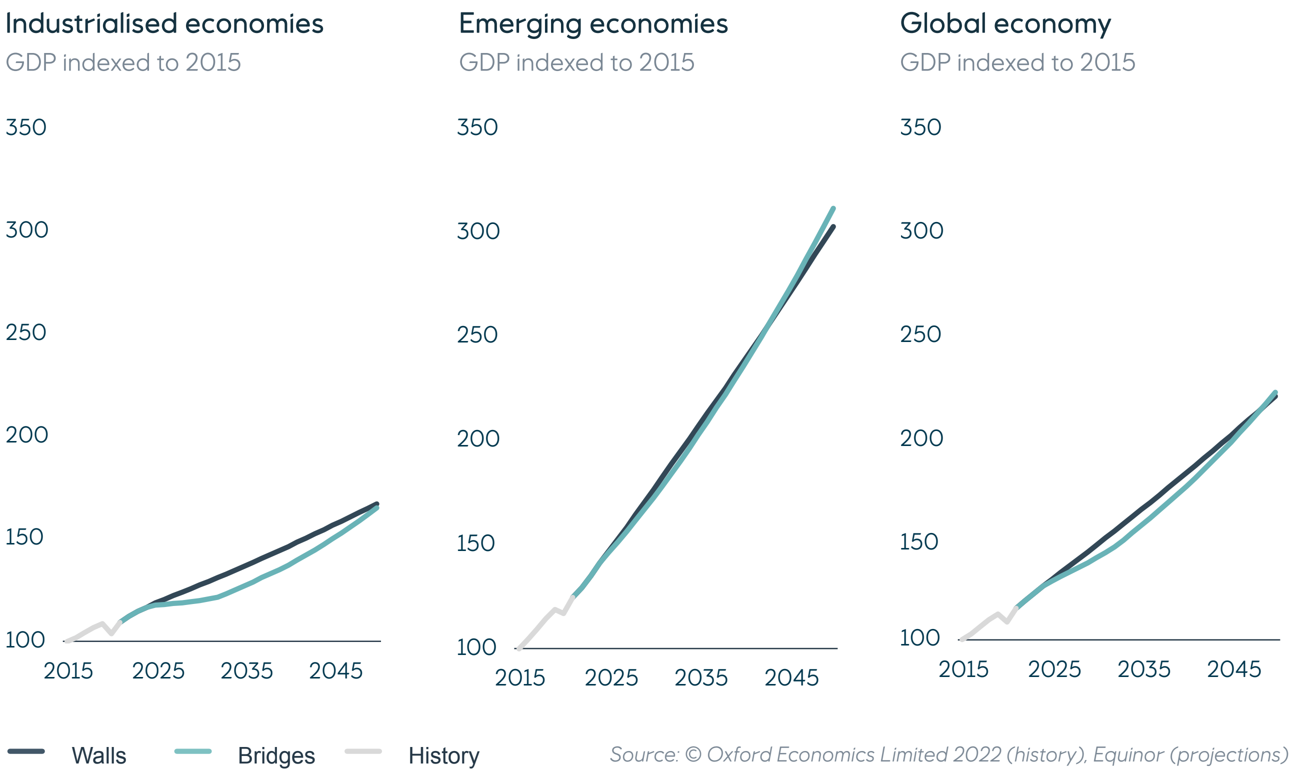
Global Wind & Solar Electricity Supply
PWh



History Walls Bridges

Source: IEA (history), Equinor (projections).

Global economy



Source: © Oxford Economics Limited 2022 (history), Equinor (projections)

Global economic growth continues throughout the scenario period, driven by emerging economies, but at a lower rate than observed historically. A declining growth in the labour force, coupled with an ageing population is assumed in both scenarios. Global growth in *Walls* is lower than the historical growth rate of 2.9% since 1990. This is caused by a decreasing catch-up potential for emerging countries when replicating technologies and production methods, compared to history. Increasing carbon levels in the atmosphere lead to a moderately negative climate impact on economies. The global economy will grow on average by 2.1% per year from 2026-2050, headed by emerging countries. In *Bridges*, consumers primarily in industrialised countries face a significantly higher carbon cost to curb the use of fossil fuels and to finance the rapid energy transition. Investments and transfer of technology and knowledge are directed towards emerging economies. The global economy grows on average by 2.2% per year during the period.

Following initial curtailed growth, *Bridges* assumes that the energy transition offers a small global GDP benefit by 2050. *Bridges*, compared to *Walls*, sees initially lower growth as consumers in industrialised economies are hit by reduced purchasing power. Over time, climate impacts in *Bridges* are reduced and higher consumption growth filters through as carbon taxation pressure eases. *Bridges* suffers some efficiency loss, for example a share of the fossil fuel infrastructure will be replaced before the end of working life, but still outpaces *Walls'* growth rate from around the mid-2030s onwards.

Russia's invasion of Ukraine and its impact on the geopolitical landscape will have long-lasting consequences for the global economy. Due to the invasion of Ukraine and intensified rivalry between the US and China, geopolitical considerations and politics are more likely to trump decisions based on pure commercial and market motives. In addition, global trade becomes more regionalised, leading to more fractured supply chains.

The future of the global economy is uncertain. Due to high debt levels and imbalances in economies, the ability of governments to reduce spending and for central banks to tighten monetary policy are uncertainties in a world that has become used to strong policy stimulus. Future productivity development is also a key unknown, affecting both scenarios. Gains like technological breakthroughs, more efficient use of labour and technology, and smarter regulations and reforms may be significant growth contributors out in time, with the speed of implementation and success influencing the future pathway.

Elevated inflation

Inflation is elevated and sticky across economies, potentially impacting the energy transition.

Global economies are experiencing a worldwide surge in inflation. Inflation is anticipated to remain higher for longer, however, the short-term outlook is uncertain. The key drivers of the current inflation surge are supply-chain bottlenecks, a shift in demand toward goods and away from services, lack of labour supply, and a supply shock to energy and food due to the invasion of Ukraine. Increasing and volatile inflation makes it more difficult for households and firms to plan for savings and investments, and central banks´ credibility may erode as high inflation persists. There is a worry that the global economy might enter a phase of stagflation, meaning slow economic growth and relatively high unemployment, accompanied by increasing food and energy prices. These high prices are fostering social unrest across economies, particularly in emerging markets.

Major central banks have responded to the rising inflation by aggressively hiking interest rates and by other tightening measures. The success of monetary policy tightening, dampening inflation without choking growth, is crucial to bringing down inflation. The cost and duration of inflation will depend on the interplay between the persistence of labour market tightness, supply-side disruptions and the central banks´ response. In addition, the duration of the war in Ukraine and its impact on energy prices, food prices and growth are of key importance. The longer-term path for inflation will depend on whether disinflationary forces seen over the past decades will fade or gradually re-emerge.

There are several possible effects of high inflation on the oil and gas industry. Higher oil and gas prices provide a natural offset against inflation, while also increasing the competitiveness of renewables. However, there is likely to be a cost-push in supply chains, and tight labour markets cause wage costs to increases. For capital-intensive projects, such as wind and solar PV, higher interest rates and financing costs are likely to improve the relative competitiveness of firms with strong balance sheets.

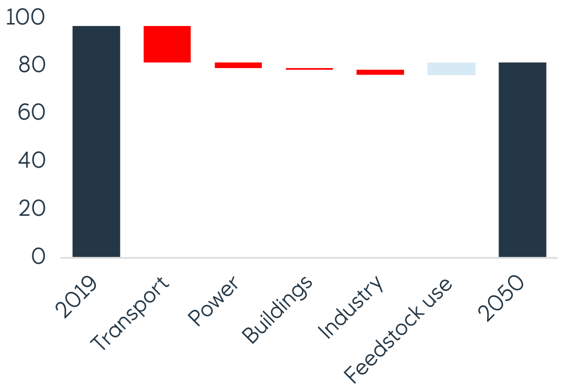
The threat of inflation and rising interest rates can create a challenging environment for industries and the energy transition. Inflation dampens economic growth if industries and households cannot substitute away from carbon-intensive energy to greener and cheaper alternatives. Higher inflation and interest rates could also limit the private sector´s ability to fund the transition and point the public sector towards short-term poverty alleviation rather than long-term climate risk mitigation. Both monetary and fiscal policy have a role to play in the energy transition. Monetary policy should recognise that investing in a more sustainable economy could pose a risk to medium-term inflation and may call for a deviation from inflation targets. On the fiscal side, governments are facing a balancing act needing to push the energy transition forward whilst at the same time protecting the vulnerable from energy poverty. Energy shortage, security of supply concerns and rising energy prices may slow the energy transition in the short-to-medium term. In the longer term, inflation, interest rates and economic growth will impact investment decisions and ways of funding the transition.

Global oil market

Oil demand declines as the energy transition continues to gain momentum. However, several years of underinvestment in upstream projects have raised concerns over supply shortages and fears that supply may decline faster than demand. Energy security remains a key factor in the energy trilemma and renewed upstream investment in the medium term may be seen.

Walls – Change in oil demand

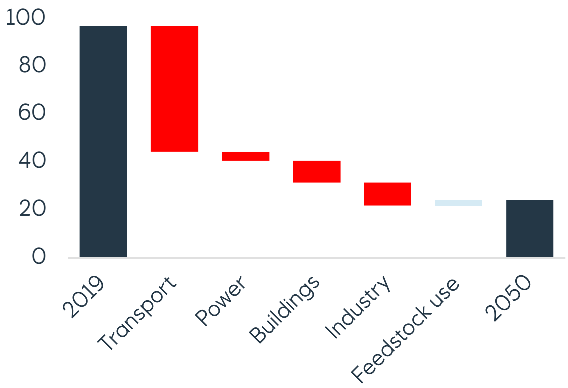
mbd



Source: IEA (history), Equinor (projections)

Bridges – Change in oil demand

mbd



Source: IEA (history), Equinor (projections)

In *Walls,* oil demand peaks in the late 2020s, followed by a decrease of 18% (19 mbd) by 2050, as the energy transition drives demand down.

The industrialised regions and China are driving the demand decline, leading to a combined decrease of 37% (24 mbd) between 2025 and 2050. This change is the result of shifts derived from carbon neutrality pledges and changes in road transport where efficiency gains and a switch to EVs reduce demand.

Key emerging regions, such as Africa, India and the Middle East, continue to see increasing oil demand, up 27% between 2025 and 2050. The sectors driving this increase are residential, industry and petrochemical as the regions continue to develop and industrialise.

Russian production levels are unlikely to return to pre-invasion levels due to a long-term lack of international investment in Russian projects going forward. Any shortfalls in the medium term are expected to be covered by other regions, most notably stronger growth in US shale, with a reconfiguration of trade flows being the largest change as a result of the conflict.

The projection for oil in *Bridges* is governed by the energy transition with policies, technology and behavioural changes driving total demand down 70% (69 mbd) from 2025 to 2050. Demand peaks in 2019 in Bridges.

The road transport sector accounts for the majority of the reduction in oil demand as LDV internal combustion engines are replaced by electric vehicles, and diesel engine trucks are replaced predominantly by electric and hybrid vehicles, but hydrogen vehicles are also introduced.

Overall demand from the non-energy sector peaks in early 2030 but continues to increase towards 2050 in regions such as the Middle East, China and CIS, reflecting a surplus of indigenous supply as external demand is curtailed.

Gasoil and gasoline see the biggest decline in demand as the road transport sector is transformed, while naphtha is the only product that continues to increase towards 2050 due to demand from the petrochemical sector.

Challenges for the future of refining

Strong competition and low profit margins have forced many refiners to make difficult decisions over the past three years; shut down production, convert to processing of renewable feedstock, or continue production and wait for better times. The world economy and global population are growing, people are becoming richer, demanding more goods and travelling the world. The demand for energy appears to be boundless, so how can refineries cope in such an environment?

The demand trend for refined products and pressure to either close or build new refining capacities is closely linked to regional variations in socio-economic development. In industrialised countries, economies are more mature and tend to grow at a slower pace, with people becoming more conscious of the effect of carbon emissions leading to stronger demand for clean energy. As a result, refiners in North America, Europe and Industrialised Asia Pacific have had to shut in part of their production. Conversely, demand for cheap energy continues to grow in the emerging regions of the world where people have less money to spend on non-fossil fuels. Demand for refined products continues to grow.

The long-term trend is that increasing demand for alternative fuels will outweigh that for refined products, but not all refinery products will be affected equally. Diesel and gasoline demand is likely to decrease as road transport is electrified, whilst products such as naphtha, LPG and jet fuel will be less affected. The first two due are to increased use in petrochemical industries and the latter due to the difficulty of replacing it with more sustainable options. Two challenges arise from this: the current refinery set-up is not equipped for the future, and demand for crude feed will change over time. To address this refineries will have to invest in new equipment, and the demand for crude oil will shift towards those refineries that yield higher quantities of products that are in demand.

Refining companies have over the past three years started to set individual targets for reducing carbon emissions, adding further incentive to close refineries amidst economic pressures. Refineries emit large amounts of CO_2 and shutting a refinery can go a long way towards companies achieving a more carbon neutral status. This weighed heavily in the recent decisions to close two refineries: LyondellBasell's Houston refinery in the US and Idemitsu's Yamaguchi refinery in Japan and is likely to play an increasing role in company decisions going forward.

The growth of alternative fuels is unlikely to make crude oil refining redundant in the foreseeable future, but adaptations will be needed for individual refineries to survive. Going forward there will be a sharp competition with winners and losers alike. Future competitive refineries are likely to be those that can adapt to the changing environment and meet the following criteria:

- Low-cost
- Flexibility to handle changing crude slates linked to changes in demand for a specific product
- Flexibility to switch to renewables production
- Tight integration with the petrochemical industry, which is expected to see future growth in demand

Decarbonising the aviation industry

Around 3.8 billion people fly every year, 63 million people are employed in the industry and air transport makes up 35% of global trade. Today, aviation accounts for around 2% of global greenhouse gas emissions. This is set to increase as the demand for air transport will grow along with the global economy, reaching 3% by 2050.

Aviation is one of the hardest sectors to decarbonise. The EU is currently working on a proposal to extend the definition of sustainable and advanced feedstocks and increase targets for their share in aviation fuel. This proposal wants a 2% share by 2025, 37% by 2040, and 80% by 2050. The previous targets were 32% by 2040, and 63% by 2050. There are efforts to build planes using batteries and electric motors, but this will only find a role in shorter-distance aviation. The energy density of batteries does not compare well with that of jet fuel, which has 30 times more energy per kilogram than lithium-ion batteries. This means that an Airbus A380, which can travel 15,000 km in a single flight using conventional fuel, would only be able to cover a little over 1,000 km with an electric engine.

More use of biofuels and other sustainable aviation fuels (SAF) will be necessary in order to decarbonise the aviation industry. SAF have the same properties as conventional fuels. They are drop-in fuels, which means they can be blended with conventional jet fuels and transported using the existing infrastructure. It is currently possible to blend 50% biofuel with traditional jet fuel without having to make any changes to existing machinery or infrastructure. Around 400 thousand flights powered by a biofuel blend have so far been carried out.

There are three main pathways for the production of SAF: Fats-to-fuel relies on the esterification of fats from biomass such as used cooking oil; Waste-to-fuel is based on upgrading of carbohydrates derived from waste; and Air-to-fuel, based on a direct combination of captured and sequestered carbon dioxide and green hydrogen and is by some seen as the holy grail of future aviation fuels.

Sustainable aviation fuels can help reduce emissions, but there are significant challenges. Fats-to-fuel has the potential to reduce emissions by 85% compared with conventional fossil fuels. It is well established, and it does not have the Indirect land use change (ILUC) problem that vegetable oil-based fuels have. However, securing sufficient feedstock for production is a challenge. The use of oils from algae could provide a solution, but so far this source has provided mixed results. Due to feedstock constraints the Air transport action group (ATAG) expects that fuel from this pathway will only be able to provide up to 8% of the sustainable aviation fuel needed for net zero emissions by 2050. Using Waste-to-fuel it is possible to reduce emissions by 95%. Residue from agriculture and forestry can be used as feedstock, but there are significant challenges. Due to low energy density, up to 10 times the amount of feedstock is typically needed compared with conventional fuel and this creates logistical bottlenecks. Production plants will have to be collocated with feedstock sources and the plant size will be small compared with a refinery. For this reason, ATAG estimates that fuel from this type of production can contribute up to 45% of SAF by 2050. With Air-to-fuel it will actually be possible to reduce emissions by more than 100%. If CO_2 is abundantly available through carbon capture and storage, this production method has no feedstock constraint. However, what will be needed, and what poses a constraint, is renewable energy to produce green hydrogen. The investment bank Barclays estimates that around 7 to 9 times the current solar and wind capacity in the US will be required to produce 50% of the sustainable aviation fuel needed for net zero by 2050.

Significant investments are needed to replace conventional aviation fuel with sustainable alternatives in an industry that is large and growing. Barclays stipulates that over USD 1 trillion in capital will be necessary to overcome all hurdles. If, or when, challenges are overcome, sustainable aviation fuel could make it possible to practically eliminate the industry's greenhouse gas emissions.

Global gas market

In *Walls*, gas demand remains a vital part of the fuel mix in the medium-to-long term. However, in *Bridges*, gas is not perceived as a transition fuel and declines rapidly after 2025.

In *Walls*, gas demand grows by 11% (435 Bcm) from 2025 to its peak demand in 2040 as it receives support from policies and regulations and aids growth and development. It also facilitates the global energy transition by phasing out more polluting forms of energy and balancing electricity systems with growing shares of intermittent renewables. After 2040 however, demand is ultimately dampened as decarbonisation intensifies.

Asia is the key driver behind demand growth, driven by industrial and power sectors and increased coal to gas switching in response to clean air concerns and announced carbon neutrality pledges.

Waning indigenous production and subsequent import dependencies continue to expose Europe to global gas market fundamentals. Reduced Russian flows to Europe drive more significant adjustments in the regional supply mix and therefore impact costs, prices, traded flows and volatility. Gas markets are tighter, more volatile and less flexible following the reduced Russian supply.

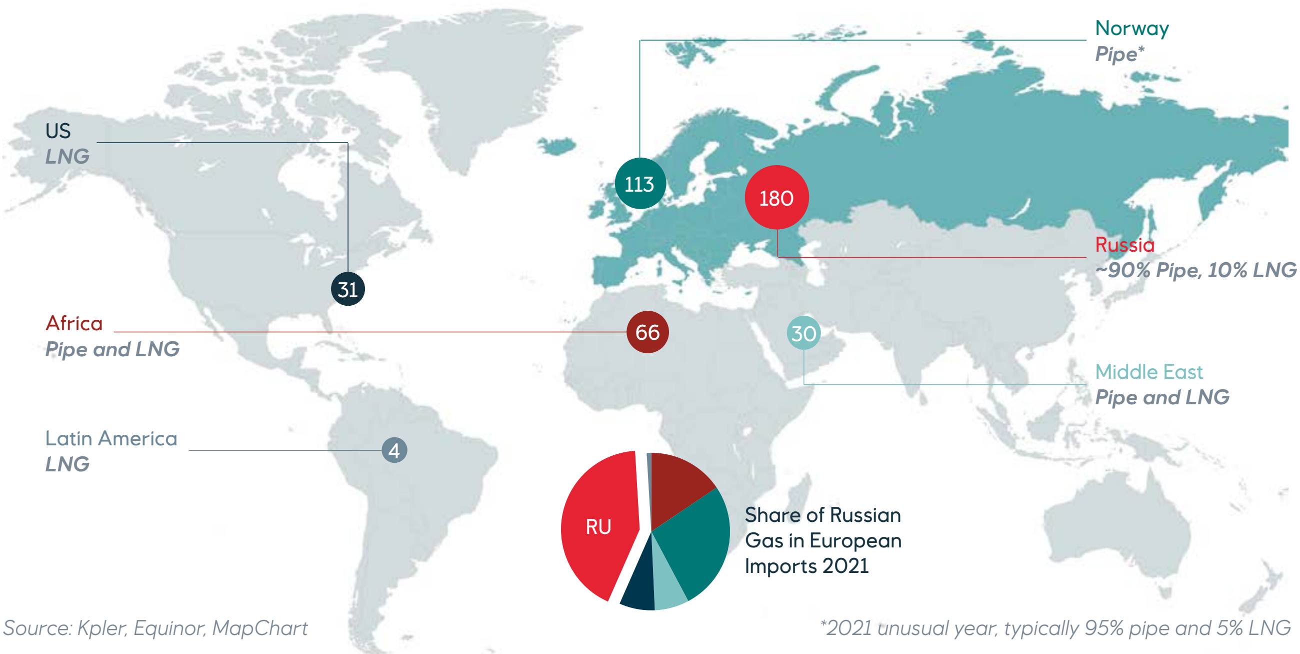
In *Bridges*, the global gas demand declines by 71% (2914 Bcm) between 2025 and 2050 due to a rapid shift towards renewables, supported by batteries and policies constraining fossil fuels. The uptake of renewables and hence the phase-out of fossil fuels occurs so quickly that the role of gas as a transition fuel is limited. The change in gas demand is most significant in the industrialised regions that see an 81% drop on average from 2025-50.

Gas demand peaks in 2025, with China's demand peaking slightly later, in 2027. The demand reduction accelerates after 2030, affecting all flows and trade (pipe, LNG and domestic) plus all investments in gas exploration, production, infrastructure and usage.

Hydrogen production and the chemical and petrochemical sectors are the only areas to see gas demand growth beyond 2025. Gas demand in hydrogen production peaks in 2040 before slightly declining towards 2050, as enough capacity is built in renewables to make green hydrogen the more feasible and sustainable choice.

Pre-war European natural gas imports in 2021

Bcm/yr - by source and type



Source: Kpler, Equinor, MapChart

*2021 unusual year, typically 95% pipe and 5% LNG

Russian gas supply to Europe

One consequence of Russia's invasion of Ukraine is a significant reduction in Russian gas exports to Europe. Growing uncertainty shrouds existing long-term contracts and future Russian flows to the continent, with global ramifications.

Since gas markets are connected globally by LNG, the loss of Russian export volumes to Europe is felt globally as Europe calls on greater LNG volumes to fill the supply gap. Importing regions, like Europe and Asia, are most exposed to supply changes. Exporting regions like North America are more sheltered from supply disruptions.

In the short term, further reductions in Russian flows will cause demand destruction, as importing nations compete for supply and end users reduce or substitute their demand in response to the tight markets, high prices and increased volatility. In the medium-to-long term, LNG volumes from US and Qatar are expected to step up and help fill the supply gap. However, additional volumes are limited by infrastructure and risk appetite, particularly without long-term contracts accompanying investments. Future gas markets are susceptible to inflexibility as well as tightness up to 2030, with additional LNG volumes only made accessible by outbidding other regions or sectors.

Further cuts to flows from Russia to Europe will have pronounced effects on gas demand, economic growth and climate ambitions, as there is not enough alternative gas supply in the world to cover the immediate supply gap left by Russia. Such cuts would potentially affect Russia's LNG export sector, and it is not inconceivable that gas flows from Russia to Europe will completely cease. Increased disruptions also endanger the connectivity and optimisation of today's gas markets, since Russian flows to Europe lack alternative routes and are lost without investment in new pipelines to Asia. However, risks of oversupply remain, due to geopolitical changes, economic recession, and exporting nations responding strongly to current market fundamentals.

Regardless of the future supply situation, risks to gas markets have unquestionably been exacerbated by growing hostilities and a breakdown in global collaboration.

Global electricity market

Clear political visions supported by appropriate regulation and market reforms encouraging investments, are required to build a decarbonised and reliable power system globally. Such systems are key to achieving global climate targets and help improve energy security for regions relying heavily on fossil fuel imports.

In *Walls*, electricity demand grows by 47% globally. A 65% growth in electricity demand is seen in the emerging regions, driven by economic development, increased standards of living and ambitions to decarbonise.

Electricity demand in the transport sector sees the largest growth, increasing by nearly 600% over the projection period, owing to the surge in the deployment of electric vehicles. Decarbonisation of emission-intensive processes in the industry sector drives a 46% increase in electricity demand, whilst a 32% increase is seen in buildings, due to electrification of heating and increased cooling needs.

Energy efficiency improvements in the residential sector, will dampen long-term electricity consumption, especially in the industrialised regions.

The power generation fuel mix changes significantly across the 2025-50 period. Fossil fuels decline by 29%, driven by net zero ambitions, whilst solar and wind grow by 562% and 260%, respectively. After 2025 coal will reduce its share in the generation mix. In 2050 fossil fuels will form 28% of the power generation fuel mix, with 45% of the share being solar and wind.

In *Bridges*, electricity demand grows by 61% between 2025-50. All regions electrify fast in the mid-term to drive out fossil fuels.

The largest electricity consumers today, China and North America, see peak power demand in the 2040s, as total final energy consumption falls due to efficiency gains. However, the regions still account for 38% of demand in 2050.

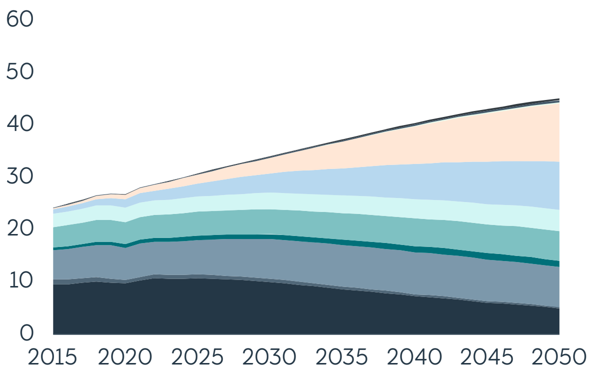
Industry and residential are the highest electricity demand sectors globally beyond 2028, with demand in industry being dominated by China throughout the period. The residential sector sees persistent high demand in China and North America, with demand in the India and Africa increasing most rapidly towards 2050.

The transport sector sees the most significant growth in electricity demand, growing almost 450% over the projection period.

The power sector sees a radical shift away from fossil fuels towards renewables, especially solar and wind, from a 57% share of fossil fuels in 2025 to 4% in 2050. Solar and wind make up 65% of the power generation fuel mix in 2050.

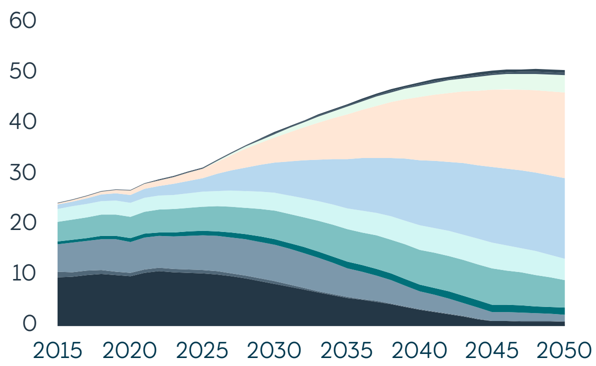
Walls – Fuel mix in power generation

Thousand TWh



Bridges – Fuel mix in power generation

Thousand TWh



■ Coal ■ Oil ■ Gas ■ Biomass ■ Hydro ■ Nuclear ■ Wind ■ Solar ■ Hydrogen ■ Geothermal ■ Other

Source, IEA (history), Equinor (projections)

Source, IEA (history), Equinor (projections)

Is the current power market design fit for purpose?

Due to the energy crisis and skyrocketing prices, many European politicians and commentators argue that "the market is broken" and that there's a need to make changes to the current electricity market design.

The current design is characterised by the most expensive unit of generation needed to match demand setting the price for all producers. With extremely high gas prices this is weighing heavily on all consumers as the price of gas sets the market price of all electricity generated in certain markets, despite gas holding a relatively small share in the electricity generation mix.

Arguments for market reforms have been offered earlier as well but have been related to an increasing share of renewables as part of meeting climate targets. Being technologies with close to zero production cost they are projected to push out the highest cost generation technologies and thereby drive down the market price. This makes it challenging to attract enough investments into new generation capacity to keep up with demand growth as lower prices will reduce the return on investments.

The high market price indicates that supply is limited with regard to keeping up with a demand that is inelastic and/or has few substitution alternatives. The current situation is serious as there is a real under-supply of gas to Europe and that has a direct effect on consumer electricity prices, as well as puts an economic strain on industry, businesses and households using gas as an input factor or for heating.

Wholesale prices are not this high due to Russia's invasion of Ukraine or the struggles of French nuclear electricity. It is the market design that is causing the spikes and the market has reacted exactly the way it was set up to do – giving a price signal to stimulate investment in more production capacity, although the short-term consequences would also be a reduction in demand or use of alternative generation capacity that might be even more expensive and less sustainable. The resulting challenge is that the current design provides neither an affordable, secure nor decarbonised power system. While the case for a fundamental change to power market price mechanisms was a controversial issue only six months ago, calls for a re-design are now heard both from European countries as well as European institutions that have acknowledged that a fundamental change is necessary.

To facilitate the tremendous investments now required to rebalance and decarbonise the electricity market, one of the most important challenges a re-design will have to address is the requirements for long-term revenue visibility. With the combination of the current market design principles, the decarbonisation objectives, and the current market situation, such visibility is low. Delivering on the three objectives of affordability, security and decarbonisation will instead most likely require better central coordination and intervention to drive the required investments, but also competition, innovation, and risk sharing.

Given the consequences of the current market design, the question now appears to be not if such intervention is necessary, but rather by what entity and mechanisms, and where in the value chain such coordination and intervention should be placed.

Global hydrogen market

The potential of clean hydrogen as a substitute for CO_2-emitting fossil fuels, including in those sectors that are hard to electrify, means that it is receiving ever increasing interest.

In *Walls*, the roll-out of hydrogen starts to accelerate in the 2030s as large new projects are being developed in parallel with hydrogen infrastructure.

In the overall energy mix, hydrogen demand remains small at less than 2% of the total energy demand by 2050, with green hydrogen making up 40%. Europe, Asia, and the US form the main hydrogen demand regions. China, EU, India, and Industrial Asia Pacific all rely on imports to meet their demand. Hydrogen demand takes off in the industry sector, replacing some grey hydrogen, as well as the transport sector, in particular in shipping where it meets 18% of demand in 2050 through conversion to ammonia.

In *Bridges* the share of hydrogen in the energy mix rapidly increases, reaching 9.8% in 2050, driven by a need to replace the remaining emissions from gas power generation.

China sees the fastest growth in demand in the short term, reaching 53% of the global total in 2030. It remains the biggest consumer in 2050, but its share shrinks to 30% by 2050. 90% of demand in 2050 comes from transport and industry. The share of green hydrogen production increases rapidly and by the mid-2030s is more than half of production. It exceeds 80% by 2050.

Obstacles to the roll-out of hydrogen

The introduction of clean hydrogen is not without political, technological and financial challenges. Short-term market issues cloud the future of developing a new marketplace for hydrogen as an energy carrier.

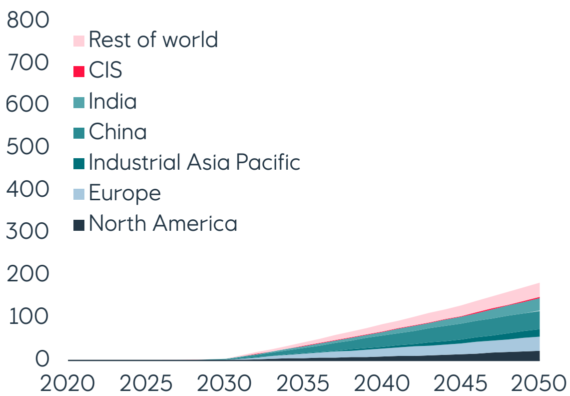
A reduced political appetite to deploy hydrogen in the short term could impede the development of a hydrogen economy in the mid-to-long term. The first projects will need strong government support to be realised. Hydrogen development in Europe is key, including for the growth expectations of potential export regions such as Africa, the Middle East, and North America.

Deployment of hydrogen could be delayed over concerns about natural gas and electricity/renewables scarcity, which are necessary to produce hydrogen. A reduction in green hydrogen technology costs is dependent on more projects being developed. The energy efficiency of hydrogen is also an issue.

Few sectors are ready to use hydrogen, and even those where it is already an integrated part of the production process (e.g., refineries, fertiliser, and methanol production) could face difficulties in switching to low-carbon hydrogen.

Walls – Hydrogen demand

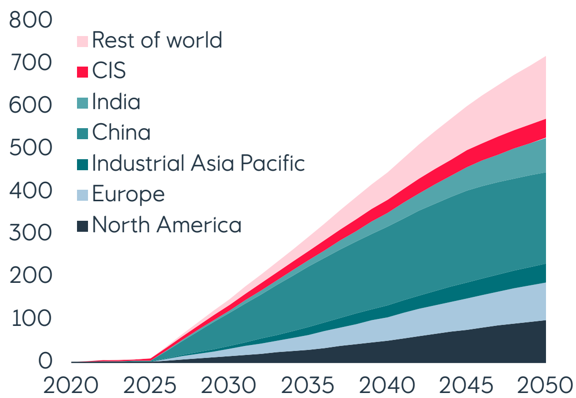
Mtoe



Source: Equinor

Bridges – Hydrogen demand

Mtoe

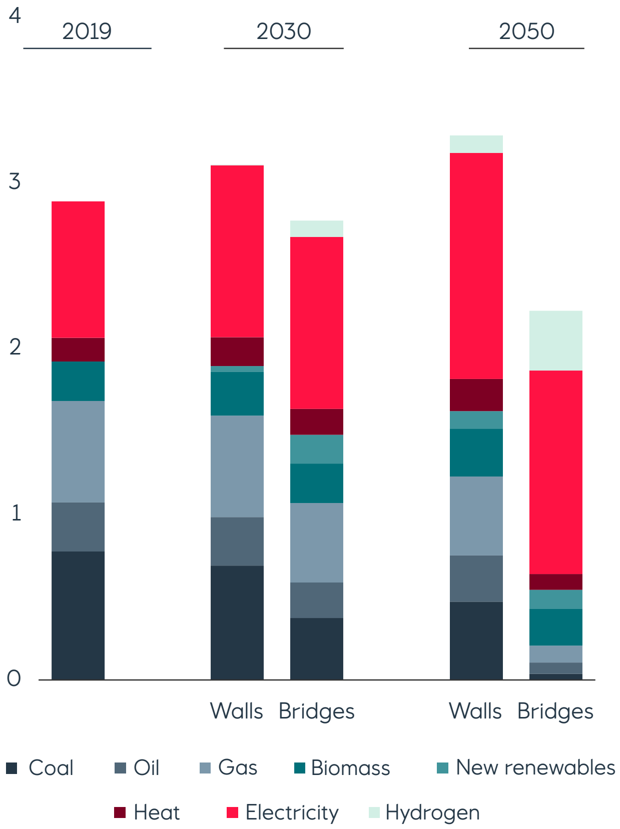


Source: Equinor

Key sector insights: Industry

Industrial demand

Gtoe



Source: IEA (history), Equinor (projections)

Transforming the industrial sector will be difficult as processes such as cement and steel rely on very high temperatures that are best achieved through the burning of fossil fuels. Since the turn of the century energy consumption in industry has increased by more than 55%, and industrial emissions in 2019 accounted for 16% of total emissions. The industry fuel mix has remained fairly constant since 1990, with fossil fuels making up approximately 60% annually. However, the share of fossil fuels has started to decline with electricity increasing its share by four percentage points since 2000, accounting for just less than 30% of the total mix in 2019.

Energy consumption in industry continues to increase in *Walls* towards 2050 but decreases in *Bridges* from 2025 onwards. Electricity consumption increases gradually in line with the historic trend from 2000 and by equal amounts in *Walls* and *Bridges*. It covers an increasingly greater share of total consumption in both scenarios. However, due to greater efficiency gains in *Bridges* the share of electricity is considerably higher than in *Walls* by 2050, accounting for 55% in *Bridges* as opposed to 42% in *Walls*. Hydrogen becomes an important part of the industry fuel mix in *Bridges*, accounting for 16% of total consumption, but covers a lower share of the fuel mix in *Walls*.

Energy intensity in the industrial sector is declining and continues to do so in both *Walls* and *Bridges*. The decline is being facilitated by a shift away from the energy-intensive heavy industries towards more service-based industries in many regions. Technological advances, the use of electric arc furnaces and a greater level of steel recycling are some of the key developments that will help further drive down demand and improve efficiency.

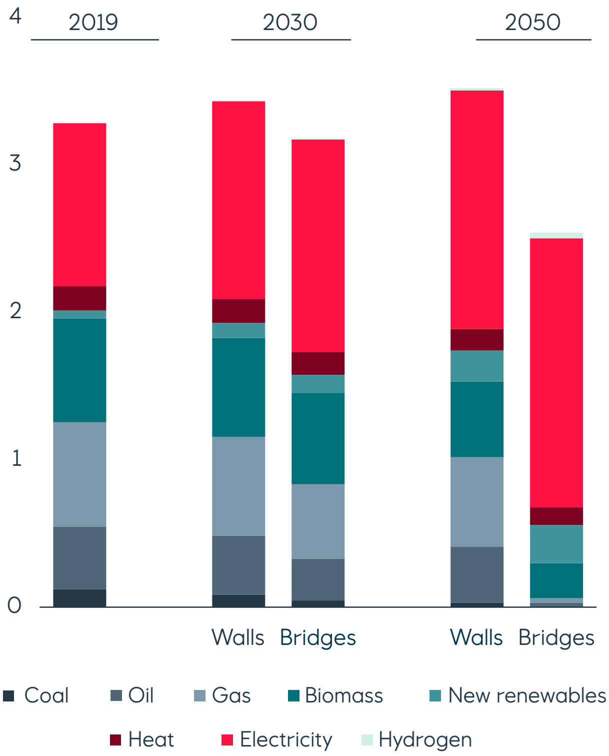
Key sector insights: Buildings

Energy demand for buildings used for residential and commercial purposes has seen a steady increase. Growing economies and populations, as well as increased urbanisation and a shift towards service-based economies, have facilitated the demand for more buildings and household appliances. Between 2000-19 the energy demand from buildings increased by nearly 30%, with the demand from commercial buildings alone increasing by more than 50%. Buildings made up a third of the total energy consumption in 2019 and accounted for 10% of global emissions. The relatively low share of emissions compared to consumption reflects a fuel mix that historically has been less reliant on fossil fuels than other sectors. In 2019 the building sector had less than 40% share of fossil fuels.

Biomass and electricity have accounted for approximately half of annual consumption throughout the 1990-2019 period, fuelling wood stoves and electrical appliances. The demand growth has mainly been covered by an increase in electricity consumption, which has risen more than 80% since the turn of the century.

Buildings demand

Gtoe



Source: IEA (history), Equinor (projections)

Electrification continues to transform the sector, accounting for an increasing share of the fuel mix as it, along with new renewables, continues to replace fossil fuels in both scenarios. In *Walls*, the energy demand from buildings continues to increase until the mid-2030s before declining gently towards 2050. In *Bridges*, the change comes sooner, and efficiency gains help drive down demand by nearly a quarter by 2050. The demand level is comparable to the early 2000s by 2050. Electricity makes up 46% of consumption in *Walls* and 72% in *Bridges* in 2050.

Technological advances, policies and behavioural changes are already having an impact that will help secure a more sustainable future for the buildings sector. The introduction of LED bulbs, smart meters and thermostats is well underway and, in many instances, incentivised. The demand for cooling units is increasing due to rising temperatures and urbanisation and overall wealth pushing up the want for comfort. A lot will be gained from technological advances improving the efficiency of these units and other household appliances, such as fridges and freezers. Several countries are putting in place policies and incentives to promote heat pumps and phase out traditional gas boilers.

Growing populations and urbanisation will lead to a significant increase in floor space demand going forward. Stricter regulations are, and will continue to be, put in place to reduce the carbon footprint of new building projects. Carbon neutral, and even carbon negative, housing is technologically attainable, but providing efficient and sustainable housing globally and at scale, not to mention making it affordable, remains a significant challenge. In addition, there will undoubtedly be a lag in transforming the overall housing stock even if future new builds meet carbon-neutral standards, as it is inconceivable that all existing inefficient buildings will be demolished early. Hence, the move towards carbon-neutral buildings is likely to accelerate over the coming decade, but a full turnover of building stock and transition to global carbon-neutral housing will take time.

Behavioural changes will also be required to drive demand down with recommendations for water and space heating and cooling temperatures, more recycling of clothes and plastics, as well as dietary changes all having a role to play.

Key sector insights: Transport

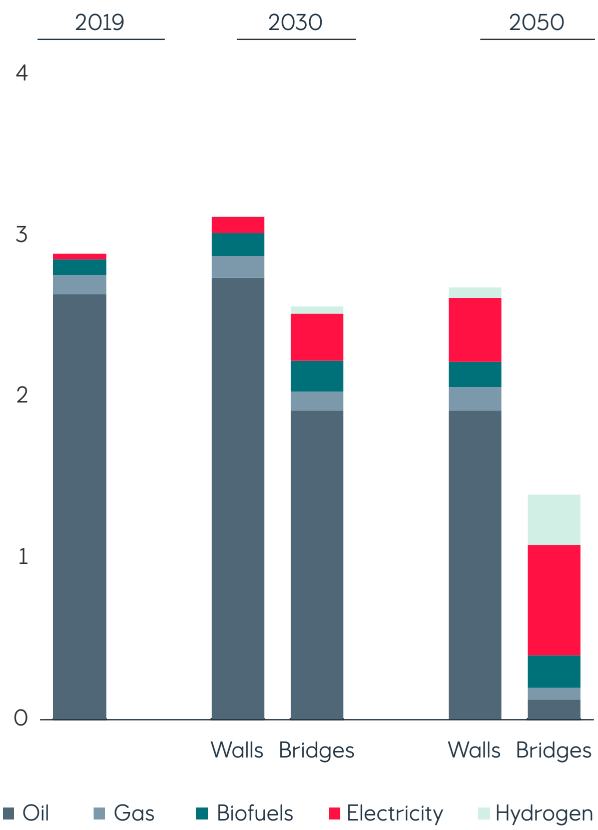
Historically, growth in GDP and population has translated into a growing number of vehicles on the roads, whilst also greatly increasing the demand for oil and pushing up greenhouse gas emissions. Since 1990, oil demand from transport has grown by 86%, reaching nearly 58 mbd in 2019. The majority of this demand increase comes from road transport such as cars, buses, trucks and two-wheelers. The transport sector is responsible for a quarter of global energy-related greenhouse gas emissions, and over the past decade, there has been a significant global drive towards lowering emissions from transport in general and road transport in particular.

The transition of the transport sector has already begun and the share of fossil fuels in the fuel mix has decreased by 3% between 2000 and 2019. Whilst this may not seem like a significant change it should be seen in relation to an overall sectorial demand increase of nearly 50% and the fact that the share of non-fossil fuels has more than tripled over the same period from 1.5% to 5%. The rate of phase-down of fossil fuels is set to accelerate, with efficiency improvements, electrification, biofuels and hydrogen transforming the sector. The fuel mix changes in a similar manner in both scenarios, but change occurs much more rapidly and to a greater extent in *Bridges* than in *Walls*, especially in the current decade.

The immense changes needed to ensure a sustainable path ahead for the transport sector will require continued government incentives and legislative measures. Such measures will reduce the number of heavily polluting vehicles, promote greater use of collective passenger transport, and replace flights with alternative means of transport, amongst other things. Initiatives to promote these pathways are already being put in place by governments with, for example, the UK introducing a ban on the sale of new pure internal combustion engine cars from 2030 and France prohibiting select flights where a train or bus alternative of two and a half hours or less exists. However, the energy use and fuel mix in *Bridges* in 2050, compared to today's situation, is a vivid illustration of the challenges ahead.

Transport demand

Gtoe



Source: IEA (history), Equinor (projections)

EMISSIONS

Energy-related greenhouse gas emissions

Sources and sinks

Carbon sources release more carbon than they absorb, while carbon sinks absorb more carbon than they release.

Fossil fuel combustion is the greatest contributor to global CO_2 emissions. Of the total man-made CO_2 emissions, fossil fuel use has recently accounted for approximately 85%, with land use changes contributing some 9%, cement and other manufacturing processes close to 4% and flaring the remainder. Global CO_2 emissions from fossil fuel combustion and cement manufacturing increased by 1.7% per year between 1990 and 2019, to some 36.7 Gt, whilst emissions from land use changes were down by 0.4% per year, according to the Global carbon project.

Land and ocean sinks are currently absorbing approximately half of the global CO_2 emissions. CO_2 absorption into oceans and vegetation fluctuates annually but was up by 1.2% a year between 1990 and 2019. The rate of absorption by sinks is not sufficient to keep up with the rate of emissions from sources. As a result, the net CO_2 additions to the atmosphere increased from 9.3 Gt in 1990 to 19.8 Gt in 2019. The pace of increase across the period was uneven reflecting ups and downs on the sink side more than fluctuations in emissions.

Global CO_2 emission sources and sinks

**Budget imbalance number netted out*

Source: Global carbon project

Methane

Methane is a short-lived but potent global warming driver. An estimated 30% of the 1.1°C warming that has occurred since the industrial revolution is due to methane emissions. Approximately 20-25% of methane emissions are due to oil and gas activities, with agriculture responsible for 40-50% and coal mining for 10-15%.

Global methane emissions levelled out in the early 2000s but have recently started to rise again. The reason for this recent rise is uncertain, but evidence suggests that agriculture and land use changes may be responsible. The oil and gas sector emissions can be more easily managed and can be reduced by changing well completion practices and fixing leaky infrastructure. Such improvements are essential for the industry's licence to operate and correspondingly high on its to-do list.

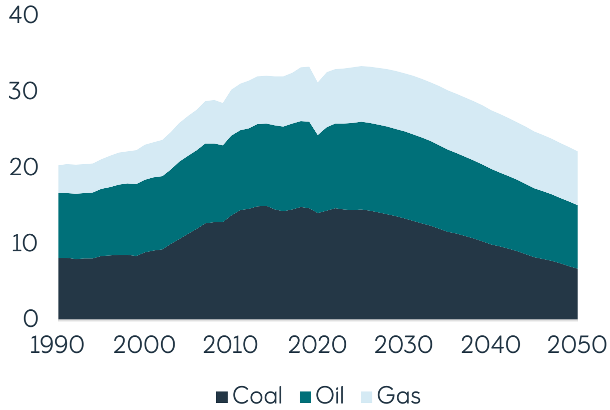
A global methane pledge was announced at COP26 in Glasgow in November 2021. It aspires to reduce global methane emissions by 30% by 2030. The pledge has been endorsed by more than 100 countries representing 45% of global methane emissions.

Global warming implications

Global warming reflects the total amount of greenhouse gases in the atmosphere, and relative to this amount, fluctuations in emissions from one year to the next make little difference. The declines in emissions in 2009 due to the financial crisis, and in 2020 due to the Covid-19 pandemic, were followed by sharp rebounds in 2010 and 2021 and provided only a brief respite. In themselves they warranted no changes in the warming projections developed in the preceding years.

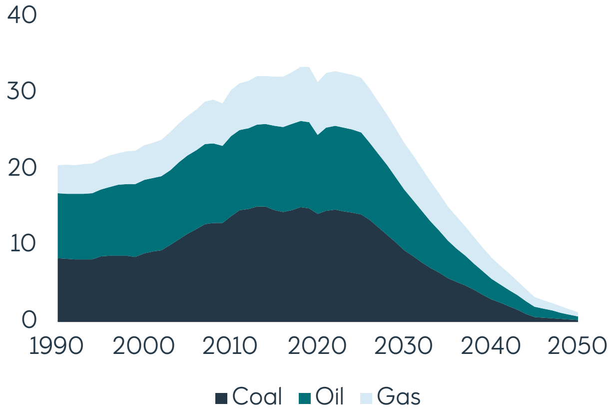
Energy-related CO_2 emissions

Walls – CO_2 emissions before carbon removal



Source: IEA (history), Equinor (projections)

Bridges – CO_2 emissions before carbon removal



Source: IEA (history), Equinor (projections)

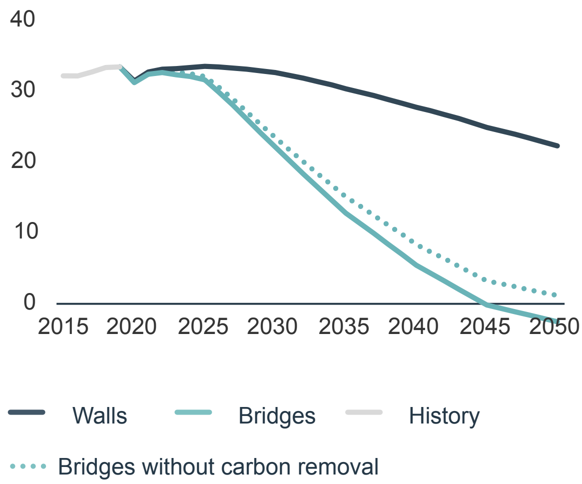
Global CO_2 emissions from fossil fuel combustion decline in both scenarios, bucking the historic trend. In *Walls*, emissions peak in 2025 and see an overall reduction by one-third between 2019 and 2050. This illustrates that *Walls* is anything but a long-term trend extrapolation exercise, but a scenario that picks up on the current signs of decarbonisation of power generation and road transport, in particular.

The decline is most significant in *Bridges* where CO_2 emissions from fossil fuel use are set to decline by around 1.7 Gt per year in the late 2020s and early 2030s. Except for 2020, which saw an extraordinary drop in emissions of several gigatonnes due to the Covid-19 lockdowns, no year since 1990 has seen emission reductions at the scale required in order to reach the 1.5°C target modelled in *Bridges*. The financial crisis in 2009, for instance, led to a decline of only around half of one gigatonne.

Reducing global CO_2 emissions from fossil fuel combustion through energy efficiency improvements, switching to lower carbon fuels, and counting in CCUS on fossil fuels, is not sufficient to deliver cumulative emissions in line with the 1.5°C target. CCUS has been applied to industry, power generation and blue hydrogen production in both *Walls* and *Bridges*. The total CCUS on fossil fuel use in *Bridges* increases to 2.2 Gt per year by 2050, which is approximately double the amount assumed in *Walls*.

In order to meet the 1.5°C emissions budget that defines *Bridges*, a further assumption has been made regarding carbon removal through BECCS, DAC and nature-based solutions. Carbon removal through these measures equates to around 1.3 Gt per year in 2030 and 4.3 Gt per year in 2050. In *Bridges* the world becomes net zero in the mid-2040s, with more developed regions having to go net negative in the early 2040s to allow other, less developed regions more time to reach the target. Volumes are low today, but there are significant efforts to ramp up carbon removal markets including from governments such as the US and UK, as well as the EU.

CO_2 emissions before and after carbon removal



Key figures

	Units	2019	2050		2019-2050 growth per year (%), CAGR	
			Walls	Bridges	Walls	Bridges
Global GDP	2015-USD trillion	84.1	162.7	164.2	2.1	2.2
North America, Europe, Industrial Asia Pacific	2015-USD trillion	51.3	78.8	77.9	1.4	1.4
China	2015-USD trillion	14.6	38.1	38.7	3.2	3.2
Rest of World	2015-USD trillion	18.3	45.8	47.6	3.0	3.1
Global energy intensity - indexed to 2019		100	54.1	38.0	-2.0	-3.1
Global population	billion	7.71	9.73	9.73	0.8	0.8
Global energy demand	Gtoe	14.37	15.02	10.64	0.1	-1.0
Coal	Gtoe	3.81	1.94	0.37	-2.1	-7.2
Oil	Gtoe	4.48	3.72	1.02	-0.6	-4.7
Gas	Gtoe	3.30	3.64	0.98	0.3	-3.8
Nuclear	Gtoe	0.73	1.01	1.14	1.3	1.4
New renewables	Gtoe	0.33	2.63	5.40	6.9	9.4
Oil excl biofuels	mbd	96.8	81.5	24.1	-0.6	-4.4
Gas	Bcm	3,977	4,379	1,187	0.3	-3.8
Global energy-related CO_2 emissions (Gt)	Gt	33.4	22.3	1.2	-1.3	-10.2
North America	Gt	5.9	2.8	0.2	-2.3	-10.8
Europe	Gt	3.8	1.2	0.0	-3.6	-15.4
China	Gt	10.1	5.1	0.1	-2.1	-14.3
India	Gt	2.3	3.0	0.1	0.9	-8.6
World CO_2 emissions from fossil fuel use removed by CCUS	Mt	14	1,144	2,211	15.2	17.6
World CO_2 emissions removed from atmosphere	Mt	0	0	4,300	-	-
Global light duty vehicles (LDVs) fleet	million	1,345	1,561	1,382	0.5	0.1
LDVS oil demand	Mtoe	1,147	543	29	-2.4	-11.2
LDVs biofuel demand	Mtoe	72	46	1	-1.4	-13.9
LDVs electricity demand	Mtoe	2	166	270	16.1	17.9

Units

Coal	Btce	billion tonnes of coal equivalent
Oil	mbd	million barrels per day
Gas	Bcm	billion cubic metre
Power	TWh	terawatt-hour
	PWh	petawatt-hour
	GW	gigawatt (1 watt x10^9)
Energy	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)
	toe	tonne of oil equivalent
	ktoe	thousand tonnes of oil equivalent
	Mtoe	million tonnes of oil equivalent
	Gtoe	gigatonnes of oil equivalent
Carbon	Gt CO_2	gigatonnes of carbon dioxide
Monetary	USD	1 US dollar

Only units used in the report are listed

Definitions

Energy demand and consumption

History: 1990-2019
Projection: 2019-2050
Short-term outlook: 2019-2025
Long-term outlook: 2025-2050

Regions

There are 12 regions modelled.
Industralised: European Union, Industralised Asia Pacific, North America, Other Europe.
Emerging: Africa, China, CIS (Commonwealth of Independent States), India, Middle East, Other Americas, Other Asia Pacific, Southeast Asia

Sectors

There are 8 sectors modelled.
Industry, residential, other stationary, transport, non-energy, power & heat, hydrogen, other transformation

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