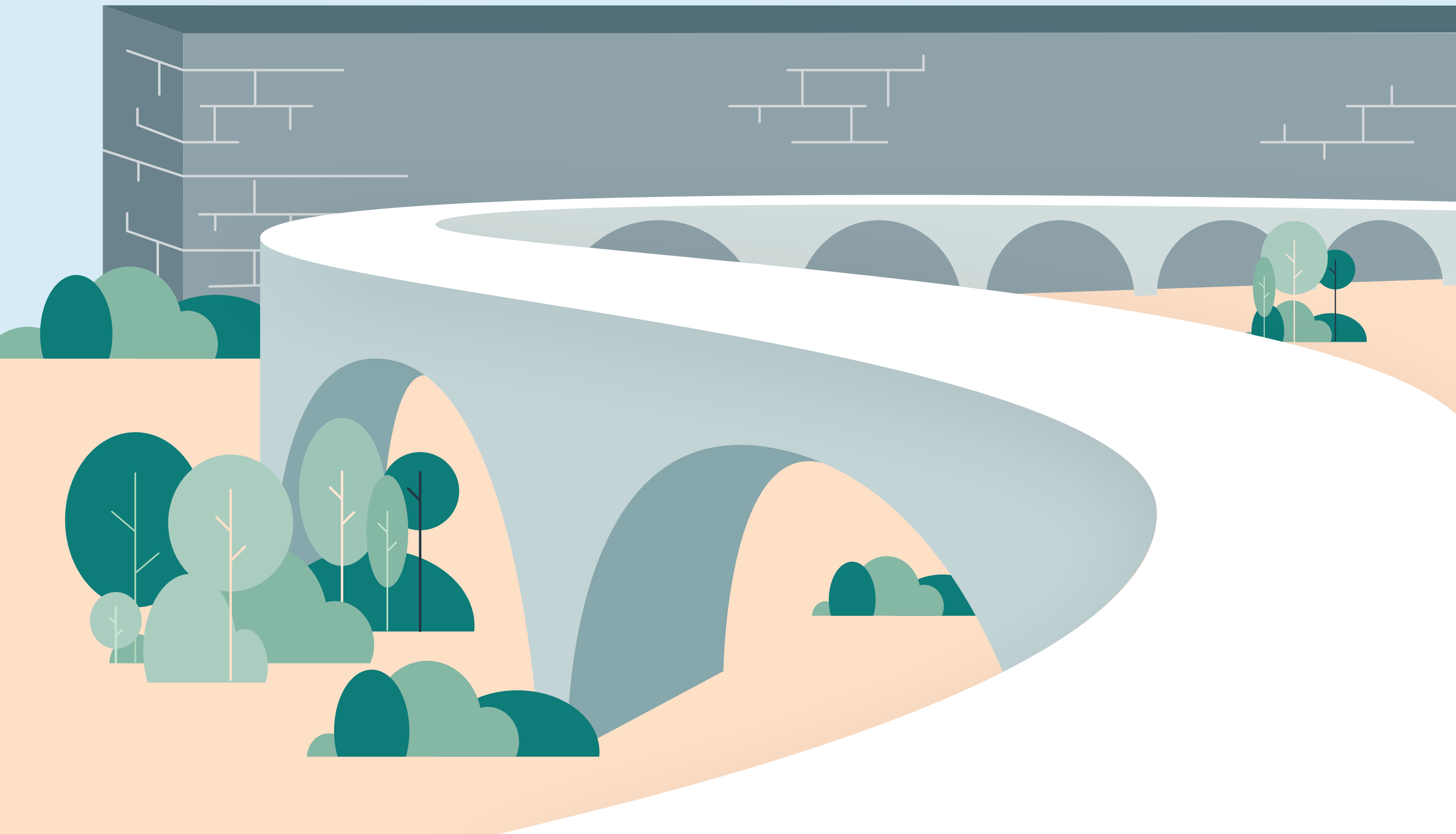
2024

Energy Perspectives

Global macroeconomic and energy market outlook



Welcome to Equinor's Energy Perspectives 2024

Driving an energy transition at the speed and scale necessary to deliver on the climate ambitions stated in the Paris Agreement is an immensely challenging undertaking. It will require a synchronised commitment from governments, industries and individuals, targeting all parts of the energy sector, with the aim to reduce CO_2 emissions as quickly and cost effective as possible, while also delivering on other sustainable development goals.

The current tense geopolitical situation caused by wars and conflicts not only has tragic consequences on people's lives and livelihoods, but also contributes to a slower and less extensive energy transition than what is needed. To bring the world on track to address long-term sustainability challenges in a balanced manner, trust, cooperation and burden-sharing must be established and accepted. This will take time, and its success 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 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, strategic planning and decision making.

The two scenarios, *Walls* and *Bridges*, aim to highlight the large challenges that must be overcome to make the move from the relatively slow, incremental changes that characterise the energy transition today (*Walls*), to the radical and fast changes needed to move the world onto a path aligned with the 1.5°C ambition of the Paris Agreement (*Bridges*).

Energy Perspectives provides important insight into the outcome space we have to consider when balancing our strategic priorities in the energy transition.

Anders Opedal
President and CEO

The current tense geopolitical sentiment has made the walls higher and the bridges narrower. With another year gone, the enormity of the energy transition challenge is more evident than ever.

Eirik Wærness
Senior vice president and Chief economist

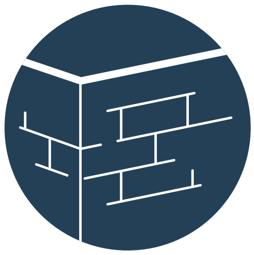

KAPADOKYABALLOONS.COM
TC-BLC

Key insights from Energy Perspectives 2024

Energy Perspectives 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 EP23 is a normative back-cast scenario complying with the 1.5°C carbon budget, demonstrating the enormous and sustained effort required to reach this target, on top of all the changes in *Walls*.



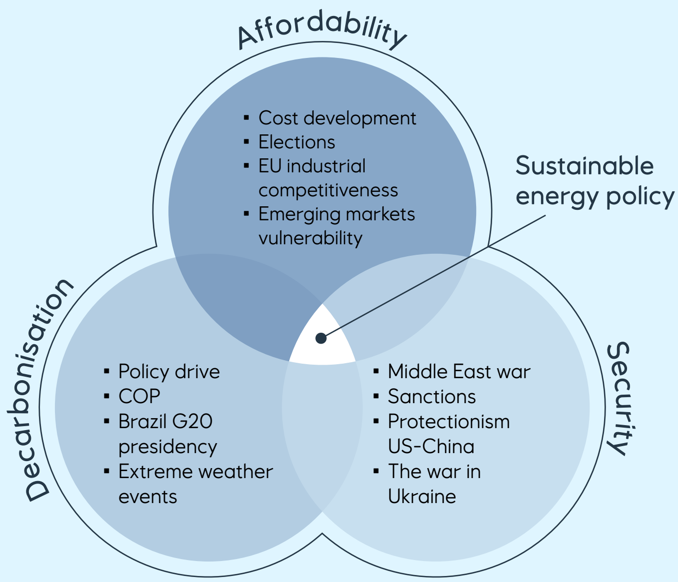
WALLS

BRIDGES

This year's Energy Perspectives presents an updated version of the Walls scenario, while maintaining the Bridges scenario as outlined in the 2023 outlook.

Competing priorities are influencing policy makers' approach to economic, climate and energy policies

Geopolitical tensions, wars and economic development are drawing focus away from energy transition goals. However, a growing sense of urgency around climate change and its adverse effects will keep the long-term decarbonisation agenda in focus.



Climate pledges are not enough to avoid global warming above 1.5°C

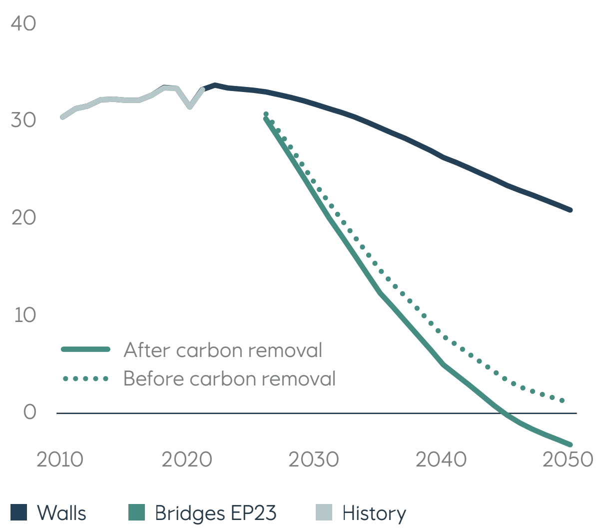
In *Walls*, the 1.5°C carbon budget is exhausted by 2033.

In *Bridges EP23*, 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) →

Annual global energy-related CO_2 emissions

Gt CO_2



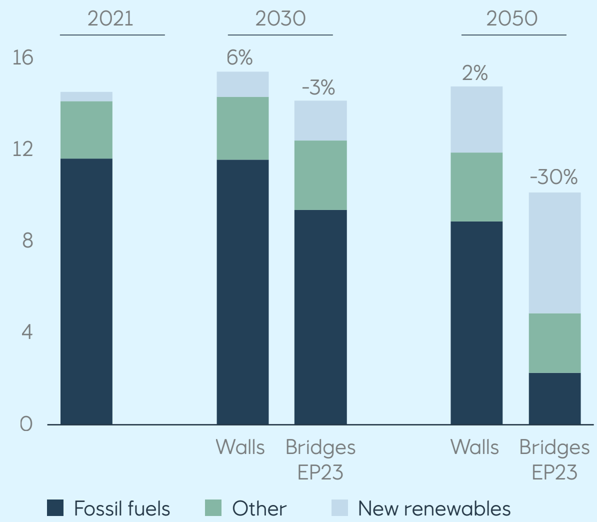
The energy transition is significant in *Walls* and radical in *Bridges EP23*

Despite growth in the global population and GDP, total primary energy demand peaks in the late 2030s in *Walls* as rapidly declining demand in industrialised regions outweighs a continued growth in most emerging regions.

In *Bridges EP23*, total primary energy demand peaks in 2025, before going into sharp decline and ending up at a global demand level in 2050 that is 30% lower than that observed in 2021.

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

Total primary energy demand
Gtoe



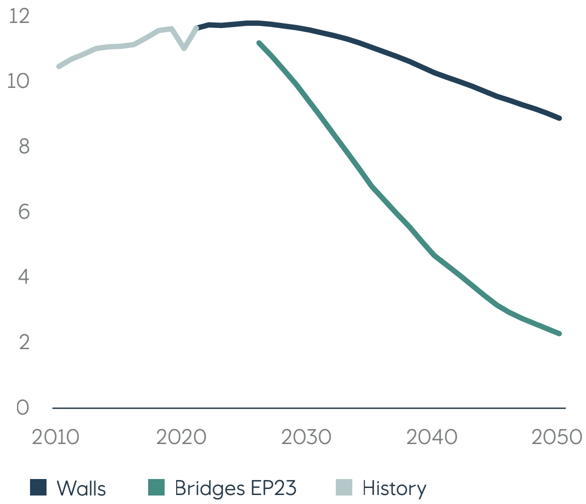
Peak demand for fossil fuels arrives before 2030

In *Walls*, combined fossil fuel demand peaks in 2025, followed by a gentle downward trajectory. Coal, oil and gas demand peak in 2022, 2027 and 2035, respectively.

In *Bridges EP23*, fossil fuel demand declines at a rapid pace from 2025. By 2050, all remaining fossil fuel use is either fully abated, compensated by carbon removal or used as feedstock in the petrochemical and other non-energy sectors.

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

Global fossil fuel demand
Gtoe



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

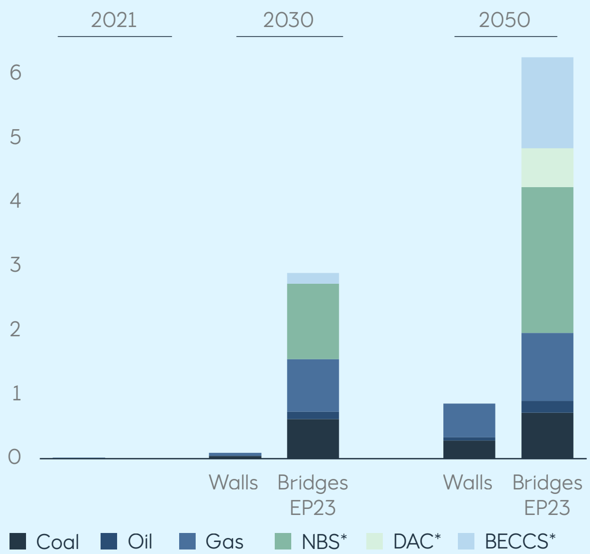
In *Walls*, CCUS on both coal and gas starts to accelerate after 2030.

In *Bridges EP23*, there is massive growth in CCUS even before 2030, and remaining unabated fossil fuel use in 2050 is compensated by carbon removal, direct air capture, etc.

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

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

Carbon removed and stored annually
Gt CO_2

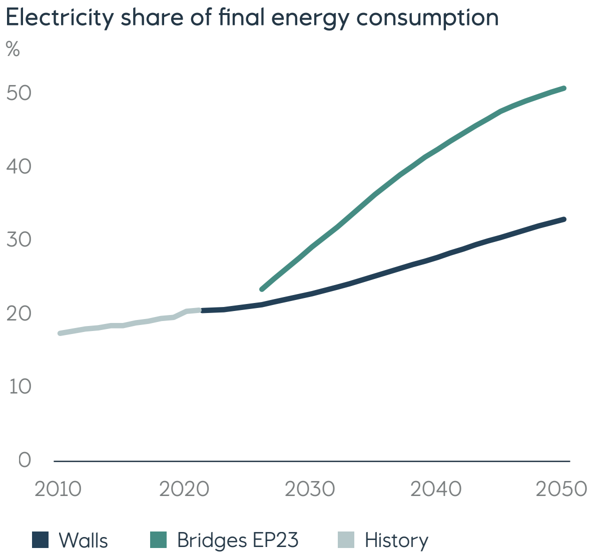


Energy consumption shifts towards electricity

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

In *Bridges EP23*, massive acceleration happens before 2030. By 2050, the share exceeds 50%, two and a half times as large as today.

Source: IEA (history) Equinor (projections) →



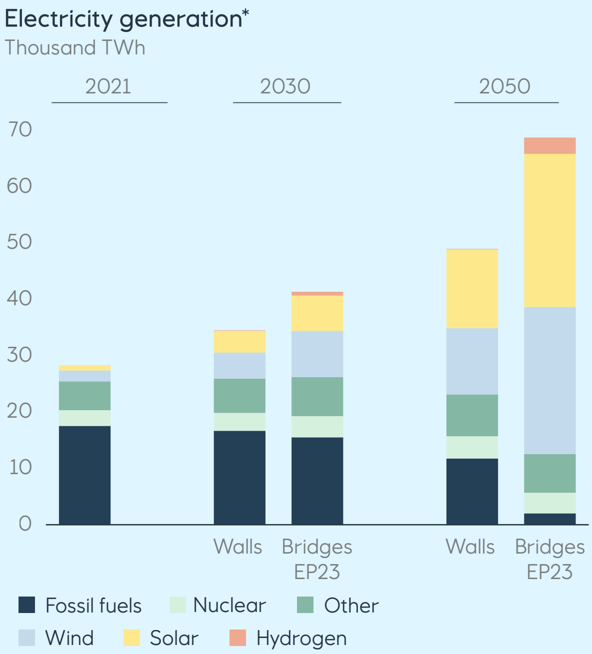
The key enabler to a sustainable energy transition is growth in decarbonised electricity

Low/zero carbon electricity production will increase significantly in both scenarios to help change the energy mix away from fossil fuels, and achieve higher energy efficiency and lower emissions.

The growth in electricity generation is enabled by significant growth in solar and wind.

Source: IEA (history) Equinor (projections) →

** Includes electricity used for grid and hydrogen production*



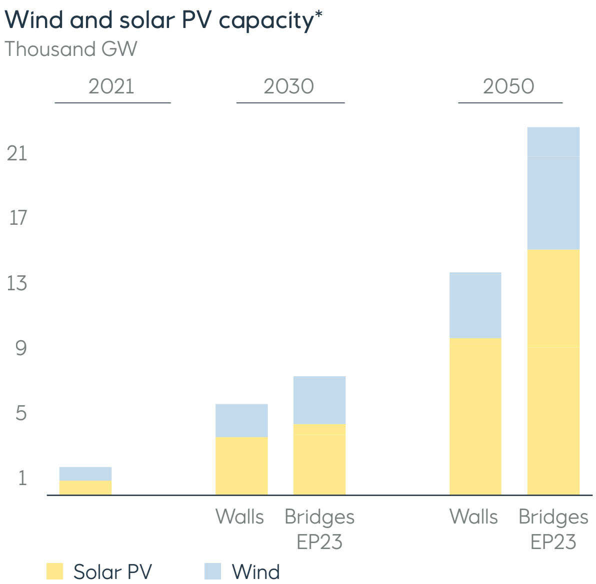
The growth of wind and solar photovoltaics (PV) capacity outruns all previous trends

In *Walls*, wind capacity is five times greater, and solar PV capacity ten times greater, in 2050 compared to 2021.

In *Bridges EP23*, wind capacity is nine times greater, and solar PV capacity is 16 times greater, in 2050 compared to 2021.

Source: IEA (history) Equinor (projections) →

** Includes wind and solar PV capacity for grid and hydrogen production*



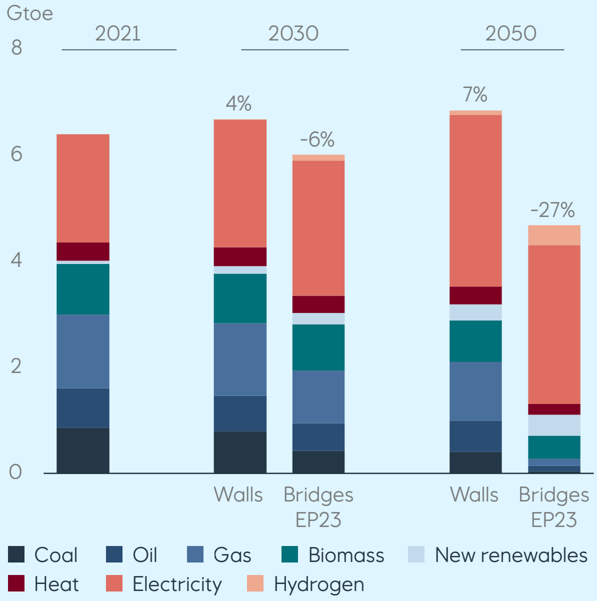
Energy demand from industry and buildings continues to stay high, but electrification reduces the share of fossil fuels in both scenarios

In *Walls*, demand from industry and buildings increases 7% by 2050, whilst demand declines by 27% in *Bridges EP23* over the same period.

The electricity share of energy demand from industry and buildings increases from 32% in 2021 to 47% and 64% in 2050 in *Walls* and *Bridges EP23*, respectively.

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

Industrial and Buildings fuel mix



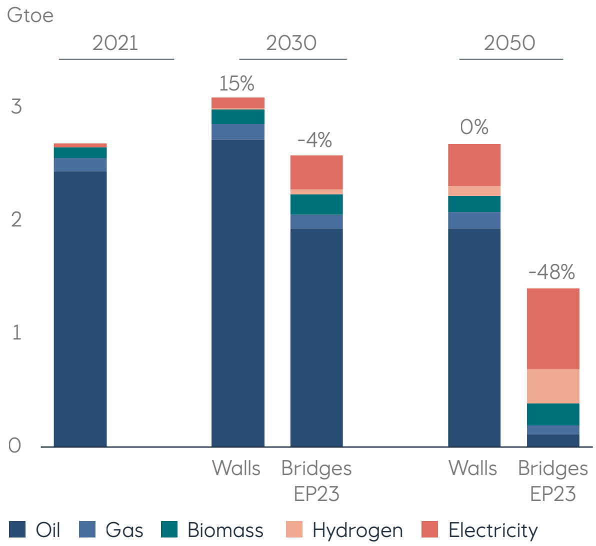
Electrification and hydrogen-based fuels will contribute to the decarbonisation of transport

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

In *Bridges EP23*, further decarbonisation is achieved by increasing use of hydrogen-based fuels in aviation and marine transport.

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

Transport fuel mix



The petrochemical sector is the only sector with continuous growth in fossil fuel demand to 2040 in both scenarios

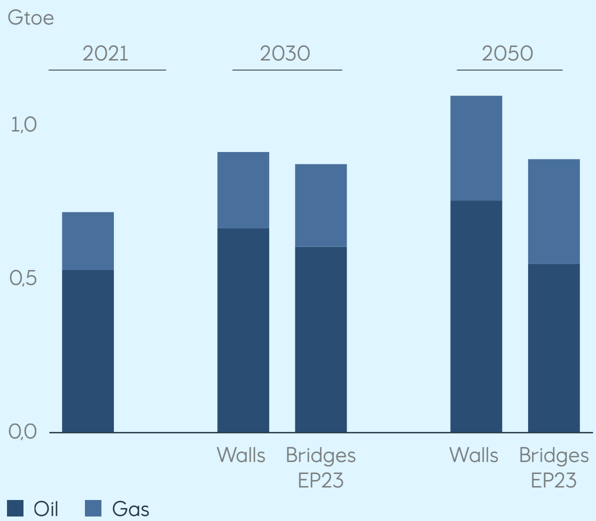
In *Walls*, petrochemical feedstock demand accounts for 10% of total gas demand and 23% of total oil* demand in 2050.

In *Bridges EP23*, petrochemical feedstock demand peaks in 2040 and plateaus towards 2050 where it accounts for 34% of total gas demand and 50% of total oil demand.

** Oil here refers to total liquids including biofuels.*

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

Petrochemical feedstock

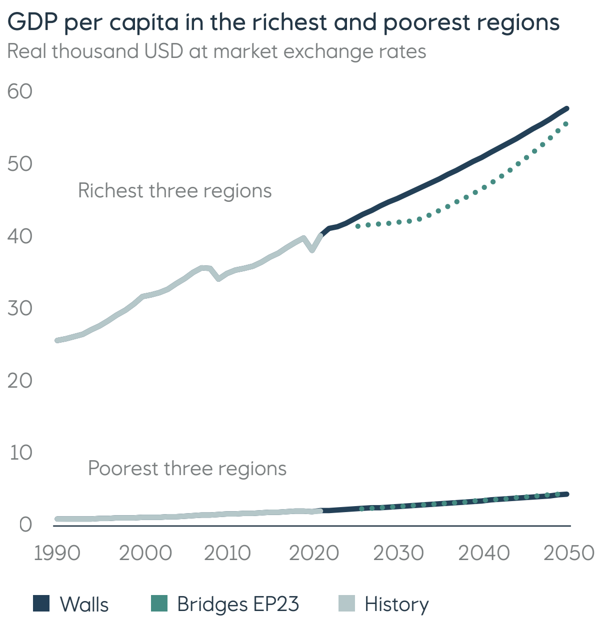


GDP per capita continues to grow globally, but the significant inequalities across regions persist

In 2050 GDP per capita is more than 13 times greater in the three richest regions compared to the three poorest regions.

In the richest regions the growth in GDP per capita takes a different path in *Bridges EP23* than in *Walls*. Initially the energy transition in *Bridges EP23* is more costly, but the economic growth catches up by 2050 in part due to avoidance of some of the costs resulting from climate change.

Source: Oxford Economics International 2024 (history), Equinor (projections), UN (population) →

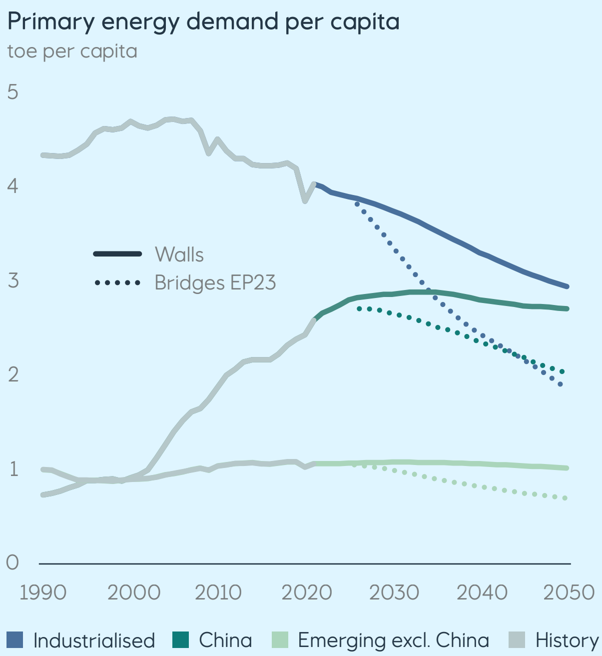


Primary energy demand per capita remains significantly higher in the industrialised regions and China than in the emerging regions

Per capita energy demand in the industrialised regions declines, with electrification boosting energy efficiency in the transport and residential sectors.

In the emerging regions per capita energy demand increases linked to economic and population growth are countered by electrification and efficiency developments.

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

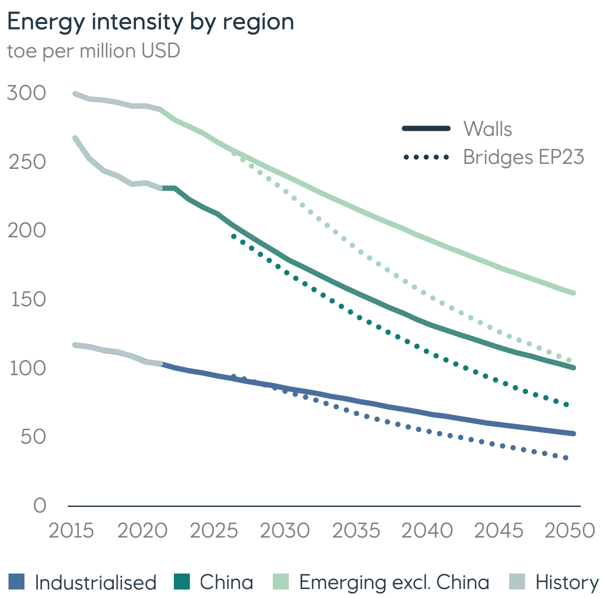


Energy intensity is approximately halved in all regions by 2050 aided by electrification and other efficiency gains

The emerging regions excluding China are much less energy efficient than the industrialised regions with energy intensity being three times as high.

The level of efficiency gains required to reduce energy intensity in the emerging regions is significantly greater than in the industrialised regions.

Source: Oxford Economics International 2024 (history), Equinor (projections) →



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SHORT-TERM OUTLOOK

Geopolitics affect energy markets

In 2024, almost half of the world's population will go to the polls. Many of these elections will demonstrate some of the key trends shaping world politics: geopolitical competition, economic nationalism, political polarisation and the rise of right-wing populism. This in turn will impact the global energy markets.

The global order that had been entrenched since the end of the Cold War appears increasingly outdated. The wars in Europe, the Middle East and Africa are being fought amid a growing great power competition, making the international system fragile and unconducive to stable development. Protectionist industrial policies, the comeback of an interventionist state and growing national security challenges promise to be the defining features of the future global economy.

The November 2024 US presidential election is the most consequential this year. The re-election of President Biden would provide broad continuity and predictability for allies. A more isolationist and unilateral Republican administration would, however, see more profound changes, especially related to security, trade and climate policy. NATO and Asian allies would be dislocated by a return to transactionalism, especially on trade, with tariff increases likely. A US withdrawal from the Paris Agreement would both damage transatlantic climate policy cooperation and undermine broader global climate goals. The need to contain and even confront China economically, politically, and militarily stands out as a bipartisan priority, and protectionist trade policies will increasingly dominate regardless of who wins the election.

Irrespective of the outcome of the US election, strategic competition between the US and China will remain the most impactful geopolitical dynamic. In the short term, competition is being managed, particularly as China attempts to reconfigure its economic growth model. Longer term, the bilateral relationship is likely to continue to deteriorate.

Russia is committed to a long war and is confident that the West will tire of supporting Ukraine. Shorter term, a diplomatic and military impasse is expected. In the medium term, with the additional US aid agreed upon in April 2024, Ukraine can likely stabilise the front in 2024, enabling it to hold out into 2025.

Even if Russia does not prevail in Ukraine, elevated defence spending will be required in Europe to counter an enduring Russian threat. This is likely to add to fiscal strain in European economies.

In response to changed geopolitical realities, the EU must now adjust by undertaking a strategic recalibration. It needs to build a credible defence strategy, especially in case of a new transatlantic rift. This may come at the expense of energy transition and climate policies. With internal divisions, it is also urgent to reestablish the Berlin-Paris axis as a driving force in EU cooperation.

The war against Hamas has isolated Israel, and the normalisation process with Saudi Arabia will be difficult to move forward without settling the conflict with the Palestinians. As Jerusalem sees the war in Gaza as part of a larger conflict with the Iran-led axis, a higher baseline of tensions should be expected in the region.

The world order is becoming increasingly competitive and less bound by rules. As competing forums proliferate, global multilateral institutions are decaying. Meanwhile, middle-sized countries such as Brazil, Saudi Arabia and Turkey, are impatient and assertively calling for a more equitable distribution of global income, power, and representation.

Climate policy is a pressure point, with G20 and BRICS* amplifying calls for an equitable energy transition. Emerging economies will aim to secure additional climate financing from developed countries to support their transitions. Simultaneously, most oil and gas producers among them are likely to increase exports to boost revenues. In most of Africa, ensuring affordable energy will take precedence over any concept of an energy transition.

** Intergovernmental organisation with Brazil, Russia, India, China and South Africa as members until recently. In 2024, the bloc is welcoming Egypt, Ethiopia, Iran, Saudi Arabia and the United Arab Emirates (UAE) as new members..*

The global economy

With nations standing at a crossroad, having to choose between competition and collaboration, economic activity across borders will be heavily influenced by policymakers.

As we navigate the mid-2020s, the global economy continues to display a profound mix of resilience and vulnerability. Challenged by tight monetary policy and inflation, the global economy displayed resilience and grew by 2.7% in 2023. In the short term, the use of protectionist industrial policies, the comeback of an interventionist state and growing national security needs, place nations at a crossroad between competition and collaboration. Fearing vulnerability, many governments seem to lean toward more competition.

Despite these challenges, there are opportunities for collaboration. Fuelled by technological advancements and a global shift towards sustainability, new markets are emerging. One nation seeking to capture its share in these new markets is China, which is now doubling down on electric vehicles (EVs), batteries, and renewables as key growth areas. This likely implies more and cheaper batteries, wind turbines and solar panels. This can also be a source of increasing trade tensions, as many economists worry that China's industrial push is stimulating overcapacity. Amid structural headwinds and deflation, growth in the Chinese economy is forecasted to slow to an average rate of 4.2% from 2024 to 2027.

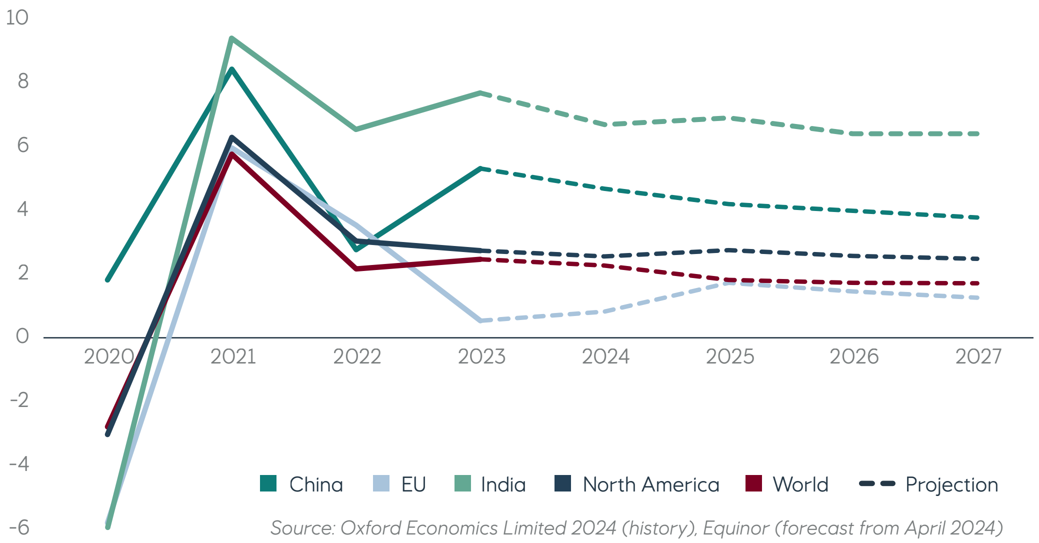
Chinese overcapacity also adds to headwinds faced by the European industrial sector, which is seeing a slowdown following spikes in energy prices and decreased demand for goods. The EU narrowly avoided a recession in 2023, and slow growth is forecasted at 1.3% on average over the next four years. Despite this, Europe is investing heavily in diversifying its energy supply. Diversification is not only viewed as a necessary part of the energy transition but now also for energy independence and de-risking efforts. Increased investments in defence add to fiscal strain in Europe.

While inflation globally is slowly fading, inflation in the US is proving sticky as economic activity remains strong. Having already surprised economists with a GDP growth rate of 2.5% in 2023, the US economy is expected to grow at 1.9% on average over the next four years. Also in the US, investments in renewable value chains provide extra economic stimuli. A similar story of resilient growth is emerging in India, where yearly GDP growth is expected to remain strong at 6.6% towards 2027. India's resilience showcases the potential for emerging markets to leverage policy reforms and strengthen capabilities despite global headwinds.

Although an improvement in economic conditions and a 'soft landing' currently appears to be within reach, overall global growth over the next four years is projected to remain below the historical average with an estimated yearly rate of 2.6%. Geopolitical uncertainties and trade tensions still underscore the critical challenges that lie ahead. Uncertainty might trigger the building of new walls, but collaboration allows for the efficient use of scarce resources and avoids misallocation. By 2027, the global economy might find itself back on a stable trajectory of growth.

GDP growth

% change Y/Y



Source: Oxford Economics Limited 2024 (history), Equinor (forecast from April 2024)

Commodities

Oil

Macroeconomic concerns, geopolitics, and OPEC+ decisions will drive the oil market.

Oil demand continues to grow, led by Asia, but uncertainty around the global economy and Chinese economic growth dampens the oil demand outlook. Increased non-OPEC+ production led by North America is expected to cover total demand growth. As a result, OPEC+ production cut agreements are key to keeping the market balanced. Oil prices are expected to remain volatile, caught between macroeconomic concerns and geopolitical tensions.

Gas

The Russian gas bubble is over.

After two years of jolting uncertainty, the global gas market has swung to a more comfortable position bringing back a lower price and a less volatile environment. Nevertheless, following the loss of Russian gas volumes in 2022, the European gas market will continue to be exposed to global supply risks and geopolitical developments. However, a new wave of LNG supplies arriving during the second half of 2025 is likely to continue balancing the market and reducing price volatility, with US LNG becoming an increasingly important factor.

Electricity

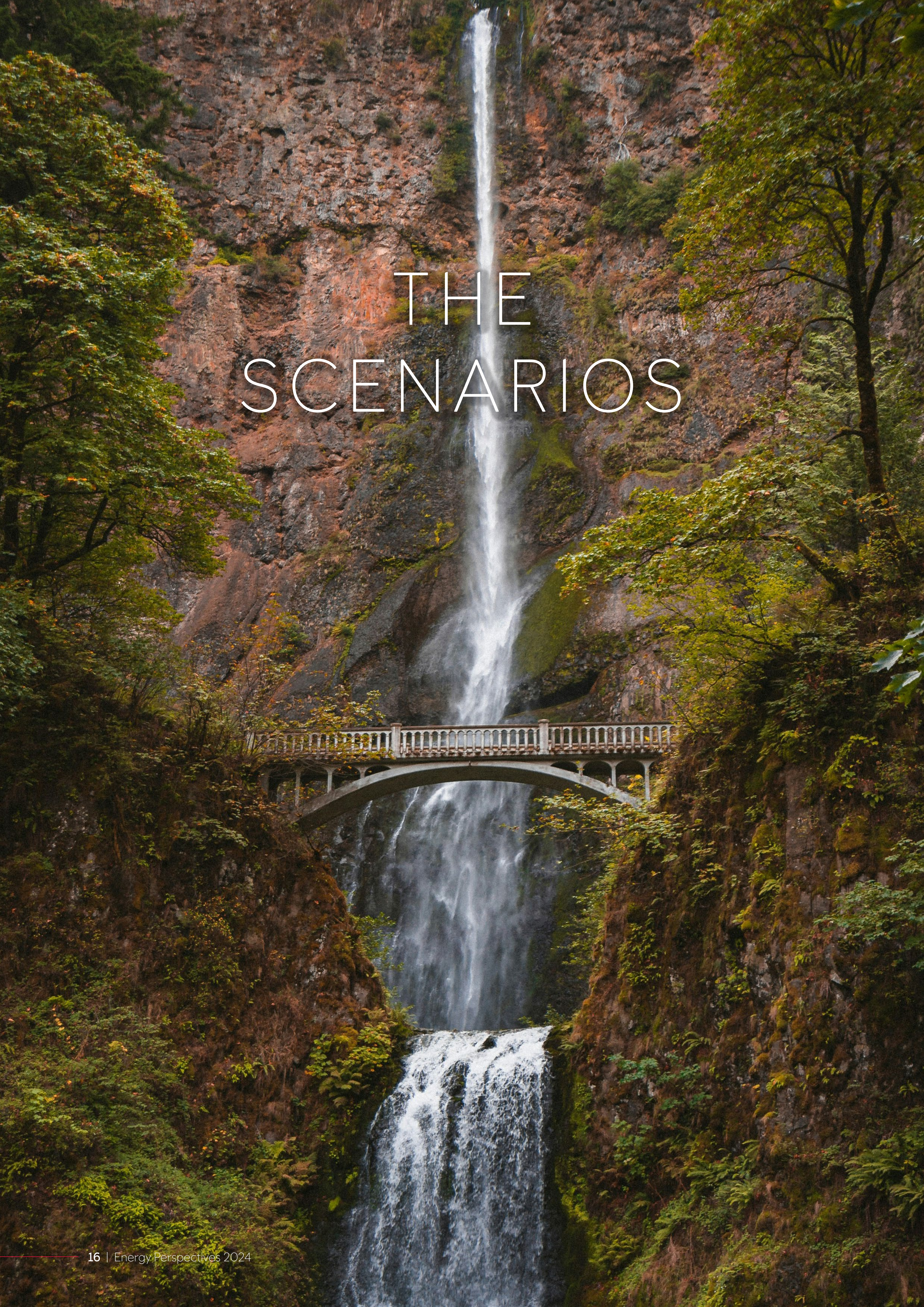
The short-term outlook is calling for prudence in the electricity market.

After two years of turmoil and prices reaching 500 EUR/MWh in the summer of 2022, the European power prices have now normalised close to pre-Covid levels. Mild weather, high gas storage levels and increased nuclear availability have contributed to the calm down. However, uncertainty remains high due to geopolitical tensions, supply chain constraints, demand destruction and extreme weather events. Politics will face increasing pressures on the back of the cost-of-living crisis while having to stay focused on ambitious energy transition goals. A strong growth in renewable generation, mainly driven by solar, is driving down average prices. CAPEX-intensive projects are undermined, calling for an adjustment of the power market design.

Hydrogen

Hydrogen looks for direction at the start of its journey into the energy mix.

Hydrogen is seen as a key element in achieving deep decarbonisation, but the first part of this journey may not be as a primary energy carrier. Current global consumption is ~90 Mt/yr mainly produced from unabated hydrocarbons. It is used in refining and in making ammonia, methanol, and fertilisers. Decarbonisation of industrial feedstocks is where low-carbon hydrogen will gain a foothold, allowing for use as a carbonless fuel in high-temperature heat processes. This will lead to the development of hydrogen hubs facilitated by governments providing the necessary financial support and framework conditions, giving clarity and direction to investors and energy consumers alike.


THE
SCENARIOS

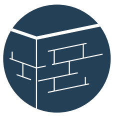
The scenarios

Energy Perspectives 2024 contains two scenarios for the future of the global energy markets: *Walls* and *Bridges*.

The scenarios highlight the contrast between the current pace of the energy transition and the swift, radical changes needed to meet the 1.5°C target. Both scenarios start from today's context, where the energy transition is underway but not fast enough to meet the goals of the Paris Agreement. *Walls* depicts a future where current trends continue to develop at a slowly accelerating pace, while *Bridges* represents a scenario where the world adopts measures to meet 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.

This year's Energy Perspectives presents an updated version of the *Walls* scenario while maintaining the *Bridges* scenario as outlined in the 2023 outlook. At the time of publication, *Bridges EP23* was compliant with the carbon budget corresponding to a 1.5°C warming towards 2100, with no overshoot. After another year of high emissions, the *Bridges EP23* CO_2 emissions curve would no longer meet this constraint exactly and further carbon emission reductions or removal of around 1 GT would be required for this scenario to comply with the 1.5°C carbon budget.

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 symbolise the barriers hindering significant and swift changes in the global energy system. Historically, walls were built for protection against threats like intruders, plagues and natural disasters but also ended up restricting movement and creating divisions.

Walls protect, but they also divide.

The *Walls* scenario suggests a moderate, but significant acceleration in energy system evolution, driven by economic growth and influenced by current market, technology, and policy trends. This includes the impacts of recent geopolitical events and legislations like the US Inflation Reduction Act and the EU Green Deal. Despite some efforts to advance the energy transition, challenges such as geopolitical tensions, market distortions and limited cooperation limit the ability to achieve the climate goals set by the Paris Agreement.

Despite falling short of climate targets, it is important to note that the changes to the global energy system outlined in *Walls* are not to be taken for granted and will require enormous efforts.

**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.*

Bridges

Where walls represent barriers to change, bridges symbolise the overcoming of these obstacles and the push for rapid transformation. Bridges facilitate connections and enable achievements that would otherwise be impossible, by promoting movement, transition, trade, and communication.

Bridges connect and enable.

The *Bridges EP23* scenario is a benchmark 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*.

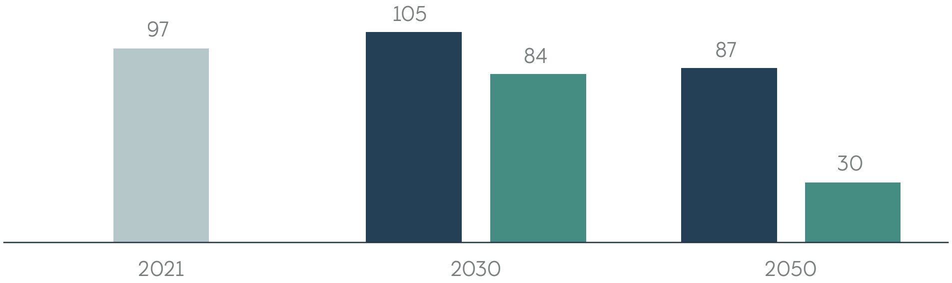
The scenario is characterised by a cooperative geopolitical environment, integrated energy markets, shared technological advancements, and climate action as the driving force. It requires a rapid shift away from fossil fuels, massive expansion of renewable energy, enhanced energy efficiency, and significant behavioural changes, aiming for a substantial energy system transformation already by 2030.

While technically feasible, the practicality, economic viability, and political acceptability of such ambitious changes are challenging. This forward-looking narrative seeks to spark discussions on the feasibility of achieving the 1.5°C climate target.

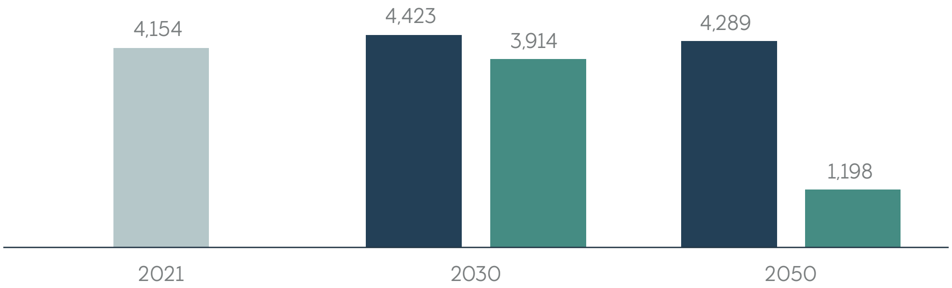
LONG-TERM OUTLOOK

The energy world in 2030 and 2050

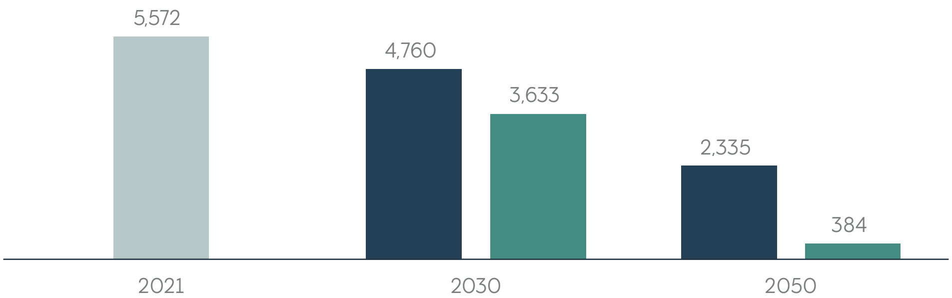
Global oil* demand
mbd



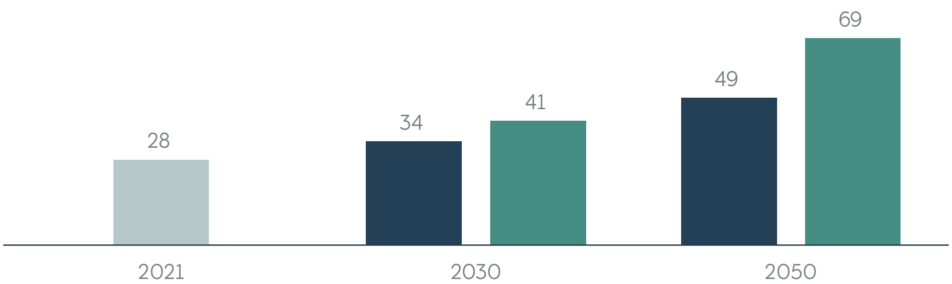
Global gas demand
Bcm



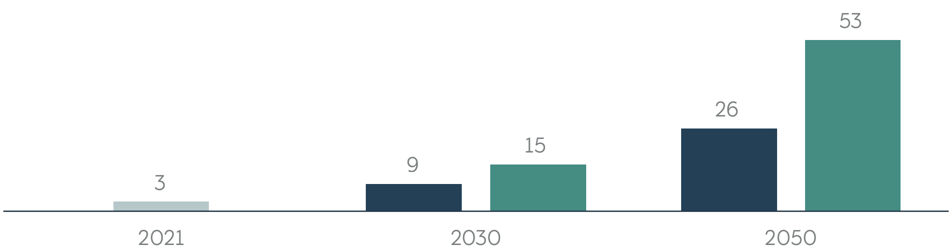
Global coal demand
Mtce



Global electricity demand*
PWh



Global wind & solar electricity supply**
PWh



History Walls Bridges EP23

Source: IEA (history), Equinor (projections)

** Oil in this section refers to total liquids including biofuels*
*** Includes demand/supply for both grid and hydrogen production*

The global economy

The long-term downward trend of global economic growth persists, and both *Walls* and *Bridges EP23* see lower growth compared to history. Global growth is challenged by long-run structural factors dampening the outlook and is maybe more uncertain than ever due to climate change and geopolitical issues.

Global economic expansion continues throughout the scenario period, mainly driven by emerging market growth. However, global growth is projected to be lower than observed historically. Some of the favourable factors supporting growth in previous decades, like rapid globalisation and productivity gains from technological advances, are fading. Demographic development is key to the long-term growth assumption, where an ageing population is often referred to as the dominant demographic trend of the 21st century. In both scenarios, lower growth in the labour force is assumed. In addition, public spending on health care and pension liabilities increases.

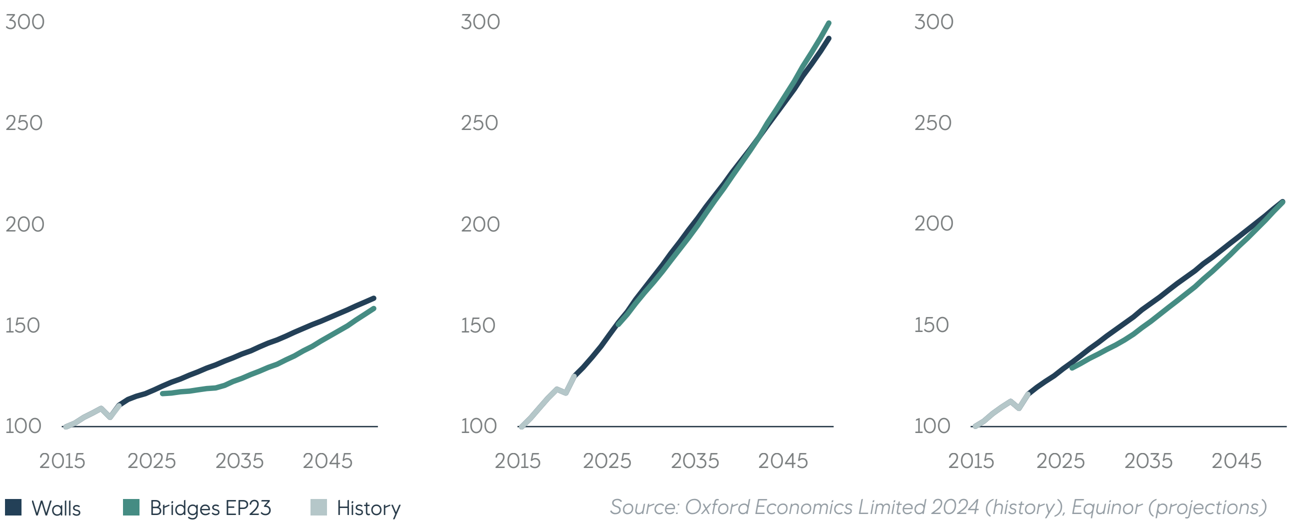
Over the last few years, the world economy has experienced several shocks. Some of the economic impacts of the elevated global tensions, such as inflation, supply-chain disruptions, and high interest rates, can be short-term challenges. Others, such as government overspending, debt sustainability threats, and changed trade patterns, could impact long-term growth.

In *Walls*, the global economy grows on average by 2.0% per year in 2028-2050. The lower growth trajectory than historically observed can partly be explained by the declining catch-up potential for emerging countries. In addition, increasing carbon levels in the atmosphere lead to a moderately negative impact on economies. In *Bridges EP23*, consumers, primarily in industrialised countries, face significantly higher carbon costs to curb the use of fossil fuels and to finance a rapid energy transition. Green investments are accelerated, and the transfer of technology is directed towards emerging economies. The global economy grows on average 2.1% per year in the period. Following initial reduced growth, over time improved efficiency and lower impact from climate change are factors that increase economic growth in *Bridges EP23* relative to *Walls*.

The narrative of globalisation benefits, a key structural factor influencing growth, is tested. Looking ahead, a more fragmented and less predictable trade policy is anticipated, resulting in more ineffective solutions to global challenges. Technological advances must accelerate substantially to counterweight demographical headwinds. Increased focus and use of artificial intelligence (AI), with potential spillovers to the wider economy, is assumed to have a positive effect on long-term growth. The degrowth theory*, which entails shrinking growth to limit the use of the world's resources and to improve sustainability, has attained more followers. The *Bridges EP23* scenario captures some of the degrowth aspects.

On the backdrop of economic imbalances, in a fragmented political landscape, the result of numerous elections this year may add uncertainty and set directions for future policy priorities.

Industralised economies — GDP indexed to 2015 | **Emerging economies** — GDP indexed to 2015 | **Global economy** — GDP indexed to 2015



Source: Oxford Economics Limited 2024 (history), Equinor (projections)

* *See Deep dive on "Accelerating climate action by degrowth" for more data.*

The global oil* market

Oil demand declines as the energy transition advances. Energy security remains a key factor in the energy trilemma and oil investments may see an uptick in the medium term.

In *Walls*, oil demand peaks in the late 2020s, followed by a decrease of 17% (18 mbd) by 2050, as the energy transition drives demand down. The industrialised regions and China underpin the demand decline, leading to a combined decrease of 35% (23 mbd) between 2025 and 2050. This is primarily the result of shifts derived from carbon neutrality pledges and changes in the transportation sector. Transport will experience efficiency gains and decarbonisation by switches to electric vehicles (EVs) and low or zero carbon liquid fuels.

Africa, India, and the Middle East continue to see increasing oil demand, up 32% between 2025 and 2050. The primary sectors driving this are residential, transport, industry and petrochemicals as those regions continue to develop.

Global petrochemical demand growth will be a key driver as a growing global middle class expands demand for home appliances and plastics.

Oil production is likely to fall in many regions as demand declines. Investment will fall and some existing producing assets will become exhausted, driving production declines. Supply shortfalls will be covered by growth in OPEC and from US shale oilfields. The US shale sector will continue to act as a key source of supply as well as being key in global market balancing and price setting.

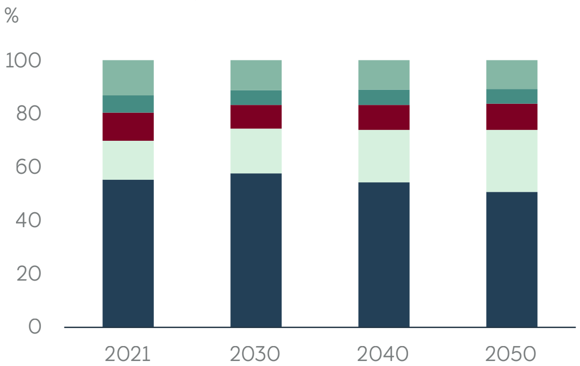
In *Bridges EP23*, oil demand must peak immediately. The energy transition drives the oil demand projection to 2050 with policies, technology and behavioural changes all contributing to a reduction in oil demand of 70 mbd (70%) between 2025 and 2050.

The road transport sector sees the most significant decrease in oil demand as light duty vehicle (LDV) internal combustion engines are replaced by electric vehicles, and diesel engine trucks are replaced predominantly by electric and hybrid vehicles. Hydrogen vehicles are also introduced.

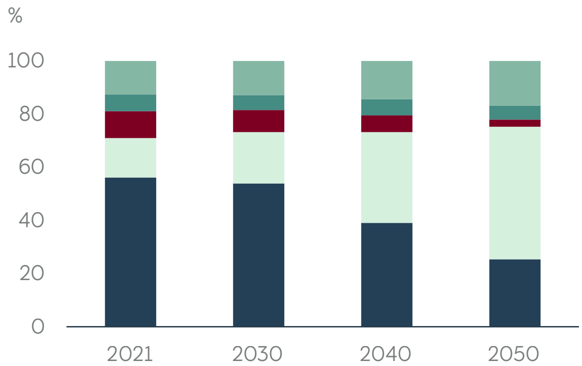
The non-energy sector is the only sector to see oil demand growth past 2025. Global non-energy demand peaks in the early 2030s but continues to increase towards 2050 in several regions including China, the Middle east and CIS, reflecting a surplus of indigenous oil supply as external demand is curtailed.

The sector changes are reflected in the demand for specific oil products, with the share of gasoil and gasoline rapidly declining from 2025 onwards, whilst the share of refinery-based petrochemical feedstock demand continues to rise until 2050.

Walls - Share of global oil demand by sector



Bridges EP23 - Share of global oil demand by sector



Transport | Petrochemicals | Buildings | Industry | Other

Source: IEA (history), Equinor (projections)

** Oil in this section refers to total liquids including biofuels*

The global gas market

In *Walls*, gas remains a vital part of the energy mix in the medium-to-long term. However, in *Bridges EP23*, gas is not perceived as a transition fuel and declines rapidly after 2025.

In *Walls*, gas demand grows by 7% (~300 Bcm) from 2025 to its peak demand in 2035. After 2035, however, demand is ultimately dampened as decarbonisation intensifies. Gas plays an important role in the global energy transition by helping to phase out more polluting forms of energy, and balancing electricity systems with growing shares of intermittent renewables.

Asia is the key driver behind demand growth from 2025 to 2035 (226 Bcm). This is due to increased demand from the industry and power sectors, as well as coal-to-gas switching in response to clean air concerns and carbon neutrality pledges.

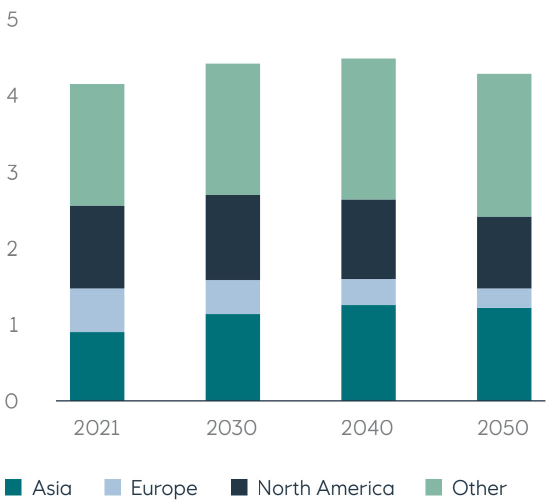
Europe has a declining gas demand along with its decarbonisation trend driven by electrification and increased energy efficiency. By the end of 2050 current demand will be almost halved. Declining gas use in the heating of buildings will be the single most important reduction factor, followed by decarbonisation of the industry sector. North American gas demand peaks in 2030 and declines by 185 Bcm to 2050 from the 2030 level. The Inflation Reduction Act (IRA) will have a negative push on gas demand in power, industry, and heating.

In *Bridges EP23*, global gas demand peaks in 2025 and subsequently declines by more than 70% (~3,000 Bcm) towards 2050 due to a rapid shift towards an all-encompassing energy transition. 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.

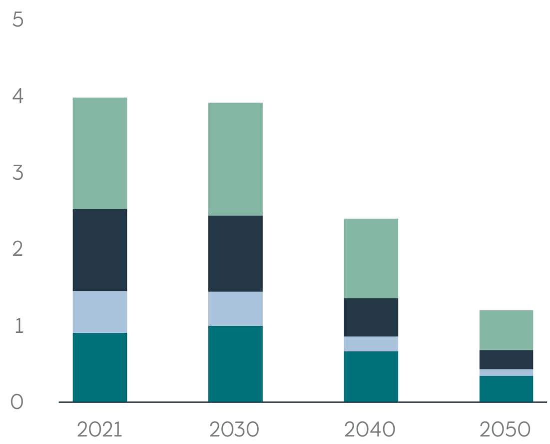
The change in gas demand is most significant in the industrialised regions, which see a 79% drop from 2025 to 2050 compared to 64% in the emerging regions including China. The global demand reduction will accelerate after 2030, affecting all flows and trade (pipe, LNG and domestic) plus all investments in gas exploration, production, infrastructure, and usage.

Power & heat represents the largest gas demand sector until the late 2040s when it is overtaken by the petrochemical sector. Hydrogen production and the petrochemical sector are the only areas to see gas demand growth beyond 2025. Gas demand in hydrogen production peaks in the early 2040s before slightly declining towards 2050, as enough capacity is built in renewables to make green hydrogen the preferred choice.

Walls - Global gas demand by region
Thousand Bcm



Bridges EP23 - Global gas demand by region
Thousand Bcm



Source: IEA (history), Equinor (projections)

The global electricity* market

Electrification and decarbonisation create major challenges in the industrialised regions, leading to a rethink of the energy system design seen both from supply and demand perspectives. In emerging regions, industrialisation is happening in parallel with electrification, allowing for a high level of integration from the onset.

In *Walls*, electricity demand grows by more than 50% towards 2050, adding ~17,000 TWh relative to 2025. By 2050, electricity makes up 33% of total energy consumption. The emerging regions are the main contributors, covering 80% of the increase.

In the industrialised regions, heating and transport are the main demand drivers responsible for a 35% increase in demand, while energy efficiency measures balance extra demand from industry decarbonisation. The existing electricity system, optimised around flexible assets dispatched to match demand pools, is shifting towards a decentralised system dominated by electricity sources that are subject to weather (wind and solar PV). Grid development, reserve capacity investments, and price volatility are adding a major cost to society.

In emerging regions, electrification is happening in parallel with an increase in industrial production and a growing need for cost-effective energy sources. Strong growth in renewables is complemented by thermal dispatchable assets (1,500 TWh added by 2050), critical to ensuring a robust and low-cost system, and supporting global gas demand towards 2050.

Electrification leads to a drastic change in energy production and consumption centres. Midstream and upstream become more integrated to enable new energy ecosystems encompassing electrons, its derivative products, and industries redesigned to embrace low-CO_2 technologies.

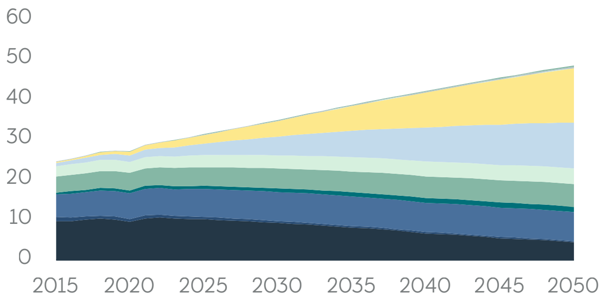
In *Bridges EP23*, electricity demand grows by nearly 60% (>18,000 TWh) between 2025-50, and by 2050 electricity constitutes 51% of the total energy consumption. All regions electrify fast in the mid term to drive down fossil fuels. India sees the largest growth in electricity demand over the outlook period, followed by Africa. Electricity demand peaks during the late 2030s and early 2040s in several regions, including China and North America, as total final energy consumption falls due to efficiency gains and behavioural changes.

Industry and residential are the highest electricity demand sectors globally beyond 2027, accounting for 28% and 24% of total demand by 2050, respectively. Demand in industry is completely dominated by China throughout the period. The residential sector sees persistent high demand in China and North America, but demand in India and Africa grows rapidly, making them the highest residential demand regions by 2050.

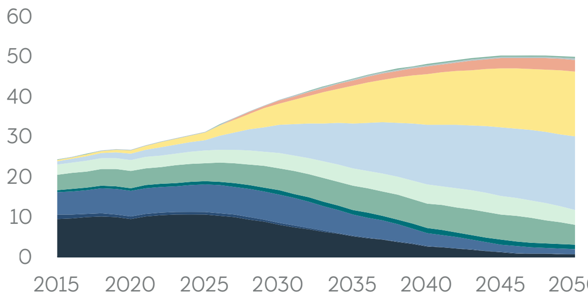
The transport sector sees the greatest growth in electricity demand over the outlook period, growing to 15 times its current level by 2050. This is spearheaded by China and North America.

Power generation sees a radical shift away from fossil fuels towards renewables, especially solar and wind, from a 58% fossil fuel share in 2025 to 4% in 2050. Solar and wind make up 69% of the power generation fuel mix in 2050.

Walls - Fuel mix in electricity generation
Thousand TWh



Bridges EP23 - Fuel mix in electricity generation
Thousand TWh



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

Source, IEA (history), Equinor (projections)

** Electricity in this section refers to electricity for grid only*

The global hydrogen market

Towards 2050, low-carbon hydrogen is anticipated to play a pivotal role in enabling carbon emission reductions in sectors with few other abatement options, and assisting the transition to a more sustainable energy landscape. Hydrogen's role is multifaceted: it is a flexible energy carrier, has a high energy density, must be produced, and can be produced in a variety of ways. The current clean front runners include green hydrogen made from the electrolysis of water using renewable energy, and blue hydrogen from steam methane reforming with carbon capture and storage.

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.

The increased integration of renewables into the energy mix through 2050 drives hydrogen production costs down, bolstering its adoption both as an industrial feedstock and as the basis for e-fuels for shipping and aviation.

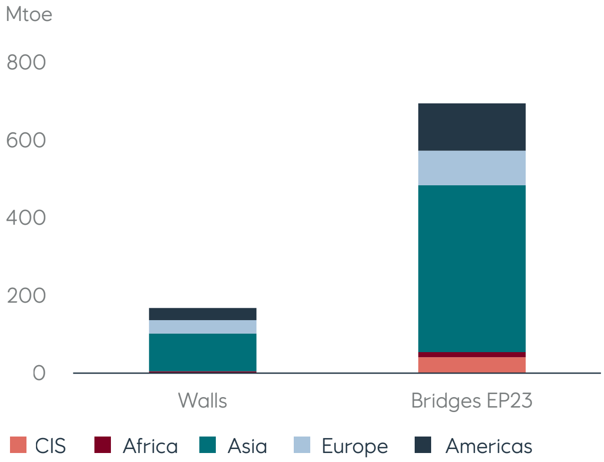
In *Walls*, despite low-carbon hydrogen growing as an industrial feedstock, demand for hydrogen as an energy carrier remains low. Hydrogen makes up less than 1.5% of the total energy demand by 2050, with green hydrogen accounting for more than 40% of that figure. Asia is the largest demand region, followed by Europe, North America, and the Middle East. China, the European Union, India, and Industrial Asia Pacific all rely on imports to meet their demand. Hydrogen energy demand takes off in the industry sector for high-temperature heat. The transport sector takes 50% of supply by 2050, through conversion to sustainable aviation fuel, ammonia and methanol for shipping.

In *Bridges EP23*, the share of hydrogen in the total final consumption rapidly increases, reaching nearly 10% in 2050, driven by a need to remove the remaining emissions from dispatchable gas power generation.

Obstacles to the roll-out of hydrogen are being overcome in *Bridges EP23*. Strong government support provides confidence in market growth in export regions, including Africa and the Middle East. Green hydrogen production dominates, and energy costs are coming down due to more projects being developed. Most sectors adapt to the use of hydrogen, led by the early movers, i.e. refineries and fertiliser and methanol production.

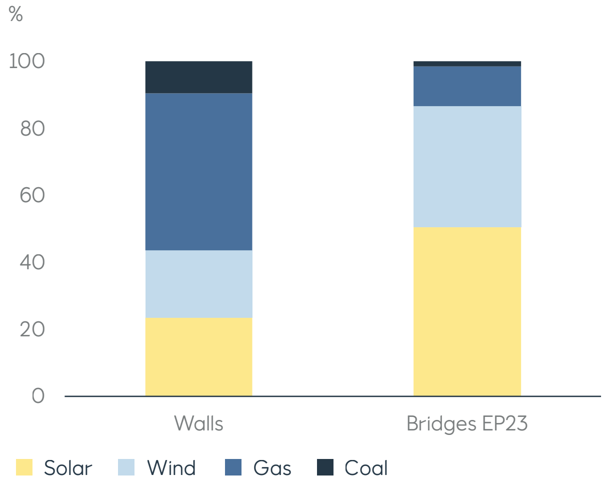
In *Bridges EP23*, China sees the fastest growth in demand in the short term, accounting for 55% of the global total final consumption in 2030. It will remain the biggest consumer in 2050, but its share of total final consumption will be reduced to 29%. More than 90% of demand in 2050 comes from transport and industry. The share of green hydrogen production increases rapidly and by the early 2030s will be more than 50% of production. It exceeds 80% by 2050.

Hydrogen used in total final consumption



Source: Equinor (projections)

Hydrogen production in 2050



Source: Equinor (projections)

DEEP DIVES

Accelerating climate action by degrowth

Curbing, or ending, economic growth by focusing on social aspects and well-being is sometimes proposed as a necessary path to limit human resource use and avoid further damage to the Earth. Such a direction would require profound, coordinated global cooperation, and revolutionary changes in consumer behaviour.

Societal progress is often measured in growth in Gross Domestic Product (GDP), a term widely used since World War II. One view is that this concept has limitations as it does not take negative externalities such as environmental damage and loss of biodiversity into account. Further, it is suggested that it overvalues consumption now at the expense of future generations, leads to rising inequalities and includes economic activities that inherently are not a productive use of money to drive human well-being, such as military spending. The GDP measurement may be supplemented or replaced by other yardsticks like people's well-being, health, and equality. Still, growth in the productive capacity of goods and services (i.e. GDP) has historically had a strong positive correlation with these variables.

In this context, lower use of resources, with the aim to stop irreversible environmental harm to the Earth, has gained traction. This may be connected to degrowth in economies focusing on social aspects. Some elements of degrowth can be found in the back-cast *Bridges EP23* scenario, which complies with the 1.5°C carbon budget. This scenario is driven by a rapid deployment of new renewables and technological development. Additionally, consumers, primarily in industrialised countries, face a significantly higher carbon cost to lower the use of fossil fuels, and producers are incentivised to increase the penetration of low-carbon solutions. Investments and transfer of technology and knowledge are directed towards emerging economies. According to IEA's Net Zero Emissions scenario (IEA, 2023), investments in clean energy must accelerate up to around 5% of global GDP to reach the 1.5°C target in 2050. In isolation, this will be a positive driver for GDP. Simultaneously, fossil fuel systems will become stranded assets if shut down before the end of their lifetime, leading to a loss in productive capacity and wealth in affected countries. In *Bridges EP23*, long-term GDP growth per capita in emerging economies is around twice as high compared to that in industrialised economies. As many people in the industrialised economies have reached relatively high living standards, it could be argued that further growth will not substantially improve the quality of life and that a more equitable wealth and income distribution will mean more for the average welfare of a population than increased total consumption. Less driving and travelling, living in smaller units, sharing capital goods and changing diets are examples of behavioural changes that lower the use of resources. However, for all this to make a meaningful impact there must be a profound change in consumer behaviour and policy making which is collectively bought into by a global society.

The rise of the service sector, through e.g. digitalisation and urbanisation, at the expense of manufacturing, is complementary with a decline in resource use and energy intensity. The service sector will nevertheless never be a complete substitute for the manufacturing sector. A circular economy with a system that is restorative or regenerative by intention and design, is helpful when trying to decouple GDP growth and resource use. Global policymakers, mandated by voters, hold a crucial role in enabling such a system to gain scale. Governments can direct spending towards a circular economy, but this is likely to come into competition with increased expenditure on energy security, defence, infrastructure, and other demands from the population.

Some countries may lead in implementing degrowth policies, but as the global economy is deeply interconnected, sooner or later all nations and regions will have to participate for it to have a meaningful impact. Emerging economies will have to cater for a growing population that aspires to improve their living standards, and currently, that correlates to increased resource use. In a world with a growing population, geopolitical uncertainties, and growing signs of climate change, there are few to no simple solutions. To improve the measurement of economic activity it will be important to place greater emphasis on sustainability and equitability.

Water scarcity in the energy sector

Water-related challenges are a growing global concern, as climate change is expected to lead to more frequent and longer droughts. Over 75% of the world's top energy companies consider water availability to be a major operational risk. The energy transition could exacerbate water stress or be hindered by it.

The UN recognises freshwater as a fundamental human right. According to the UN, freshwater makes up just 2% of global water, of which agriculture corresponds to 72% of its withdrawals, followed by industry at 19%, of which the energy sector uses 10%. Municipalities consume the final 9% (Koncagül & Conner, 2023). Water, energy and food rely on the same scarce water resources. This is most evident in biofuels where crops could be used as food, and in hydropower which has different reservoir management criteria for irrigation. Furthermore, unconventional oil production and mineral extraction can adversely impact water availability, diverting water from agriculture to more profitable sectors.

Severe water stress is most prevalent in the Middle East, India, North-East Asia, Southern US, and Southern Europe, but short-term droughts are causing water restrictions across the globe, affecting human health and livelihoods. Such restrictions have curtailed energy generation, leading to economic loss and volatile power prices. For example, between 2017 and 2021, thermal power plant shutdowns in India due to lack of water forced multiple factories to cease operations (Kuzma et al., 2023). In 2022, hydropower output was reduced in Italy and Portugal, coal transport was affected in Germany, and nuclear plants were temporarily shut down in France due to low river levels, highlighting the severity of the water stress problem (Bhargava & Granados, 2022).

Climate change is predicted to worsen water scarcity and increase the frequency and severity of droughts. As urban water and total water demand are estimated to increase by 20% and 80% by 2050, respectively, groundwater will be depleted at a record speed, threatening two billion people's daily freshwater needs and over 40% of agricultural irrigation (Koncagul & Conner, 2023).

The shift from fossil fuels could decrease water usage in energy generation as oil, gas, and coal have high water footprints (Jin et al., 2019). Water usage for renewables varies by area, project stage, and technology employed. While water consumption in the operational stages of solar photovoltaics (PV) and wind power is negligible, their water footprint primarily comes from the construction, transportation, and supply chain. Other renewables such as geothermal power and concentrated solar power (CSP) have medium water usage in the operational stages. Conversely, biomass can have a high water footprint, similar to or higher than that of fossil fuels and nuclear.

The societal needs for food and energy services are expected to increase. As a result, countries like India and China will face the dilemma of either overexploiting non-renewable water resources or potentially hindering their economic growth. The World Bank estimates that water scarcity, intensified by climate change, could cost some regions up to 6% of GDP by 2050 due to adverse impacts on agriculture, health, and income. While some regions have ample physical water reserves, they lack the economic capacity to develop and maintain water infrastructure. This will pose significant growth hurdles.

The picture might seem bleak; however, it is important to remember that water stress does not necessarily translate to a water crisis. Cities like Singapore and Las Vegas have demonstrated resilience, thriving in water-scarce conditions through water-saving techniques and long-term planning. Furthermore, all economic sectors globally have seen an increase in water use efficiency. Going forward, investments in new or already existing power plants situated in vulnerable regions should incorporate strategies for climate adaptation and employ water-saving technologies. Adopting an integrated approach to managing energy and water can mitigate the risks associated with both resources, as clean energy helps ease the water crisis by reducing reliance on water-intensive fossil fuels. Green hydrogen development must also balance the conditions for energy generation and the availability of water.

The petrochemical dilemma

Petrochemical products are an integral part of modern life, and rapidly rising plastic consumption is driving up demand. Petrochemical feedstock demand is set to increase its share of total oil demand from 15% in 2021 to 23% in 2050 in the *Walls* scenario. Balancing the use of fossil fuels and sustainability is a significant challenge for the sector.

The petrochemical sector is essential to several societal functions such as food production and the manufacturing of medicines and medical equipment. In addition, electric vehicles (EVs) and renewable energy technologies are emerging as key growth areas for plastics consumption. Thus, the petrochemical sector is set to play an important, albeit controversial, role in the energy transition.

China, the US, and the Middle East are the three largest petrochemical producers in the world today and will play a key role in shaping the future of the industry.

China is in the middle of an investment boom that will see large amounts of capacity being added in a drive towards self-sufficiency. In the longer term, China is strategically building large refining and petrochemical capacities within industrial clusters to enhance profitability and efficiency. The risk of demand shortfalls and depressed margins increases the risk of permanent shutdowns in higher-cost regions.

The US has benefited from an ample supply of oil and gas from unconventional shale for the past 15 years and production is expected to continue to see significant growth before peaking in the mid-2030s and then plateauing. This trend is expected to be mirrored in the production of petrochemicals. The US is a leader in ethane-based petrochemicals, holding approximately 40% of global capacity in 2018 (IEA, 2018). Most of the ethane is produced from natural gas liquid (NGL) and consumed by the domestic petrochemical industry, with the rest exported.

Historically, the petrochemical industry in the Middle East has relied on low-cost ethane feedstock, but access to cheap feedstock is becoming more challenging, and more expensive refinery-based feedstocks are set to increase their share. Multi-feedstock integrated petrochemical plants are emerging across the region to accommodate this change. Petrochemical exports from the Middle East are impacted by China's self-sufficiency drive, but in the near to mid term, they will be needed to compensate for a drop in European supply.

The petrochemical industry will need to decarbonise both feedstock and process energy demand to satisfy expectations and targets. Several technology options are already deployed, and others are under development. Carbon capture, utilisation, and storage (CCUS) plays a critical role in decarbonising the petrochemical industry. Steam cracking is the largest CO_2 emitter in high-value chemical (HVC) production, however, CO_2 concentrations from flue gases are only 8-10% by volume. Here, multiple sources may need to be aggregated to keep costs low. It is estimated that there will be a cost premium of up to 25% for HVC production with CCUS compared with conventional production.

Another way of reducing the environmental impact of the petrochemical sector is through increased recycling. Today, only 9% of global plastic waste is recycled, with nearly 50% going directly to landfill (OECD, 2022; Our World in Data, 2022). Mechanical recycling accounts for nearly all current recycling, but is limited by the low volume of waste collected and the effectiveness of the process. Chemical recycling is a potential solution for scaling up, as it is less sensitive to waste quality and can process plastics otherwise discarded.

Growing awareness of the environmental impact of plastics is forcing the petrochemical industry to consider feedstock alternatives. Bio-based feedstocks are the most common way to produce low-carbon petrochemicals today. However, these products are not necessarily more sustainable than their fossil-based counterparts as the manufacturing processes can be less energy efficient, and controversy exists over the use of primary biomass and land for feedstock rather than for farming for food production.

The petrochemical sector is growing and fossil-based feedstock demand with it. Decarbonising the industry is essential, but costs, upscaling technology, development of alternative feedstock options, lack of mandatory targets and fragmented nationwide legislation may delay the decarbonisation of the industry in key regions.

Adapting the refining industry to a low-carbon future

Facing an energy dilemma, the refining industry must adapt as the low-carbon shift disrupts both fuel demand and crude oil feedstock availability.

As the world progresses towards a low-carbon future, demand for alternative fuels will outweigh that for refined oil products. The impact on different products will vary. As road transportation electrifies, demand for diesel and gasoline is expected to fall, whereas naphtha and liquefied petroleum gas (LPG) demand is supported by the petrochemical industry, and jet fuel is supported by air transport for which there are few sustainable alternatives.

The shift in refined product demand will affect crude feedstock intake as refineries will look to source lighter, lower sulphur crudes with a higher content of LPG and naphtha. Due to lower production costs, the Middle East will likely increase its market share for crudes in the future. However, the type of crude oil produced in this region is relatively heavy and high in sulphur content and hence does not easily lend itself to the change in product demand.

The imbalance between crude demand and supply might present an obstacle to the future of the refining industry and the energy transition. Even with additions of more suitable crudes sourced at a higher cost from regions outside the Middle East, demand for the lightest products will likely not be met. On the other hand, heavier products like gasoline, diesel and fuel oil will experience oversupply as these are unavoidably produced together with the lighter cuts.

To overcome these challenges and enable the transition, the refining industry will have to make large investments in new equipment and new technologies to reconfigure their operations.

Some innovative technologies have already been put into play. This includes pyrolysis which converts waste materials into valuable products like pyrolysis oil and syngas. The pyrolysis oil can then be used directly or be further processed into chemicals or fuels, whilst the syngas can be employed for power generation or as a feedstock for producing chemicals through processes like Fischer-Tropsch synthesis. These advances aim to increase the yield of lighter products and enable a partial shift from conventional crude oil processing to renewable feedstock processing.

The refining industry stands at a crossroads, confronting a future where traditional demand patterns are upended by the global shift towards electrification and sustainable energy alternatives. The survival of this industry will depend on its ability to navigate and adapt to the complex terrain of balancing production, managing shifting feedstock qualities, and investing in innovative technologies in the emerging low-carbon economy, while having its customers facilitate the development by paying for the necessary investments.

US shale oil and gas

While US shale development used to be characterised by huge gains in well productivity and production growth, recent years have seen a shift in focus towards operational efficiency, capital discipline, and cash flow optimisation. Looking to the future, US shale has a large number of drilling locations, but the cost of supply will most likely increase gradually due to core inventory exhaustion.

The development of shale plays continues to dominate oil and gas activity in the US. The industry's rapid expansion phase has settled into a more mature era that values efficiency and financial stability. Gas fields are becoming more productive, with less flaring and higher gas-to-oil ratios likely to boost supply growth in the future. This gas supply will be needed as Liquefied Natural Gas (LNG) export capacity expands. Furthermore, gas in the power sector becomes an ever more important source of flexible generation as intermittent renewable capacity increases. Crude and liquids will grow as well, albeit at a slower pace, with the Permian Basin continuing to attract substantial investment.

Companies are now using disciplined capital spending strategies, investing less money, and returning more to shareholders through dividends and buybacks. Reinvestment rates have dropped from over 100% to about 50%, meaning wells must be much more profitable to fund the same amount of investment as before. As the industry consolidates, a higher portion of the shale sector is held by major players, which leaves a smaller portion of the market owned by private equity and junior companies. The result is structurally lower growth and less supply elasticity, requiring higher prices under scenarios which demand more production from the US.

Cost-wise, the pandemic sparked significant inflation in the US onshore oilfield service sector, compounded by challenges in supply chains and the workforce, most notably in steel tubular goods. Fortunately, those bottlenecks are now easing, which should help contain costs unless there is a dramatic shift in commodity prices.

After years of consecutive gains in productivity, further improvements are now harder to come by. This is especially the case for mature plays such as the Eagle Ford where normalised (BOE/1,000 ft) productivity has declined for several years in many parts of the play. The main oil-producing basin, the Permian, continues to show resilience, but with slightly deteriorating productivity on a normalised basis in certain regions. Interestingly, gas plays such as the Marcellus and Haynesville continue to perform better than expected, implying continued improvement in capital efficiency. It is also worth noting that, while productivity growth may slow down going forward, improvements in operational efficiency and economies of scale through mergers and acquisitions can still boost the rate of return.

Various estimates place US shale recoverable resources at approximately 100 billion barrels of oil, and 1,000 trillion cubic feet of natural gas, a significant portion of which is associated with oil reserves. While these are enormous numbers, the quality of these reserves remains uncertain. Global balances will largely dictate the rate at which reserves get developed, and what the marginal shale resources will be at any given time. Drilling and completion technology is still evolving, which, given the low recovery rate in shale drilling, leaves plenty of upside.

The evolution of the US shale sector has broad implications for energy markets globally and thus is of particular importance. Over the long term, it will be relevant to monitor trends in productivity which are expected to decline due to exhaustion of core acreage, as well as technology advancement that can unlock new resources and provide improvements in efficiency and recovery rates.

Emerging fuels

So-called emerging fuels will be key to the energy transition, acutely so for the hard-to-abate aviation and marine sectors. However, significant barriers remain to their growth beyond today's niche industry.

Emerging fuels are alternative fuels that are intended to reduce emissions and reliance on non-renewable energy. These fuels include biofuels, hydrogen-derivative fuels, and other advanced technologies yet to reach commercialisation. They are particularly useful for the hard-to-decarbonise international aviation and marine sectors.

However, their development faces significant challenges, such as:

- Availability of feedstock materials and renewable power
- The pace of technological and infrastructure developments
- End-user costs
- Government mandates, incentives, and other policy initiatives

Currently, biofuels are the most developed emerging fuel type and account for 3 mbd of demand, primarily blended into existing road fuels. However, available bio-feedstock materials, such as corn and sugar cane, are limited and their production is not without sustainability issues. Improved technology is expected to boost biofuel production, but feedstock availability will remain a limiting factor. Other advanced bio-feedstocks such as seaweed, algae, and non-food crops have been explored, but have yet to make a significant contribution.

Hydrogen-based e-fuels are a key part of a new generation of emerging fuels, which are produced from renewable power, carbon dioxide and other feedstocks. Most rely on abundant renewable power which could theoretically provide more emission reductions if used directly to substitute fossil fuels.

E-fuels are costly due to a low conversion efficiency from power to fuels and are likely to remain so in the medium term. While cost reduction is expected, the scale of that reduction remains a contentious subject. Technological gains are likely in production processes, but a revolutionary development is unlikely unless the challenges of conversion efficiency and cost can be overcome.

Expensive infrastructure needs to be developed to produce and transport renewable power, hydrogen, and other feedstocks. However, these projects are expensive and are struggling to obtain financing. Gaining planning permission from communities has also proven to be challenging. As such, unless existing infrastructures can be repurposed, e-fuels may struggle to scale up from today's niche market.

Given the challenges, government support will be essential for developing emerging fuel projects and their end-user adoption. Recent policies signal continued support from governments, such as the FuelEU Maritime regulation in the European Union, the Inflation Reduction Act (IRA) in the US, and the GX bond in Japan. However, due to a lack of funding commitments and uncertain costs of these policies, substantial policy risks remain. The regional evolution of emerging fuels will be subject to policy as well as logistical developments. As such, their evolution is likely to take place at varying speeds.

Emerging fuels will no doubt be part of the energy transition as the nascent alternative fuels industry gradually matures despite near-term challenges. Technology improvement, feedstock access and policy support will be crucial for their long-term development.

Ammonia (NH_3)

Ammonia is an emerging fuel sponsoring significant amounts of interest, especially for use as marine fuel

Advantages	**Challenges**
Burns CO_2 free	Requires new logistical chain
Easy to store and transport	Toxic chemical
Higher energy density than LNG	Unproven technology in real world
Can be produced via natural gas and CCS to be low/no carbon	Cost of production
Can be produced from renewable power	Competes for gas and renewables with other uses

EU industrial decarbonisation

The cement and steel sectors account for nearly 40% of the European industrial emissions. Legally binding targets under The European Emissions Trading Scheme (EU ETS) are increasing the pressure on these hard-to-abate sectors, but the pathway to net zero is challenging, and the needed technologies for deep decarbonisation are not yet available at scale.

While global cement emissions continue to increase, EU cement emissions peaked at 170 Mt in 2007 and have dropped by 40% (Joint Research Centre, 2021; Marmie, 2023) since. Although the carbon intensity of cement production slightly improved, this is mainly due to decreased European cement production. Thermal fuel combustion to heat cement kilns is responsible for 35% of the emissions, and the remaining 65% are direct process emissions, i.e. chemical reactions transforming limestone during the process of making cement.

The prevailing heating fuels in cement production are mainly fossil (gas, coal, and oil products), waste and biomass. Switching from coal to natural gas as a transitional fuel gives substantial CO_2 savings and contributes to reducing thermal emissions. Also, biomass could theoretically provide 15% of thermal emission reductions, but the availability of sustainable biomass with competing demand from other sectors is a challenge.

Carbon capture and storage (CCS) plays a huge part in decarbonisation of the process emissions as there are no alternatives. Cement plants tend to be located close to limestone quarries and are dispersed all over Europe. Infrastructure connecting emitters with carbon storage providers is a key enabler of deep decarbonisation. Although CCS is unavoidable for decarbonising the sector, some innovative technologies substituting clinker with fly ash (from coal-fired power plants) or blast furnace slag (from steelmaking) in cement might reduce process emissions, but compromising the strength of the cement is a concern.

Decarbonising the European steel sector also presents a significant challenge. More than half of the EU27 crude steel is produced using the blast furnace–basic oxygen furnace route (BF-BOF), a carbon-intensive process, emitting about two tonnes of CO_2 per tonne of steel. The other widely used production process utilises an electric arc furnace (EAF) and mostly scrap material as input, emitting only about 0.3 tonnes of CO_2 per tonne of steel, providing a valuable alternative for reducing emissions.

While short-term efficiency improvements and the use of biomass can deliver carbon reductions in the steel industry, full decarbonisation is only possible through other technologies, most notably Direct reduction of iron (DRI) and CCS.

DRI extracts iron from ore without smelting by using either a reducing gas containing carbon (from natural gas or coal) or hydrogen. The subsequently produced sponge iron can then be processed in an EAF. Using low-carbon or green hydrogen in this process can offer significant emission reductions. It will require significant investments in new facilities across the EU, and the availability and cost of hydrogen add to the uncertainty. CCS could be applied to blast furnaces and reduce emissions. However, the technology is still in the pilot phase and is currently not the preferred solution in the EU27. Other options for iron and steel production, such as electrolysis, are still in the early stages of development. If proven on a large scale, they could be game-changing for the steel industry.

Whilst alternative fuels such as natural gas and biomass could help address some of the challenges posed during the transition, deep decarbonisation of the steel and cement industries in Europe by 2050 will require significant investments in technologies such as CCS and low-carbon hydrogen-based DRI.

The decarbonisation of the cement and steel industries in the EU primarily depends on (1) the build-out of infrastructure necessary for the transport of both CO_2 and hydrogen, (2) additional funding for the first movers kickstarting the market and (3) realisation of expected technological and cost improvements.

Decarbonising the maritime sector

The maritime sector covers 90% of world trade, uses around 280 Mt of fuel per year and is responsible for about 3% of global greenhouse gas emissions. A significant regulatory push will be necessary to trigger investments in low-carbon fuels, infrastructure, technology development and fleet renewal.

Shipping is a hard-to-abate sector, and one of the main options for decarbonisation is to introduce more low-carbon fuels in the fuel mix. An increasing push to decarbonise the maritime sector is driven by regulations as well as by climate ambitions in the corporate sector.

In its revised greenhouse gas (GHG) strategy, the International Maritime Organization (IMO) is targeting net zero emissions from the shipping sector by 2050 and a 20% reduction in total emissions by 2030 compared to 2008 levels. Current IMO incentives are not in themselves sufficient to increase the uptake of alternative fuels. However, in its latest revised strategy, the IMO aims at introducing a global carbon price by 2027 which would partially incentivise the adoption of alternative fuels.

Various EU policies are targeting the decarbonisation of the maritime sector, most notably the inclusion of the maritime sector in the EU's emissions trading scheme (ETS) and the FuelEU Maritime regulation. The latter aims to reduce the carbon intensity of marine fuels by 80% on a lifecycle (well-to-wake) basis by 2050 and to boost alternative fuel infrastructure. Non-compliance penalties in the FuelEU Maritime regulation will incentivise the uptake of alternative fuels.

The major consumers of shipping services in the corporate sector, such as Equinor, BP, Shell, Microsoft, Amazon, and IKEA have high decarbonisation ambitions. Also shipping giants such as Maersk and NYK lines have ambitious decarbonisation plans going forward.

Although an increasing uptake of alternative fuels in the shipping sector is expected, driven by regulatory changes and corporate climate ambitions, the decarbonisation targets are ambitious and hard to achieve. This is due to a range of significant constraints on the supply of various fuels and supply infrastructure, as well as limited shipyard capacity for newbuilds and slow renewal of the shipping fleet.

It takes time to decarbonise the shipping fleet. Newbuilds normally operate for several decades before they are scrapped. In the 2023 order book, almost 80% of new vessels ordered will run on internal combustion engines (ICE), which mainly consume fossil fuels. Around 20% of the new vessels in the order book have dual fuel propulsion technology, which enables them to use alternative fuels, led by liquified natural gas (LNG, 15.3%) and methanol (3.4%).

Conventional marine fuels will be gradually displaced by alternative fuels. The most relevant low-carbon fuels are biofuels, methanol, ammonia, and potentially other e-fuels such as e-LNG and e-MGO (marine gas oil).

Shipping companies and fuel producers are targeting biofuel blends for existing vessels as a relatively easy carbon emission reduction measure, since biofuels can be used as a drop-in fuel in existing vessels. The supply of biofuels will be constrained by feedstock availability and competition with other sectors. LNG and methanol are at present the preferred alternative fuels for new vessels mainly due to technology maturity. Despite not being considered viable in the short term, some shipping companies and fuel producers consider ammonia a good option for maritime fuel in the long term.

It will be difficult to achieve regional and global decarbonisation targets in the maritime sector. Adoption of emerging fuels faces high cost, supply constraints, lack of infrastructure and investments, and shipyard constraints. The current and future anticipated carbon price alone is not sufficient to incentivise a shift towards high-cost alternative fuels such as low-carbon ammonia and methanol.

Much of the traction observed at present in the alternative fuels newbuilds is driven by corporate climate ambitions of shipping companies and consumers, and anticipation of stricter regulations. Increased shipping costs due to alternative fuels could cause inflation and impact trade flows with the container segment having the greatest potential to transfer costs to end consumers.

Key figures

	Units	2021	2050		2021-50 growth per year (%), CAGR	
			Walls	Bridges EP23	Walls	Bridges EP23
Global GDP	2015-USD trillion	87.1	158.9	158.0	2.1	2.1
North America, Europe, Industrial Asia Pacific	2015-USD trillion	52.2	77.3	74.7	1.4	1.2
China	2015-USD trillion	16.1	35.6	37.0	2.8	2.9
Rest of World	2015-USD trillion	18.8	46.0	46.3	3.1	3.2
Global energy intensity - Indexed to 2021		100	55.8	38.5	-2.0	-3.2
Global population	billion	7.88	9.69	9.69	0.7	0.7
Global energy demand	Gtoe	14.55	14.80	10.15	0.1	-1.2
Coal	Gtoe	3.90	1.63	0.27	-3.0	-8.8
Oil	Gtoe	4.33	3.74	1.02	-0.5	-4.9
Gas	Gtoe	3.41	3.51	0.99	0.1	-4.2
Nuclear	Gtoe	0.73	1.04	0.98	1.2	1.0
New renewables	Gtoe	0.41	2.89	5.28	6.9	9.2
Oil ex biofuels	mbd	94.2	83.1	24.3	-0.4	-4.6
Gas	Bcm	4,154	4,289	1,197	0.1	-4.2
Global energy related CO_2 emissions	billion tonnes	33.3	20.9	1.1	-1.6	-11.2
North America	billion tonnes	5.5	2.6	0.2	-2.5	-11.4
Europe	billion tonnes	3.6	1.1	0.0	-4.0	-16.6
China	billion tonnes	10.7	4.3	0.1	-3.1	-15.7
India	billion tonnes	2.3	3.0	0.1	0.9	-9.5
World CO_2 emissions from fossil fuel use removed by CCUS	million tonnes	15	860	1,964	14.9	18.2
World CO_2 emissions removed from atmosphere	million tonnes	0	0	4,300		
Global light duty vehicles (LDVs) fleet	million	1,413	1,631	1,368	0.5	-0.1
LDVs oil demand	Mtoe	1,102	550	29	-2.4	-11.8
LDVs biofuel demand	Mtoe	68	39	1	-1.9	-14.6
LDVs electricity demand	Mtoe	3	191	292	15.6	17.3

Units

Coal	Mtce	million tonnes of coal equivalent
Oil	mbd	million barrels per day
Gas	Bcm	billion cubic metre
Electricity	MWh	megawatt-hour
	TWh	terawatt-hour
	PWh	petawatt-hour
	GW	gigawatt
Energy	Mt	million tonnes
	Gt	gigatonnes
	BOE	barrels of oil equivalent
	toe	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	US dollar
	EUR	euro

Definitions

Energy demand and consumption

History: 1990-2021
Projection: 2022-2050

Regions

There are 12 regions modelled.

Industrialised: European Union, Industrialised 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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