equinor

# Energy Perspectives 2021

Long-term macro and market outlook

**Anders Opedal**

President and CEO

# Welcome to Equinor's Energy Perspectives 2021

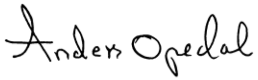
While the Covid-19 pandemic continues to have a negative impact for individuals, societies and businesses, signs of hope are emerging, as vaccines are rolled out and economies start to recover. Exactly when the recovery will take place, what it will look like, and how the pandemic will affect long-term developments, remains to be seen.

When preparing Equinor for the future, we must mature strategies that will be robust and successful in different future scenarios. Be it geopolitical development, economic growth, the speed of the energy transition or technological development, we must navigate the uncertainties in the best possible way for our employees, our shareholders, and the societies in which we operate. Our fundamentals remain firm: Always safe, high value and low carbon; and we are inspired by our vision of shaping the future of energy.

Equinor is committed to being a leader in the energy transition. This is a sound business strategy to ensure long-term competitiveness, and we have taken significant steps in that direction. We have pledged to become net zero by 2050, including emissions from the use of our products, and we are accelerating our investments in renewable energy production. We have combined our efforts to continuously reduce emissions from oil and gas production with investments in carbon capture and storage, and other low-carbon solutions. These will help move the world towards a sustainable energy future.

Around the time of this publication, Equinor will give more details on its strategic priorities going forward. Driven by a motivation to continuously improve, our employees are committed to working together with partners, governments and consumers to overcome the technological and commercial challenges necessary to deliver on our value proposition and climate targets.

Energy Perspectives provides me and my colleagues with important insight that helps us make sound decisions. I hope you will enjoy this edition of the Energy Perspectives report.



# Plotting the course to a sustainable future

One and a half years in, large parts of the world are gradually recovering from the massive shock of the Covid-19 pandemic. Other parts are still in the middle of the crisis, fighting against premature deaths and the danger of collapsing health services. Economic activity is picking up as lockdown measures are scaled back, accompanied by record high public spending. Energy demand is growing, as are greenhouse gas emissions, since the economic recovery, as usual, still depends on available sources of fossil fuels.

The pandemic is not behind us, and we might have to live with it for years. Fortunately, the extraordinary efforts in developing vaccines have provided hope that we will be able to limit the most disastrous consequences of the virus. In the rich parts of the world, the pandemic will leave a lasting mark on our economies, through massive increases in public debt, modified working habits and changed travel patterns, as well as potential changes in goods supply chains. For some emerging economies, the emergency is far from over, and the extremely skewed allocation of vaccines is a stark reminder of our inability to cooperate in solving common global challenges in an efficient and fair manner.

In recent months, we have seen both increasingly bold ambitions on the energy transition – China's net zero ambition by 2060 being the prime example – and signals that such ambitions could be supported by effective measures, such as the EU's Green Deal and the political ambitions from the new US administration. By contrast, near-term policies such as China's five-year plan and the components of some stimulus packages show just how difficult it is to follow up aspirational long-term goals with immediate, effective and just measures.

The challenge of delivering on the energy transition is massive. This is demonstrated in our *Rebalance* scenario, and even more so in the recently published IEA Net Zero Emissions scenario. Key elements include: unprecedented global cooperation; massive growth in new renewables; rapid technological development and scaling; profound changes in consumer behaviour; energy efficiency improvements far beyond anything experienced in recent years; the revival of growth in nuclear and hydro electricity generation; as well as huge investments in infrastructure, mining, and carbon capture and storage. All of these are necessary to enable a rapid, large decline in fossil fuel demand, while allowing economies to continue to grow and ensuring energy access for all across a growing global population.

Given all the uncertainties surrounding future energy market developments, this report, like previous editions, contains two other outlooks in addition to the Paris compliant *Rebalance* scenario: *Reform* and *Rivalry*. Neither of these two alternative pathways deliver on climate ambitions or targets, but build on drivers and developments we are seeing today and still entail massive changes in the energy system. Both *Reform* and *Rivalry*, to varying degrees, imply a host of business opportunities, especially in new renewables, but also in the low carbon space in some regions.

The discussions on our common energy future, where it might go, and where it should go, continue as never before, even during the Covid-19 crisis. Long-term development in the world's most important markets, and how we can steer them in the direction we want, continue to make headlines. Energy Perspectives 2021 is our contribution to a fact-based dialogue on this vital topic.

Eirik Wærness

Senior vice president and
Chief economist

# Emerging from the Covid-19 pandemic – into an uncertain energy transition

With the Covid-19 pandemic, the world is facing an unprecedented set of medical, economic, societal and geopolitical challenges. While the pathway out of the health crisis seems much more certain now than a year ago, the pandemic is far from over. At the time of writing, daily infections and deaths are still close to the all-time-high. On a positive note, vaccines have been developed faster than anticipated. Their efficacy seems sufficient to be the game changer that they were hoped to be. Now, a slew of vaccines is being rolled out across the globe, although too slowly in many emerging economies. The first countries have reached or are closing in on herd immunity, with daily infection rates dropping despite societies reopening. It will, however, be a long time until most countries reach this point.

The global economy contracted by 3.6% in 2020. Governments have reacted with increased spending, exceeding 10% of GDP for some countries. The decisive actions taken seem to have stopped the downward trajectory and initiated a forceful economic recovery. Government debt has increased as a consequence and has risen from 104% to 120% of GDP in industrialised countries and from 55% to 65% in emerging economies, according to the International Monetary Fund (IMF). The medium to long-term effects of this debt increase will influence nations' monetary flexibility, but by how much is yet to be seen.

Scenarios provide a basis for analysing and understanding the uncertainties surrounding this crisis. The outcome space – while significantly reduced from last year – is still vast. The distinct long-term trajectories of the three scenarios in Energy Perspectives share the same short-term development path towards 2023. This is based on an accelerating vaccine deployment, helping to get the pandemic under control in large parts of the world, along with a strong rebound in economic activity, surpassing the pre-pandemic GDP level during 2021. Access to vaccines and governments' ability to further elevate fiscal spending will greatly affect the outcome at a regional level.

While the current rebound in activity is highly desirable, the shape that it is taking is at odds with the goals of the energy transition. Government funded growth support – like the US American Rescue Plan – has mainly been focused on stimulating consumption. Sustainability and infrastructure focused recovery plans, like the EU's Green Deal, are taking longer to deliver effects. Fossil fuel demand is increasing, and the International Energy Agency (IEA) is currently forecasting $CO_2$ emissions in 2021 to grow by almost 5% - the largest single increase since the global financial crisis more than a decade ago.

Besides the EU and the UK, which are focusing strongly on building back better and greener, concrete near-term plans to tackle climate change still appear lacklustre. This goes for the proposed US infrastructure plan and the country's apparent unwillingness to tax emissions, as well as China's latest five-year-plan. Looking further ahead, however, a dramatic change in ambitions is materialising in the lead-up to the COP26 summit in November: China has set a 2060 net zero target and the US re-joined the Paris Climate Accord. Once the US adopts a widely anticipated net zero goal, nine of the ten largest economies will have made pledges to neutralise emissions. Pressure on other nations to join this group will increase ahead of the summit and hopefully result in real measures to reduce emissions.

The gap between long-term targets and current policies is vast, with swift, strong legislative action needed to create a realistic pathway. Bottlenecks, like insufficient electricity grids or land space for new renewables, need to be addressed and resolved. Potential obstacles, such as the growing not-in-my-backyard sentiment and perception of unfair burden sharing, have to be cleared without losing democratic support. Suitable regulatory frameworks and market design structures must be implemented to harness the efficiency of market forces where possible. Industry sectors need predictability regarding policy developments for their investment decisions. Where markets are deemed not to be changing sufficiently quickly, politicians will have to choose winning technologies and force investments – accepting the risk that betting on the wrong horse might threaten long-term success. In addition, the major shift in human behaviour required for a successful energy transition also needs to be motivated with the right incentives and encouragement.

# The energy world in 2050

**1.8 - 1.9 x**

Size of the global economy compared to 2019

**50 - 115 mbd**

Global oil demand compared to 100 mbd in 2019

**32 - 52 %**

Share of solar and wind in the global electricity generation mix, up from 7% in 2019

**9 - 32 Gt**

Global energy-related $CO_2$ emissions compared to 33 Gt in 2019

**3,100 - 4,750 Bcm**

Global gas demand compared to 3,900 Bcm in 2019

**0.5 - 1.3 billion**

Electric light duty vehicles on the road, equivalent to 30% - 90% of the total fleet

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# The three scenarios

# The three scenarios

The unprecedented events and subsequent turmoil of 2020 have shown scenario thinking to be more relevant than ever. Energy Perspectives contains three distinct scenarios for future energy demand, providing a platform for debate and decision making based on quantitative analysis. These scenarios are not predictions, but possible pathways based on the choices we make and outcomes for key drivers and assumptions. The future of energy markets is highly uncertain, and we are constantly bombarded by conflicting signals. It can be difficult to distinguish noise from significant events that will set the world on a new trajectory. The three scenarios – *Reform*, *Rebalance* and *Rivalry* – show a wide outcome space driven by several factors, ranging from economic growth and technological development to climate policy and geopolitics.

The Covid-19 pandemic is a reminder that it is not only the long term that is uncertain, even what happens over the coming months may be different to what is expected. To distinguish between short-term events and long-term trends, the three scenarios are all based on a similar recovery over the next couple of years, after which they begin to diverge. Since the last edition of Energy Perspectives, we are starting to see the true impacts of the pandemic and the measures implemented to control it. From them the longer-term impacts and trends that will affect future energy, can be identified.

The scenarios recognise that the world is on the cusp of an energy transition. *Reform* is a story about an accelerating energy transition driven by market forces, but one not sufficient to reach climate targets. *Rivalry* represents the least sustainable outlook, where an energy transition is hampered by lack of cooperation and trust. *Rebalance* is a back-cast showing a path to the well below the 2°C goal of the Paris Agreement, and also delivering on other UN Sustainable Development Goals. It recognises the stark imbalances present in the world today, and illustrates the profound systemic change required to reach the emissions targets and build a sustainable future for us all.

## Reform

*Reform* builds on current trends in markets, technology and policy, expecting them to continue to unfold and develop at a similar pace. Today, the energy transition is not moving fast enough to achieve the goals of the Paris Agreement. The International Energy Agency (IEA) tracks progress in six main sectors: power, fuel supply, industry, transport, buildings and energy integration, none of which are transitioning fast enough. In *Reform*, it is assumed that climate policies continue to tighten, but not all stated policy targets are met. The momentum is mainly driven by the industrialised regions and in particular Europe. Short-term economic growth continues to be prioritised over long-term climate goals by national governments, and high emitting assets are not as a rule retired ahead of their normal economic lifetimes. There is limited penetration of solutions like carbon capture, utilisation and storage (CCUS) and hydrogen, which remain too costly for generally moderate $CO_2$ prices to make much difference. Global energy-related $CO_2$ emissions bounce back to almost pre-pandemic levels, before stabilising and gradually going into decline. This is due more to technological advances and market forces rather than through policy design.

The geopolitical landscape is largely benign with both cooperation and friendly competition among nations. Globalisation continues and the global economy becomes increasingly interlinked. This leads to more integrated energy markets and shared technology advancements. As a result, this scenario has the highest GDP growth, despite the increasing costs of climate change impacts. The pursuit of low-cost energy to power economic growth is prioritised over security of supply and the environment. Fossil fuels therefore remain an important part of the fuel mix where alternatives would result in higher costs. New technologies allow the continuation of historical advances in energy intensity (energy demand per unit of GDP) while an acceleration in the rate of electrification improves efficiency. Continued economic growth brings development to poorer countries, but not fast enough to see convergence with the richest nations.

## Rebalance

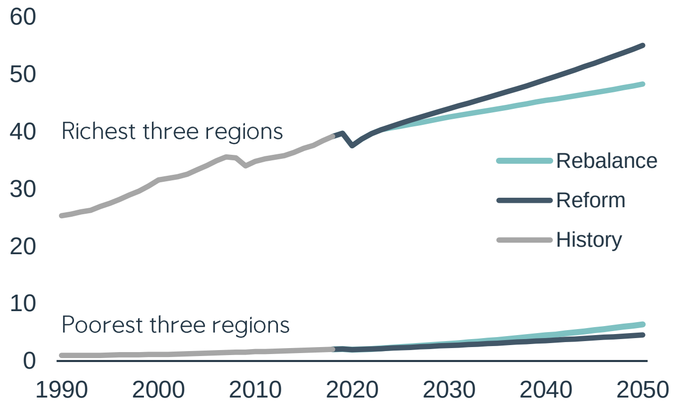
The world has reached a critical point where a new balance must be struck between prioritising resource-intensive economic growth and the well-being of people and the environment. *Rebalance* is a well below 2°C scenario challenging the assumption that the world can reach its climate and sustainability goals without significant systemic changes addressing inequality and excessive consumption. The changes needed will have consequences for both economic growth and global income distributions. To achieve the goals of the Paris Agreement, global energy-related $CO_2$ emissions must drop by an average of 4% every single year. To put this into perspective, estimates for 2020 with its massive decline in global GDP and fossil fuel use, suggest a 6% drop in $CO_2$ emissions.

Economic growth can no longer be the only, or dominant, global development success criterion. Economic growth has raised living standards to levels unimaginable a century ago. But the resource intensity of modern lifestyles in industrialised countries is unsustainable. Over-consumption and waste have become the rule rather than the exception in parts of the world. A vision of a future for these regions based on a wider selection of well-being metrics and pricing of hitherto unpriced "nature" services is needed. *Rebalance* therefore requires low – although consistently positive – economic growth in North America, Europe and Industrialised Asia Pacific. Wealth is highly unequally distributed between rich and poor countries, as well as within countries themselves. As an example, energy consumption per capita is eight times higher in North America than in Africa, while GDP per capita is more than 20 times higher. Currently, economic evaluations do not include the negative impacts of overconsumption. In *Rebalance*, these externalities must be priced into commodities and labour costs, in a way that provides poorer nations with the capital to build a sustainable future. Price increases in richer nations will act to reduce waste and promote efficiency as well as promote a more circular economy. The transition must be to an economy that breaks the link between growth and resource use and therefore also becomes much more energy efficient.

*Rebalance* shows a development path where economic growth is accelerated in the emerging regions and slows in the industrialised regions. Economic growth is undoubtably positive, however, continued resource-intensive growth in the richest countries is now bringing about marginal improvements in living standards, while growth is not fast enough in the poorest countries to facilitate the kinds of advancements required for decarbonisation and the UN development goals to be met. Without significant reductions in resource intensity,

### GDP per capita in the richest and poorest regions

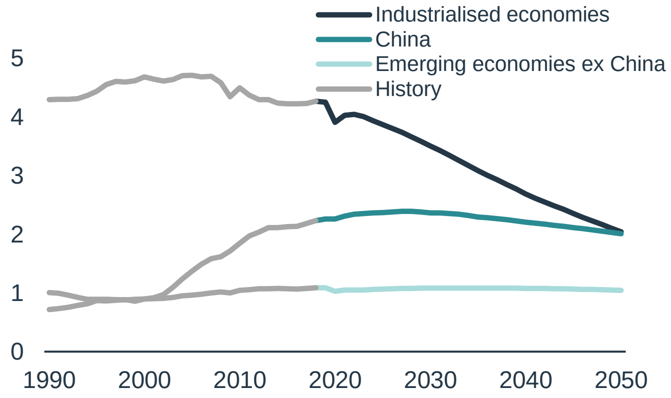
Real thousand USD at market exchange rates




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

### Energy demand per capita in Rebalance

Toe/capita




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

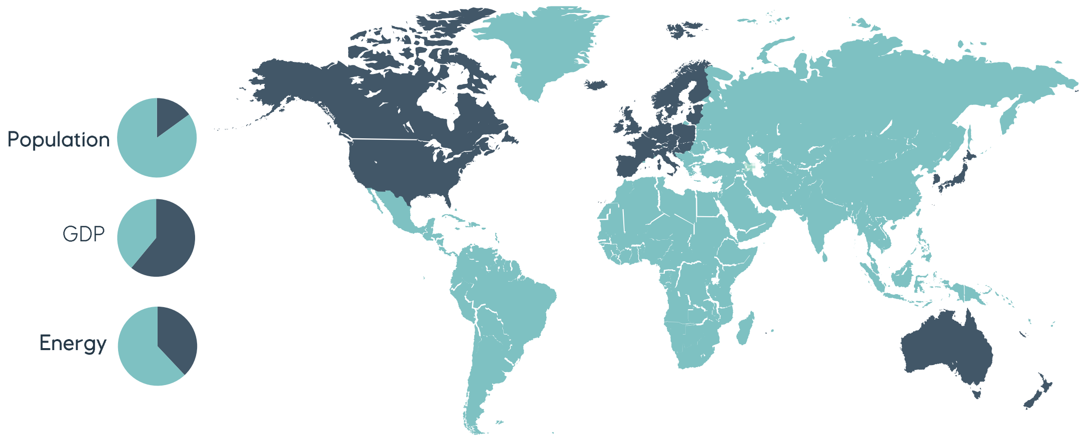
## Rebalance, cont.

ecological sustainability is not possible. In *Rebalance*, both absolute and per capita GDP grow in all regions, albeit more slowly in the richest countries than in recent history. In the poorest countries, the increase in GDP per capita allows not only for a faster energy transition, but improved health care, education and living standards. This, but particularly progress in female education, reduces birth rates which in turn helps to reduce potential energy demand. Although there is unprecedented growth, the poorer countries do not catch up with their richer neighbours over the course of the scenario period, but the gap narrows. In 2018 India's GDP per capita was 6% of the EU27's and in 2050 it is 27% (measured at exchange rates).

Richer nations must shift focus from maximising GDP growth to optimising other indicators of human development, well-being and the environment. Indicators such as the UN's measure of happiness, gross national happiness (GNH), or the social progress index can be used as measurements. These would need to be combined with a broader measure of wealth that includes not only GDP, but also other assets, including nature based ones, to cover environmental value as well. Pricing natural capital and negative externalities will affect economic decision making and promote sustainable development. The industrialised countries must work collectively to address poverty and environmental degradation, particularly in the developing world. This would include technology transfer and the provision of finance to allow increased investment to boost growth in emerging countries, reducing global inequality and income disparities. This 'just transition' must take place at a national and international level and it is critical to sustain a democratic mandate for these policies. There is little voter support in democracies for handing personal investment, dietary and other lifestyle choices over to the authorities. Raising the level of acceptance for the transitions implied by *Rebalance* is essential.

### An unbalanced world

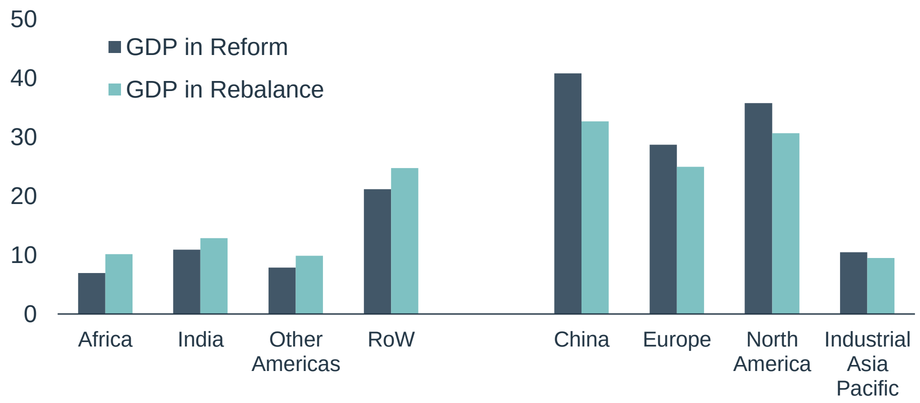
15% of the world's population has two thirds of the income and use more than a third of the energy




**Source:** Equinor

### GDP difference in Reform and Rebalance by 2050

Real trillion USD at market exchange rates



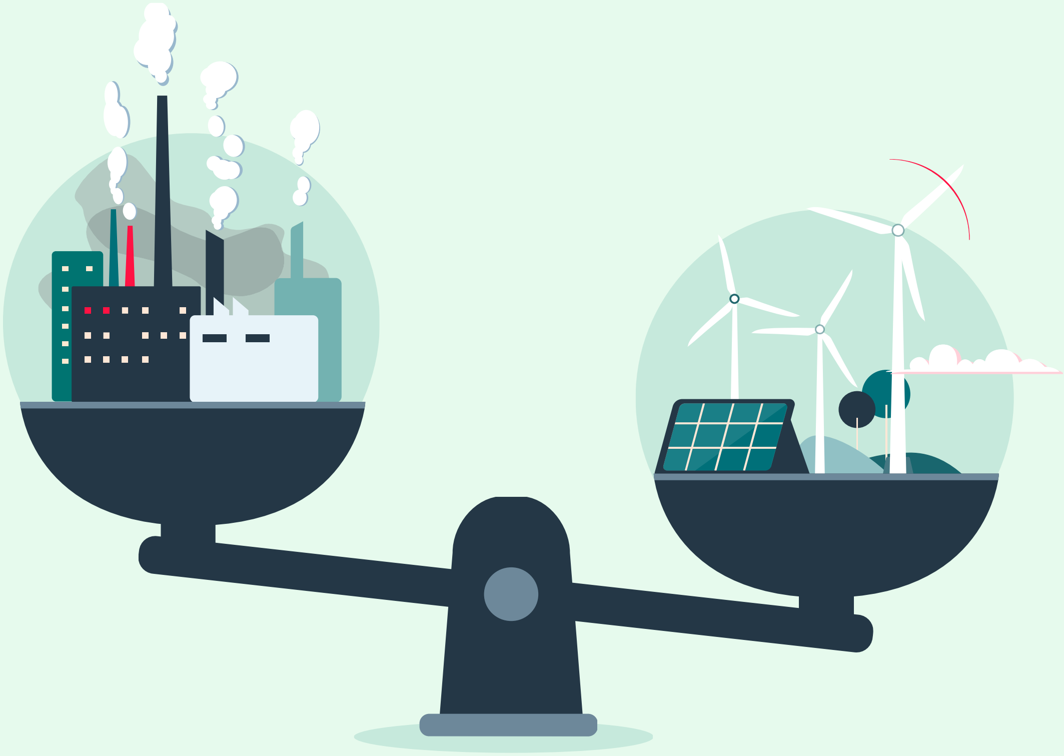

**Source:** Equinor

# Rebalance, cont.

The policies in *Rebalance* are aimed at significant improvements in energy intensity relative to historical developments, and also relative to *Reform* and *Rivalry*.

The remaining carbon budget must be shared equitably, prioritising the poorer countries and giving them the opportunity to develop, using fossil fuels where necessary. The emission reduction burden put on them should be tailored to their legitimate needs for continued economic expansion and access to energy. Global energy-related $CO_2$ emissions must not return to pre-pandemic levels and have to drop by more than two thirds by 2050. Global energy demand must also peak as soon as possible, leading to an absolute decoupling of economic growth from energy demand at a global level – something never seen in modern history. Technologies that allow this already exist, but require a significant increase in policy support and financing. A high carbon price and – at least while there is no global carbon price established – a carbon border adjustment mechanism would play a major role in supporting this. Electrification rates must rapidly increase, with electricity eventually making up the largest share of total final energy consumption, and the majority of that generation coming from renewable sources. This will need to be combined with two gigatonnes (Gt) of carbon dioxide being captured and stored per year by 2050. However, technology alone can only take us so far and living within our planetary boundaries will also require a significant shift in consumer expectations and behaviour, toward more ecologically sustainable goods and services.

*Rebalance* is an idealistic world and quite unlike anything seen historically, but it is a clear reminder of the challenge we face in avoiding climate change.



## Rivalry

In *Rivalry*, nationalism, xenophobia and key leaders' penchant for grandstanding and scepticism to science and expert advice put security of supply at the top of countries' energy agendas. Focus on economic growth and climate change take a back seat in terms of policy priorities. The energy transition limps along, more as a way to secure energy independence rather than for economic or environmental reasons. There are many indications that the world is at risk of following such a path: Trade wars, anti-globalism, neglect of international institutions, social and political unrest and regional conflicts have shown signs of escalating. In *Rivalry*, these trends continue leading to more protectionism, more authoritarianism, less global cooperation, slower technology development and weaker economic growth. This makes *Rivalry* the least sustainable scenario in several dimensions. In terms of economic growth, the imbalances persist, and emerging economies are significantly worse off compared with the other scenarios. Economic growth is also much more energy intensive in *Rivalry* than in the other scenarios and takes a higher toll on the world's resources.

As energy security takes priority over climate change, regions with access to cheap and abundant supplies of coal continue to rely on it as an important part of the energy mix. Coal to gas switching does not accelerate due to the higher cost and a reluctance to rely on other countries for supply, making LNG imports less attractive. Oil demand in *Rivalry* is the highest of all our scenarios, with much of the difference explained by slower electrification rates, particularly in the transportation sector. This higher demand requires renewed exploration in environmentally sensitive regions and supply from higher carbon intensity resources. Renewables continue to grow due to their low cost and importance as an indigenous source of energy, but at a slower pace compared with the other scenarios. There is lukewarm interest in energy efficiency as a lever to secure energy independence, and progress is hampered by a lack of capital and a reluctance to invest for the long term under volatile, uncertain circumstances.

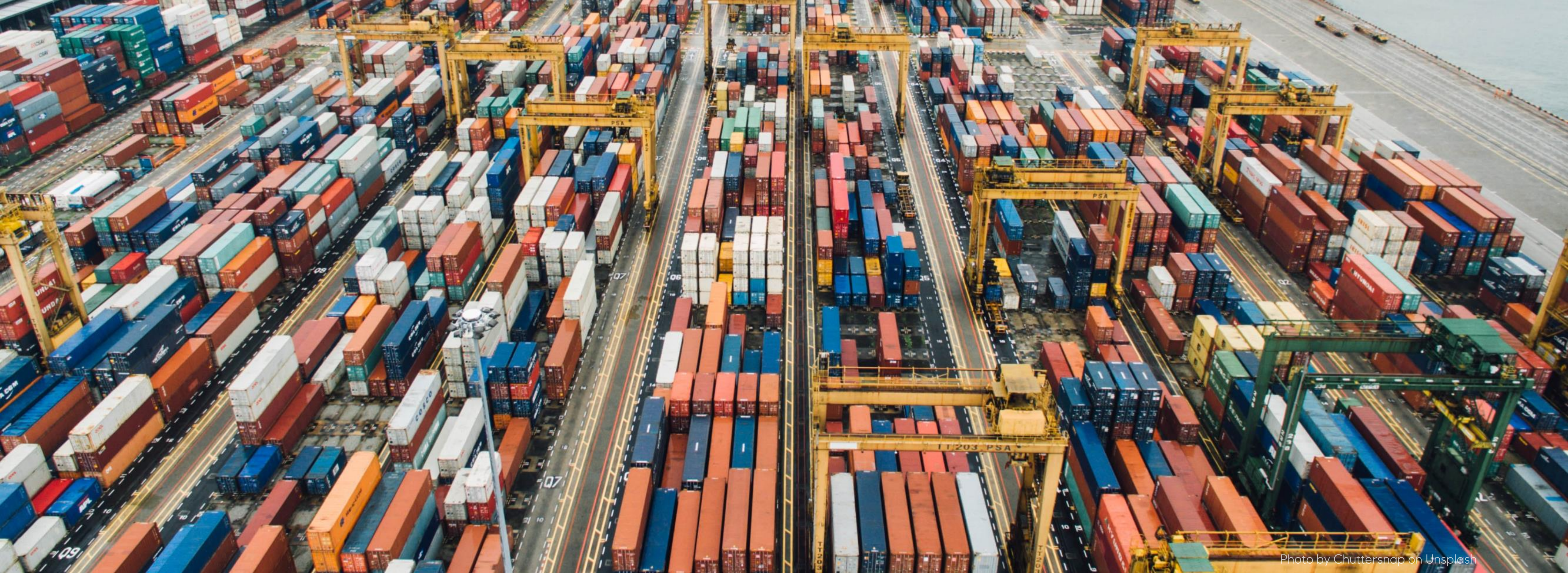
## Beyond 2050

From a climate perspective, 2050 is not a natural end-point to the outlooks. Even in *Rebalance*, the $CO_2$ emissions must continue to decline rapidly after this time and probably reach net zero globally around 2070. The full impact of climate change on the environment and economy will not be seen until well after 2050.

The assumptions that the scenarios are built on are based on today's knowledge of markets, policies and technology. Moving beyond 2050 it becomes more likely that we will see technology breakthroughs and black swan events that are unforeseeable now, but that may completely change the energy landscape. Companies' planning horizons do not typically extend further than a few decades, thus the strategic value of looking beyond 2050 becomes limited as well.

There are some technologies such as direct air capture of $CO_2$ or nuclear fusion that are currently being developed, but are still a long way from being commercially available or deployable at scale. It is possible that in the latter half of the century such technologies could play an important role in energy supply and tackling climate change. In order to limit global warming to 1.5°C, several projections indicate that there must be significant negative emissions post 2050. For this target to be reached, negative emissions from direct air capture, reforestation and the expansion of other carbon sinks will be required.

Because *Reform* and *Rivalry* overshoot the well below 2°C carbon budget by 2050, they will require the removal of carbon from the atmosphere on a massive scale as well as a sudden transition away from fossil fuels – if severe negative impacts of climate change are to be avoided. This will result in significant unnecessary expense and put further strain on an already unsustainable demand for resources. They will also require adaptation, if possible, to a global temperature that is significantly higher than today.



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# The global economy

## Current situation and outlook to 2025

The Covid-19 pandemic has led to the largest global economic downturn since the 1930s, dwarfing the Great Recession of 2009. The second quarter of 2020 was the lowest point of the economic collapse, followed by high growth in the third quarter and a more moderate recovery in the second half of the year. During 2020 the global economy contracted by 3.6%. The fallout in economic activity hit industrialised countries hardest, particularly in service sectors and among low-paid workers. The economic recovery varies across nations: China has outperformed, while continental Europe is a laggard due to resurgent waves of Covid-19, virus mutations, a slower than hoped vaccine roll-out, and continued lockdown measures. In economic terms the US has been less hard hit than Europe, and the country looks to be in a phase of rapid growth supported by ambitious government spending. Vaccinations are well under way in several countries. Assuming an improving health situation for key economies during the second half of 2021, the global economy may expand by around 5.5% this year. At the time of writing, developments in India are a source of concern.

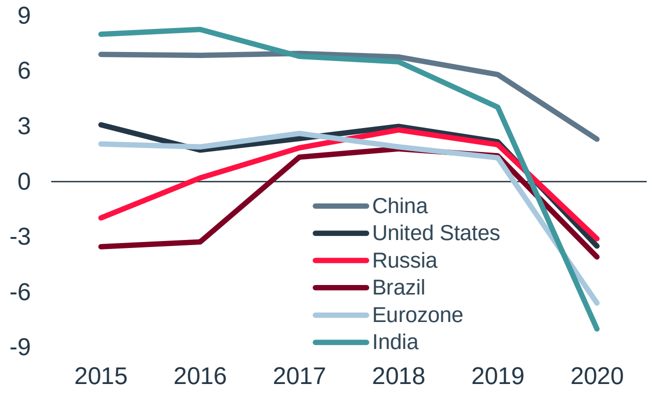
The global economy looks set to return to its pre-virus level this year and is expected to grow solidly in 2022. Thereafter, GDP growth rates will normalise back to trend towards the middle of the decade. This assumes control of the Covid-19 situation in all regions. In *Reform*, the global economy grows at an average rate of 3% per year during 2022-25. The employment situation is expected to improve, and China returns as the growth engine of the world with a yearly GDP growth of around 5%. The US and Eurozone return to trend growth, underpinned by pent-up consumer demand.

In the short term, global economic growth in *Rebalance* is similar to growth in *Reform*. In *Rebalance*, a transfer of wealth, technology and learning from the industrialised world to the emerging economies begins. A rapid improvement in international cooperation enables policies that focus on the environment and well-being, allowing a redrawing of the global economy. In *Rivalry*, regional disparity strengthens, with a widening gap between industrialised and emerging regions. The economic growth in this scenario is 2.8% on average per year during 2022-25.

The economic outlook over the near term is uncertain and dominated by risks that may curb all three scenario paths, such as a worse Covid-19 development, high unemployment suppressing consumption, economic policy support being withdrawn too early and a sharp tightening of financial conditions, potentially in response to higher than expected inflation.

### GDP growth by region 2015-2020

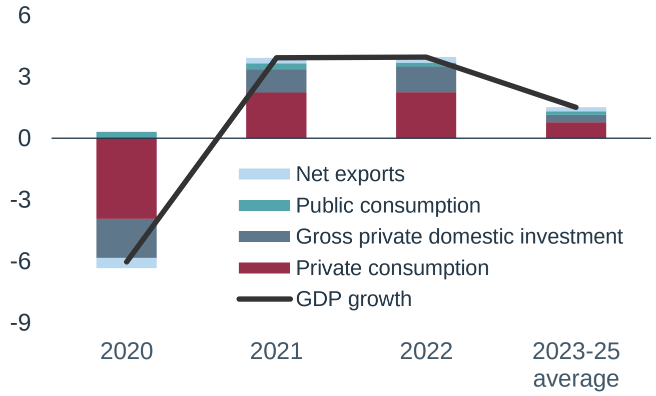
Real annual change at market exchange rates, %




**Source:** IMF

### GDP and its components for the Eurozone in Reform

Real annual change at market exchange rates, %




**Source:** European Commission (history), Equinor (projections)

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# Outlook beyond 2025

The long-term implications of Covid-19 are uncertain, but on balance they point to a slight dent in economic activity compared with pre-Covid-19 expectations. Historically, crises have been followed by a long-lasting increase in unemployment rate and lower labour participation rates. The existing economic imbalances increase the risk of macroeconomic policy mistakes and might lead to a less efficient economy. This could be partially offset by an accelerated uptake of new technology. Going forward, the world may experience similar outbreaks of virus, but better preparedness, and thus reduced impact, is expected.

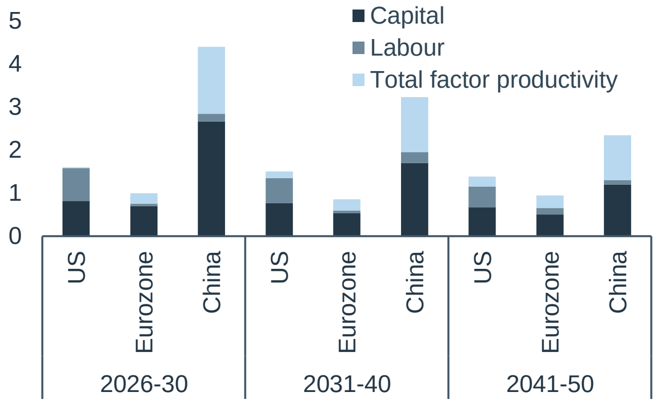
Global growth in *Reform* is lower than the historical growth rate of 2.9% seen since 1990. This is primarily caused by weaker demographics and decreasing catch-up potential for emerging market economies. Increasing carbon levels in the atmosphere lead to a moderately negative climate impact on economic growth from the mid-2030s onwards. The global economy grows on average by 2.2% per year between 2026 and 2050, and China surpasses the US economy around 2030.

*Rebalance* describes a movement towards a more just world, where economic activity to a larger extent takes place within the limitations imposed by our planet's ecological boundaries. Western governments facilitate a rapid transmission of know-how and technology to emerging economies, coupled with debt relief and investments. Imports of goods and services are made more expensive by pricing of negative externalities, to aid emerging countries and stem excessive consumption. There is a significant cut in waste and the phase-in of a circular economy, shifting focus to well-being rather than resource-intensive consumption. Although GDP growth in industrialised regions slows, they all experience a positive development in absolute and per capita terms. This, along with rapid growth in emerging economies, results in the beginnings of a convergence between the richest and poorest countries. Environmental and societal externalities are priced into products and energy subsidy schemes are mostly removed. In *Rebalance*, the world experiences reduced negative climate impact, and average GDP growth for the period as a whole is 2% per year.

*Rivalry* depicts a world with sanctions and inefficient markets that dampen technology development. Political and economic resources are channelled to less productive purposes. The economic growth in *Rivalry* averages 1.8% per year, increasingly impacted negatively by climate change. GDP is 9% lower than in *Reform* by 2050. Economic development is markedly poor, especially in the Middle East and North Africa.

### GDP growth by source in Reform

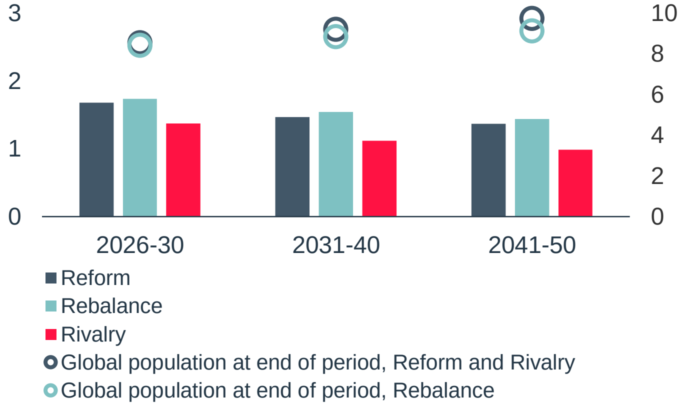
Real annual change at market exchange rates, %




**Source:** Equinor

### GDP per capita growth and population development

Real annual change, % (lhs) and billion people (rhs)




**Source:** Equinor, United Nations

Photo by JuniperPhoton on Unsplash

# Global energy demand

# Global energy demand

World total primary energy demand (TPED) is estimated to have fallen 5-6% in 2020, with the transportation sector hardest hit. The pandemic is expected to have a lasting impact on demand, in part by dampening economic output, but also by driving long-term behavioural changes. In the transport sector, remote working practices will reduce commuting. Restrictions on business travel and a reluctance to resume mass tourism could further impact demand, especially in aviation. All this will affect fossil fuel demand, most notably for oil.

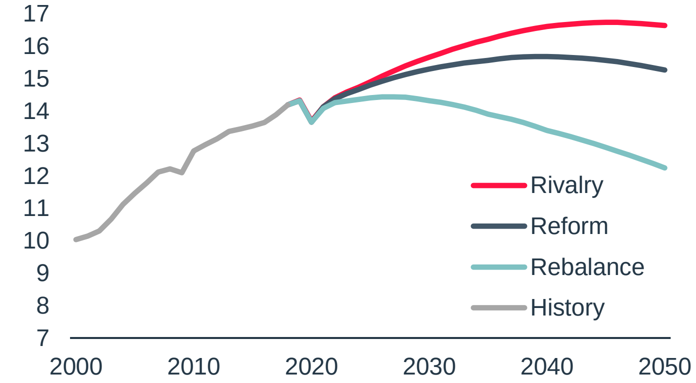
Renewable energy has suffered less as a result of Covid-19. Wind and solar photovoltaic (PV) capacity grew at record speed in 2020, 18% and 22% respectively. The low running costs of renewable power plants also supported capacity utilisation. A global recession or rising interest rate expectations could still impact investment decisions and slow capacity growth in the short term. However, green recovery plans will aim to counter this by targeted economic stimuli and green job creation.

In *Reform* and *Rivalry* global energy use rebounds with the economy and returns to its pre-pandemic level in 2022. In *Reform*, energy demand continues to grow by 0.5% per year, before peaking in 2040 and declining 0.3% per year through the 2040s. In *Rivalry*, growth is faster due to slower improvement in energy intensity, or energy demand per unit of GDP. Demand eventually levels out in the mid-2040s . In *Rebalance*, energy demand is subdued by green recovery initiatives and behavioural changes. Demand peaks in 2027 and declines thereafter at a rate of 0.7% per year.

Energy demand slows despite continued growth in populations and GDP in all our scenarios. Energy demand has already decoupled from its traditional drivers on a long-term basis in large parts of the world. OECD countries´ energy use was lower in 2019 than in the mid-2000s, albeit partially due to an ongoing deindustrialisation, which led to increased energy demand in other countries. Decoupling at a global level has only been seen in single years, under exceptional circumstances such as the financial crisis and the Covid-19 pandemic. Global TPED peaking is a key component of climate stabilisation scenarios, and a credible long-term proposal. Energy intensity has a large scope for improvement. Accelerated electrification, declines in the most energy intensive sectors, and changes in behaviour are set to play key roles. The sense of urgency that global warming has instilled in people will likely ensure that politicians, investors and consumers contribute to this development. To which degree, however, remains to be seen.

World total primary energy demand

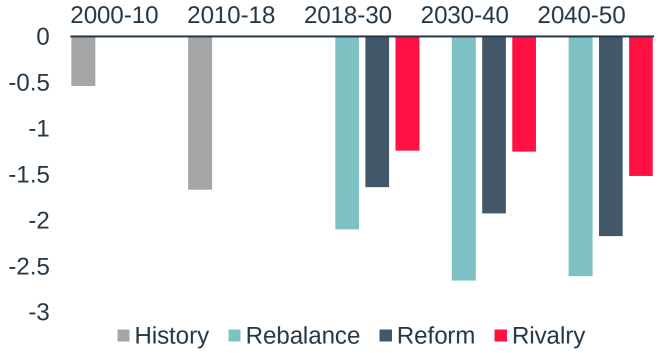
Gtoe




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

World energy intensity change, CAGR

%




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

# Energy intensity and sectoral demand

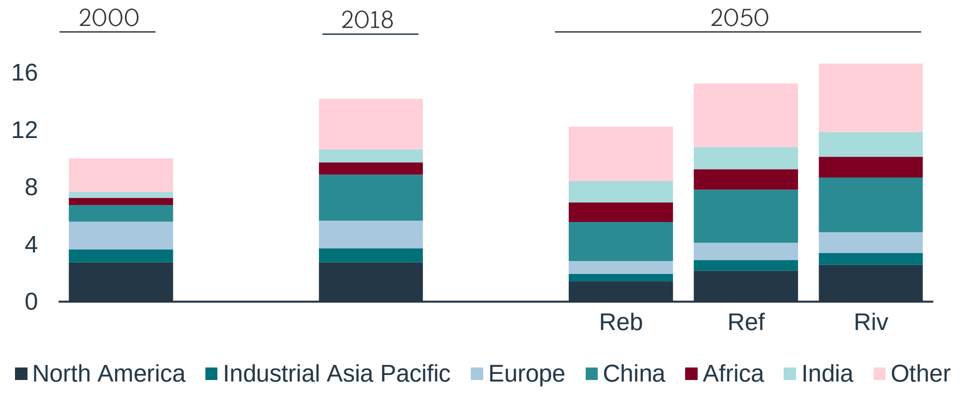
In *Reform*, global energy demand per unit of global GDP declines by an average of 1.9% per year between 2018 and 2050, a significant improvement relative to the 1% per year seen between the turn of the century and 2018. In *Rebalance*, the decline rate is 2.5% per year and in *Rivalry* it is 1.3% per year. These world averages mask considerable regional variation with the emerging economies on balance enjoying faster energy intensity declines than the developed ones.

Lower population and economic growth, as well as efficiency improvements and environmentally motivated behavioural changes, result in developed countries´ energy demand being lower by 2050 than in 2018 in all scenarios. Developments in these countries deepen trends observed since 2008, when the global financial crisis lowered industrial energy demand and accelerated the offshoring of energy intensive industries. In *Rebalance*, China sees rapid economic restructuring with resources migrating from heavy industry to the service sectors. Other emerging economies use more energy by 2050 than in 2018, in response to population and economic growth and the emergence of a middle class. Still, demand in the more advanced countries in Latin America, Southeast Asia and the Middle East peaks in the 2040s and is declining by 2050.

The power and heat sector remains the largest source of demand in all three scenarios, driven by electrification. By 2050 electricity makes up 25% and 31% of total final consumption (TFC) in *Rivalry* and *Reform*, respectively. It reaches 44% in *Rebalance*. As for the sector split of world final energy demand, in *Rebalance* the transport share drops by 10 percentage points from 29% to 19% between 2018 and 2050, while industry´s share increases from 29% to 33% and feedstock for petrochemical production is up from 7% to 11%. Feedstock requirements is the part of oil demand that holds up best in *Rebalance*, in spite of increased recycling. In *Rivalry* there are only minor changes from today´s split while *Reform* positions in between.

## Energy demand by region

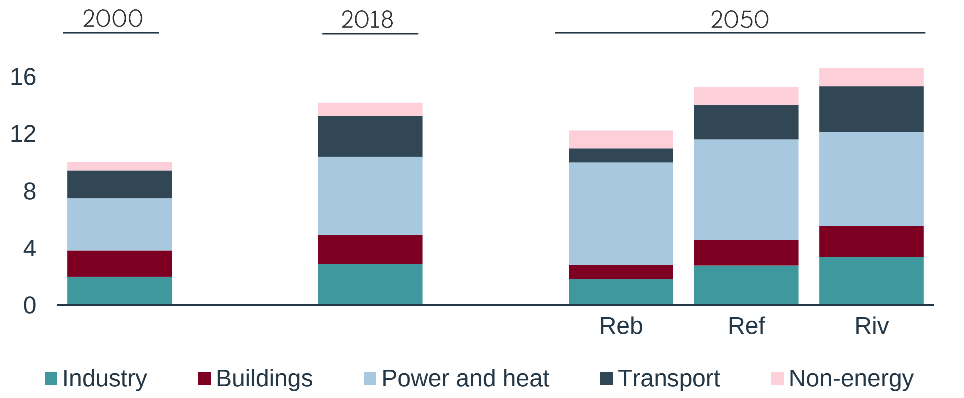
Gtoe




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

## Energy demand by sector

Gtoe




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

# Energy use per capita

There are large variations in per capita energy demand today, predominantly driven by economic inequality and the divide between rich and poor, as well as differences in climatic conditions. The industrialised countries' populations are the largest energy consumers by far. Energy efficiency improvements over recent decades have not been fast enough to put demand on a sustainable path. If emerging economy populations were to emulate their richer neighbours, there would be no chance of achieving the goals of the Paris Agreement or other sustainability targets. The challenge is exacerbated by a likely growth in the world population to nearly 10 billion by 2050.

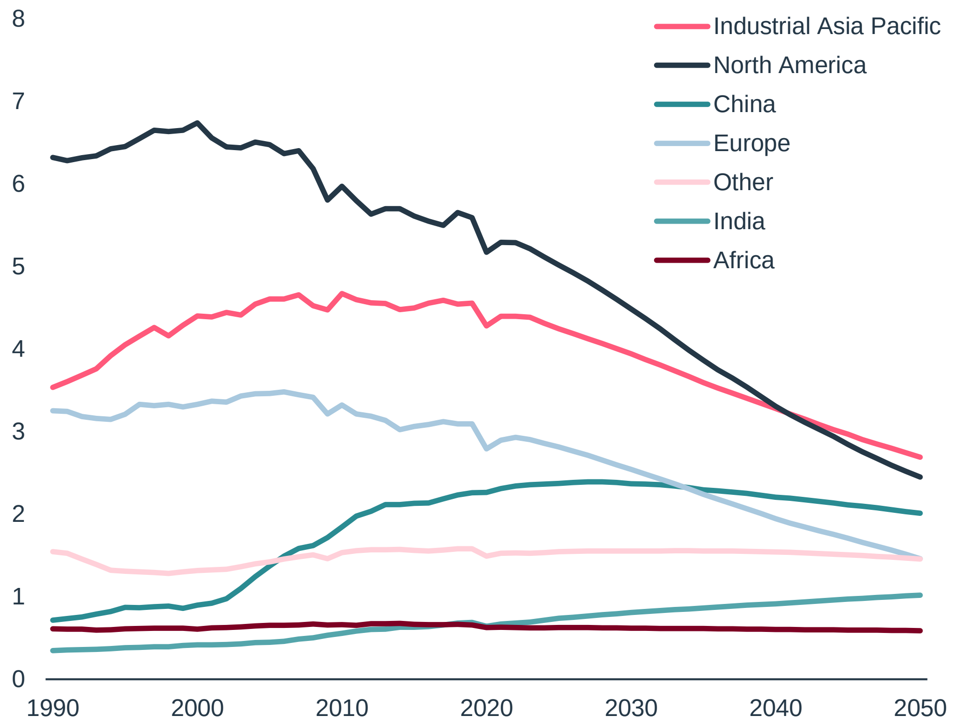
Electrification is a unifying theme across our scenarios, and will bring huge efficiency improvements. Electric engines generate less waste heat than internal combustion engines. Electric lighting and cooking is superior to fuelwood or oil based solutions, not only from a climate point of view, but also from a health and life expectancy perspective. When electrification is combined with renewable sources, it becomes a key component in a sustainable development path.

Per capita energy demand does not increase significantly in most of the poorest regions in any of our scenarios as the demand effects from economic growth are countered by electrification and efficiency developments. Per capita energy demand is down in the richest regions, with electrification boosting energy efficiency in the transport and residential sectors. In *Rebalance*, these effects are amplified by tougher efficiency standards, taxation, subsidies and changes in behaviour and consumption habits.

In *Reform*, per capita energy demand develops in line with historical trends, with North America and Industrial Asia Pacific regions remaining on top of the scale. In *Rivalry*, progress is slower, with some regions such as CIS and the Middle East performing unsustainably due partly to a lingering reliance on indigenous fossil fuel supplies.

## Per capita energy demand in Rebalance

Mtoe per thousand people




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


# The global oil market

# Current situation and outlook to 2025

Emerging from the challenges of 2020 was never going to be easy, but 2021 has shown all the signs of uncertainty and volatility that could be expected – following the worst oil market crisis in history. Nevertheless, market conditions have improved as global economic activity has rebounded. Tight lockdowns have been relaxed in some parts of the world and oil demand has shown signs of pickup. The oil price (Dated Brent) rose by over 85% between November 2020 and March 2021. It helped that the Opec+ countries remained united and held off some 6 mbd of supplies for the first half of 2021.

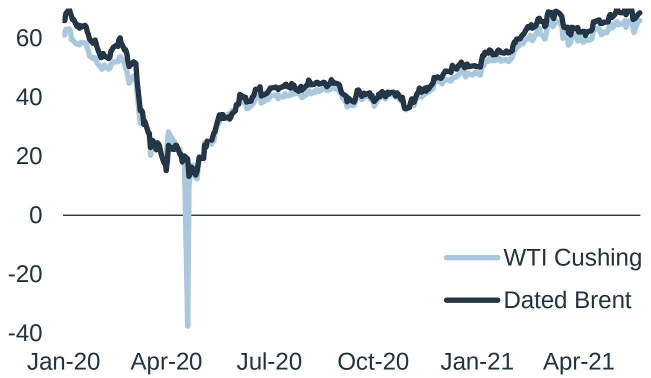
Optimism surrounding a market rebalance by mid-2021 was given weight by strong global oil inventory draws. However, headwinds were never too far away as evidenced by the sharp disparity by the goings-on in paper vs. physical markets and repeated mutations of Covid-19, casting longer shadows over the speed of the global recovery. Asia, which had great demand expectations, experienced an uneven geographical recovery. On the supply-side, the potential return of Iranian barrels in the event of a US-Iran nuclear deal weigh on the market sentiment.

As much as a return to normality is hoped for, behavioural changes caused by the pandemic will remain for years. Home working flexibility is unlikely to disappear outright, thereby sapping transportation demand, some of which is oil dependent. Aviation, the sector most deeply hit by the pandemic, will only gradually get back to pre-Covid-19 levels, if at all.

Regionally, Europe shows the greatest promise for the shift from oil to electricity. It will also be here where ambition first meets reality: the electrification of cars, for example, will only have an impact on emissions if the electricity is renewable. The US is developing ambitious climate goals while also expecting relatively strong economic growth. As a result, oil demand should remain robust up to 2025, with the main growth area being Asia. African development is expected to remain slow, although improvements in living standards could include a switch from biomass to liquified petroleum gas (LPG) for residential use. Within the products market, gasoline is the most vulnerable to car fleet electrification as that is its only market. However, gasoline is made from naphtha, which will see rising demand in the petrochemical sector. Diesel is likely to see resilient demand from industry and trucking. Fuel oil will remain the main shipping fuel towards 2025. A main concern for product markets is that global refinery capacity will be higher than product demand.

### Oil price development

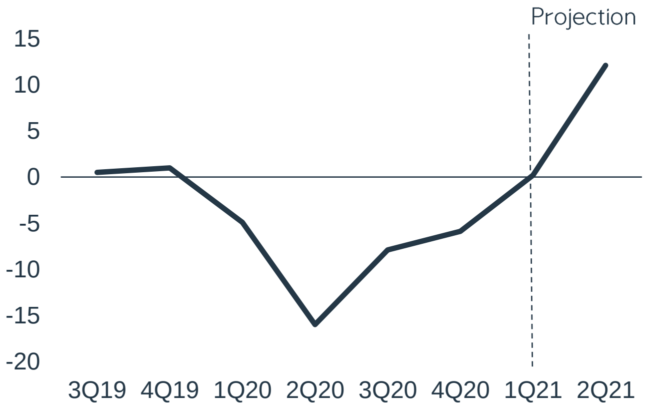
USD/bbl




**Source:** Platts

### Global oil demand growth

mbd per quarter year-over-year




**Source:** IEA

# Outlook beyond 2025

The uncertain impact of the ongoing energy transition on future oil demand may be the key challenge facing international oil companies (IOCs). The outcome space is vast. By 2050, there is a 64 mbd difference in consumption between *Rivalry* and *Rebalance*. *Rivalry* has the highest demand, at 110 mbd. 2020 offered a glimpse of what a lower oil demand world could look like. The question now is whether a permanent dent has been made in our consumption or whether the world will return to its old trajectory.

*Rivalry* sees oil consumption continue to grow in sectors such as road, aviation and shipping. Lack of policy support and investment slows the uptake of alternative fuels and new technology, which would help reduce emissions. Battery technology development is slow and internal combustion engine (ICE) vehicles outcompete electric vehicles (EVs) in many markets. By 2050, oil consumption growth has flattened, but at a higher level than today, without showing signs of decline.

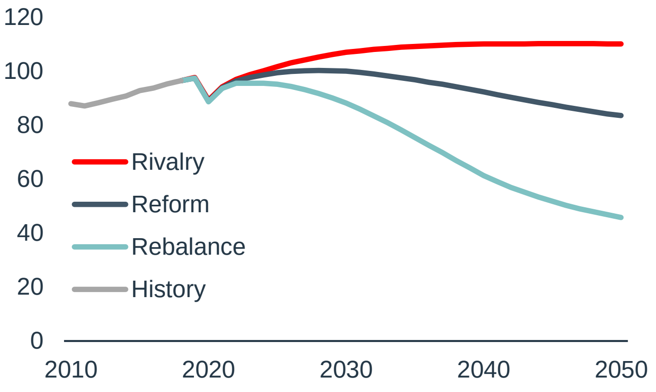
In *Reform*, high economic growth means that despite a stronger shift towards alternative fuels, it is not enough to reduce global demand significantly. Improved efficiency and a faster uptake of electric vehicles (reaching 56% of the fleet by 2050) means oil demand will peak in the late 2020s, before gradually declining.

In *Rebalance*, policy, new technology and changes in behaviour lead to significantly lower consumption of oil in the transport sector. Aircraft and ships will make use of advances in battery technology, alternative fuels and digitalisation to emit less $CO_2$. However, complete decarbonisation is still a challenge. Renewables displace oil demand in industry and buildings, leading to significantly lower consumption overall. Oil demand growth remains strong in the petrochemical industry, which relies on petroleum to produce the strong, lightweight materials used in new vehicles, as well as other vital products such as clothing, medicine and packaging. However, environmental concerns increase recycling rates, meaning less need for new oil feedstock than in *Reform*.

Although the world in some ways would appear to be on a *Rivalry* path in the short term, particularly geopolitically, there are also strong forces pointing towards the *Rebalance* pathway. Whichever path is taken, oil products will be needed for decades to come. This demand requires investments in oil supply to mitigate the natural decline of producing oil fields. Without investment there will be a significant supply gap. With targeted investment and policy, any new supply can be of the lowest carbon intensity possible and allow the most cost-effective transition to low carbon alternatives.

Oil demand

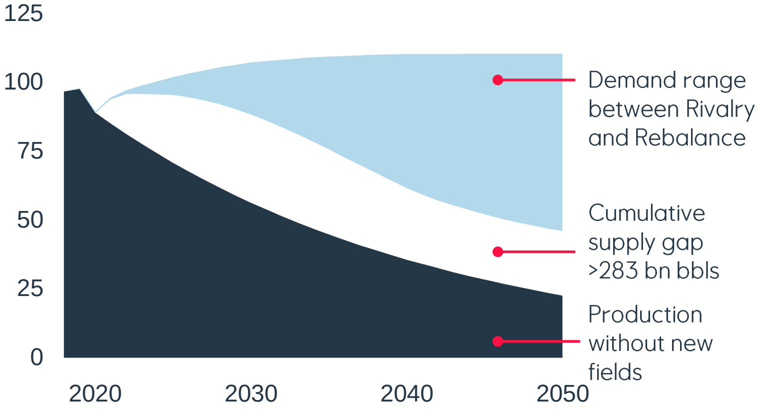
mbd




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

Oil demand and supply from existing fields

mbd




**Source:** IEA, Equinor


# The global gas market

# Current situation and outlook to 2025

Even before the pandemic hit in 2020, natural gas demand was declining due to unusually mild temperatures in the northern hemisphere. This trend was then exacerbated by the drop in industrial and power sector demand due to lockdowns. Gas demand and prices have now recovered from the Covid-19 lows, although the start of 2021 has been volatile. This has been due to weather extremes in Asia and the US, and subsequent pressure on supplies. Initially, record full storage facilities in Europe offered supply flexibility, but ultimately gas prices rose due to higher storage refill needs and the prevailing uncertainty of pipeline supply for the remainder of the year. Such events demonstrate the fragility of gas markets. In acute peak demand situations, when liquefied natural gas (LNG) is required to balance markets globally, the current complexity of the LNG value chain and a lack of local storage capacity make price spikes common.

The price fluctuations also illustrate the relationships between gas markets. Asian and European markets are linked, with prices reacting similarly to global demand and supply changes. North American markets remain sheltered from external pressures due to high domestic production and LNG exports flexibility.

Towards 2025, demand in Europe and North America is predicted to remain stable, as growing renewables are balanced by coal retirement in the power sector, with other sources of demand being stable. Meanwhile, gas demand in Asia is expected to increase by 5.2% each year between 2020 and 2025, as economic and population growth continues.

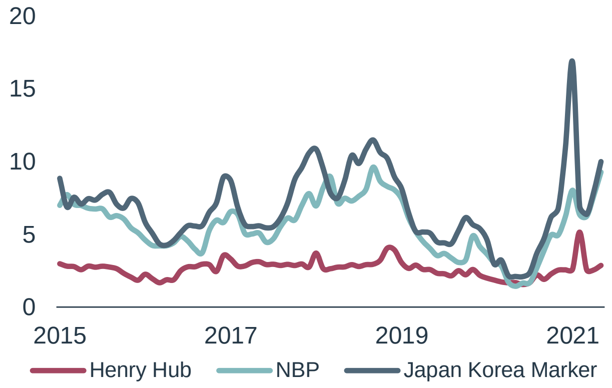
With regard to supply, Europe will see a decline in domestic production, leaving space for more LNG and pipeline imports. New import routes targeting both southern and northern Europe will diversify the traditional flow patterns and markets.

In addition, a rise in global LNG supply is also expected from North American and Russian Arctic projects to meet the rising energy demand in Asia. Storage expansion in major gas consuming countries like China is already underway, and Russia will continue to ramp up exports to China via the Power of Siberia pipeline.

Overall, the global supply and demand balance is expected to experience some tightness until 2025, leaving gas markets exposed to continued volatility. However, the post Covid-19 recovery, rate of decarbonisation, and timing of LNG and pipeline projects as well as weather impact, will remain key variables in this balance.

## Regional gas prices

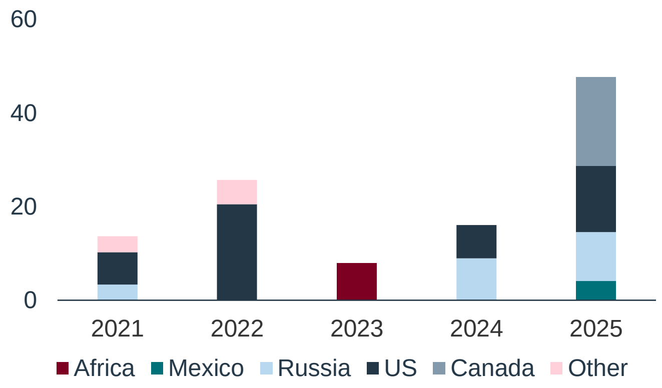
USD/MMBtu




**Source**: HH- NYMEX, NBP and JKM - ICE

## Estimated commercial start for global LNG projects

Added capacity by start-up year, Bcm




**Source**: IHS, Equinor

# Outlook beyond 2025

Scenarios for long-term gas developments encompass many drivers. These range from access and affordability to geopolitics and climate ambitions. Gas could play a crucial role in the transition towards decarbonising the energy sector, as it facilitates a move away from higher emissions fuels, balances intermittency from renewables, and can be used in the generation of blue hydrogen.

In *Rebalance*, gas demand in Europe starts to decline from the mid 2020s, driven by growth in new renewables. The world's largest gas user, the US, does not follow suit until after 2030, as demand initially remains supported by the petrochemical, power and industrial sectors. Carbon capture, utilisation and storage (CCUS) plays a role in the power and industrial sectors, allowing gas to remain part of the fuel mix in 2050. Meanwhile, demand continues to rise in China and other emerging countries, as coal to gas switching in growing industrial and power sectors persists until 2040. Global gas demand ultimately starts to decline after 2035, giving way to growth in renewables and accelerating electrification.

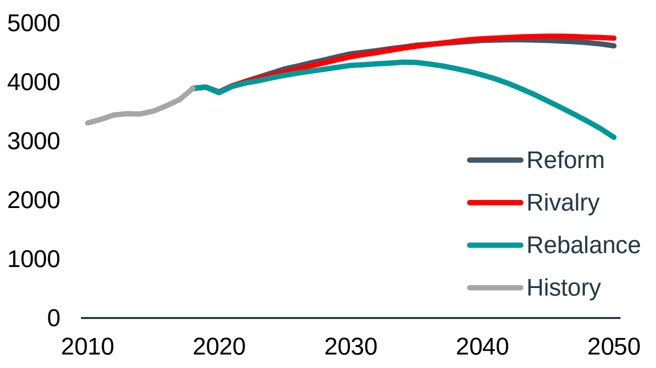
In *Reform*, natural gas demand peaks just after 2040, declining only marginally towards 2050. Rising demand is mainly driven by sustained use from power sectors in North America, the Middle East and the Commonwealth of Independent States (CIS), combined with industrial and power sector growth in China and India. China sees an annual growth of 3.9% per year from 2020 to 2040. Such demand will assert a pull on supply, including LNG value chains. Piped gas and LNG flow connectivity will increase, facilitating optimised-dispatch and trade.

In *Rivalry*, nationalistic policies and a break down in trade relations result in the prioritisation of energy security. Consequently, although *Rivalry* and *Reform* have similar profiles, the breakdown of supply and demand by countries and regions differ as local resources are favoured over imported gas. Gas producing regions such as North America, CIS and the Middle East will see an increase in demand, whereas importing regions in Europe and Asia will shift priorities away from imported gas and rely more upon indigenous energy sources. In the case of Asian countries, such as China and India, this will result in prolonged reliance on coal. By 2050, Europe is the only region to see significant gas demand decline.

Methane is a key feedstock in the production of blue hydrogen ($H_2$). In the event of $H_2$ as an energy carrier taking off it is likely that there will be an increase in gas demand in the short to medium term. However, in the longer term large green $H_2$ production from new renewable electricity will likely diminish the need for future gas supply.

Global gas demand by scenario

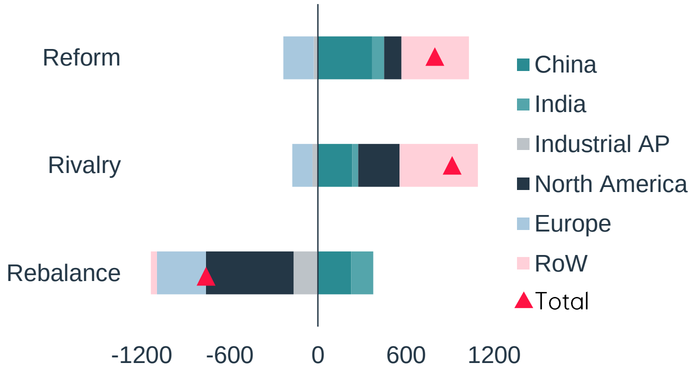
Bcm




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

Change in regional gas demand 2018-50

Bcm




**Source**: Equinor


# Global electricity markets

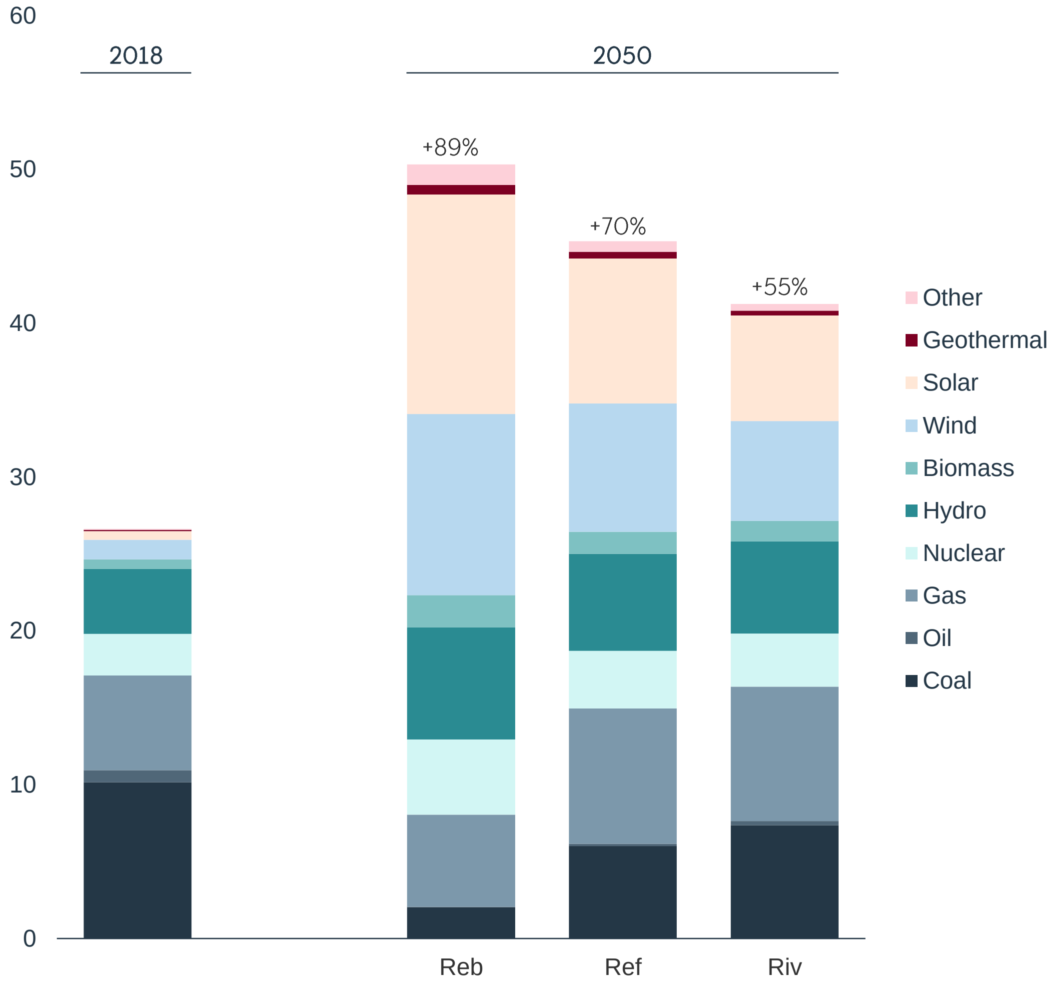
# Current situation and outlook to 2025

Demand reductions and falling fuel prices made 2020 a turbulent and volatile year for the electricity sector. Global electricity demand is expected to have fallen by 5% in 2020 due to the impacts of the pandemic, with the United States, India and the European Union seeing some of the steepest declines. Increased demand in the residential sector due to people spending more time at home has been countered by the far greater reduction in demand from commercial buildings and industrial sectors. The decline in demand has necessitated a reduction in generation, which has had a disproportionate effect on fossil generation due to its higher fuel costs and dispatchable nature. Renewable sources have proven to be more resilient, growing their share of supply as their output is largely unaffected by prices or demand. Renewable capacity is expected to grow by 4%, driven mainly by growth in wind, solar and hydro.

In many countries, the power sector has led the way in terms of decarbonisation efforts. Decarbonised electricity is a key component in the energy transition. Electrification, in most circumstances, also brings energy efficiency improvements. The levelised costs of energy (LCOE) for wind and solar generation have declined to the point of making coal power uneconomic, even in coal dependent Asia. While the scope for making coal power cheaper is limited, wind and solar generation costs are set for further declines. From being the main source of electricity generation, it is now difficult to see growth in coal power. China has the world's largest coal demand, and despite the fuel appearing to be in long-term decline globally, the lack of specific targets in the recent five-year plan and the need for economic stimulus within China may entail that coal phase out will not be slower than market forces would suggest. Globally, gas plants will take a major role in the development of new flexible capacities in the short and medium term. Gas has a lower carbon intensity than coal and remains flexible enough to provide swing generation, allowing further development of intermittent renewables.

Global electricity generation in 2018 and 2050

Thousand TWh




**Source:** IEA (history), Equinor (projection)

# Outlook beyond 2025

Electricity demand is set to grow in all three scenarios – most rapidly in the emerging economies, driven by growing income and consumption. The energy transition will see electricity demand growing at the expense of other fuels, by a direct switch to electricity and potentially also the development of green hydrogen. World electricity demand increases by between 52% and 85% between 2018 and 2050, with the fastest growth in *Rebalance*. The electricity share of world final energy consumption increases from about 20% today to 25% in *Rivalry*, 31% in *Reform and* 44% in *Rebalance*.

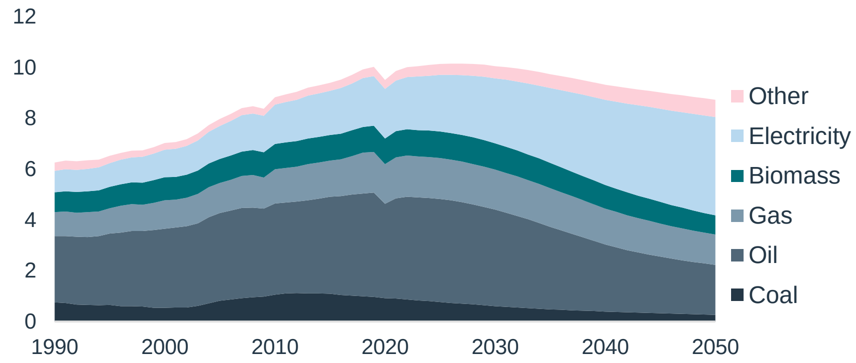
Increased global demand for electricity is met with a change in the generation mix, where production of electricity from renewables is set to grow across all the scenarios. Policy support in Europe, North America and China for wind and solar photovoltaic has enabled mass production and cost reductions, and will in turn boost deployment in the rest of the world. Generation of electricity by wind and solar increases from 7% of the global electricity production in 2018 to 52% in *Rebalance*, 39% in *Reform* and 32% in *Rivalry* towards 2050.

Wind and solar capacities alone will not be enough to meet future demand due to the intermittency of their generation. Other available technologies for dispatchable electricity generation with no or low $CO_2$ footprints are hydro power (including pumped hydro storage), gas turbines with post combustion carbon capture, and nuclear power plants. There is a growing interest seen towards small modular nuclear reactors, both from established nuclear countries and in countries with no current capacities. Such growth of renewable electricity generation will require changes to the electricity market design. High shares of electricity from zero marginal cost resources will put downward pressure on the wholesale market prices, cannibalise revenues and discourage much needed investments.

Governments will therefore need to consider how the market design is developed to ensure that appropriate investment incentives are in place to find the right balance between decarbonisation targets, network stability and cost efficiency. This may lead to replacement of the current wholesale market with a centralised planning and coordination market design. Demand management may be an effective solution to reallocate resources, for example in prosumer households. As digitalisation costs come down and the electrification of vehicles shoots up, smart charging solutions have the potential to reduce power bills. This will require efforts to upgrade and digitalise the network, as well as defining a way of pricing this service for customers.

Total final consumption by fuel in Rebalance

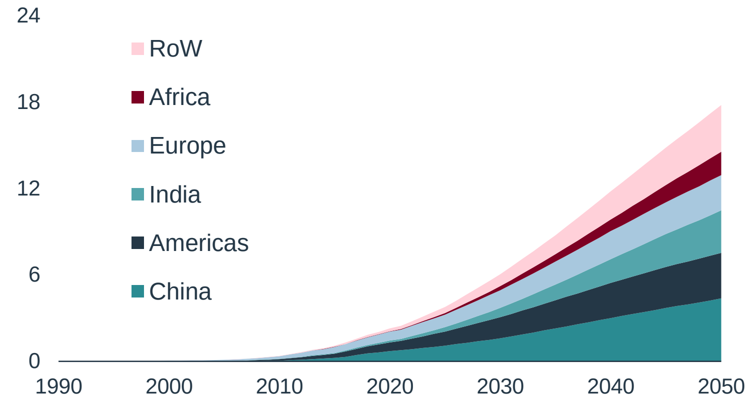
Gtoe




**Source:** IEA (history), Equinor (projection)

Wind and solar generation in Reform

Thousand TWh




**Source:** Equinor


# Global greenhouse gas emissions

equinor

# Greenhouse gas emissions

Almost three quarters of global greenhouse gas (GHG) emissions come from use of energy. A further fifth comes from agriculture, forestry and land use, with the remainder coming from industrial processes and waste management. Lockdowns and reduced economic activity in 2020 have had a significant impact on emissions, especially in the energy sector, with a projected year-on-year drop of 5.8% from 2019 to 2020. This will bring emissions back to a level last seen 10 years ago of approximately 30 gigatonnes (Gt).

In *Reform*, global energy-related $CO_2$ emissions never recover to their 2019 peak, although they do increase with economic growth from 2020, peaking at 32.6 Gt in 2025. Gradual decarbonisation of the power sector and electrification of the transport sector are the main drivers for the long-term decline. Despite the reduction in emissions, *Reform* is far from meeting the well below 2°C target.

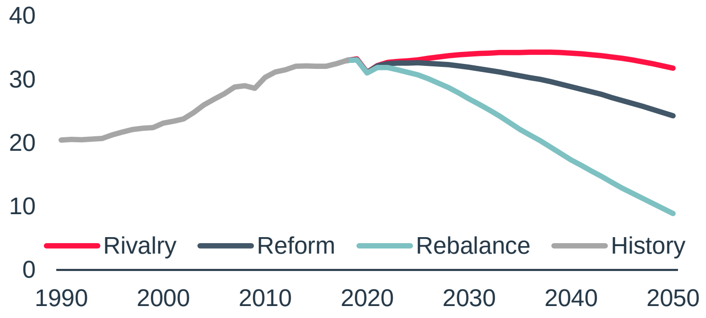
In *Rebalance*, to achieve the well below 2°C target, global $CO_2$ emissions must have peaked in 2019. Future emissions have to decline with an average rate of 4.1% per year from 2020 throughout the outlook period. *Rebalance* is a back-cast scenario, with cumulative emissions of 740 Gt assumed for the 2018-50 carbon budget. The North America, Europe and Industrial Asia Pacific regions have such low emissions after CCUS by 2050 that they can be offset by carbon sinks and can therefore be considered net zero. Emerging regions like Africa, India and Southeast Asia can allow emissions to increase until around 2030 before they must start contracting.

In *Rivalry*, emissions continue to grow from today's level until the late 2030s when they peak at just above 34 Gt per year, before slowly declining. Such high cumulative emissions will have profound negative impacts on both the environment and the global economy, as a consequence of climate change.

$CO_2$ is not the only greenhouse gas of importance. Methane ($CH_4$) emissions account for an estimated 23% of the global warming potential. Methane is a much more potent greenhouse gas than $CO_2$, but decays into other, less harmful gases faster. While fossil fuel use accounts for the bulk of $CO_2$ emissions, it is not a main source of methane emissions. Agriculture and natural processes contribute much larger shares. The fossil fuel sector has emitted an estimated 19% of the total between 2008 and 2017. These emissions were not due to the combustion of its products, but stem mostly from venting and leaks in wells, mines and mid- and downstream infrastructure.

Global energy-related $CO_2$ emissions by scenario

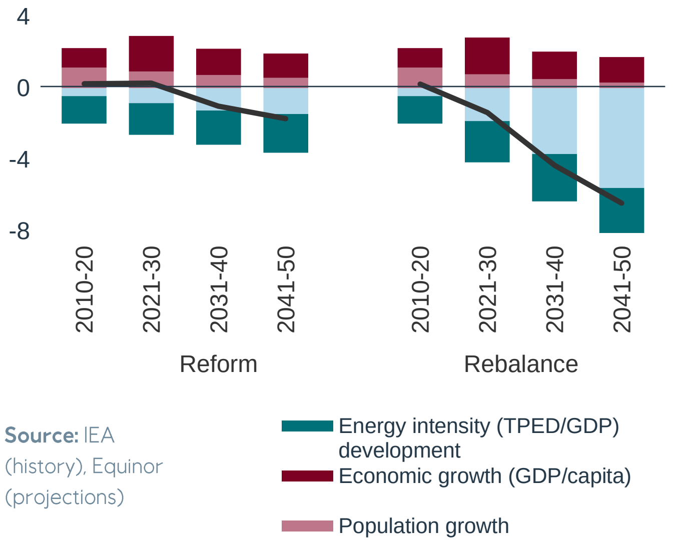
Gt




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

Global energy-related $CO_2$ emissions

Average % change per component




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


# Hydrogen sensitivity study

# The hydrogen frenzy

Interest in hydrogen ($H_2$) as a fuel for the future is booming. It has caught attention before, especially in periods of oil market unrest, when the search for substitute fuel accelerated, only to disappear from sight again when worries about oil shortages had subsided.

Hydrogen is not a new product. Current production is almost 70 million tonnes (Mt) per year. In addition, some 45 Mt are supplied jointly with other commodities as a by-product. If all this $H_2$ was used as a fuel it would provide close to 400 million tonnes of oil equivalent (Mtoe) of energy, enough to supply almost 40% of EU's final energy demand. However, only a tiny fraction of produced $H_2$ is used as fuel. Most of it is used by the refining and chemical industries to make plastics and petrochemicals.

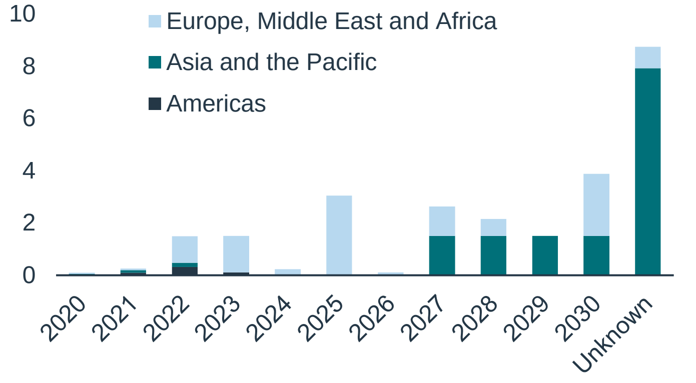
The current excitement around hydrogen is tied neither to its possibilities as a mitigator of oil supply risk, nor its function as an industrial feedstock; rather it is linked to its potential as a clean substitute for $CO_2$-emitting fossil fuels. The world needs substitutes, and $H_2$ can be used everywhere, including in those sectors that cannot easily be electrified. $H_2$ emits no greenhouse gases when burned and can be produced cleanly. $H_2$ is thus seen by many as a key piece in the puzzle supporting the goal of net zero emissions by the middle of the century.

Clean hydrogen comes in two variants: blue and green. Blue $H_2$ could be produced from mostly natural gas, with $CO_2$ emissions captured and stored or utilised. Green $H_2$ is produced from the electrolysis of water using renewable electricity. The bulk of current $H_2$ production, which is mainly used as an industrial feedstock and not as an energy product, is neither blue nor green but *grey* – produced from fossil fuels without CCUS.

Despite the concepts and technology being available, the envisaged $H_2$ break-through depends on production cost decline, demand growth, and infrastructure build-out. Storage is a key challenge, while transportation is costly and requires the adaptation of existing natural gas infrastructure. Significant policy support is needed to meet these requirements. Clean $H_2$ costs are expected to come down, with green $H_2$ set for particularly strong declines on the back of cheaper renewable electricity and electrolysers. Some consultants see clean $H_2$ becoming competitive with grey $H_2$ in the foreseeable future and competing with natural gas before 2050. However, such expectations factor in economies of scale. Thus, policy incentives are needed to stimulate investments despite currently challenging economics. Confidence in a rosy future for $H_2$ requires governments' loyalty to net zero targets, and taxpayers and consumers' preparedness to pay dearly for it.

### Announced green $H_2$ capacity over the next decade

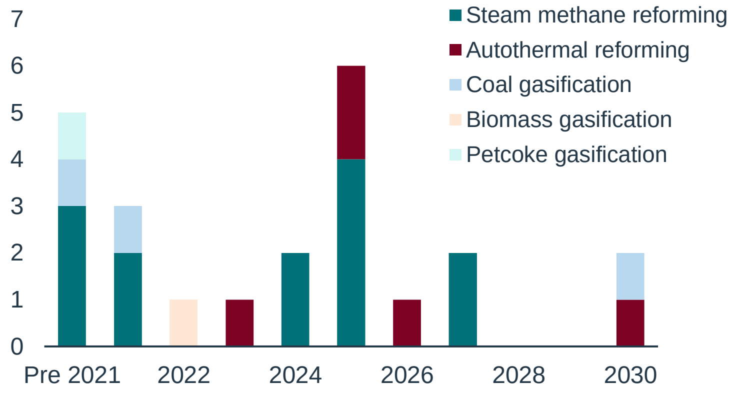
Added capacity by commissioning year, GW




**Source:** BNEF

### Announced blue $H_2$ projects set to commence

Number of projects for start-up by technology




**Source:** BNEF

# Rebalance and hydrogen

Projections vary widely for energy-related hydrogen demand, which is to be expected since the market does not yet exist and relies on massive, prolonged policy support. It therefore lends itself better to aspirational outlooks rather than to modelled scenarios. To this end, a $H_2$ sensitivity study has been applied to the *Rebalance* scenario, presented here, to illustrate the potential impacts on total energy demand, fuel mix and $CO_2$ emissions, if $H_2$ were to be introduced.

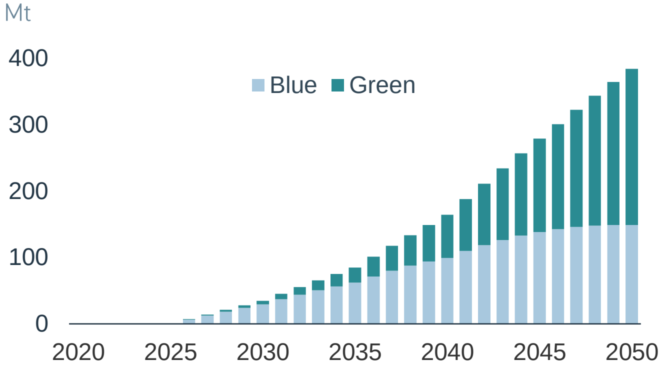
In the reimagining of *Rebalance*, slow initial growth is assumed in the global $H_2$ market, with 53 million tonnes (Mt) of demand by 2030. This accelerates to 385 Mt by 2050, with China accounting for 28% of demand. $H_2$ shares of total final energy demand (TPED) vary from only a few per cent for Africa, to 10-11% for Europe, Industrialised Asia Pacific and China. By 2050 the power and heat sector is the biggest off taker, absorbing 162 Mt against industry's 120 Mt. Another important sector is transport. Heavy road transport makes up 17-18% of total $H_2$ demand in the OECD countries and China by 2050. Shipping, where $H_2$ is assumed to be used in the form of ammonia, constitutes 35% of demand in the OECD countries and 26% in China. $H_2$ captures only a 2-4% share of the buildings sector in these countries, and is not utilised as a buildings sector fuel in any other regions.

Hydrogen is seen to take market share mainly from fossil fuels, primarily gas. From a $CO_2$ emission reduction standpoint, $H_2$ should replace coal, but in a scenario where $H_2$ takes off it is likely that coal use is already marginalised and in some regions eliminated before 2050. In some cases such as heavy road transport, $H_2$ is the preferred energy carrier– not only for emission reduction reasons, but because clean $H_2$ is understood by many to be a more promising decarbonisation option for the trucking industry than batteries.

The assumed growth in the use of $H_2$ as a fuel from zero in 2020 to almost 400 Mt by 2050 affects all sectors and most other fuels. Oil loses market share to $H_2$ in industry, transport, and transformation sectors outside power and heat. By 2050, some 270 Mt of oil, equal to 13% of demand in *Rebalance*, is replaced by $H_2$. As no blue $H_2$ production from oil is assumed, there is nothing to compensate for this loss.

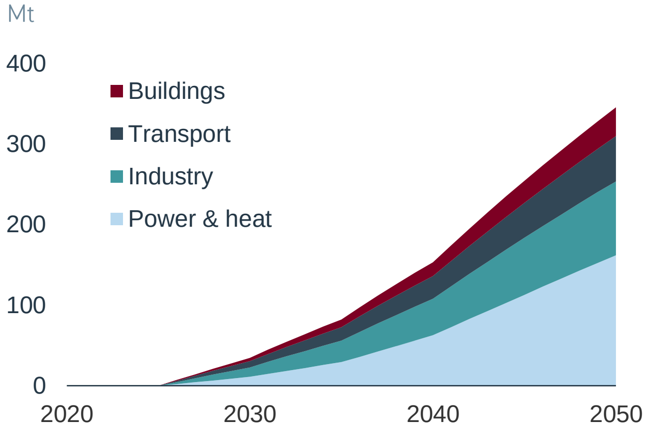
Natural gas demand is also down. Gas receives a boost from blue $H_2$ production, but globally from around 2030 the declines in demand from end use and power and heat sectors become the dominant influences. China and other regions also produce blue $H_2$ from coal, which further reduces gas demand. The suppliers of gas rely on their indigenous supply as feedstock for blue $H_2$.

## $H_2$ study applied to Rebalance: Global hydrogen for energy production




**Source:** Equinor

## $H_2$ study applied to Rebalance: Global hydrogen demand by sector




**Source:** Equinor

# Rebalance and hydrogen, cont.

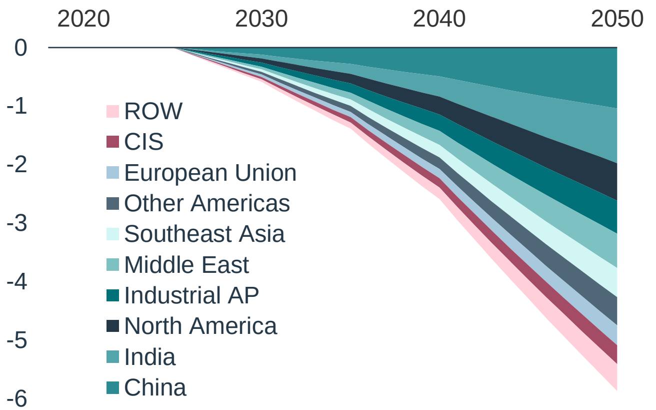
benefitting from hydrogen demand in the short term. However, from 2040 demand drops sharply. World gas demand is 482 billion cubic metres per year (Bcm/y) in our $H_2$ study, 16% lower by 2050 than in *Rebalance*. European demand is 37 Bcm/y lower, a 21% reduction.

World electricity demand growth, which is up 90% between 2018 and 2050 in *Rebalance*, increases to 133% over the same period in the $H_2$ study. This gives an additional demand compared with *Rebalance* of about 11,500 terawatt hours (TWh), or 1.6 times China's 2018 electricity use. Some fuel switching from electricity to hydrogen is assumed in certain end use sectors, but the dampening impact on electricity use from this substitution is dwarfed by the boost from green $H_2$ production. It is assumed that all green $H_2$, for energy purposes, will be produced from new renewable energy. Therefore, the $H_2$ study augments pressure on the wind and solar power industries to scale up quickly. Wind generation in the $H_2$ study needs to supply some 4,800 TWh in 2050, close to 42% additional supply compared with *Rebalance*, while solar must deliver some 7,000 TWh or 50% extra.

$H_2$´s emergence in the global fuel mix is premised on its use for $CO_2$ emission reduction. Global energy-related $CO_2$ emissions by 2050 are 6.6 Gt in the $H_2$ study as opposed to 9.4 Gt in *Rebalance*. Cumulative emissions are reduced by 30 Gt over the outlook. The study illustrates the role $H_2$ can play in an even deeper decarbonisation scenario, enabling emission reductions in hard-to-abate sectors and supporting intermittent renewables.

### Change in global oil demand, $H_2$ study vs Rebalance

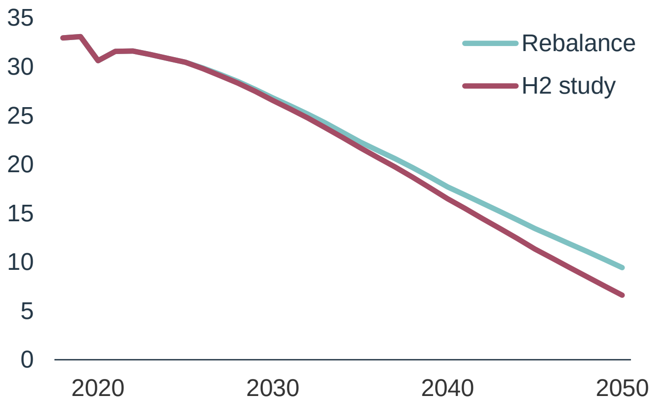
mbd




**Source**: Equinor

### World energy-related $CO_2$ emissions

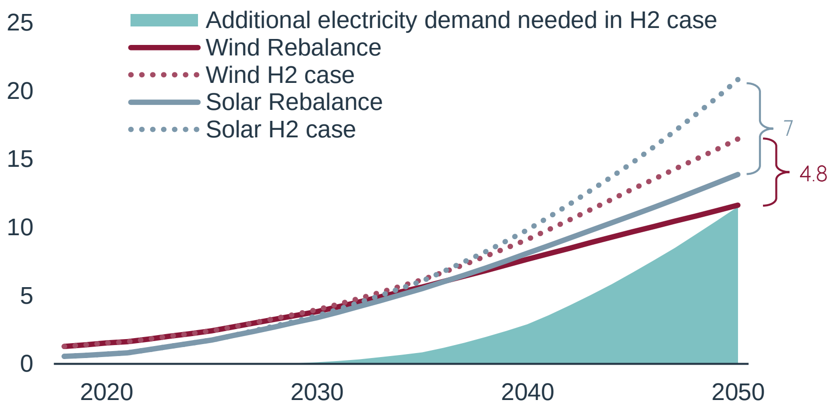
Gt




**Source:** Equinor

### Additional electricity demand in $H_2$ study vs Rebalance

Power generation (Thousand TWh)




**Source:** Equinor

# An even brighter future for carbon capture, utilisation and storage?

Carbon capture, utilisation, and storage (CCUS) remains a disputed, but probably critical tool in the global warming risk mitigation toolbox. A key message from 88 of the 90 scenarios considered by the Intergovernmental Panel on Climate Change (IPCC) for its 1.5°C report is that reducing greenhouse gas emissions to net zero will likely be impossible without CCUS, and in some cases in very large volumes. The IPCC expects bioenergy use with CCS (BECCS), which promises negative $CO_2$ emissions, to become more important than fossil fuel use with CCUS, but encourages all types of CCUS. However, sceptics continue to argue that climate change mitigation money is better spent on wind, solar and green hydrogen than on what they see as mainly a measure to extend the fossil fuel era.

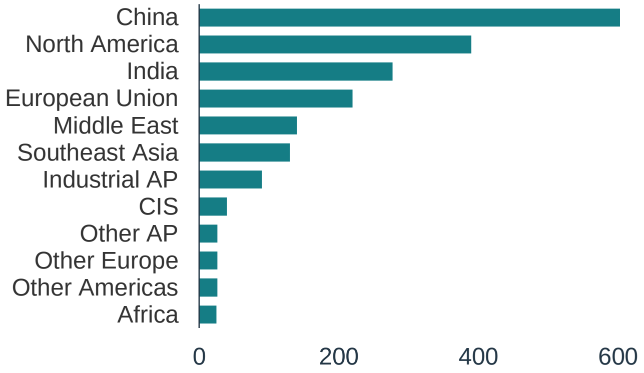
CCUS has not developed at the speed envisaged a decade ago due to high costs, limited demand for $CO_2$ outside areas with enhanced oil recovery (EOR) opportunities, feeble support from carbon pricing, unclear regulation and in some cases popular distrust. All these factors have prevented CCUS activity from scaling up and the industry from learning by doing, optimising operations and cutting costs.

Energy Perspectives has been on the conservative side on the topic of CCUS. We do not find assumptions of global $CO_2$ capture increasing to perhaps 10 Gt/y by 2050 entirely convincing, given that current capture is only about 40 Mt/y and that few existing CCUS projects would have gone forward in the absence of EOR opportunities. However, by requesting decarbonisation solutions for sectors that cannot easily electrify, the net zero target has boosted interest in CCUS and led to a string of new project announcements (more than 30 since 2017, according to the IEA) and several final investment decisions. Other positive signs are the EU Emissions Trading System (ETS) price developments, the impacts of policy measures like the US 45Q tax credit, and the efforts around hubs or clusters. In *Rebalance*, it is assumed that 2Gt/y of $CO_2$ is captured by 2050, far less than the 7.5 Gt/y required in the IEA Net Zero scenario.

In the $H_2$ sensitivity study, global CCUS increases from 2 Gt in *Rebalance*, to 3.5 Gt by 2050. Blue $H_2$ production is 150 Mt by 2050, calling for a capture of roughly 2 Gt of $CO_2$. Adding that amount to the CCUS assumed for 2050 in *Rebalance* would have given a total of 4 Gt. However, $H_2$ replaces industry and power sector fossil fuel use, replacing these sectors' need for CCUS and scaling them accordingly, from 2 Gt to about 1.4 Gt $CO_2$. Boosting global CCUS capacity some 86 times over in less than 30 years may seem a tall order, but is below average for well below 2°C and net zero scenarios.

CCUS by 2050 in Rebalance

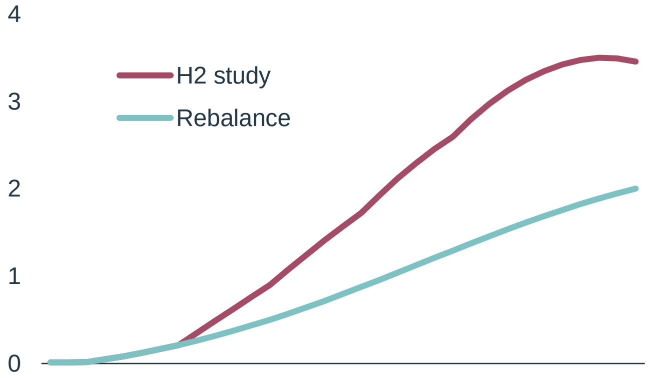
Mt $CO_2$




**Source:** Equinor

Global CCUS in Rebalance and $H_2$ study

Gt $CO_2$




**Source:** Equinor


Photo by James Wainscoat on Unsplash

# In detail

# The circular economy – key to sustainability?

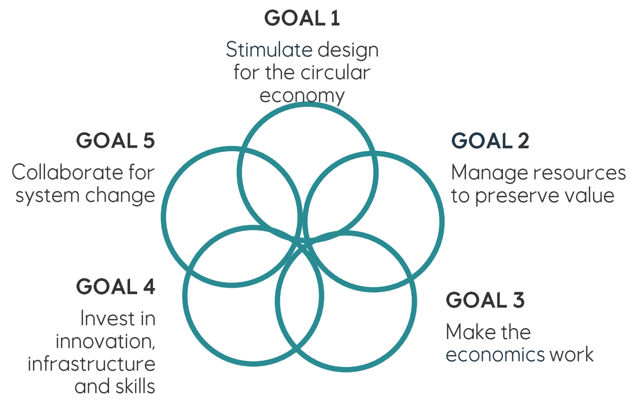
A circular economy (CE) is a system that is restorative or regenerative by intention and design. The CE model aims to optimise the use of limited resources and minimise emissions to the environment through product processes and system innovation. Compared with today's linear model it uses and reuses natural resources as efficiently as possible, finding value during the life cycles of products. A CE is underpinned by three principles: eliminate waste and pollution, keep products and materials in use, and regenerate natural systems.

Economic growth often refers to the growth in the productive capacity of goods and services, measured in terms of change in GDP. Technological development is one of the main sources of economic growth. In a circular business model, this can translate into innovative ideas on how to make products as efficiently as possible. In order to achieve sustainable growth, the environmental impact of natural resources needs to be decoupled from economic growth. The current linear economy generates significant negative externalities. Internalising such cost and finding a solution within the market mechanisms, such as setting a price on pollution, can represent a powerful incentive to realise a CE. It is important to set a transparent price for negative externalities to show who bears the costs with regards to society, environment and health.

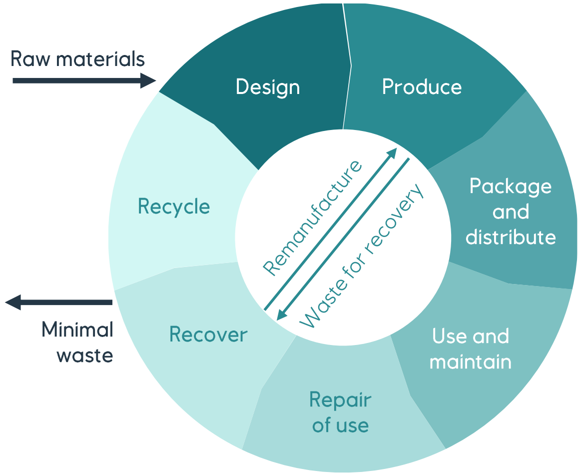
CE is a system solution framework that contributes to the delivery of the United Nations' Sustainable Development Goals. Global policymakers hold a crucial role in enabling the needed transition to scale. The Covid-19 crisis has spurred unprecedented fiscal spending and more aid will likely be needed to re-establish growth. As support is shifted from emergency to recovery, further fiscal aid should aim at an economic framework in line with CE principles to promote the transition. However, most of the increased public spending over the last year is set to flow into existing sectors, rather than attempt to support a path of long-term sustainability and resilience.

Coordinated fiscal measures are needed to support the transition, as they affect and provide investors, businesses and consumers with incentives their to change behaviour. Tools that can be deployed include targeted taxation, subsidies to promote future areas of growth and employment in specific sectors and incorporating CE into trade policies. The Ellen MacArthur Foundation presents five universal complementary CE policy goals for governments and businesses to achieve their common objectives. The CE transition faces impediments, such as regulatory barriers, that can be overcome with the aid of comprehensive policy goals and cooperation.

## The circular economy




**Source:** Adapted from Ellen MacArthur Foundation Universal Circular Economy Policy Goals, 2021




**Source:** Adapted by University of Cambridge Institute for Sustainability Leadership from Ellen MacArthur Foundation, 2019

# The road ahead for plastics – from linear to circular

Modern human consumption has evolved hand in hand with the development of the plastics industry. From food packaging to wind blades, plastics utilisation continues to expand, owing to the qualities that the material offers: it is light, durable, resistant and cost competitive. Plastics demand increased by 4% annually over the last 10 years. However, it also creates environmental challenges, which have alarmed civil societies and governments. While recycling offers some solutions to reducing plastic waste, current global recycling rates stand at 5-10%. Scaling up is proving challenging.

In order to curb plastics consumption and increase recycling, governments in Europe have imposed certain measures. For example, some plastic items have been banned, recycled content in packaging has been increased, collection targets have been agreed, and taxes on plastics dumped in landfills have been introduced. These policies have borne fruit – in the EU, plastic demand is declining, and plastic waste dumped in landfills decreased by 44% between 2006 and 2018. Recycling rates also improved, but they still account for barely 5% of what is consumed yearly. The EU aims to double this to 10% by 2025, but there are significant barriers ahead to achieving this target.

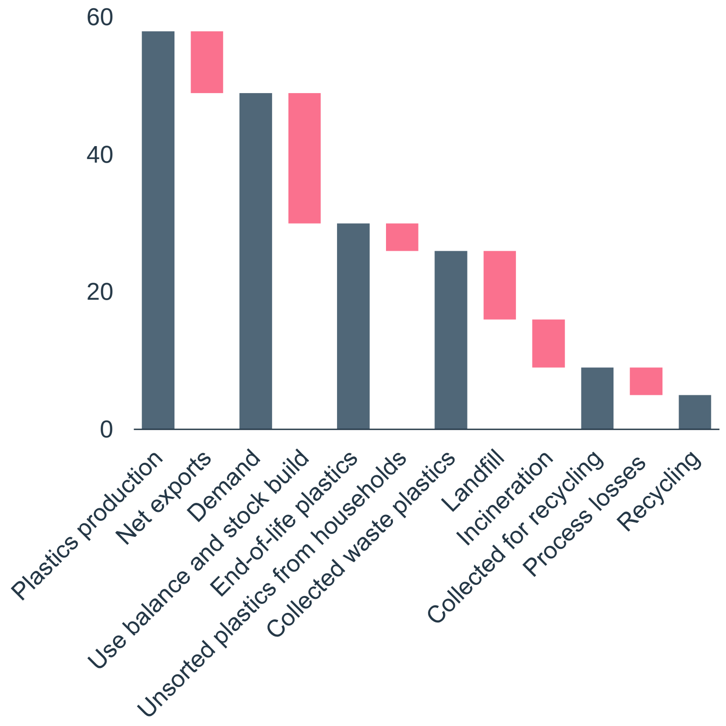
Mechanical recycling accounts for almost all plastic recycling. While the process is mature and simple, it is constrained by plastic waste collection rates. These rates are negatively impacted by the presence of contaminants and multilayering of materials.

A potential new route that can lead to higher recycling rates is chemical recycling. It can process virtually all kinds of plastics, meaning waste supply could be significantly higher. The process yields a type of oil, which can be reintroduced into the plastic value chain as feedstock for petrochemical units or co-processed in refineries to produce transportation fuel. Chemical recycling is currently in its infancy, undergoing technical evaluation before it potentially can achieve industrial scale.

There is no silver bullet to fix the problem of low recycling rates, but governments and companies must work together to increase rates of waste collection, improve plastic waste recyclability and mature chemical recycling technologies. In *Reform,* recycled plastics demand will grow faster than for virgin plastics. However, the share is estimated to grow to only 10-15% by 2040 and the impact on oil feedstock demand will be marginal. On the other hand, under a *Rebalance* scenario, with a recycling rate of 30-40%, oil feedstock demand growth will be placed under pressure.

Post consumption breakdown of plastics in Europe, 2015

Mt per year




**Source:** PlasticsEurope

# Bioenergy

Bioenergy has a longer history in the global fuel mix than any other energy carrier. People heated their homes and cooked their food on wood for millennia until fossil fuels and electricity became available. Traditional bioenergy use on a large scale is unsustainable, due to the prevalence of ineffective devices associated with high pollution and fuelwood becoming a scarce resource. By contrast, modern bioenergy is widely considered essential, in addition to being pursued for local environmental and energy diversification reasons.

Both the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA) assume growth in modern bioenergy supply and demand. In IEA's Sustainable Development Scenario (SDS), the modern bioenergy share of world total final energy consumption (TFC) increases from 4% in 2018 to 11% by 2040. In IEA's Net-Zero Emission by 2050 Scenario (NZE), the share of bioenergy reaches 19% in 2050 and the share of bioenergy in world power generation triples from 2 to 6%. IRENA sees the modern bioenergy share of world TFC hitting 18% by 2050.

Bioenergy is a carbon neutral option. When fuels from plants are burned, $CO_2$ is released. When the plants regrow, they soak up $CO_2$ from the air so that carbon released is eventually matched by carbon re-absorbed.

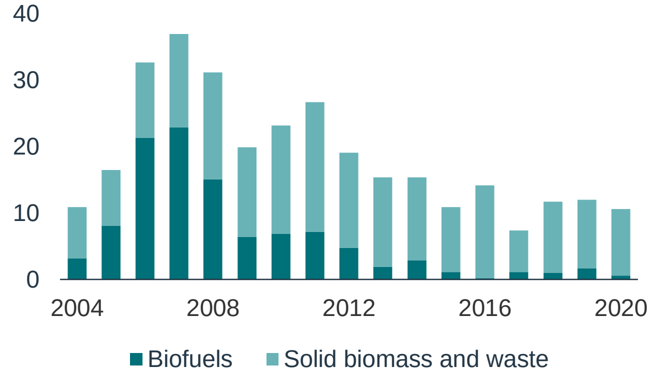
However, it may take too long for the harvested biomass to grow back, so that the balance between $CO_2$ released and $CO_2$ reabsorbed becomes irrelevant. It is possible to replace harvested vegetation by fast growing trees or grass, but these are often less able to hold carbon than the original species.

Other well-known problems with bioenergy production are that it may crowd out food supply, harm biodiversity and require a significant amount of land. In the three IPCC "Illustrative pathways to net zero emissions" that rely on bioenergy with carbon capture, utilisation and storage, the areas reserved for this purpose by 2050 vary from 0.93 million km$^2$ (equivalent to the landmass of Nigeria) to 7.24 million km$^2$ (Australia). So-called 2$^{nd}$ and 3$^{rd}$ generation biomass (e.g. forest and agricultural residue, organic waste, and algae) represent costly alternatives to extensive land use.

Investment in bioenergy peaked in 2007. Since then, investor interest in liquid biofuels has cooled. The ongoing adoption of more aggressive emission reduction targets could change this. In both *Reform* and *Rebalance* bioenergy consumption increases by 20-21% between 2018 and 2050. Demand peaks in the mid-2040s. *Rivalry* sees an increase of 34%, with bioenergy benefitting from the supply security concerns co-driving this scenario.

## Global investment in biofuels, biomass and waste

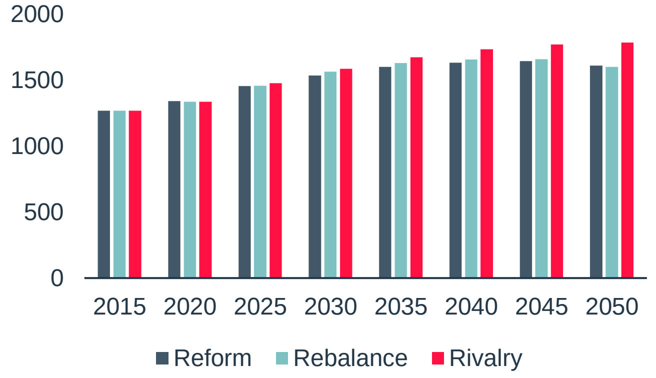
USD billion




**Source:** BNEF

## Bioenergy supply and demand

Mtoe




**Source:** IEA, Equinor

# Oil supply in light of the pandemic and an energy transition

The demand disruption caused by Covid-19 will be felt by the oil industry for many years to come. However, a major long-term challenge will be production capacity growth, due to significant investment cutbacks.

Upstream investment in 2020 was almost a third lower than in 2019 and projections for 2021 are only marginally higher than 2020. Conservative oil price forecasts and reduced access to financing suggest investments in oil will remain subdued.

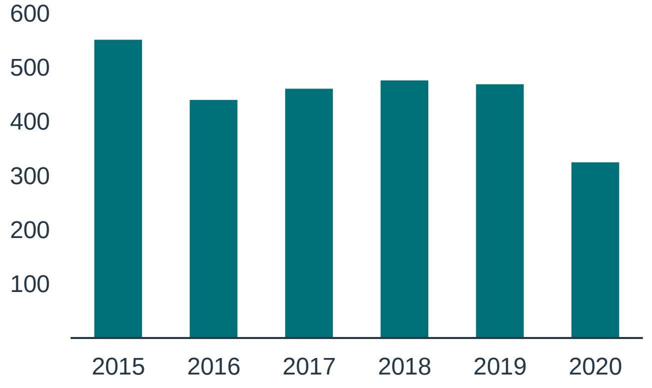
As a result of pandemic demand destruction, at the time of writing there is around 9 mbd of spare production capacity. This will keep markets sufficiently supplied for the next few years, even as demand gathers pace. However, without new investments in oil fields, the natural decline from existing fields will be around 5% from 2040-2050, based on data from Wood Mackenzie. Expectations of a quick rebound and strong economic growth in key markets such as Asia would signal a supply crunch over the medium term. The US has provided some of the fastest production growth to date**.** While US output is likely to grow as prices rise and investment picks up, production levels may not return to the dizzying heights of yesteryear. Instead, Gulf States will be forced to take on the burden of both production and maintaining spare capacity to meet future demand. Saudi Arabia, the UAE, Kuwait and Iraq, with relatively lower-cost barrels, will be required to turn on the taps at near all-time highs.

Along with financial distress comes the pressure on transitioning to a low carbon future. This presents both threats and opportunities to key producer states, especially those in Opec+ that are likely to continue providing more than 50% of the world's oil. By far the grandest ambitions come from the UAE, which seeks to grow production capacity by over 25% by 2030. The UAE's ambitions of becoming a leading player in the energy transition as well as in oil and gas production may create tensions within Opec. Competing strategies and bids to capture market share could rupture internal unity. Outside of core Opec, production from Russia, Brazil, Norway and Guyana will not be anywhere near enough to offset declines elsewhere.

In the short term, ample supply and lower oil prices are likely to drive international oil companies (IOCs) to prioritise enhanced recovery projects of existing fields and near infrastructure-led exploration over frontier exploration. A stronger focus on producing volumes with a lower carbon intensity to meet climate ambitions will likely result in undeveloped discoveries remaining in the ground.

## Upstream investment spending

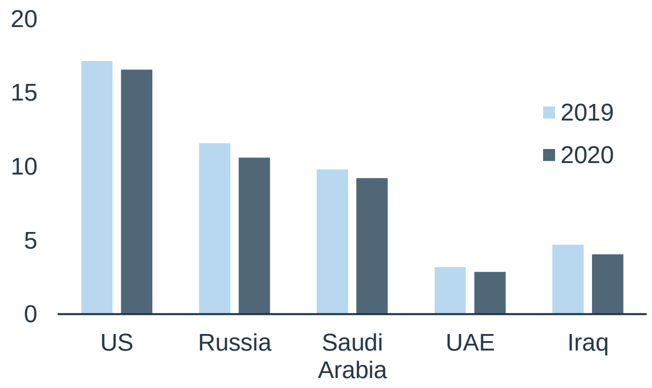
Real USD billion




**Source:** IEA

## Oil production

mbd




**Source:** IEA

## The future of aviation fuels is up in the air

Aviation has been severely hit by the Covid-19 pandemic, with global jet fuel demand falling by as much as 43% in 2020 and 24% in 2021 so far, compared with 2019. As international flights are constrained by rigid travel restrictions, many analysts forecast air transportation demand not to return to pre-pandemic levels for several years. Targets of net zero emissions by 2050 will be an additional challenge to an already struggling industry. Compared with road and maritime transportation, air travel is the furthest from having feasible and scalable technologies in place for full decarbonisation, and the crisis that has hit the sector is a threat to their potential development.

Current solutions, such as increased operational efficiency, efficient engines, and carbon offsetting mechanisms, have provided some support. However, aviation is still far from meeting carbon emission reduction targets. Significant structural changes and investments will be needed. Alternative propulsion used in other industries, such as electricity or hydrogen, could become a longer-term option, but physical and logistical challenges currently limit their potential. Power-to-liquid synthetic fuel derived from hydrogen ($H_2$) and captured emissions could provide a further option; however, green $H_2$ and direct air capture costs are a long way from making this economically viable.

The refining industry is currently investing in production of sustainable aviation fuel (SAF). This biofuel leads to a reduction in emissions of 70-100% on a life-cycle basis. Despite being significantly more expensive than kerosene and with challenges such as limited feedstocks, lagging supply chain and environmental risks, SAF is the most promising and mature option in the near term. Targeted regulations and incentives from policymakers, investments from financial institutions and collaboration between suppliers and the aviation industry will be needed to make it scalable. In the meantime, the underlying demand for air travel will probably increase as economies return to growth, especially in Asia.

## Maritime – sailing into uncharted waters

Shipping represents 3% of the global energy-related carbon emissions. A combination of innovation, policy and investment are likely to accelerate the maritime energy transition, paving the way for future carbon efficiency in the industry.

The path towards decarbonisation will be long and can be seen as a two-stage process towards 2050. In the first stage, over the short to medium term, shipowners may focus on operational efficiency measures rather than new technological solutions to comply with regulations. This would involve use of low carbon bunker fuels, speed reduction and/or carbon offsetting mechanisms. Technical improvements, such as retrofits, hull modifications or propeller upgrades, may be too expensive for the remaining economic life of vessels. Old vessels will not be competitive enough despite operational efforts. It is therefore expected that scrapping numbers will rise if and when the International Maritime Organization's (IMO's) regulations come into force for most segments around 2023. This will then tighten availability of tonnage and push up freight rates.

For bunker fuel, it is likely that the fuel mix will be diversified, moving from fuel blending of very low sulphur fuel oil (VLSFO) with biofuels to liquefied petroleum gas (LPG), methanol, or liquefied natural gas (LNG). LNG appears to be the most accepted fuel choice today, given its availability, maturity of technology, energy density, infrastructure, and price. However, it is worth noting that the use of LNG, as well as biofuels, is transitional and comes with its own challenges, such as methane slippage.

Over the longer term, alongside the use of LNG and LPG, blue and green ammonia might mature and become commercially viable as low carbon fuels. Manufacturers aim to have commercially viable engines that can run efficiently on ammonia by 2025. These types of developments, in addition to retrofits and other technical innovations, could contribute to the adoption of new fuels and an increase in ship orders by 2030.

# Norway – an EV rise to be replicated

The electric vehicle (EV) revolution is progressing rapidly in Norway. The Norwegian electric vehicle association, "Norsk elbilforening", reports that 75% of all new passenger cars sold in Norway in 2020 were battery or plug-in hybrid EVs and expects further growth in 2021. Norwegians seeing Leafs and Teslas on every street could be tempted to conclude that EVs are ubiquitous. This is far from being the case. Globally 4.6% of passenger cars sold in 2020 were battery or plug-in hybrid EVs, and about 1% of the car stock was electric.

This is not to say that EV sales are not making rapid progress elsewhere. Between 2015 and 2020 the global EV stock grew from 1.3 million to 10.1 million, an average increase of 51% per year. China is in the lead with an EV fleet of about 4.5 million. Last year, however, the highest sales were in Europe. BloombergNEF reported that in 4th quarter 2020 more than 15% of new cars sold in Europe were electric. The pandemic has hit gasoline and diesel car sales, but largely spared the EV market.

Car manufacturers are churning out new EV models. Last year, buyers had dozens of brands and 370 models to choose from, representing a 40% increase on 2019. Moreover, 55% of new models put on the market in 2020 were SUVs, the fastest growing segment of the vehicle market and the dominant type of car in the US. To an extent, this growth reflects car manufacturers' need to meet obligated average emission standards, but the effect is production cost reductions and technological advances making EVs more enticing to buyers.

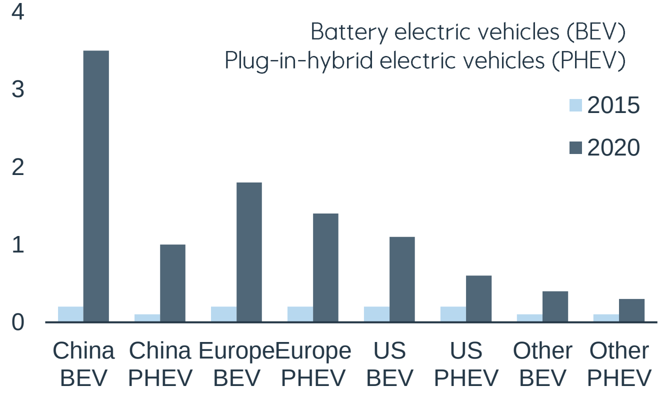
EV enthusiasts often present Norwegian EV sales as proof of how fast car fleets can be electrified. The numbers in Norway speak for themselves, but few countries could replicate these support schemes. These include, among other things, exemption from the world's highest import taxes, VAT, road tolls and municipal parking fees, all on top of Norway's comparatively low electricity prices. It is estimated that the implicit $CO_2$-abatement cost is NOK 10-15,000/t (USD 1,200-1,800/t). Low speed limits and the fact that most Norwegians can charge their cars overnight are also beneficial. Moreover, for countries which unlike Norway still generate high shares of their power from fossil fuels, fast-tracking road transport electrification could have unintended consequences for overall emissions.

Battery and car manufacturers believe that while public support was essential for the explosive growth in the EV share of the Norwegian car fleet, EV penetration is on the verge of becoming self-sustaining. EVs will eventually become competitive on costs without subsidies, whilst range and charging concerns are abating.

equinor

## Electric passenger car stocks, 2015 and 2020

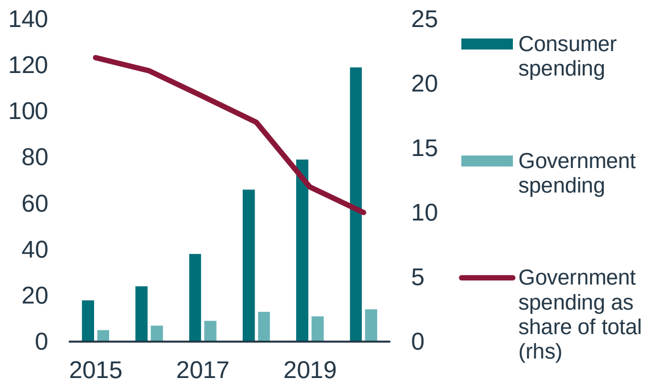
Million




**Source:** IEA Global EV Outlook 2021

## Global spending on EVs

USD billion (lfh), % (rhs)




**Source:** IEA Global EV Outlook 2021

# Expectations for wind and solar photovoltaic cells (PV)

Wind and solar PV power generation growth has been, and will likely remain, a locomotive of the energy transition. In 2019 wind and solar PV power generators including rooftop solar panels as well as utility scale plants, accounted for 8% of the global power supply. Wind and solar PV contributed almost a third of the growth in global power supply between 2010 and 2019. This is significantly more than any single fossil fuel, and the pandemic has not slowed growth in wind and solar PV capacities. According to IRENA, the world added almost twice as much wind capacity, and 30% more solar PV capacity, in 2020 compared with 2019.

The wind and solar PV power success stories reflect plummeting costs. Policy support in the early years provided economies of scale, competition, learning and technology refinement. Lazard, an investment bank specialising in levelised cost of electricity (LCOE) analysis, puts the declines between 2009 and 2020 in the average LCOEs of wind and solar PV at 71% and 90% respectively. Lazard estimates the lowest cost onshore wind power available globally, to be cheaper than any other power available. Also, the costs of utility scale solar PV power have declined below the costs of non-renewable power.

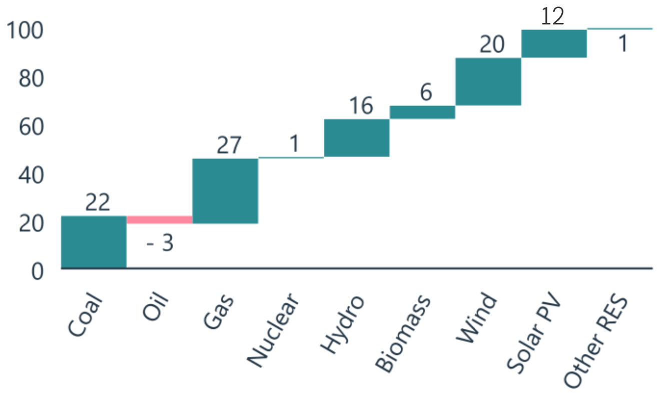
The next cost threshold for wind and solar PV to aim for is competitiveness with depreciated fossil and nuclear power plants with respect to operating, fuel and carbon cost basis. Lazard puts these costs at about USD 30 per megawatt hour (MWh) for combined cycle gas turbine gas (CCGT) and nuclear plants and USD 40 per MWh for coal plants. Cheap onshore wind power is already at this level.

Wind and solar PV power is widely expected to become even cheaper. IHS suggests for Western Europe scopes for further LCOE declines between 2020 and 2050 of 40-60% for solar PV, 25-40% for onshore wind and 50-60% for offshore wind.

Favourable LCOEs suggest that wind and solar PV could come to dominate electricity supply. The challenges of fitting variable power into total supply are small in the beginning, but may increase exponentially as the ratio of variable to total power passes approximately 60 to 70%. Grid stability may suffer and the problem of negative prices in periods of wind and solar oversupply, call for an overhaul of electricity market design. Some countries can import or export their way out of imbalances, others cannot. Electricity storage is assumed to be the most promising solution, with grid-scale batteries coming to the forefront of the power industry's attention.

Individual generation technologies' shares of growth in global power supply, 2010-19

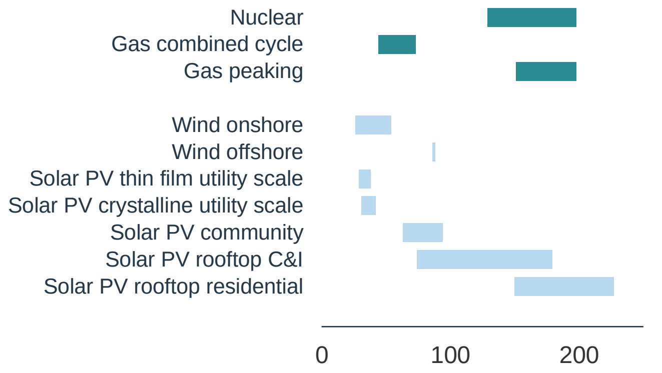
%




**Source**: IEA

Estimated levelised cost of electricity ranges, 2020

USD/MWh




**Source:** Lazard

# What about other new renewables?

The known giants of new renewables are wind turbines and solar photovoltaic (PV) panels. However, two other technologies could also play a part towards global clean energy goals.

Tidal power converts energy obtained from tides into electricity. It requires tides that are either strong (tidal stream) or have a high differential between low and high tide (tidal barrage or lagoon). Although intermittent, tides are highly predictable, contributing to grid stability.

Concentrated solar power (CSP) technologies use mirrors to concentrate a large area of sunlight onto a receiver to produce heat. The heat is used to create steam, which drives a turbine to generate electricity or is used directly in industrial processes.

Although based on different energy sources, tidal power and CSP share several characteristics. Both are dependent on a geography where the technologies can maximise the conversion of tidal flows or direct solar radiation. Secondly, like many renewable energy sources, tidal power and CSP have large up-front capital costs, but relatively low operation and maintenance costs. Projects require bespoke solutions for the geographies they are in, making it hard to benefit from cost reductions driven by standardisation.

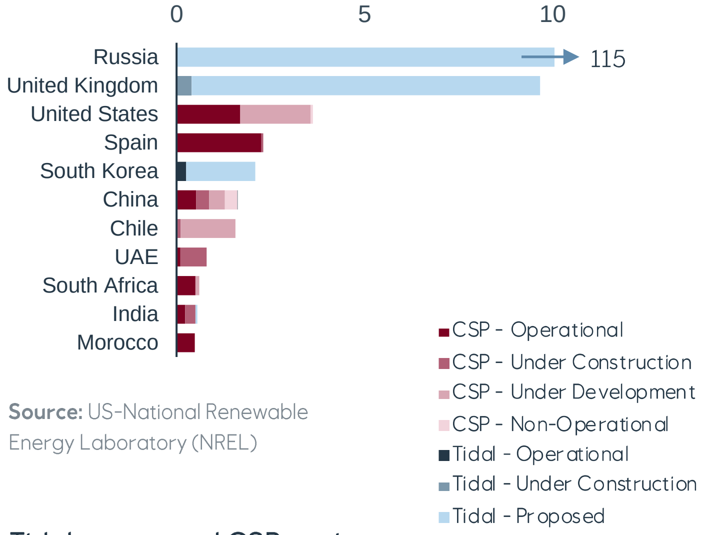
Demand for baseload power production or storage technologies is rising, as the share of intermittent wind and solar PV increases in a power system. Uniquely, tidal power and CSP typically incorporate an element of physical energy storage (water or heat), allowing for dispatchable energy. Intra-day storage is up to 12 hours for tidal power and 18 hours for CSP. This can serve as an attractive alternative to baseload resources as well as a substitute to battery storage.

The Cerro Dominador solar power plant, adjacent to a vast mining area in Northern Chile, is an example of how CSP can be cost competitive. The plant comprises 100 megawatt (MW) of PV capacity and an additional 110 MW of CSP capacity, utilising the combined strengths of two solar technologies. Such combinations could decarbonise energy intensive operations like copper and lithium mining – crucial elements for electrification. Similarly, the cost of a tidal power range or lagoon may be offset by secondary benefits, including flood and natural ecosystem protection.

Tidal power and CSP are dispatchable and predictable forms of renewable technologies. They may not move the needle on a global scale, but with the right government incentives, they could help countries reach clean energy goals.

## Capacity

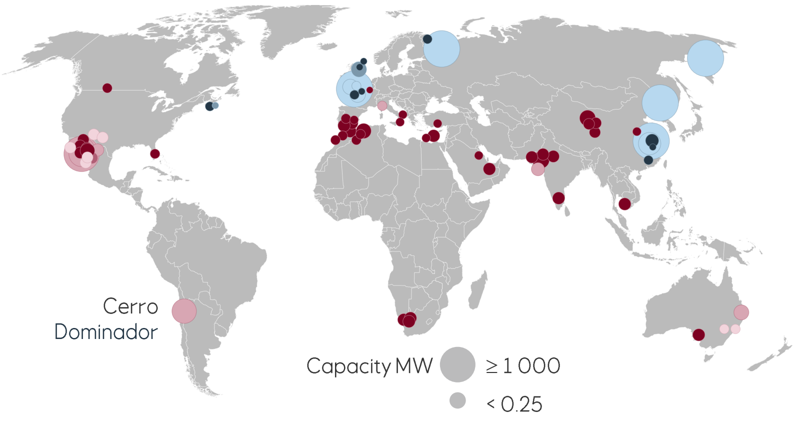
GW




**Source:** US-National Renewable Energy Laboratory (NREL)

## Tidal power and CSP projects

In operation, under construction and under development




**Source:** US-National Renewable Energy Laboratory (NREL)

# Electricity storage remains a massive challenge

As power systems decarbonise, the retirement of existing thermal capacity, growth of intermittent renewable generation, and electrification of new sectors increases the need for sources of system flexibility. Utility scale storage is one source of flexibility that can help manage and balance the system, providing a backup for intermittent generation and ancillary services traditionally offered by thermal generation. Historically, pumped hydro storage has been used in this role. However, lower investment costs, shorter lead times and environmental considerations have seen lithium-ion batteries emerge as the dominant new storage technology.

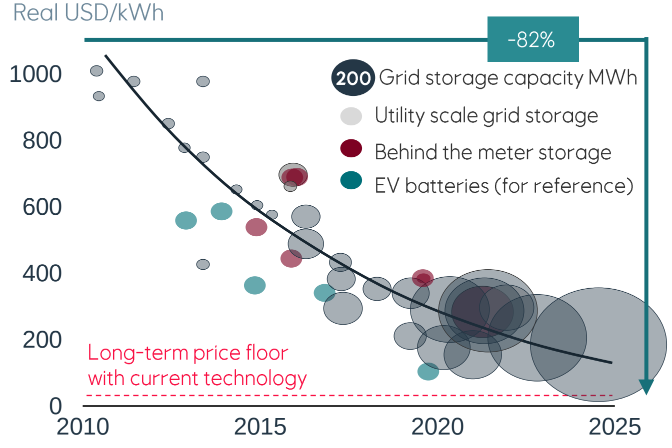
The pace of battery storage development will be driven by the rate of electrification, decommissioning of thermal plants and the emergence of other forms of flexibility, such as demand side management, while requiring the emergence of a market design supporting such a development. While lithium-ion may be the front runner, there are a wide range of storage technologies with different characteristics available. Each of them is appropriate for different costs, capacities, discharge rates and storage duration requirements. Demand side management and increased interconnectivity, allowing for easy transfer of electricity between regions, are other possibilities.

BNEF reports additions of 5.3 gigawatt (GW) of behind-the-meter and utility scale capacity during 2020, up 56% on 2019 additions. Despite high growth, absolute installed capacity is still low. Battery growth in 2020 is on the low side, when compared with offshore wind capacity growth of 6 GW. The car industry's instalment of batteries in electric vehicles (EV) comes in addition. Lithium-ion batteries dominate the utility scale market, supplying 92% of demand in 2020. The costs of batteries have, like those of wind and solar PV generation, fallen dramatically in recent years. BNEF reports the average levelised cost of electricity (LCOE) from utility scale batteries at USD 150 per megawatt hour (MWh) by 1st half 2020 , down from USD 803/MWh by 2nd half 2012. These estimates include charging costs. IHS provides a range of estimates for the US which broadly supports BNEF's average, putting the current LCOE at between USD 114/MWh for 8 hours of supply from a 50 MW facility and USD 289/MWh for 1 hour of supply from a 5 MW facility. IHS foresees further declines in utility scale battery costs of 40-45% over the period to 2050.

In terms of large-scale battery storage development, China and the US are leading the way with 2020 seeing record deployment. In Europe, the UK was the largest market for utility scale development.

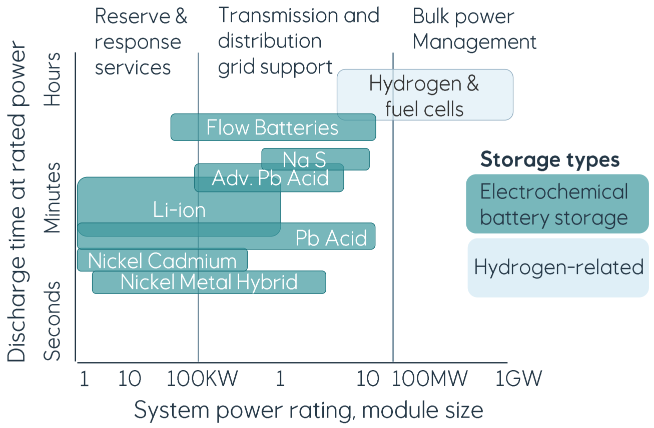
## Capital cost development battery storage

Real USD/kWh




**Source:** Adapted from Rystad Energy

## Electrochemical and hydrogen related storage




**Source:** Adapted from gov.uk

# The net zero target

The Paris Agreement committed signatories to reduce their greenhouse gas (GHG) emissions to levels compatible with a 2°C cap on global warming and aim to keep warming at 1.5°C. In 2015, there was no clear understanding of the emission pathways compatible with the 1.5°C target. Recent research has filled that information gap. Global energy-related $CO_2$ emissions should be net zero by the middle of the century, with total greenhouse gas emissions reaching net zero during the 2060s or early 2070s. To get to net zero, remaining emissions from agriculture, industry and transport that cannot be prevented from entering the atmosphere must be removed.

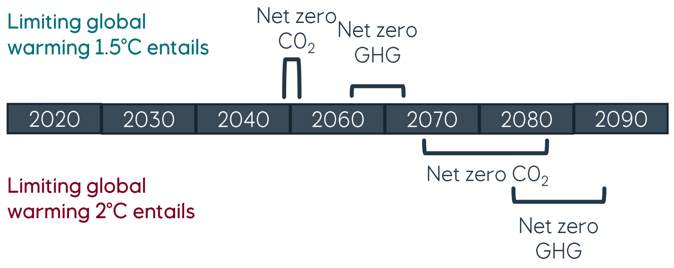
The net zero concept suggests a range of global warming mitigation options. Ranging from slashing emissions now to avoid the need for as of yet speculative GHG removal technologies, to cutting emissions at a more lenient pace in anticipation of extensive use of removal technologies in the latter half of the century. IPCC's "Illustrative pathways" highlight this trade-off.

Many countries and companies aim for net zero status around the middle of the century, although it is not always clear whether they refer to $CO_2$ or total GHG emissions, and few have published intermediate targets or details about how they intend to get to net zero. There is broad agreement on what needs to be done to cut emissions, but uncertainty about the merits of individual carbon removal or negative emission technologies.

The cheapest way of removing $CO_2$ from the atmosphere is to prevent deforestation and grow new forests. More costly options are bioenergy combined with carbon capture and storage (BECCS) and direct air capture (DAC), which involves pushing ambient air past a solvent absorbing the $CO_2$ and then storing the carbon.

Forestation projects are feasible at today's moderate carbon prices and therefore important to many countries or industries' net zero plans. However, they can have issues regarding measurement, verification and additionality. BECCS is controversial for the same reasons as bioenergy is controversial, with the alleged carbon neutrality of burning biomass open to question. DAC is very energy intensive and very expensive. Although both technologies have been proven to work, neither has been tested at scale. By contrast, cutting $CO_2$ emissions at the paces suggested by IPCC's illustrative pathways P1 or P2 seems at least equally challenging, so the options may be more limited than the public likes to believe.

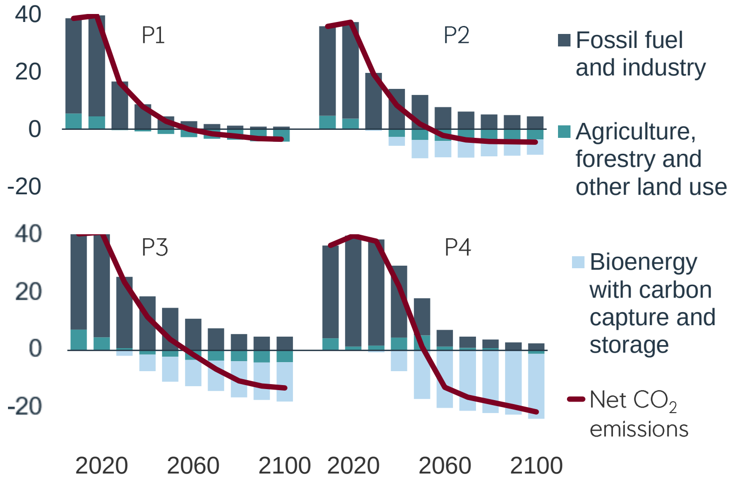
### Global timeline to reach net zero emissions




**Source:** Adapted from the World Resources Institute

### Illustrative pathways to net zero emissions

Billion Gt $CO_2$ per year




**Source:** Adapted from IPCC Special Report on Global Warming of 1.5°C

# Rebalance and net zero

*Rebalance* is far from qualifying as a "global net zero by 2050" scenario. It shows world energy-related $CO_2$ emissions declining by some 73% between 2018 and 2050, to about 9.4 gigatonnes (Gt). This would be a remarkable achievement, but requires significant emissions offsetting to be considered net zero. Nature-based solutions, bioenergy with carbon capture and storage (BECCS), and direct air capture (DAC) would be needed to offset remaining emissions.

Some of the academic scenarios relied on by the IPCC foresee negative emissions on an even bigger scale. "Illustrative pathway P4" (ref. chart on the previous page) suggests a scope for neutralising more than 15 Gt of $CO_2$ emissions per year by 2050. However, these scenarios are outliers. There are plenty of warnings against relying on options that remain controversial and technologies that remain speculative.

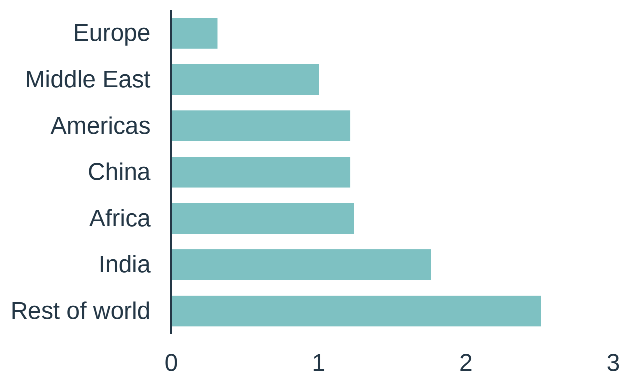
Regions with the highest decarbonisation ambitions and most favourable starting points could get to net zero in *Rebalance* by 2050. North America, EU and Industrialised Asia Pacific emit 0.57, 0.18 and 0.23 Gt of $CO_2$ respectively by 2050. Their combined emissions of 0.97 Gt (after CCUS is taken into account), down 92% between 2018 and 2050, could feasibly be offset through nature-based solutions. If clean hydrogen becomes a fuel option, even bigger emission reductions might be possible, further narrowing the gap to net zero.

The main constraints on the scope for executing carbon removal projects are the land requirements for growing or regrowing forests, and for BECCS and DAC, the high costs of CCUS. The absence of incentives to take on these costs has stopped many fossil fuel linked CCUS projects. There is available area that could be used for growing forests, but there may be biodiversity, social and other concerns complicating execution. In addition, most of these opportunities are in the tropics, not in the developed north, calling for a standardising of global offset markets. As far as CCUS is concerned, this will be used for industry, and power plants requiring solutions for their emissions. BECCS and DAC will come in addition to, not as a substitute for, CCUS.

China, which in *Rebalance* emits 1.5 Gt of $CO_2$ by 2050, has committed to net zero by 2060. It is another likely contender for investment in nature-based solutions as well as BECCS and DAC. Assuming that global decarbonisation pressure sustains, other regions are likely to join the race. There is little disagreement that the world needs to move towards net zero GHG emissions as quickly as possible, but the feasibility of the 2050 deadline remains as hard to assess as ever.

### Rebalance: Energy-related $CO_2$ emissions with CCS in 2050

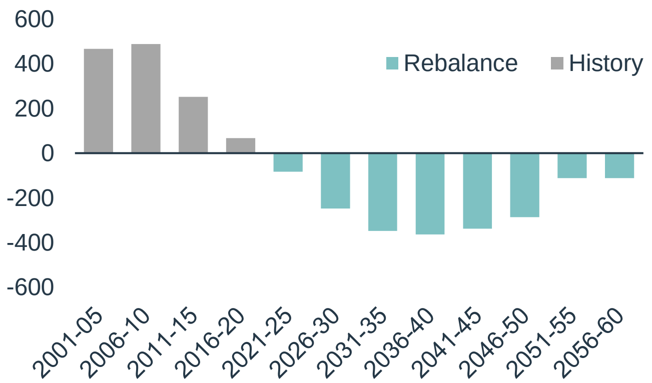
Gt




**Source:** Equinor projections

### Average annual changes in $CO_2$ emissions, China

Mt




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

# Rare earth minerals and other resource requirements

The pace of the energy transition may be constrained by the variability of wind and solar photovoltaic (PV) power, or by electricity prices failing to provide adequate investment signals. However, another risk is the shortage of metals and minerals that are essential for growth in new renewable energy supply. According to the IEA's Stated Policies Scenario, world mineral demand for clean energy technologies is likely to double by 2040.

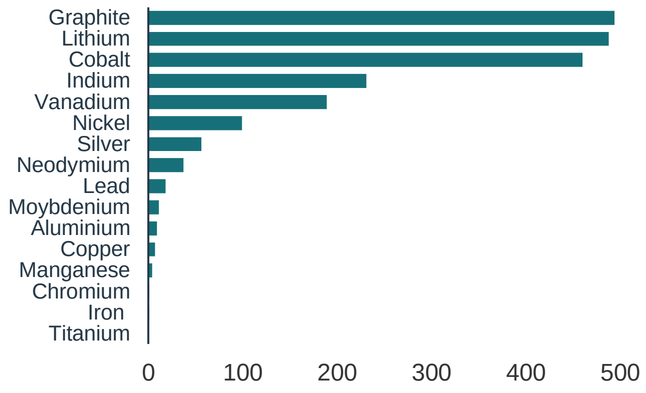
Copper is fundamental for future electricity demand needs as a conductor. Metals such as lithium, cobalt and nickel give batteries greater charging performance and increased energy density. Rare earth elements such as neodymium make powerful magnets that are vital components of wind turbines and electric vehicles (EVs). The IEA notes that an EV uses six times more minerals than a conventional vehicle, and an onshore wind plant uses nine times more minerals than a gas-fired power plant.

The United States Geological Survey puts the global reserves to production ratios for rare earth minerals, graphite and lithium at 500, 291 and 256 years respectively, and those of cobalt and copper at 51 and 44 years respectively. However, energy sector demand for select metals is expected to grow rapidly to support the energy transition and therefore proven reserves, mining and processing capacities could come under pressure in the relatively near future. If cobalt production increases fivefold, R/P falls to 10 years. Wood Mackenzie estimates that annual additions to the global supply of lithium and cobalt will need to be almost 700% and 500% bigger in the 2021-26 period than they were as recently as in the mid-2000s. The World Bank, looking further ahead, estimates that energy sector demand for graphite, lithium and cobalt by 2050 in IEA's and IRENA's 2°C scenarios could be close to five times current production levels. Developing new mines and processing facilities takes time, suggesting a risk for at least temporary supply-demand mismatches and price volatility.

Observers are worried by the fact that in some metals and minerals markets, single countries wield significant market power. Cobalt supply is dominated by the Democratic Republic of Congo, a poor country with a record of instability and poor labour legislation. Rare earths supply is almost as heavily weighted towards China, a country currently waging a trade war with the US. Oligopolistic supply may be a problem not only for geopolitical reasons, as Covid-19 has demonstrated. Three-quarters of world platinum comes from South Africa, when mines were locked down because of the pandemic the impact was felt around the world.

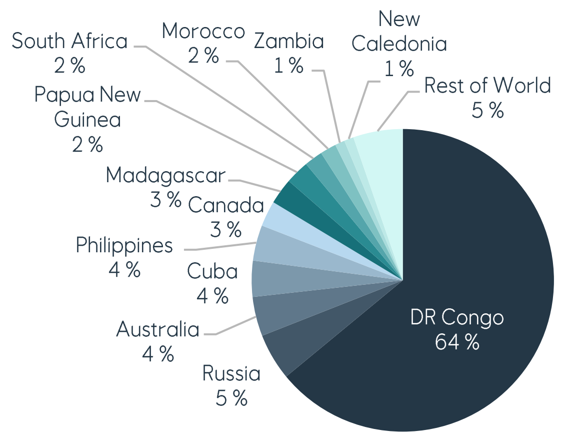
### Projected energy sector demand for select minerals by 2050 in 2°C scenarios

% of production in 2018




**Source:** World Bank

### Split of cobalt production per country




**Source:** Thunder Said Energy

# Putting a price on carbon

Putting a price on carbon is a cost-effective way to incentive reduction in $CO_2$ emissions. Carbon prices, either through emissions trading systems or carbon taxes, make the polluters pay. They encourage consumers and firms to look for solutions with lower emissions and raise public revenues. In 2019, governments raised more than USD 45 billion from carbon pricing, which could finance public spending in general or be used on climate change related investments such as protection from flooding and reforestation.

The concept of carbon pricing has also met resistance. When companies can pass on the costs of taxes to the consumers, the heaviest burden for climate change regulation costs often falls on lower income groups, as necessities like energy take up a larger part of their budget, compared with the rich. Such problems of regressive taxation can be resolved by transfer payments, such as reducing the payroll tax for lower income groups to make a carbon tax fairer.

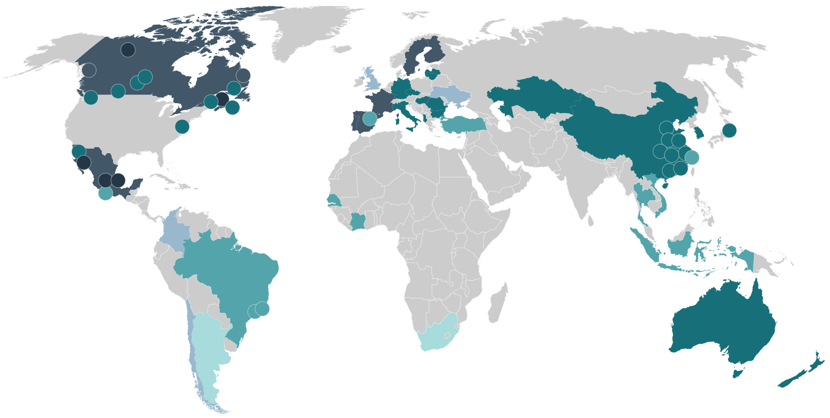
Another challenge is the risk that $CO_2$-emitting industries, like steel, move their production to regions without carbon pricing, to save taxes. To avoid such "leakage" of $CO_2$ emissions, a country or supranational union, like the EU, could introduce carbon border taxes on imported products. Hence, industries, both inside and outside of the carbon pricing region, would have incentives to reduce their $CO_2$ emissions to maintain or strengthen their market position.

Some fundamental critiques of carbon pricing point to climate change being a system problem, rather than a market failure. Successful policies will have to address fundamental changes within sectors like energy, mobility, food, and industrial production. Some argue that carbon pricing should not be the primary policy strategy, as many levers will need to be pulled and aligned (e.g. innovations and decommissioning of existing technologies).

Despite this, carbon pricing as a tool has been expanding. In 2020 the World Bank reported 64 implemented or planned carbon pricing initiatives, which would cover more than 22% of the global greenhouse gas emissions.

The EU's Emissions Trading System (EU ETS) is an important tool in meeting their emission reduction targets of 55% in 2030 and net zero in 2050. To achieve this, the EU ETS prices will likely have to increase significantly above the levels currently observed.

## Regional, national and subnational carbon pricing



- ETS implemented or scheduled for implementation
- ETS or carbon tax under consideration
- ETS implemented or scheduled, ETS or carbon tax under consideration
- Carbon tax implemented or scheduled for implementation
- ETS and carbon tax implemented or scheduled
- Carbon tax implemented or scheduled, ETS under consideration

**Source**: World Bank Group and State and Trend Carbon Pricing

# Winners and losers in the energy transition

The global energy transition will upend well established patterns of trade and commerce, which will have disruptive effects on the global order. This will exacerbate some global, regional, sub-state tensions and instabilities, and redress others.

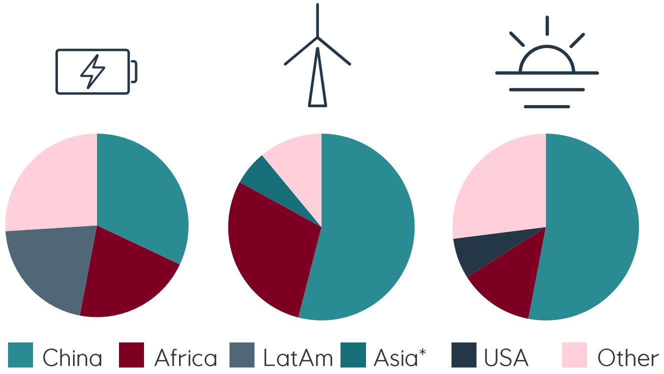
Countries currently dependent on hydrocarbon resource rents need not be losers, nor is it a given that hydrocarbon consuming countries will be the clear winners. Rather, it will be those societies that are able to leverage the new demands of the energy transition that will shift the balance of power in their favour. This could be societies that have an abundance of other natural resources, those that play a key role in shaping the norms, values and standards governing the energy transition, or those that control key supply chains in terms of technology and raw materials. In this context, rentier economies that have the vision and capacity to enact industrial strategies that facilitate their green transitions will remain competitive. This includes retraining the workforce to take advantage of new opportunities.

Whether the energy transition will be peaceful or a catalyst for conflict will be determined by the extent to which it is driven by global cooperation or competition. The energy transition is being driven by both well-meaning objectives (e.g. protecting public goods) and more confrontational dynamics (e.g., strengthening energy security). It is a fundamental assumption in this report that the scale and scope of the energy transition will be larger in a setting of peace and cooperation. Below are some factors that will shape and be shaped by the energy transition.

1) **Demographics** – How will differences in population growth and aging impact energy demand and the pace and progress of the transition?
2) **Migration** – What bearing will migration (e.g. rural-to-urban, global South to global North) have on a given country's energy mix and energy systems?
3) **Inequality** - Will the global energy transition exacerbate or alleviate inequalities?
4) **Ideology** – How will differing governance models impact countries' policy priorities?
5) **Public opinion** (incl. populism) – Climate sceptics vs. climate activists – who will gain the upper hand?
6) **Technology** – How will breakthroughs in artificial intelligence, quantum computing, bioengineering, etc. impact the take-up of new energy technologies?
7) **Conflict** – How will conflicts over lost revenue streams or control of resources manifest?
8) **Shock events** – Will these accelerate or decelerate the energy transition?

## Supply of raw materials by region

For batteries, wind and solar PV technology

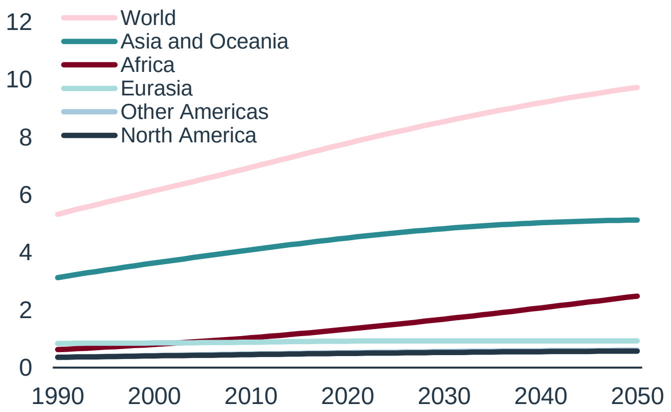



*Excluding China and Japan

**Source:** CSIS

## Population growth by region

Billion




**Source:** UN, Equinor

# The costs of the energy transition

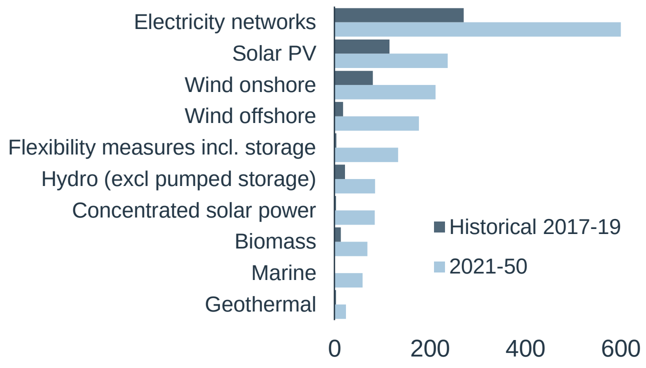
Sustainability will not come for free. The need for investments looks overwhelming with the present estimates. On the energy demand side, buildings will need to be retrofitted at a much-increased pace, and polluting factories and power plants may need to be retired before the end of their economic lifetimes. On the supply side, power systems will need to be massively expanded. Carbon capture, utilisation and storage (CCUS) must take off, requiring the establishment of $CO_2$ transportation corridors and depositories. If the use of hydrogen is implemented on a large scale, it will further boost either CCUS expenses if the $H_2$ is blue, or power and electrolyser expenses if it is green, or both. Necessary modifications across consumption sectors and infrastructure will come in addition.

The energy transition is not only about costs. Fossil fuel import dependent countries may see improvements in their trade balances, and consumers that can afford passive houses and electric vehicles (EVs) will benefit from smaller heating bills and zero gasoline and diesel expenses. Since a fair amount of investments in energy will need to be made anyway, it would be wrong to pin 100% of the envisaged growth in expenses on the energy transition. Finally, the whole point of the transition is to stave off potentially greater expenses linked to the negative impacts of global warming. The challenges are the sheer size of the required outlays and that they need to be funded long before the savings that they will enable materialise.

IRENA puts average annual power sector investments over the 2021-50 period required for the realisation of its 1.5°C scenario at USD 1,680 billion. This sum represents more than a tripling of average annual investments between 2017 and 2020. The same source puts total energy sector investments at USD 4,400 billion per year. The investment implications of our scenarios have not been estimated, although they are likely smaller than those suggested by IRENA. This is due to *Rebalance* being less radical. Whereas IRENA sees a 77% decline in world fossil fuel to 2050, the *Rebalance* scenario has a 54% decline. Whereas IRENA assumes a 90% renewables share in world power generation by 2050, a 74% share is used in the *Rebalance* scenario. This is not to suggest that *Rebalance* might be unproblematic from a funding point of view. Mobilising capital is already, at the beginning of the energy transition, proving to be a challenge. In 2018, officially supported transfers for climate issues to poor countries totalled about USD 90 billion in today's dollar value, a fraction of estimated needs.

## Estimated average annual power sector investments related to the energy transition

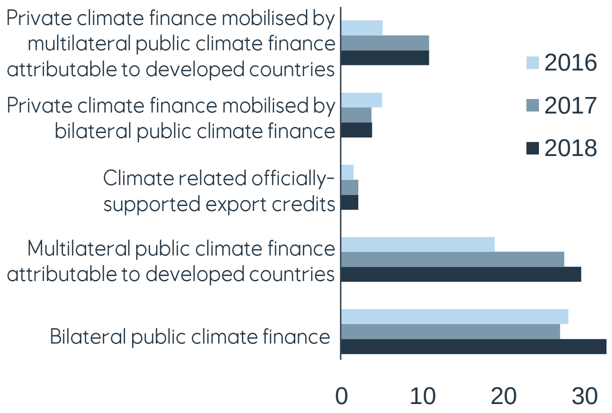
2019-USD, billion




**Source:** IRENA

## Climate finance provided and mobilised by developed countries

2013-USD, billion




**Source:** OECD

# Towards a more just and equitable world

In *Rebalance*, the world achieves the objectives of the Paris Agreement as well as the UN Sustainable Development Goals (SDGs). The scenario builds on a somewhat slower economic development in the richer countries compared with *Reform*, where continued economic growth is bringing marginal improvements in well-being. This lower growth must therefore be countered by improvements in other measures of development, to ensure a democratic mandate for such changes and to maintain the social contract between people and governments.

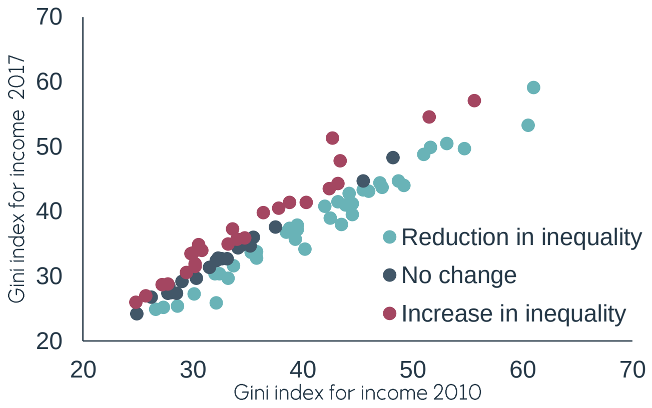
One key measure is the perceived fairness of such a transition, and an understanding that the pursuit of a sustainable economy in which the SDGs are achieved is being carried out in a just and equitable way. The social and geopolitical tensions of recent years have shown what direction the world can take when inequality widens and people lose faith in the fundamental institutions on which they rely. The transition to sustainability will undoubtably bring enormous changes across all levels of society, as well as resultant winners and losers. How this is addressed, and how those who lose out are compensated, will be critical. The impact of relatively moderate climate policy has already contributed to global protest movements, such as the 'yellow vests movement/mouvement des gilets jaunes', while the downplaying or ignoring of climate science has become government policy in some countries. Populist leaders have used a distrust of change to win power and further exacerbated social and political tensions. Clear and transparent policy is required to build public support. Increased taxation on emissions must be countered by direct subsidies of alternatives, and those made jobless through changes in one sector must have support and training to find work in others.

The energy transition is not a short-term event, but will take place over decades. This raises the issue of cost, consumption and resource use between generations. Many fossil fuel producing nations have become reliant on economic rents derived from production, but it is possible for the benefits of finite resources to be passed down through generations. Norway's sovereign wealth fund is an example of how future generations can benefit from the current oil wealth.

The most critical aspect of a just energy transition will be how the remaining carbon budget will be shared among nations. In *Rebalance* the emerging economies must be prioritised and allowed to develop their economies using appropriate fossil fuel technology, just as the industrialised nations have done before.

### Income inequality still high in many countries

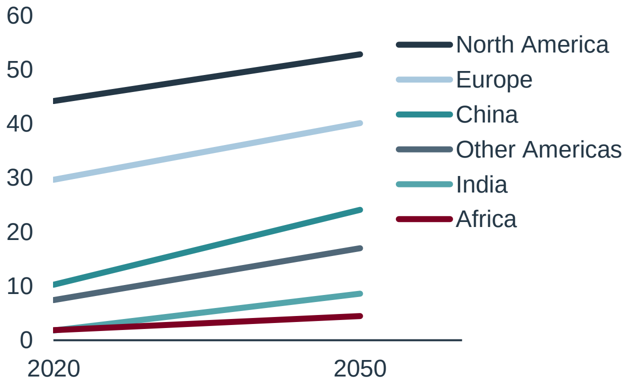
Gini index for disposable income by country 2017 vs 2010




**Source:** United Nations

### Real GDP per capita by region in Rebalance

Real thousand USD at market exchange rates




**Source:** Equinor

# Sectoral developments in economies

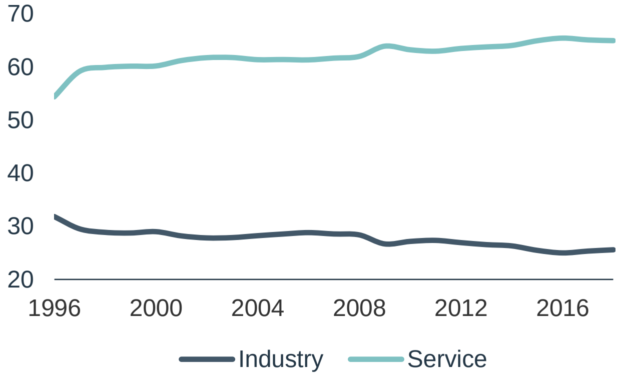
The sectoral development of national and regional economies plays a significant role in both their long-term economic growth and carbon intensity. High emitting industries have largely relocated from the wealthier, industrialised regions to emerging economies, particularly in Asia. This has resulted in an apparent reduction in carbon intensity in the former, and a significant leap in emissions in the latter. A sustainable future requires all economies to move away from resource intensive consumption, towards more service-based economies, as well as minimising their industrial sector carbon intensity.

Profound structural changes in the global economy have taken place in recent decades. Technological innovation, and especially digitalisation, have emerged as drivers that accelerate economic growth and facilitate job creation. Digital proliferation is causing a rapid rise of the service sector as it lowers barriers to market entry and enhances utilisation of excess capacity. For example, the advent of smartphones led to the development of applications for almost everything. Instead of requiring a massive manufacturing capacity, entrepreneurial individuals can take a business idea, learn how to or hire someone to code software, and utilise the platforms built by Apple, Google, or Microsoft to distribute their software solution to a truly global market. Digitalisation is also impacting the way employment is perceived. Traditional roles such as taxi services are being replaced by ride hailing apps that connect a large, part-time workforce to consumers. This also drives significant changes in consumer behaviour and potentially allows energy efficiency improvements as well as cost savings. The impact of technological innovation on the service sector in terms of employment and value added shares varies across countries. Digitalisation improves productivity in industrialised countries, but it has also contributed to job losses as lower skill, lower value added jobs have moved abroad where labour is cheaper. By contrast, digitalisation in emerging markets raises capital and labour productivity. It also lowers transaction costs and facilitates access to global markets.

Most emerging economies are rebalancing not just from manufacturing to services, but also from investment to consumption, from rural to urban, and from public to private growth, at varying speeds. Digitalisation in China has accelerated the e-commerce boom and led to a larger service sector, while heavy industry has declined due to upgrading and relocation. This profound sectoral change, coupled with a greater desire for carbon reduction and more sustainable growth, has transformed consumption and production styles and enhanced the pursuit of cleaner energy.

Global service and industry sector

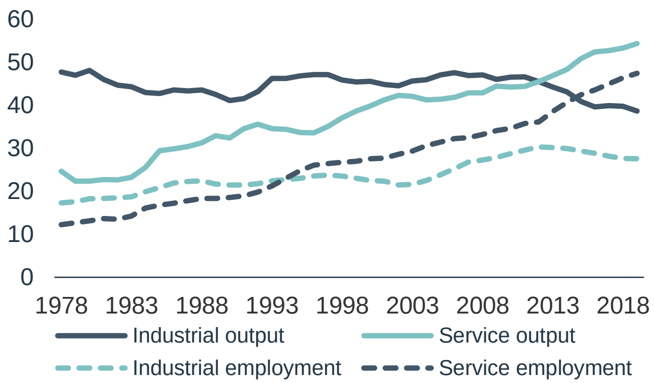
% of total economy




**Source:** World Bank

China's service and industrial sectors' share of employment and output

%




**Source:** CEIC

# Stepping up on climate ambitions

The 2015 Paris Agreement represented a breakthrough in multilateral climate action. Each signatory country must submit an updated Nationally Determined Contribution (NDC) on emission reductions every five years, with the objective of keeping global average temperatures to well below 2°C above preindustrial levels. These NDCs must represent progress and reflect the country's highest possible ambition. The first round of updated NDC's were required to be submitted by the end of 2020. Norway's updated target committed to reduce GHG emissions by at least 50% and towards 55% by 2030. The EU committed to a target of at least 55% GHG reductions by 2030 and climate neutrality by 2050.

Climate ambitions have accelerated in 2021 following the election of President Biden in the US and the return of the US to the Paris Agreement. In April 2021, the US announced its updated NDC, which committed the US to reducing emissions by 50-52% by 2030. The announcement, at a summit hosted by President Biden, was intended to demonstrate renewed US leadership on climate at both the domestic and international levels. At the same summit, Japan and Canada both submitted new NDCs, aiming for emissions reductions of 46% and 40-45% by 2030. South Korea also pledged to strengthen its own NDC, while Brazil and Russia promised additional actions on climate, while stopping short of new economy-wide GHG commitments. To add to the growing momentum, and as the host for the next UN climate conference (COP26), the UK supplemented its own ambitious target with an additional goal of a 78% reduction in GHG emissions by 2035.

Despite an acceleration in ambitions among developed economies, the single most important question for the multilateral climate agenda is whether and how China updates its own NDC. At the April 2021 summit, China reiterated its commitment to peak $CO_2$ emissions before 2030 and achieving carbon neutrality by 2060. President Xi Jinping also committed that China would "phase down" coal consumption beginning in 2025. More than any other single factor, the decisions taken on coal by China will determine the ability of the world to achieve the Paris Agreement goals. In addition to China's climate commitment, it is crucial that the US, being the world's second largest $CO_2$ emitter, reasserts its role on global climate, partly pushed by the EU, which is aiming for Europe to be the first climate-neutral continent in the world.

In the end, whether the world will be successful depends on the ability to take action, accelerate the energy transition and ensure sustainable energy growth in developing countries – all while delivering on the UN's Sustainable Development Goals.


Photo by Mathias P.R. Reding on Unsplash

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# Key figures

| | 2018 | 2050 | | | 2018-50 growth per year (%), CAGR | | |
|---|---|---|---|---|---|---|---|
| | | Reform | Rebalance | Rivalry | Reform | Rebalance | Rivalry |
| **Global GDP (2010-USD trillion)** | **81.9** | **162.5** | **155.3** | **147.5** | **2.2** | **2** | **1.9** |
| North America, Europe, Industrial Asia Pacific | 50.3 | 74.9 | 65.1 | 71 | 1.2 | 0.4 | 1 |
| China | 13.8 | 40.8 | 32.7 | 35.5 | 3.5 | 2.8 | 3.1 |
| Rest of World | 17.8 | 46.8 | 57.5 | 40.9 | 3.1 | 4.2 | 2.7 |
| **Global energy intensity - Indexed to 2018** | **100** | **54.2** | **45.5** | **65.1** | **-1.9** | **-2.5** | **0.8** |
| **Global population (billion)** | **7.63** | **9.73** | **9.12** | **9.73** | **0.8** | **0.6** | **0.8** |
| **Global energy demand (Gtoe)** | **14.19** | **15.27** | **12.25** | **16.64** | **0.2** | **-0.5** | **0.5** |
| Coal | 3.79 | 2.09 | 0.68 | 2.83 | -1.8 | -5.2 | -0.9 |
| Oil | 4.48 | 3.82 | 2.06 | 5.05 | -0.5 | -2.4 | 0.4 |
| Gas | 3.23 | 3.84 | 2.55 | 3.95 | 0.5 | -0.7 | 0.6 |
| New renewables | 0.3 | 2.36 | 3.43 | 1.62 | 6.7 | 8 | 5.4 |
| **Oil ex biofuels (mbd)** | **96.5** | **83.5** | **45.8** | **110.2** | **-0.5** | **-2.3** | **0.4** |
| **Gas (Bcm)** | **3,895** | **4,621** | **3,066** | **4,752** | **0.5** | **-0.7** | **0.6** |
| **Global energy-related CO2 emissions (Gt)** | **33.0** | **24.3** | **8.9** | **31.8** | **-1.0** | **-4.0** | **-0.1** |
| North America | 6.1 | 3.1 | 0.6 | 4.7 | -2.0 | -7.2 | -0.8 |
| Europe | 3.9 | 1.4 | 0.3 | 2.2 | -3.3 | -7.6 | -1.8 |
| China | 9.5 | 6.5 | 1.2 | 8.5 | -1.2 | -6.2 | -0.3 |
| India | 2.3 | 2.9 | 1.8 | 3.8 | 0.7 | -0.9 | 1.5 |
| **World CO2 emissions from fossil fuel use removed by CCUS (Mt)** | **14** | **520** | **2,000** | **53** | **11.9** | **16.8** | **4.2** |
| **Global light duty vehicles (LDVs) fleet (million)** | **1,262** | **1,484** | **1,423** | **1,807** | **0.5** | **0.4** | **1.1** |
| **LDVs oil demand (Mtoe)** | **1,131** | **598** | **133** | **1,035** | **-2** | **-6.5** | **-0.3** |
| **LDVs biofuel demand (Mtoe)** | **66** | **44** | **3** | **88** | **-1.2** | **-9.5** | **0.9** |
| **LDVs electricity demand (Mtoe)** | **2** | **223** | **275** | **194** | **16.9** | **17.7** | **16.4** |


Photo by Taner Ardali on Unsplash

# Units

| | | |
|---|---|---|
| **Area** | km$^2$ | square kilometre |
| **Oil** | bbl | barrel of oil |
| | mbd | million barrels per day |
| **Gas** | Bcm | billion cubic metre |
| | Bcm/y | billion cubic metre per year |
| **Power** | kWh | kilowatt hour |
| | MWh | megawatt hour |
| | GWh | gigawatt hour |
| | TWh | terawatt hour |
| | MW | megawatt (1 watt x $10^6$) |
| | GW | gigawatt (1 watt x$10^9$) |
| **Energy** | t | tonne |
| | Mt | million tonnes (1 tonne x $10^6$) |
| | Gt | gigatonnes (1 tonne x $10^9$) |
| | Mt/y | million tonnes per year |
| | Gt/y | gigatonnes per year |
| | Toe | tonne of oil equivalent |
| | Mtoe | million tonnes of oil equivalent |
| | Gtoe | gigatonnes of oil equivalent |
| | Toe/capita | tonne of oil equivalent per capita |
| **Heat** | MMBtu | Metric million British thermal unit |
| **Monetary** | USD | 1 US dollar |
| | NOK | 1 Norwegian krone |

*Only units used in the report are listed

## Acknowledgements

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