Energy Perspectives 2020

Long-term macro and market outlook

Anders Opedal

President and CEO

Welcome to Equinor's Energy Perspectives 2020

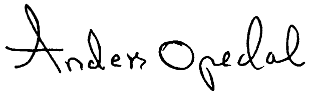
2020 has been, and still is, a year of unprecedented uncertainty in the energy industry. While the humanitarian costs of the Covid-19 pandemic are still being counted, the world is suffering a global economic downturn and an increase in geopolitical uncertainty. The energy market turmoil we have seen this year far outweighs anything else I have experienced through my career in Equinor.

The pandemic is still affecting societies and markets, uncertainty is high, and no one can predict what the short- and long-term effects will be. There are many important questions with no clear answers at present. What effect will lower oil and gas prices have on supply? How will setbacks in global trade affect demand? What impact will the pandemic have on the energy transition? Attempting to answer these questions makes scenario thinking more important than ever.

We always develop our business plans to cater for different future scenarios, and as a company, we must navigate the uncertainties in the best way we can for our employees, our owners and the societies where we operate. Our strategy remains firm: Always safe, High value and Low carbon; and we are inspired by our vision of shaping the future of energy.

Rooted in Energy Perspectives is a recognition of the massive changes the global energy mix must go through for the world to reach the climate targets set out in the Paris Agreement. During the last year we have set clear actions and targets for emission reductions in our operations and the carbon intensity of our products. We have decided to invest in the Northern Lights carbon storage project and further matured our large offshore wind portfolio. To become a leading company in the energy transition, we will leverage technology and innovation at scale to further optimise our oil and gas portfolio, accelerate profitable renewable energy projects and increase our efforts to develop new low-carbon solutions.

We are transitioning towards becoming a broad energy company. Our success rests on our people, managing risks and staying competitive in a continuously changing business and policy environment. Energy Perspectives provides my colleagues and me with important insight that helps us make sound decisions, and I am very proud of how far it has come over the last 10 years. I hope you will enjoy this 10th edition of the Energy Perspectives report.



Back to the future

2020 will be remembered. A global pandemic, more than a million deaths, lockdowns, travel restrictions, crash in energy demand and energy prices, recession and unemployment, and an abundance of predictions about the potential long-term effects of the pandemic. We are still in the middle of the recovery towards a potentially new normal. Where the world and the global economy will be in a year or so, is all but clear.

Speculating about the global energy future towards 2050 is more difficult than ever. But for a company that is in the energy business, keeping a long-term focus also in times of extreme short-term uncertainty is a necessity. Given the uncertainty, our long-term perspectives must be based on scenarios that span out a very wide outcome space and build on different plausible combinations of assumptions that tell stories about where global energy markets may develop. Stories that serve as background for making robust investment decisions, and that describe explicit signposts that can be used as indicators for where we are heading some years from now. Stories that not only address a development we wish for, but also developments that are undesirable, but still possible.

A lot has changed since we first published our long-term perspectives. Back in 2011, we expected oil and gas demand in 2020 to be almost 92 mbd and 4200 Bcm, respectively. And we imagined that electricity supplied from new renewable sources (solar and wind) could be 5.5 times higher than in 2010. The forecasts for oil and gas are reasonably close to what will be the actual outcome, but in the case of oil especially, for the wrong reasons: Our forecast then did not take into account the crash in oil demand due to Covid-19, but was affected by the slow growth after the financial crisis and a very optimistic view on the speed of electrification.

And, surprisingly to some, our forecast on growth in new renewable electricity was remarkably close to the actual outcome, as generation in 2020 will probably be 5.7 times that in 2010.

As previously, our outlook on global energy to 2050 is based on three very different scenarios, this year called *Reform*, *Rivalry*, and *Rebalance*. They are all based on a forecast for the most likely development from the current crisis to around 2023. Then the development takes three distinctly different paths, based on different combinations of economic and demand growth, energy efficiency, climate policy cooperation, technology development and geopolitics.

The most important change in this year´s Energy Perspectives is the new combination of assumed drivers that are necessary to deliver on the well below 2º Celsius target established in the Paris Agreement. We think a plausible pathway towards this target is a combination of rapid and radical changes in global energy, climate policies, technologies, and a more balanced economic development between industrialised and emerging economies. This scenario has therefore been renamed from Renewal to *Rebalance*.

Even during a global crisis with an unknown outcome, it is important and necessary to keep our eyes on long-term developments in the world's most important markets, and on the possibilities for addressing our biggest long-term challenges. Energy Perspectives 2020 is an attempt to contribute to an informed dialogue about these issues.

Happy reading!

Eirik Wærness

Senior vice president and
Chief economist

The energy world in 2050

1.8 - 1.9 x

Size of the global economy compared to 2019

51 - 117 mbd

Global oil demand compared to 100 mbd in 2019

28 - 49 %

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

10 - 35 Gt

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

3,200 - 4,800 Bcm

Global gas demand compared to 4,000 Bcm in 2019

0.5 - 1.2 Billion

Electric light duty vehicles on the road, equivalent to 29% - 87% of the total fleet

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Covid-19 and the outcome of the current crisis

The Covid-19 pandemic has had enormous impacts. At the time of publication, there have been around 50 million confirmed cases and over 1 million deaths worldwide, and the humanitarian costs are still being counted. It is still unclear if, and when, the virus will be under control, much less how and when the pandemic will end. Governments have responded with draconic containment measures that include travel restrictions and lockdowns. These measures have not only disrupted peoples' lives, but also plunged the global economy into a deep recession. Government and central bank responses have been decisive. Their policies seem, for now, to have prevented a financial crisis in addition to the collapse seen in the real economy. The cost, however, has been immense and has led to steep increases in already high public and corporate debt levels, on top of the costs of unemployment, bankruptcies and loss of value creation.

Just as for the long-term development of energy markets, scenario development is necessary to analyse potential outcomes and understand the uncertainties around the main drivers in this current crisis, be it health, economy, society or geopolitics. For the three scenarios in Energy Perspectives, the starting point in 2022-23 is the same, based on the following expected outcome of the crisis: Targeted social distancing measures and increased testing capacity are used to contain the virus spread enough to allow for a slow and bumpy, yet steady recovery of economic activity from the nadir in the second quarter of 2020. Vaccines are developed, and roll-out starts during the second half of 2021. This allows for an accelerated re-opening of the economy and a rebound from the 2020 lows, though economic development is not expected to catch up with the pre-crisis trajectory.

The outcome space is large. An earlier vaccine approval with faster production and distribution than expected might reduce the economic damage. Conversely, delayed vaccine development, destabilisation of financial markets, loss of trust in governments, or deteriorating geopolitical relationships could worsen the development significantly. The risk picture seems to be skewed to the downside.

Whether and how much the Covid-19 pandemic will accelerate the energy transition can be debated. Some governments, led in their efforts by the EU, are combining plans to stimulate economic recovery with an ambition to "build back greener". They want to invest heavily in renewables, hydrogen and energy efficiency measures. Others are more focused on the short-term increase of economic activity and prioritise measures to support employment, consumption or "shovel-ready" construction projects. All of this has to be set against a back-drop of high debt levels. Governments might be forced to make tough choices on prioritisation in spending, as well as taxation, and corporations might have to cut back on capital expenditure. Consumers have less money available for any kind of investment. The long-term effects of the currently enforced behavioural changes are no less uncertain: How sticky will the imposed adjustments on our travel habits be going forward?

After treading the same path in the wake of the pandemic, the three scenarios part ways. In *Rebalance*, Covid-19 sensitises the world to the reality of global threats and the need to face them in a proactive and coordinated manner. The EU is leading the way with its Green Deal and is joined by other countries who accept the premise that clean energy growth may be as potent a tool for job creation as more traditional stimuli. In *Rivalry*, the pandemic reinforces the short-term, nationalist bias characterising this scenario. Fierce competition for vaccines worsens the outlook for international cooperation, while arguments for energy transition stabilisation packages appear unconvincing to most global leaders. In addition elevated debt levels prevent replacement of existing energy value chains. In *Reform*, a lacklustre attempt at an energy transition-led rebuild without strong global cooperation leads to a gradual acceleration of the energy transition trends in some regions only.

Photo by Javier Allegue-Barros on Unsplash

The three scenarios

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The three scenarios

Energy Perspectives contains three distinct scenarios for future energy markets, called *Reform*, *Rebalance* and *Rivalry*. The future of energy is highly uncertain, and we are constantly being bombarded with conflicting signals. It can be difficult to distinguish what is noise and what are significant events that set the world on a new trajectory. Energy Perspectives does not try to predict the future, but shows possible paths based on the choices we make.

The Covid-19 pandemic is a reminder that it is not only the long term that is uncertain and hard to predict; even what happens next year or over the next months may be very different from what we expect. The three scenarios are all based on a similar recovery over the next couple of years, after which the scenarios begin to diverge. The main impact of Covid-19 on the global economy and energy markets occurs in the short term, although there are some lasting impacts for the medium and long term.

Reform is a story about an accelerating energy transition, but one that is not sufficient to reach climate targets. *Rivalry* represents the least sustainable outlook, describing a world where a slow energy transition does take off, but is hampered by lack of cooperation and trust. *Rebalance* replaces last year's Renewal as the well-below 2º C scenario. This new scenario recognises that there are large imbalances present in the world today, and that profound systemic change is required to reach emission targets in a sustainable and just way.

Reform

Reform builds on the trends we see today in markets, technology and policy, expecting them to continue to unfold and develop at a similar pace. Even though a lot is happening, the energy transition today is unfortunately not moving fast enough. In *Reform*, it is assumed that climate policies continue to tighten, but not all stated policy targets are met, and momentum is driven mainly by the industrialised countries. There is limited penetration of zero carbon technologies and energy carriers such as carbon capture, utilisation and storage (CCUS) and hydrogen, as CO_2 prices do not rise sufficiently to make them commercially viable. Global energy-related CO_2 emissions bounce back to pre-pandemic levels before stabilising and gradually going into decline. The geopolitical landscape is largely benign, with both cooperation and competition among nations. There are occasional setbacks in global trade, but overall globalisation continues and the global economy becomes increasingly interlinked. Global energy markets continue to become more integrated and technology advances are shared among regions. This results in the scenario having the highest GDP growth throughout the period to 2050.

Global energy demand peaks in the early 2040s at a level about 10% higher than pre-pandemic levels, before plateauing and gradually going into decline. The share of fossil fuels decreases from over 80% of the energy mix today, down to 65% by 2050. Coal sees the biggest reduction, followed by oil, while gas demand increases both in absolute terms and as a share of the mix. Electricity demand grows rapidly, up about 70% over the projection period, as the share of electricity in final consumption of energy goes from around 20% today to 30% by 2050. Solar and wind electricity generation rises from around 8% of the global power mix today to over one third by 2050.

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Rebalance

The *Rebalance* scenario is a well below 2º C scenario challenging the assumption that the world can reach its climate and sustainability goals without significant consequences for economic growth and global income distribution. In order to achieve a well below 2º C outcome, global energy-related CO_2 emissions must drop by an average 4% every single year. To put this into perspective, estimates for 2020 with its massive decline in global GDP, suggest a 7% drop in CO_2 emissions. The partial phasing out of fossil fuels required by the well-below 2º C target may be hard to combine with significant economic growth across all regions. "Green" growth will create jobs, but not everywhere on a scale matching the polluting activities that will need to disappear.

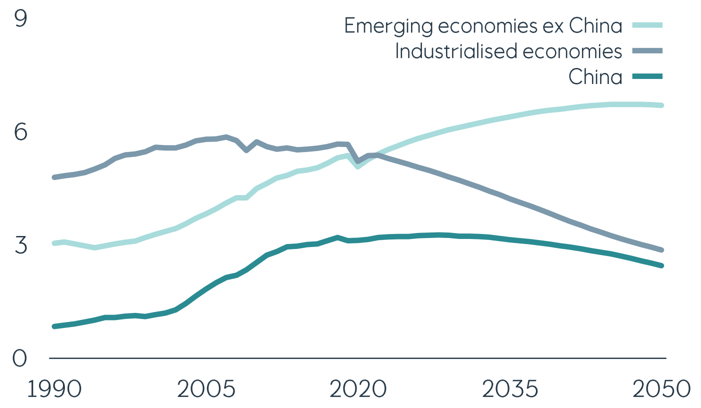
Today, income is highly unequally distributed internationally between rich and poor countries, and within countries. As an example, energy consumption per capita is eight times higher in North America than in Africa, with differences in climate explaining only part of the gap. GDP per capita is more than 20 times higher. The rich world uses resources without facing the true costs of its consumption, and with climate and other environmental externalities not reflected in market prices for commodities and labour.

Rebalance shows a development path where economic growth accelerates in the emerging regions and slows in the industrialised regions. There is a repricing of goods and services to reflect negative externalities. This provides incentives for the rich world to reduce waste and overconsumption, while shifting focus from maximising GDP growth to optimising for other indicators on human development and wellbeing. At the same time, economic aid and the emission reduction burden put on the emerging economies are tailored to their legitimate needs for continued economic expansion dependent on access to energy.

In *Rebalance*, global energy-related CO_2 emissions never return to pre-pandemic levels and drop by more than two thirds by 2050. Global energy demand declines by about 15% compared to 2019 levels, with this average masking highly diverging paths across industrialised and emerging regions. Energy demand in North America, Europe and Industrial Asia Pacific is reduced to half of what it is today, while demand in the rest of the world (excluding China) grows by around 30%. Electricity demand increases more in *Rebalance* than in the other scenarios, and is up by almost 90% in 2050. The share of electricity in energy end use by then exceeds 40%, with solar and wind reaching close to 50% of the mix.

Energy demand in Rebalance

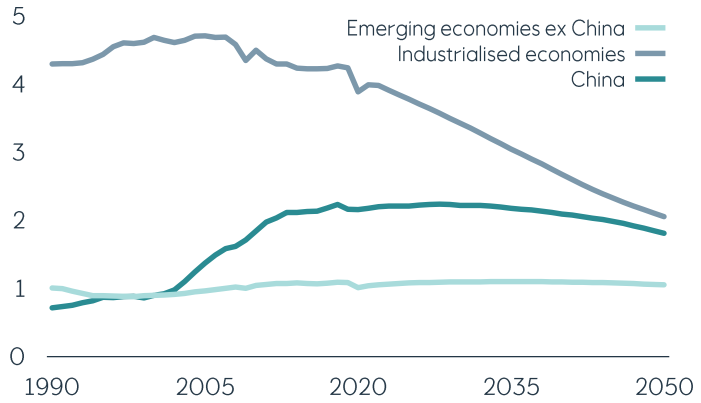
Billion toe



Source: IEA (history), Equinor (projections)

Energy demand per capita in Rebalance

Toe



Source: IEA (history), Equinor (projections)

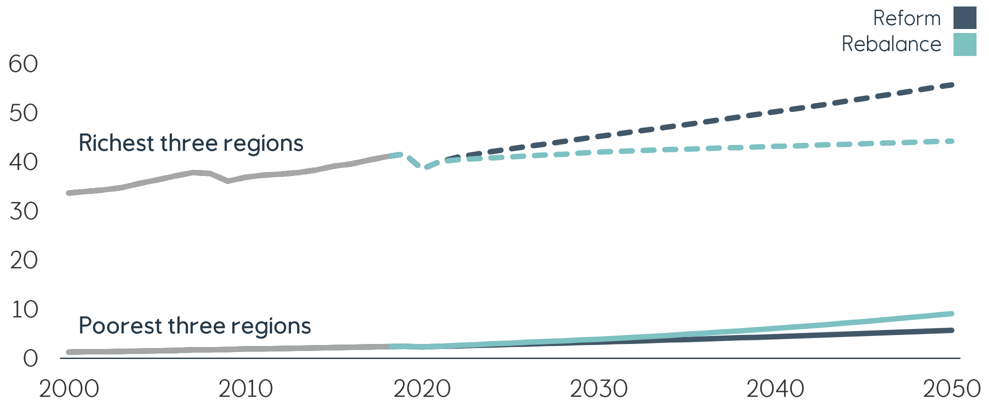
Why Rebalance is a necessity

The world has moved on since our previous climate-target scenario, Renewal, was first introduced. Though *Rebalance* still maintains the fundamental back-cast concept of a world limited to a well below 2º C carbon budget, we no longer find it realistic to suggest that such a world should have the highest GDP of all our scenarios by 2050. Continued economic growth has meant that carbon emissions have grown since Renewal was first proposed, meaning that with every scenario iteration the rate of necessary emission reductions grew faster and faster. In 2020, the world has reached a point where a new balance must be struck between prioritising economic growth, and the wellbeing of people and the environment, if we are to deliver a plausible path to achieving climate targets.

Economic growth is undoubtably a positive thing, having improved living standards to levels unimaginable to those living even a century ago. However, continued growth in the industrialised countries is now only bringing about marginal improvements in living standards, while growth in the emerging regions is not fast enough to facilitate the kinds of advancements required for decarbonisation and the UN Sustainable Development Goals to be met. In *Rebalance*, absolute GDP grows in all regions, but is far slower in the industrialised countries than at any point in recent history. GDP per capita continues to rise, however, allowing living standards to continue to improve for all. In the emerging regions, 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 gives a further boost to GDP per capita and helps reduce potential energy demand. *Rebalance* is an idealistic world and quite unlike anything that has gone before, but it is a clear reminder of the challenge we face in avoiding a climate crisis by the end of the century, and is in our view the most credible way in which the world can reach the emission reductions required.

GDP per capita comparing richest and poorest regions

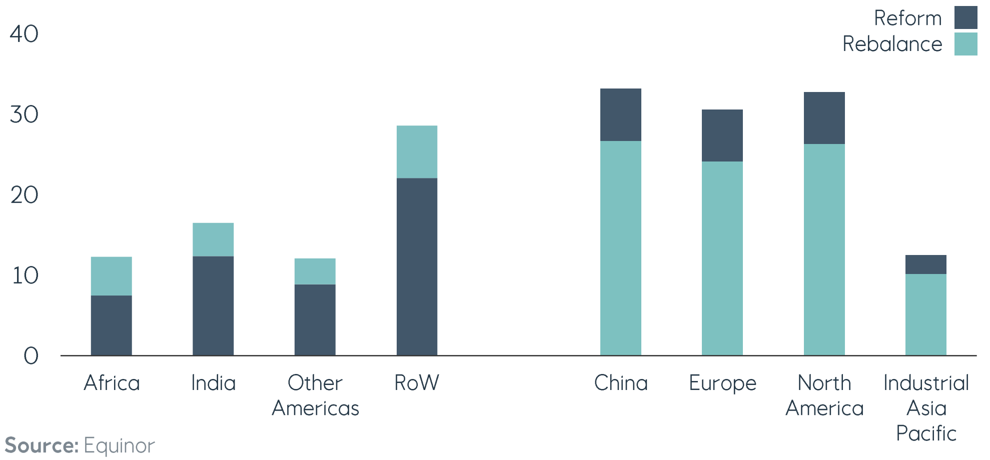
Real thousand USD at market exchange rates



Source: IEA (history), Equinor (projections)

GDP levels in Reform and Rebalance, 2050

Real trillion USD at market exchange rates



Source: Equinor

Rivalry

In *Rivalry*, focus on climate policies and climate change takes a back seat in terms of policy priorities, and the energy transition does not take off. There are many indications that the world is at risk of embarking on such a path; the world has been troubled by trade wars, social and political unrest, and regional conflicts with the potential to escalate further. In *Rivalry*, these trends continue, leading to more protectionism, more authoritarianism, less global cooperation, slower technology development and weaker economic growth.

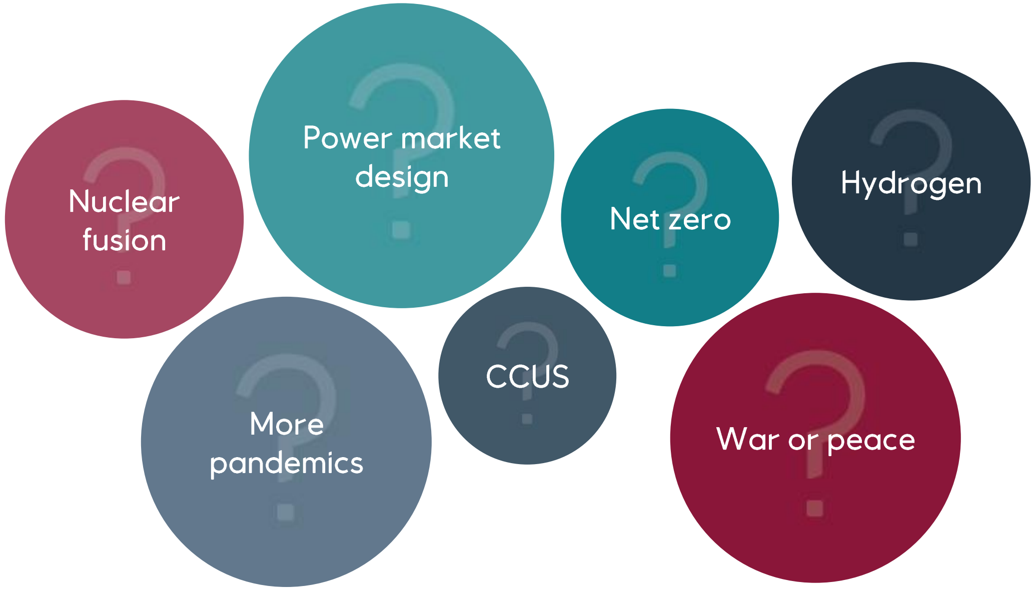
This makes *Rivalry* the least sustainable scenario in several dimensions. In terms of economic development the imbalances persist and emerging economies are significantly worse off compared with the other scenarios. The economic growth in *Rivalry* is also much more energy intensive, taking a higher toll on the world's resources.

Energy security takes priority over climate change, and regions with access to cheap and abundant supplies of coal continue to rely on it as an important part of the energy mix. Gas loses out in these regions, both due to its higher cost and the focus on energy independence, making LNG imports less attractive. Oil demand in *Rivalry* is significantly higher compared to *Reform*, with much of the difference explained by a slower electrification in the transport sector. Renewables grow rapidly, due to their low cost and importance as an indigenous source of energy, but at a slower pace compared with the other scenarios.

Overall, global energy demand increases by 21% compared to 2018 and global energy-related CO_2 emissions do not peak until the late 2030s. Electricity demand grows by just over 50%, and the share of electricity in final consumption of energy remains below 25%, the lowest of all scenarios.

Beyond 2050

From a climate perspective, 2050 is not a natural end-point to scenarios. Even in *Rebalance*, the CO_2 emissions must continue to decline rapidly after 2050 and probably reach net zero some time before 2070. In order to limit global warming to 1.5º C, several projections indicate that there must be significant negative emissions after 2050. The full impact of global warming on the climate and economy will not be seen before well after 2050. However, from an energy market perspective there are other arguments to end at 2050. The assumptions that the scenarios build on are based on what we know today about markets, policies and technology. Moving beyond 2050, there are very few policy targets, and it becomes more likely that we will see technology breakthroughs that may completely change the energy landscape. The planning horizons of companies typically do not extend further than 2050, so the strategic value becomes limited as well.



The global economy

Current situation and outlook to 2025

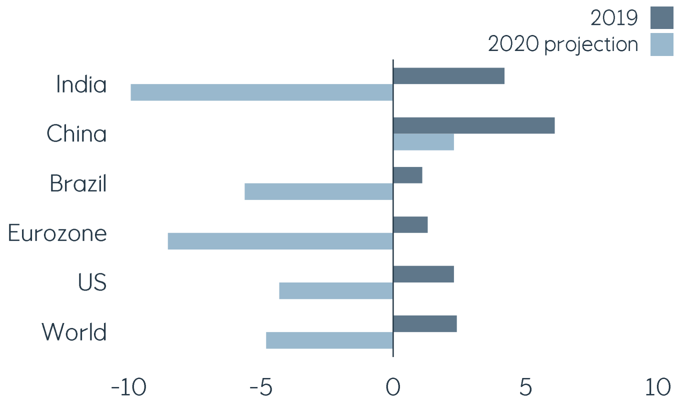
The Covid-19 pandemic has led to the largest global economic downturn since the 1930s. After a global economic expansion of 2.4% last year, this year looks to contract by around 5%. The second quarter of the year seems to have been the trough of the economic collapse, as strict lockdown measures and the pandemic shell-shocked economies. The second half of 2020 is likely to see a rebound in activity mostly thanks to unprecedented fiscal and monetary policy stimuli. However, the increase in Covid-19 virus cases in key countries over the last months indicates a soft economic uptick, as many measures to control the spread must be maintained over time. Global GDP for 2021 is forecast to grow by around 5.0%, given a more controlled virus situation and a Covid-19 vaccine ready for roll-out during the year. The outlook is highly uncertain and dominated by downside risks, such as significant virus infection flare-ups and lockdowns, high unemployment suppressing consumption, and increasing public and corporate debt, to mention a few.

The cyclical economic upturn is expected to continue in 2022. Thereafter, GDP growth rates normalise back to trend towards the middle of the decade. The three scenarios will have somewhat different development paths, but a controlled Covid-19 situation is assumed for all. In *Reform*, the global economy grows at an average rate of 3.0% per year during 2022-25, meaning the global economy does not reach its pre-virus level before 2022. The employment situation is expected to improve and China returns as the growth engine of the world as it trails a yearly GDP growth of around 5%. The US, the world's largest economy, returns to trend growth supported by solid consumption.

Economic growth in *Rebalance* is on average 0.1 percentage point weaker than in *Reform*. Here, a transfer of income, technology and learning from the industrialised world to the emerging economies emerges – along with decarbonisation of economies. A rapid change to international cooperation enables policies that allow the start of reimagining the global economy to be put in place. *Rivalry* portrays a multipolar world where populist, nationalist, inward-looking and short-term priorities direct policy making. Regional disparity strengthens, with a further separation of industrialised and emerging regions. The economic growth in this scenario is 2.7% on average per year during 2022-25, as especially the emerging economies undergo economic suffering.

GDP growth by region 2019-2020

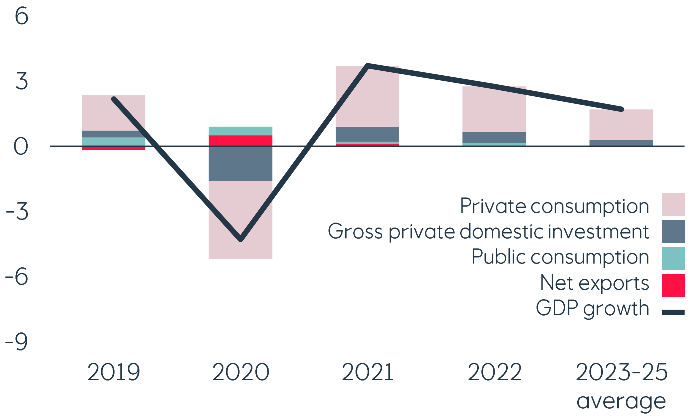
Real annual % change at market exchange rates



Source: IMF (history), Equinor (projections)

GDP and its components for the US in Reform

Real annual % change at market exchange rates, percentage points



Source: Bureau of Economic Analysis (history), Equinor (projections)

Outlook beyond 2025

The long-term implications of Covid-19 are highly uncertain. However, on balance they point to a slight dent in economic activity compared to the pre-Covid expectations. This reduction has been blended into all three scenarios. A small negative productivity impact from a less efficient economy, combined with an increased risk of macroeconomic policy mistakes due to economic imbalances stemming from today, may come through. Partly offsetting this could be increased innovation and a positive technology impulse due to the pandemic. Throughout the forecasting period, the world might experience similar outbreaks – but a better preparedness, and thus reduced impact, is expected.

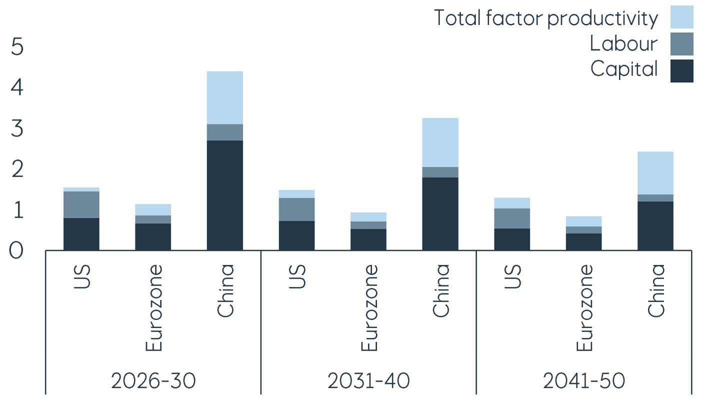
Global growth in *Reform* is lower than the historical growth rate of 3.0% seen since 1990. This is primarily caused by demographics, and in addition the catch-up potential for emerging market economies is decreasing, and global growth abates over time. Increasing carbon levels in the atmosphere lead 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.

Rebalance is a movement towards a less unequal world. In the industrialised countries transfers to the emerging economies continue, excessive consumption is discouraged, and there is a huge cut in waste. Environmental and societal externalities are priced into products. GDP growth in industrialised regions slows dramatically, while emerging regions catch up somewhat. Faster economic development and improved female education reduce population growth in the emerging countries. Extensive digitalisation helps a transition towards more investment in renewables. Energy subsidy schemes are mostly removed. In *Rebalance*, the world avoids negative climate impact on growth. World GDP growth for the period in *Rebalance* is 2.1%.

In *Rivalry*, focus on the climate challenge takes a back seat, while disorder, conflict and power struggles dominate at the expense of cooperation and trust. This is a feature in a world with escalated regional conflicts, sanctions and inefficient markets that dampen technology development. Political and economic resources are channeled to less productive purposes, such as security and military spending. The economic growth in *Rivalry* is 1.9% on average per year, increasingly impacted negatively by the effect of climate change. Economic development is markedly poor first and foremost in the Middle East and North Africa.

GDP growth by source in Reform

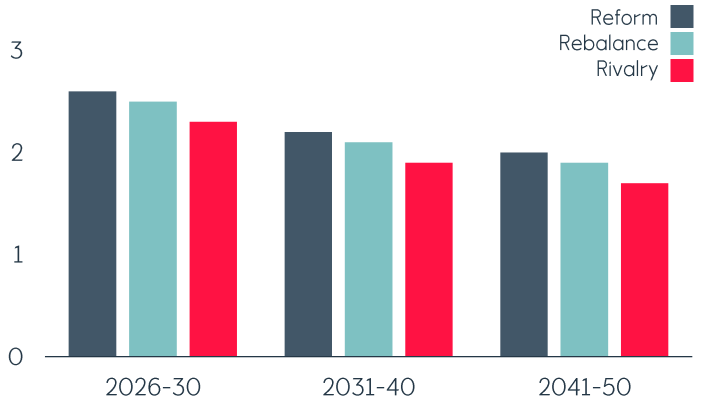
Real annual change at market exchange rates, %



Source: Equinor

Global GDP growth by scenario

Real annual average change at market exchange rates, %



Source: Equinor

Global energy demand

Global energy demand

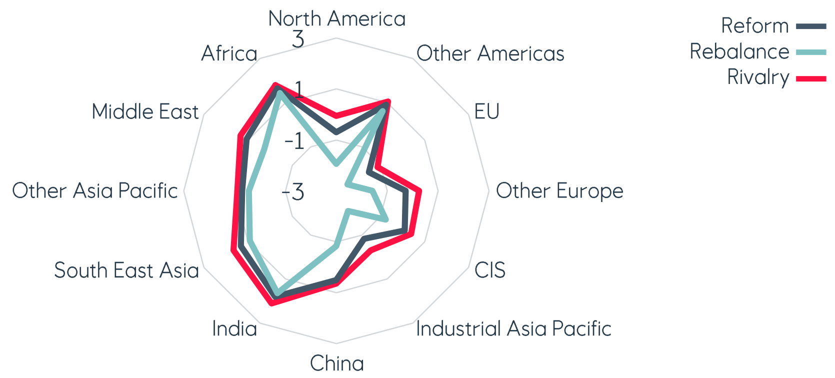
Covid-19 is on track to depress world total primary energy demand (TPED) by 5-6% in 2020 and could impact energy demand for years to come. If growth reasserts itself at pre-Covid levels from 2021, world TPED will soon be higher than before the pandemic. Regional energy intensities and global energy demand growth therefore must come down faster to put the world on track towards sustainability. Energy use needs to be delinked from economic growth also in the emerging economies. How doable could that be?

Since 1990 the ratio of world primary energy demand growth to world economic growth has averaged about 0.6. Recently it has dropped toward 0.4. Globally, we are still left with a link between energy demand and economic activity, though it is weakening. This is a process known as decoupling. Individual country experiences suggest that the link can be broken further, so that economic growth can continue without associated growth in energy demand. Parts of the world have for more than a decade achieved respectable economic growth at flat or declining energy use levels. Thus North America, Europe and Industrialised Asia Pacific used 2% less energy in 2018 than in 2008 to generate 16% more GDP.

Stabilising or reducing energy demand in the face of continued economic growth will require continued attention to energy efficiency, electrification and significant lifestyle changes. The pool of energy efficiency improvement opportunities that may be realised at low, or even negative costs, is significant in most regions and sectors and keeps replenishing itself as technology improves. Further electrification will help, since electric engines on balance are two to three times more efficient than fossil fuel powered equivalents. To achieve ambitious emission reduction targets, lifestyle changes will likely have to be a part of the solution.

Growth in TPED by region per scenario, 2018-50

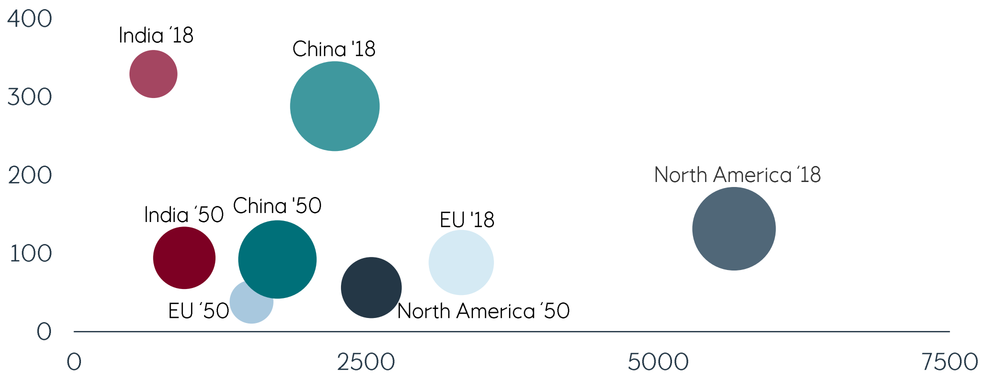
Average annual change, %



Source: Equinor

TPED per unit of GDP and per capita in Rebalance , 2018 and 2050

Toe/million USD (vertical axis), per capita in USD (horizontal axis), TPED (circles)



Source: Equinor

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Energy intensity

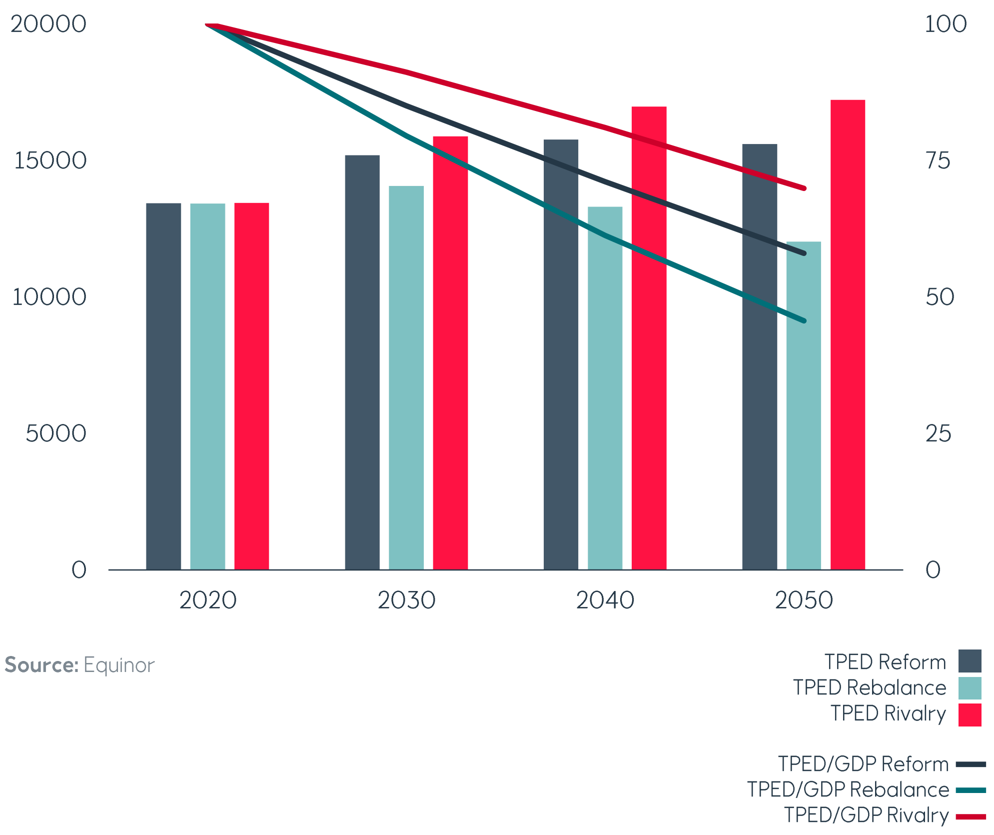
The energy intensity of the world economy – i.e., the ratio of world TPED to world GDP – declines in all our scenarios, by 2.5% per year in *Rebalance*, 1.8% per year in *Reform* and 1.2% per year in *Rivalry*. In comparison, the world became 0.8% less energy intensive annually between 1990 and 2010, though the pace has quickened in recent years. None of our scenarios assume slower improvements in energy intensity than over extended periods in the past. *Rivalry*, our least optimistic scenario, assumes a continuation of current trends, while the others suggest different degrees of acceleration.

These assumptions translate into energy demand increases of 21% for *Rivalry*, 10% for *Reform* and -15% for *Rebalance* by 2050. Thus, even if *Rivalry* is our lowest economic growth case, the comparatively slow pace of technology development and limited attention to energy efficiency make it the highest energy demand case. Demand in *Rivalry* only begins to plateau in the late 2040s. In *Rebalance*, demand picks up after the pandemic, but then structural dampeners linked mostly to climate concerns take over, resulting in a prolonged period of declining demand. In *Reform*, demand flattens in the late 2030s and starts declining in the second half of the 2040s.

Our global outlooks hide big variations across regions, especially in *Rebalance* due to its premise that the most industrialised regions will see lower economic growth than in *Reform*, to keep the world on track toward sustainability. These regions see declines of 2-2.5% per year in their TPED. Changes in industrialised country values and lifestyle choices come on top of leaps in energy and material efficiencies, and drive significant reductions particularly in the buildings and transport sectors' energy use. In contrast, Africa and India see TPED increases of 1.5% and 1.7% per year, respectively, ensuring some convergence across regions in energy use per capita terms.

World primary energy demand and energy intensity

Mtoe (lhs), index 2020=100 (rhs)



Source: Equinor

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Global fuel mix

Energy demand can be measured in two main ways; as the fuel input into the energy system, known as TPED, and as the usable energy output, known as total final energy consumption (TFC). The difference between the two is accounted for by transformation and transmission losses. Electricity is measured as part of TFC and can bring significant efficiency savings, as well as decarbonising the energy system if it is produced from non-emitting sources.

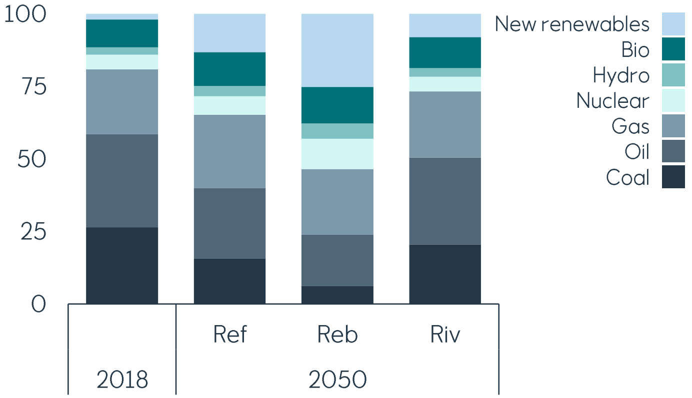
The electricity share of TFC is increasing, but at a pace well below that considered needed to reach climate goals. It was 19% in 2018 against 17% in 2008. In *Rebalance*, the pace of electrification picks up significantly, driven by a combination of technology developments and policy support, while *Reform* sees some acceleration too. In *Rivalry*, electricity continues to capture market share at about the same pace as in the recent past.

The oil share of energy demand declines as a result of the electrification of road passenger transport, impacting all scenarios, with the strongest reduction in *Rebalance*. At the global level, the gas share does not change very much in any of our scenarios, but there are major shifts at the regional level. In *Rebalance*, the EU's gas share drops from well over 20% today to 9% by 2050, reflecting this region´s uniquely ambitious decarbonisation agenda. In China, where coal to gas switching is good climate policy, the share almost doubles from 7% to 13%. CCUS enables some gas power generation in *Rebalance*, but is not applied to such an extent that it changes the renewable profile of the scenario.

The main change at the world TPED level is growth in the wind and solar shares, which increase 9-fold and more than 20-fold, respectively, between 2018 and 2050 in *Rebalance*. Coal power generation in *Rebalance* is wiped out in all regions apart from China, India and South East Asia, and even in those regions it is severely reduced. Coal holds up better in *Reform* and especially in *Rivalry*, but it is difficult to see a comeback for coal regardless of scenario, as coal power generation is being marginalised on costs everywhere. Coal mines and coal power plants may be kept alive for supply security and employment reasons, but such concerns will eventually be side-lined. We see nuclear power holding up in *Reform* and *Rivalry* and increasing its share of TPED in *Rebalance* – if not in Europe, then in a string of middle-income emerging economies.

World total primary energy demand

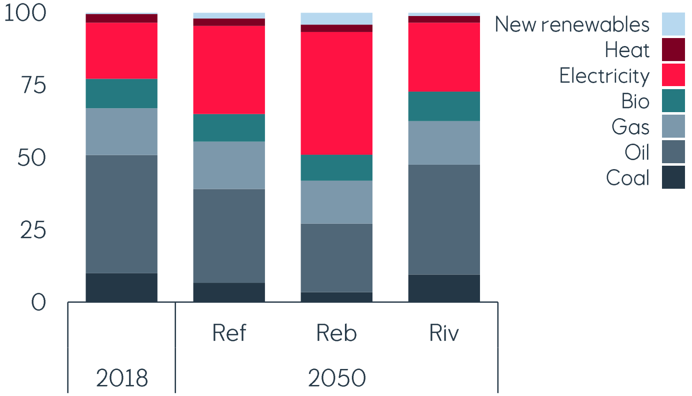
Percentage



Source: IEA (history), Equinor (projections)

World total final energy consumption

Percentage



Source: IEA (history), Equinor (projections)

The global oil market

Current situation and outlook to 2025

Amongst all commodities, the global oil market has probably been the hardest hit by the containment efforts during the Covid-19 pandemic. As country after country went into lockdown, oil demand fell dramatically. Planes were grounded as international air travel seized across entire regions. Car traffic and public transport were also greatly reduced as people were ordered to work and study from home. Oil demand is estimated to have dropped by 16 mbd in the second quarter of 2020 – an unprecedented dip. As oil demand plummeted, a supply war commenced between two of the largest oil producers, Saudi Arabia and Russia. Both pledged increased supply in retaliation for non-compliance and disagreements around the ongoing Opec and contributing non-Opec countries' (Opec+) production deal. Forming a perfect storm, record-low demand coincided with record-high supply. Global oil storage was in danger of overfilling due to the massive oversupply, and prices plummeted. Dated Brent fell more than 80% from a January high of 70 USD/bbl to its lowest point of 13 USD/bbl in April.

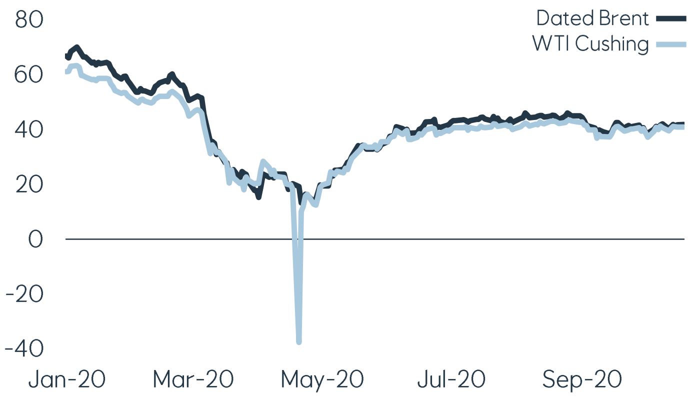
For another historical first, the US crude oil benchmark, WTI, went negative at -37 USD/bbl, as paper traders got stuck with physical cargoes they had to pay to get rid of.

As the severity of the situation hit home, the Opec+ alliance renewed their attempt to manage the market. Since lockdowns have eased over the summer, oil demand has started to pick up and oil prices have stabilised. Opec+ are currently holding back 7-8 mbd of supply to draw down inflated storage, which puts a lid on prices.

Assuming the worst is behind us in terms of lockdowns, the next big question is how fast demand will recover, and how many of our new consumer habits will remain in the "new normal". Many of the sectors which have been hit, such as the service sector, will likely pick up quickly as the threat of the pandemic is reduced. Air traffic, on the other hand, is still a long way off normal activity levels. It is likely that demand for aviation fuels will suffer for many years to come, as the pandemic may have permanently altered the frequency with which we fly. On the supply side, upstream spending has been cut significantly in response to uncertainty and price collapse. This will contribute to a tighter market some years from now if, or when, demand growth returns to pre-pandemic pace. For the next few years, however, the market is expected to be well supplied and Opec+ management may be necessary for some time, before the effects of the pandemic have been fully offset.

Oil price development

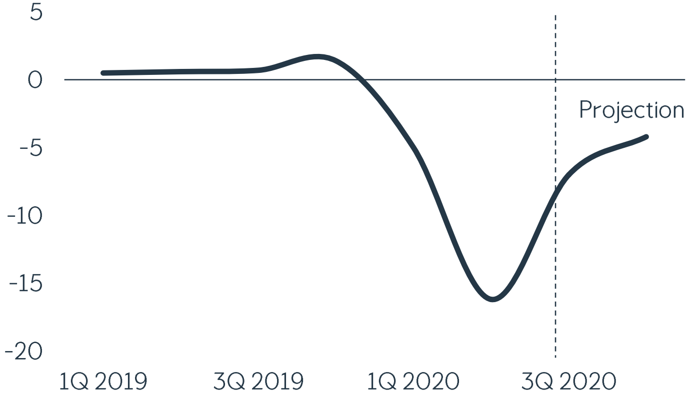
USD/bbl



Source: Platts

Global oil demand growth

Mbd per quarter year-over-year



Source: IEA

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Outlook beyond 2025

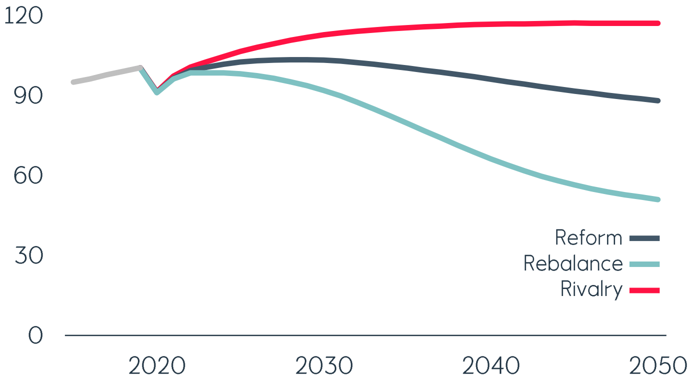
The uncertain impact of the energy transition on future oil demand may be the key challenge facing international oil companies. The outcome space is vast. By 2050 there is a 66 mbd difference in demand between our high and low scenarios, with *Reform* ending at 88 mbd. During 2020 we have seen a glimpse of what a lower demand world could look like, the question is whether a permanent dent has been made in oil use or whether the world will return to its old trajectory.

Rivalry is the highest oil demand scenario and sees continued growth in sectors such as road, aviation and shipping. Lack of policy support and investments reduces the push for alternative fuels and new technology to reduce emissions. Battery technology development is slow and internal combustion engine (ICE) vehicles continue to outcompete electric vehicles (EVs). By 2050, oil demand growth may have flattened, but at a significantly higher level than today and without necessarily showing signs of declining. Though *Reform* has the highest economic growth of the three scenarios, there is a stronger shift towards alternative fuels, improved energy efficiency and, most significantly when it comes to oil demand, a much faster uptake of electric vehicles.

In *Rebalance*, new mobility technology and changes in behaviour lead to lower demand of oil in the transport sector. Aeroplanes and ships will make use of advances in battery technology, alternative fuels and digitalisation to emit less CO_2, though complete decarbonisation is still a challenge. Renewables displace oil demand in industry and buildings, leading to significantly lower use overall. Demand continues to grow in the petrochemical industry which relies on petroleum to produce the strong, lightweight materials used in the new vehicles, as well as in other vital products such as clothing, medicines and packaging. However, environmental concerns increase recycling rates, meaning less need for new oil feedstock. Although the world in some ways would appear to be on a *Rivalry* path in the short term, particularly on the geopolitical side, there are also strong forces pushing hard to get us on to the *Rebalance* path. Whatever path we eventually take, oil products will be needed for decades to come. This demand requires investments in oil supply to mitigate the natural decline of currently producing fields. Without investment there will likely be a significant supply gap, though with targeted investment and policy any new supply should be of the lowest carbon intensity possible and allow the most cost-effective transition to zero carbon alternatives.

Oil demand by scenario

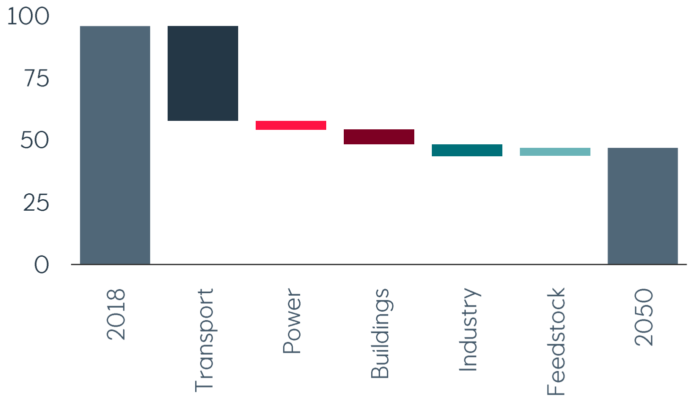
Mbd



Source: IEA (history), Equinor (projections)

Change in global oil demand by sector in Rebalance

Mbd



Source: IEA (history), Equinor (projections)

Photo by Ole Jørgen Bratland, Equinor

The global gas market

Current situation and outlook to 2025

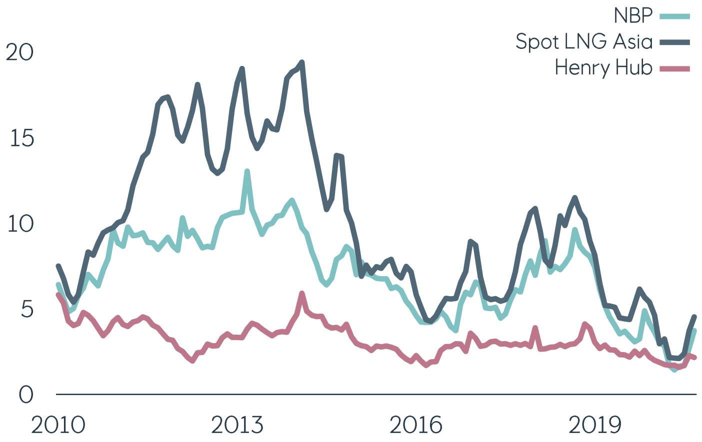
The gas market is shaped by the combined effects of negative natural gas demand growth, high storage injections in 2019, and 40 Bcm of new LNG supply capacity added to the market over the last year. With the unfolding of the Covid-19 pandemic, gas demand dropped as businesses closed, power demand was reduced, and industrial demand slumped. The already well supplied global gas market was overwhelmed, with producers chasing demand among contestable customers in Europe. This resulted in unprecedented low prices and production shut-ins.

Pre-Covid, some 85 Bcm of new LNG capacity was expecting investment decisions over this year and next. Both capital constraints and low prices are now putting projects on hold and delaying new project developments.

Low gas prices are expected to incentivise demand growth in the medium term, and a slower capacity build-up in the LNG market could contribute to market tightening towards the mid 2020s. Producer behaviour and timing of the next LNG investment cycle will be key drivers for the market.

Regional gas prices

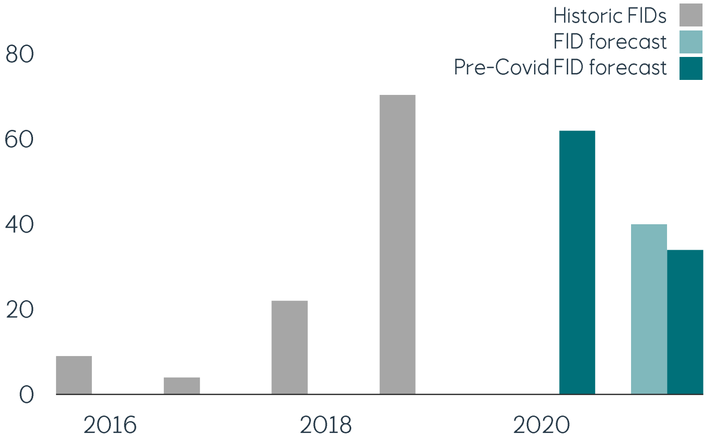
USD/MMBtu



Source: ICIS Heren, Platts

Change in LNG final investment decisions (FIDs)

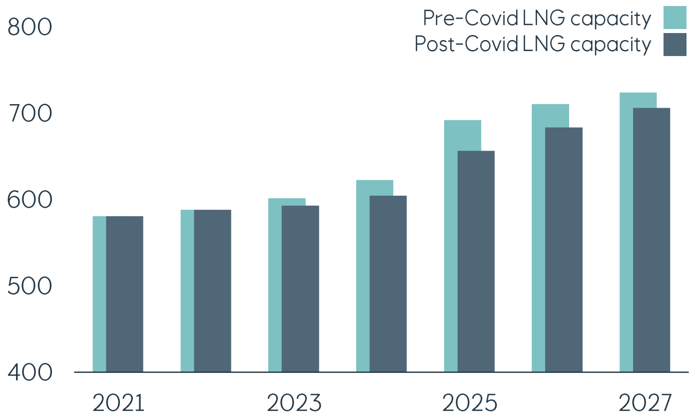
Bcm



Source: WoodMac, IHS, Equinor (projections)
Note: No FIDs expected for 2020

LNG construction delays

Bcm



Source: Equinor

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Outlook beyond 2025

Our scenario-based assessment of long-term gas developments encompasses drivers like affordability, fuel substitution, geopolitical tensions and lack of market integration. In addition, the energy transition will eventually challenge the role of natural gas in the global fuel mix. The outcome space after 2030 is large, spanning from around 3250 to around 4800 Bcm in 2050. The strategic implications for resource owners are considerable.

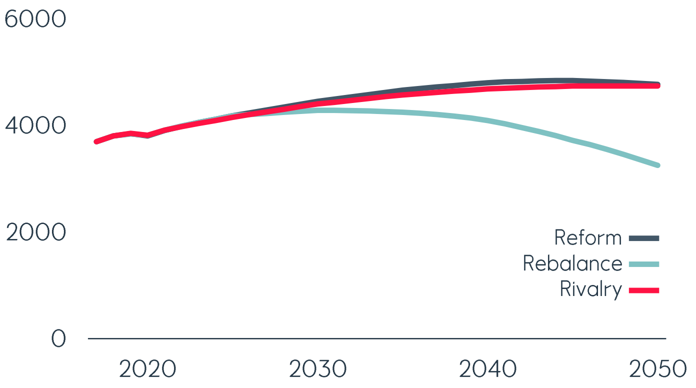
Reform sees gas growing at an annual growth rate of 0.5% 2025-50. Asia makes up 63% of growth, providing a pull signal on supply in all geographies, including LNG value chains. LNG supply reaches 980 Bcm in 2040. In *Rivalry*, policies shift away from emission reductions and energy efficiency towards energy supply control, favouring local resources over imported gas. LNG projects are discouraged due to increased political risk. Gas producing regions such as the US, Russia and the Middle East increase demand, whereas Europe and Asia reduce fuel imports. Overall, gas demand is slightly reduced vs *Reform*.

Following the approach of international cooperation in order to deliver on global sustainability targets, *Rebalance* includes use of new technology, energy efficiency and more even distribution of income. Increased economic growth and hence energy use in emerging regions, relative to industrialised regions, implies growing gas demand vs *Reform* in India, Africa and South East Asia, whereas mature markets reduce their gas reliance. China is still the main growth engine in this scenario, but a weaker GDP outlook and the shift from the energy intensive industries to service industries dampen gas growth vs *Reform*. As a fossil fuel, gas is exposed in the long term, as the renewables share in the power sector increases. It does however play a vital role in the rapid phase out of coal in the power sector and complements intermittent renewable supply.

Intermittent generation and demand variability mean there will be a significant need for flexibility in the electricity system. CCUS and "blue" hydrogen production are means to address this issue in a low-carbon context and will support gas demand. However, competitiveness of unabated natural gas declines as end users face increasing costs from emitting CO_2. Resource owners, partners and not least governments must develop strategies and incentives to promote clean energy value chains. Considerable work and efforts remain to realise such new projects and investments.

Global gas demand by scenario

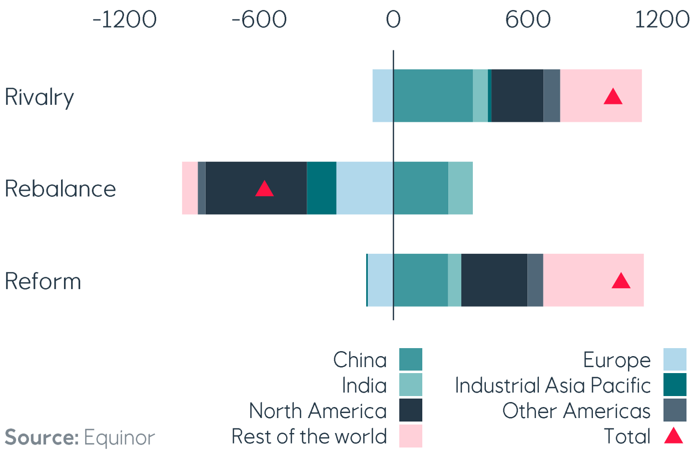
Bcm



Source: IEA (history), Equinor (projections)

Global gas demand growth by region and scenario 2018-2050

Bcm



Source: Equinor

Photo by Vidar Nordli-Mathisenon on Unsplash

The future of transport

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Road transport

The transport sector is going through momentous structural changes, brought about by a convergence of demographic, social, political, and technological factors. In 2019, the road transport sub-sector used about 45 mbd of oil products, corresponding to some 45% of total oil demand. This was an all-time high and further boosted sub-sector CO_2 emissions. But also EV sales set another record last year, with EVs becoming much more prominent in major automotive markets. However, average fuel efficiency in the new car fleet is negatively affected by the significant growth in SUVs sales.

Covid-19 has hit transport activity hard and could help usher in a new era for the road sub-sector in the long term. The following four key drivers and trends impact future growth in our scenarios, albeit to varying degrees: automation, connectivity, decarbonisation and shared mobility. Up until 2022 the three scenarios follow the same trajectory, but then they part ways and portray very different situations by 2050, with total transport oil demand ranging between 10 mbd and 48 mbd.

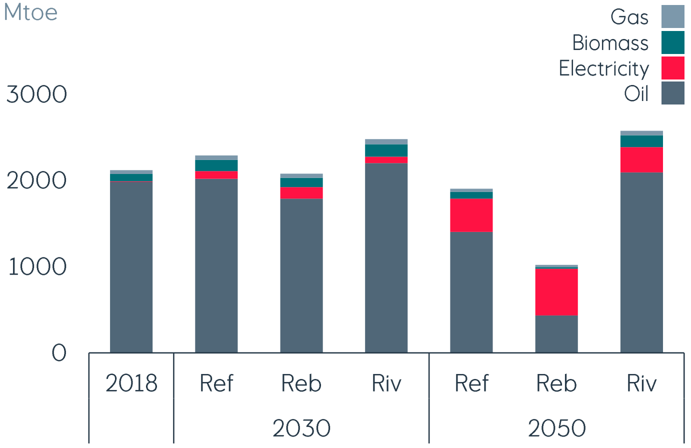
In *Reform*, developments continue along current trends. The virus subsides, as well as governments, businesses and people, want to make up for lost time. Fuel demand developments are influenced by improvements in conventional vehicle fuel efficiency and a steady increase in the number of EVs on the road, with EVs, hybrids and plug-in hybrid EVs (PHEVs) dominating by 2050.

Rebalance depicts a coordinated global effort driven by climate concerns to facilitate transport and trade needs, while at the same time drastically reducing greenhouse gas emissions. Facilitated by strong regulatory policies and incentives, the combination of new technologies and alternative fuels enable the decarbonisation of road transport. Personal ownership will be challenged by car pooling and ride sharing, enabled by ever-evolving digital technologies. A mode shift towards a greater share of public transport and alternative vehicles such as e-bikes and scooters will reduce the growth in the global car fleet. Digital technologies and automation will enable greater efficiencies in the freight sector, reducing the footprint from transporting goods on land or at sea.

In *Rivalry*, failure to respond to the climate challenge limits decarbonisation policies around the world and dampens economic growth, technological development and the uptake of EVs and alternative technologies such as hydrogen. ICE vehicles stay dominant for years to come, with behavioural changes limited by smaller efficiency gains and less stringent carbon policies.

Road transport fuel demand by scenario

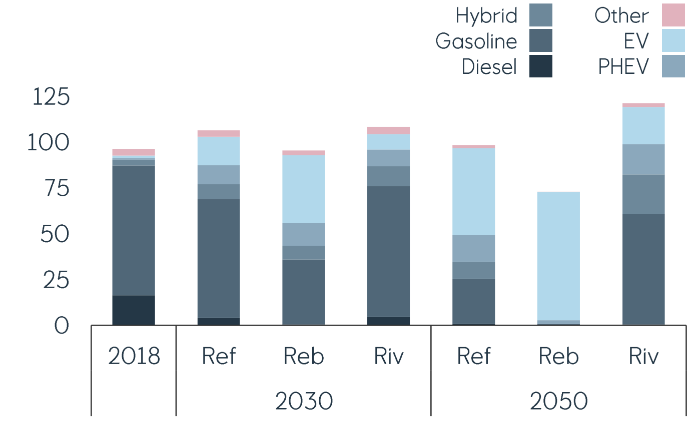
Mtoe



Source: IEA (history), Equinor (projections)

Light-duty vehicles new sales by technology and scenario

Million vehicles



Source: IEA (history), Equinor (projections)

Non-road transport

The non-road share of transport sector fuel use has hovered around 25% since 2000. Both the road and the non-road sectors, apart from rail, have experienced increases in fuel use of 2.2-2.3% per year. Rail has increased more slowly at an average 0.6% per year. Inside the non-road category there was a shift from domestic to international shipping, but since 2010 that trend has reversed. There has also been a shift from domestic to international aviation and that trend has continued – until now.

All non-road transport apart from rail depends almost entirely on oil. Electric propulsion is becoming an option for ferries and other local, small scale shipping, but can only power larger vessels over short distances. Batteries may become an option for small aircraft, but are too heavy and bulky for larger aircraft designed for long-haul flights. Shipowners look to alternative fuels such as biofuels and LNG to cope with IMO's 2020 sulphur emission cap and, further out in time, ammonia and hydrogen to reach the net zero target. Airlines are banking on biofuels and, again further out in time, synthetic fuels produced from hydrogen and captured CO_2.

Covid-19 has had a devastating impact on non-road passenger transport, especially aviation. We project a 30% decline in aviation fuel use in 2020, though more pandemic waves could well make matters worse. We suggest for *Reform* and *Rivalry* a return to pre-crisis levels around the mid-2020s, while in *Rebalance* aviation never fully recovers, with fuel use levelling out below its 2019 level under the combined weight of pandemic concerns, climate policies and energy efficiency improvements. Shipping is mostly freight transport and thus less affected by Covid-19. We see a 12% decline in global marine fuel use in 2020 and a recovery to 2019 levels by 2022-23 in *Reform* and *Rivalry*. In *Rebalance* fuel use never rises much above its 2019 level before going into decline in the second half of the 2020s.

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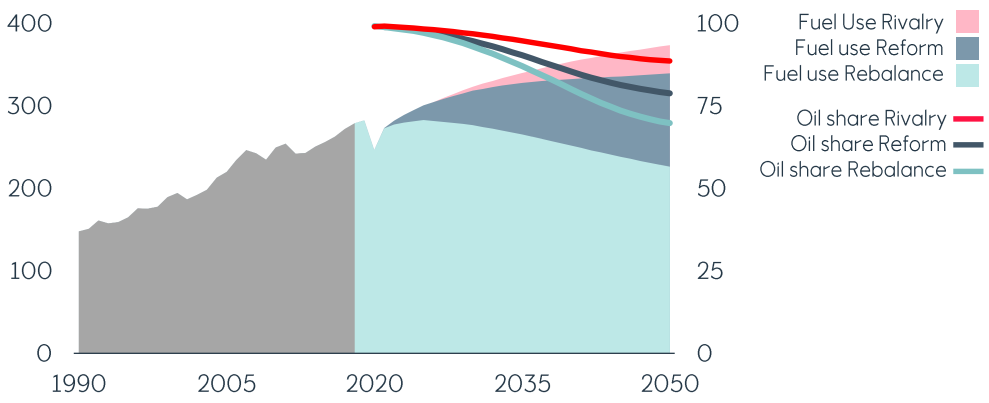
Global marine fuel use and oil share of fuel use

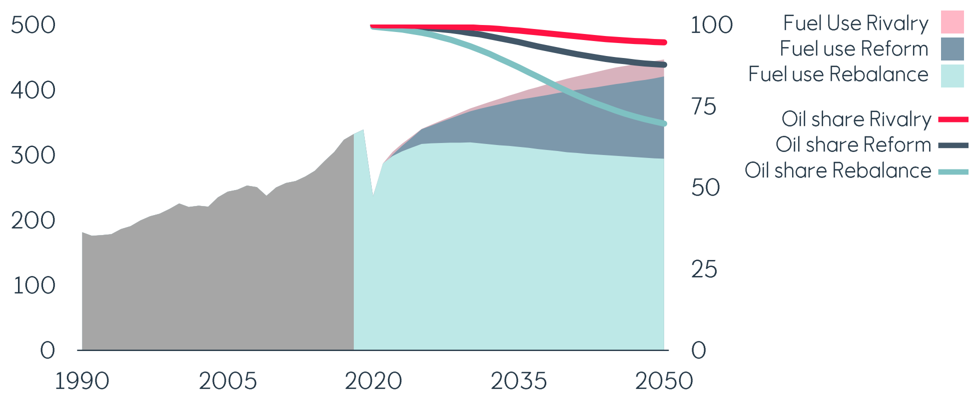
Mtoe (lhs), % (rhs)



Source: IEA (history), Equinor (projections)

Global aviation fuel use and oil share of fuel use

Mtoe (lhs), % (rhs)



Source: IEA (history), Equinor (projections)


Photo by Matthew Henry on Unsplash

Global electricity markets

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Current situation and outlook

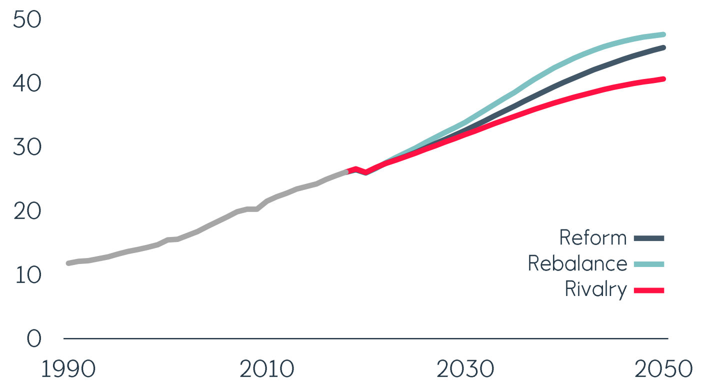
2020 has been a tough year for the electricity sector, as demand dropped due to lower economic activity. Still, electrification is a key element in decarbonising the energy sector. Electricity does not emit greenhouse gases when used and does not need to cause emissions when generated. Electrification also means energy efficiency improvements. In our scenarios, world electricity demand increases by between 52% and 80% between 2018 and 2050, with the fastest growth in *Rebalance*. The electricity share of world final energy consumption increases from about 20% today to 30% in *Reform*, 42% in *Rebalance* and 24% in *Rivalry*. Electricity demand will grow everywhere, but most rapidly in the emerging economies, with clean generation technologies increasing their combined market share. Policy support in Europe, North America and China for wind and solar photovoltaic (PV) development has enabled mass production and cost reductions, and will in turn boost deployment in the rest of the world. A question right now is whether efforts to lift the world out of its current recession will emphasise clean energy growth based in part on renewable electricity, or conventional growth based on the fossil resources most easily at hand.

It is difficult even in *Rivalry* to see a bright future for coal power generation. The so-called levelised costs of wind and solar PV generation have declined to the point of making coal power plant projects uneconomic even in coal dependent Asia. Plant level costs are however not the only factor determining the relative attractiveness of different generation technologies. The intermittency of wind and solar power may require investments in back-up and interconnectivity that should be taken into account. These are however no longer seen as important enough to possibly sustain the positions of coal, especially since the scope for making coal power cheaper is limited. That said, the historic resilience of coal power generation needs to be kept in mind. The coal share of world power generation was exactly the same in 2018 (38%) as in 1973.

While the new renewables share of world power generation increases to 38% in *Reform* and 53% in *Rebalance*, this will require electricity market design changes. High shares of electricity from zero marginal cost resources like wind and sunshine in an electric power system will put downward pressure on wholesale market prices, potentially discouraging much needed investments. Governments may have to rethink if the wholesale market is the most appropriate place to have market mechanisms, or if they should change the market design to guarantee investments in infrastructure.

Electricity demand evolution

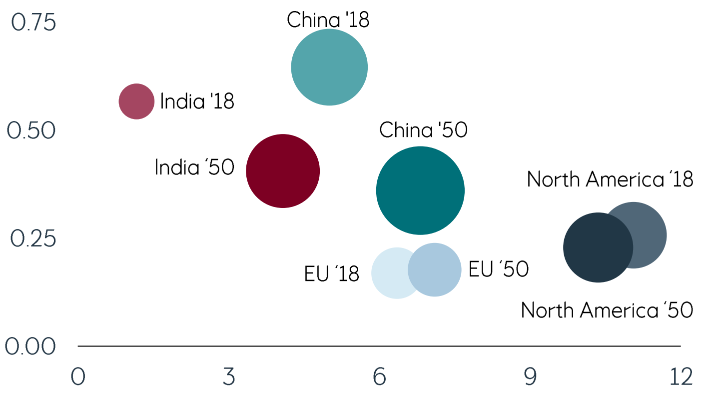
Thousand TWh



Source: IEA (history), Equinor (projection)

Electricity demand per GDP and per capita in Rebalance, 2018 and 2050

kWh/USD (vertical axis), MWh (horizontal axis), electricity demand (circles)



Source: IEA (2018), Equinor (2050)

Wind, solar and other renewables

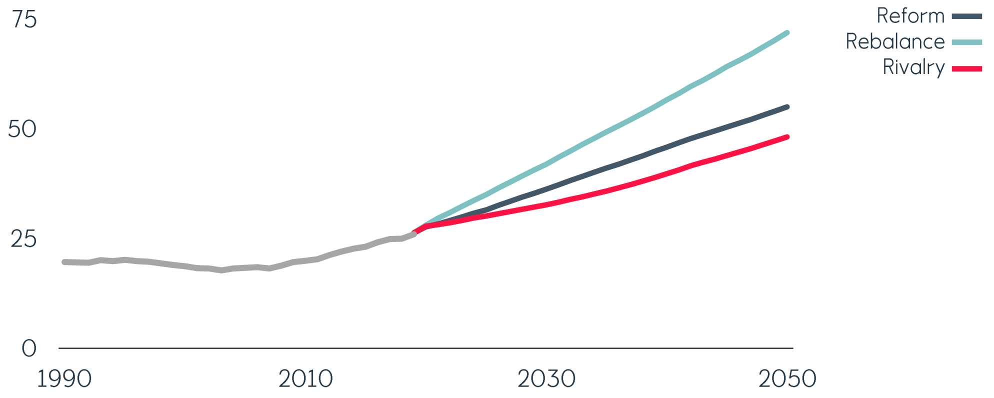
While the main rationale for increasing renewable capacity in industrialised countries remains decarbonisation, security of supply and affordability considerations are also playing roles. Fuel imports account for high shares of many net-energy importing countries' trade deficits. As an example, 18% of South Korea's imports were fuel imports in 2018, the equivalent of 7% of GDP. Once built, renewable capacity relies on indigenous resources, thus improving the trade balance and ensuring domestic supply of energy.

Deficit reduction will be a key element for emerging economies, especially as significant cost reductions over the past decade have left renewable power a cost-effective option. However, infrastructure bottlenecks put a dampener on renewables development in many emerging economies. Nonetheless, solar panels paired with batteries could provide an effective alternative to more expensive and polluting diesel generators in non-connected communities.

As large-scale hydro power projects have become increasingly controversial, renewable power growth will, at least in the short and medium term mean wind and solar PV growth. Wind and solar capacity alone will not be enough to meet demand requirements due to the intermittency of their generation. Inevitably, it will have to be supplemented with back up capacity, initially based on existing technologies, mainly gas, moving towards either CCUS solutions, batteries or hydrogen storage in the future.

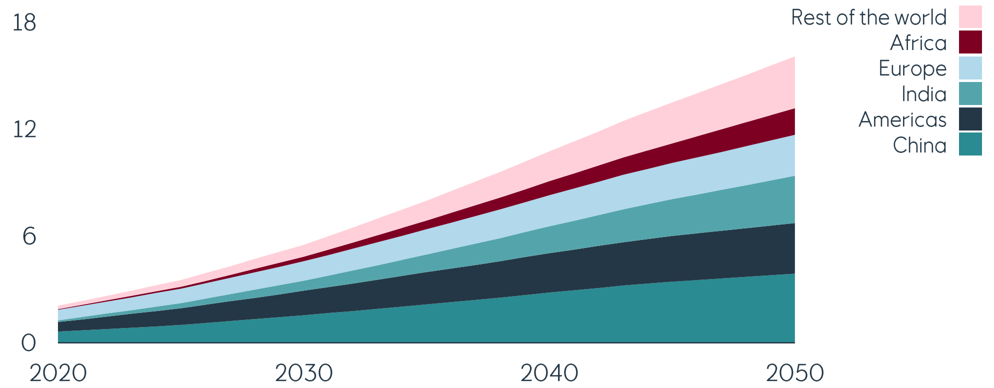
Where the quality of the infrastructure allows it, demand management may be a solution to improved allocation of resources. This will require efforts to upgrade and digitalise the network, as well as defining a way of pricing this service for customers.

Share of renewables in electricity mix
Percentage



Source: IEA (history), Equinor (projections)

Wind and solar generation in Reform
Thousand TWh



Source: Equinor

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Coal, gas and nuclear power

Coal power plants have been the backbone of electricity systems since the late 19th century. Recently, however, its carbon intensity and desire for cleaner air have caused governments to move away from the technology. This has been exacerbated by the commitment from parts of the financial industry to not finance new coal-based projects or divest from existing ones. We expect some emerging economies to still build new plants, but this will be a short-term solution to keep up with growing demand.

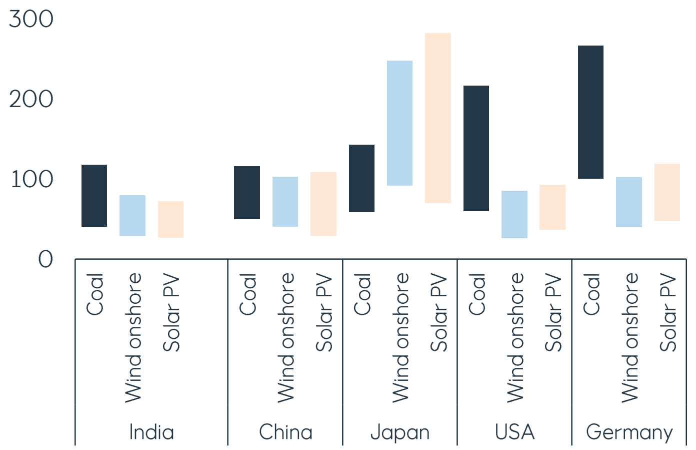
In the medium term, coal to gas switching is likely to be the front runner in the eyes of many governments. Gas not only has a lower carbon intensity, but also does not suffer from the same problems linked to air quality that coal does. In addition, gas plants remain flexible enough to provide swing generation, allowing further development of intermittent renewables. Down the line, as carbon constraints increase in emerging economies, gas power plants may morph into burning "blue" and "green" hydrogen (H_2) to provide flexibility. If the costs of the H_2 value chain were to come down, there could be a real incentive for emerging economies to invest in "green" H_2 as a backup technology.

Nuclear could play a role in accommodating the growth in electricity demand and meeting the emissions reduction challenge, thanks to its carbon-free reliability and high energy density. Today, about 440 nuclear power reactors in 30 countries provide some 10% of global electricity supply. In 2018, 12 countries generated at least 25% of their electricity from nuclear. Most of the existing capacity is in Europe and North America, but fleets are ageing and not being replaced. High costs and public acceptability remain issues. Most of the new capacity is being built or planned in Asia and CIS.

Going forward, there is increasing interest in small modular nuclear reactors (SMRs), both in newcomer and established nuclear countries. SMRs are flexible enough to be deployed close to demand centres and can be built in clusters to achieve any needed level of power capacity. They offer opportunities for minimising expensive on-site work and standardising design. Further into the future are more radical concepts like fusion reactors. In the medium term, fourth-generation fission designs could potentially take off and supply much of the needed electricity as the world economy progresses into the middle decades of the century. Ultimately, replacing fossil fuel with nuclear power is a political decision as much as technical and cost issue, as we have seen in Germany, UK and Japan.

Levelised cost of electricity (LCOE) estimates, 2019

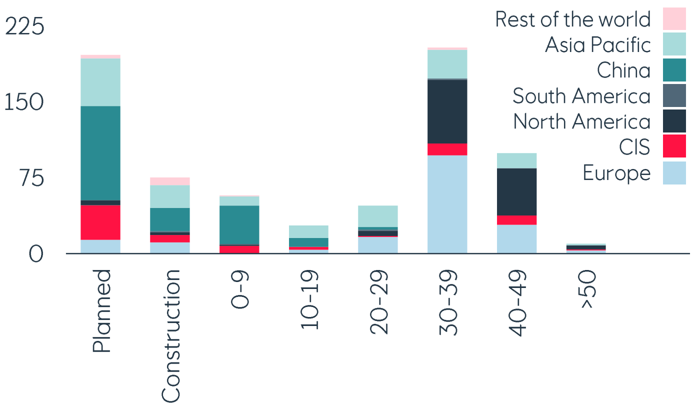
USD/MWh



Source: BNEF

Nuclear capacity by age and region

GW



Source: IAEA, Equinor


Photo by Martin Sepion on Unsplash

Global greenhouse gas emissions

Did carbon emissions peak in 2019?

After two consecutive years of increasing global energy-related CO_2 emissions in 2017 and 2018, emissions flattened in 2019 at around 33 Gt. A drop in coal use in the industrialised regions was the main driver of the flattening. Covid-19 has already made an impact on CO_2 emissions globally, with a projected year-on-year drop of 6.5% from 2019 to 2020. This will bring emissions back to a level seen 10 years ago – at 30 Gt. During the pandemic the most carbon-intensive fuels, namely coal and oil, have experienced large declines in demand. This has been driven by slowdowns and lockdowns in the power and transport sectors. Conversely, renewable energy supply has been more resilient.

In *Reform*, global energy-related CO_2 emissions are projected to have peaked in 2019, ending up at 26.3 Gt in 2050. Decarbonisation of the power sector and electrification of the transport sector are the main drivers for the long-term decline. Despite the expected peak in emissions in 2019, *Reform* is far from meeting the well below 2° C target.

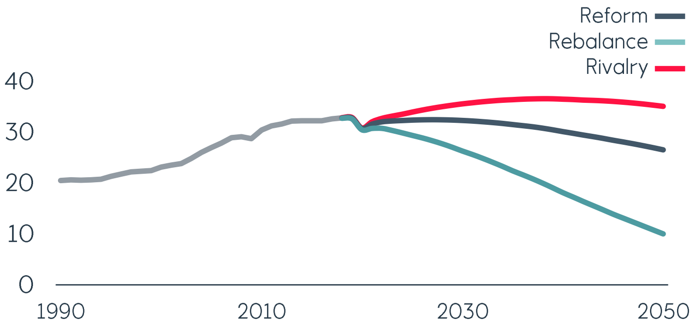
In *Rebalance*, we also predict that global CO_2 emissions peaked in 2019. Further, emissions decline with an average rate of 3.6% per year from 2020 throughout the outlook period. *Rebalance* is designed to be a well below 2° C scenario, and we assume cumulative emissions of 740 Gt for the 2018-50 time period to be within this target. Emerging regions like Africa, India and South East Asia can allow emissions to increase until around 2030 before contracting, while industrialised regions will need to see immediate emission declines.

In *Rivalry*, emissions continue to grow from today's level until the end of the 2030s when they peak just above 36.5 Gt per year, before slowly declining during the 2040s. An increase in the negative effects of climate change on both the environment and the global economy will filter through as a consequence.

According to the UN's Emission Gap Report 2019, countries must increase their Nationally Determined Contributions (NDCs) ambitions threefold to achieve the well below 2° C goal, and more than fivefold to achieve the 1.5° C goal. The lessons from the pandemic have given governments and policy makers the opportunity to dedicate investments towards cleaner energy carriers and encourage significant behavioural changes. Implementing changes will be vital to avoid a rebound in emissions due to the expected near-term economic recovery, which could well see emissions growth exceeding the declines seen during 2020.

Global energy-related CO_2 emissions by scenario

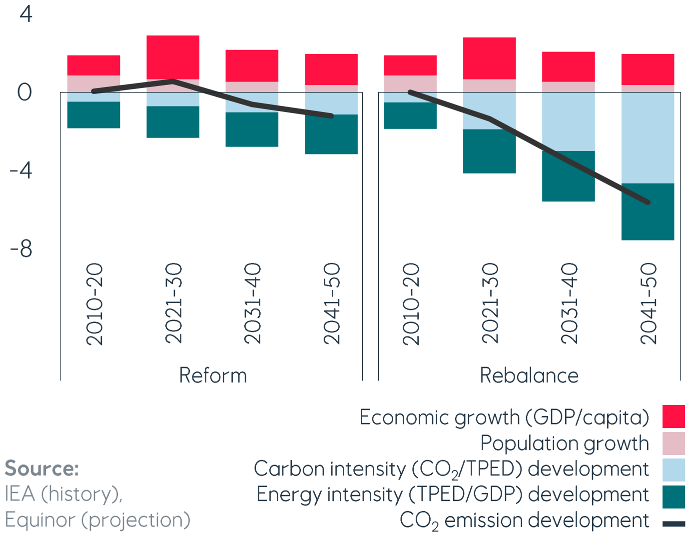
Gt



Source: IEA (history), Equinor (projection)

Global energy-related CO_2 emissions in Reform and Rebalance

Average % per decade



Source:
IEA (history),
Equinor (projection)

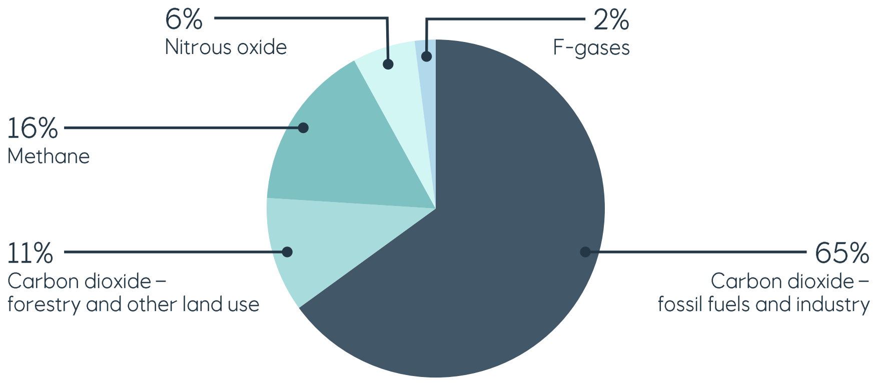
Methane emissions

CO_2 is not the only greenhouse gas of importance. Methane (CH_4) emissions account for an estimated 23% of global warming potential. Methane is a much more potent greenhouse gas than CO_2, but decays into other, less harmful gases much faster. Combining these facts, scientists put the warming impact of CH_4 at 86 times that of CO_2 in a 20-year perspective, and 28 times that of CO_2 in a 100-year perspective. World methane emissions levelled out for a period in the early 2000s, but have been on a rising trend since 2007 and totalled 596 million tons in 2019, according to IEA. In a 100-year perspective these emissions thus have a warming effect comparable to that of 16.7 bn tons of CO_2. Methane emissions, like CO_2, are partly absorbed back into nature, so the warming effect of the CH_4 actually added to the atmosphere was smaller, but still significant. Agriculture and natural processes are the main source of CH_4 emissions. IEA estimates methane emissions from fossil fuel value chains in 2019 at 123 million tons, corresponding to 21% of world total methane emissions. These emissions were due not to the combustion of products, but from venting and leaks in wells, mines and mid- and downstream infrastructure.

The climate scientific community urges the fossil fuel industries to act on their methane emissions, which are considered low hanging fruits compared to agricultural and natural CH_4 emissions, and to the bulk of CO_2 emissions, which require a deeper transition. The members of OGCI, a CEO-led initiative consortium that aims to accelerate the oil and gas industry response to climate change, have agreed to cut the methane intensity of their upstream operations from 0.3% in 2017 to 0.2% by 2025. We do not try to model methane emissions as they are not a function of fuel use or any of the other variables addressed in Energy Perspectives. A moderately optimistic view on these emissions is nevertheless informing our *Rebalance* scenario, as a co-driver of the size of the CO_2 budget adopted for this outlook.

Global greenhouse gas emissions by gas

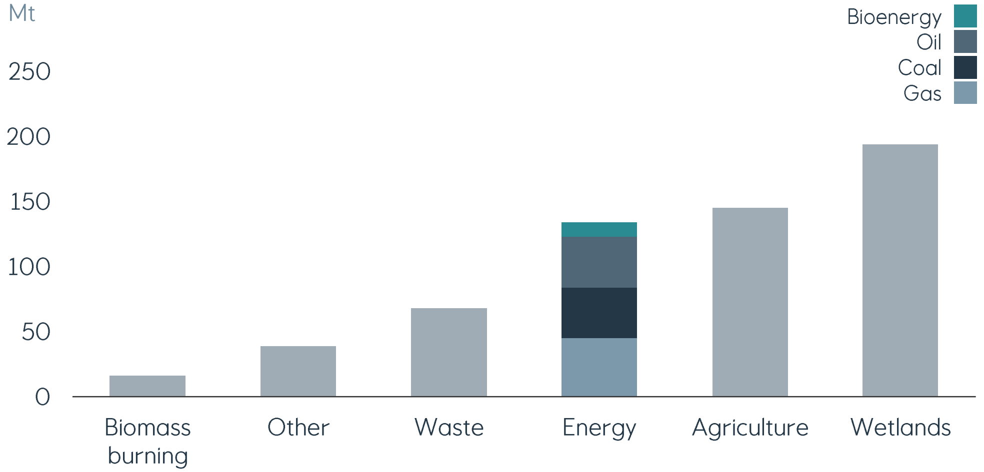
Percentage



Source: US Environmental Protection Agency

World methane emissions by source, 2019

Mt



Source: IEA

Photo by Stephen Kraakmo on Unsplash

In detail

Towards a net zero emissions world?

Several nations and companies around the world have committed to reducing their greenhouse gas emissions to "net zero" by 2050. "Net zero" means that remaining emissions should be captured and utilised, stored, or compensated for by removing already emitted greenhouse gases (GHGs) from the atmosphere. Reducing GHG emissions to "net zero" is a massive endeavour. The current commitments until 2030 in the Paris agreement do not amount to anything like the trajectory needed for a 1.5° C cap on global warming, instead suggesting a 3° C temperature increase by 2100.

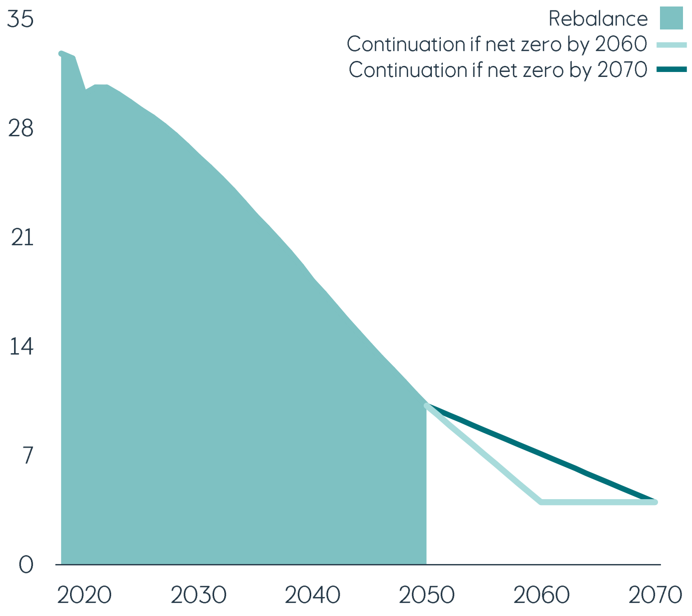
Methods for removing CO_2 from the atmosphere and utilising or storing it have become central to the vision of climate stabilisation. Most scenarios portraying a sustainable future assume considerable amounts of CO_2 removal, mainly through bioenergy use with CCUS taking care of the emissions (BECCS), forestry solutions contributing in the early stages, and so-called direct air capture (DAC) becoming feasible on a large scale further out in time. Balancing the availability of land for regular harvesting of biofuel crops against the need for forest protection, on top of land use requirements for food supply, is a complex issue.

Rebalance does not portray "net zero" by 2050, but could it be compatible with "net zero" by 2060 or 2070? World energy-related CO_2 emissions in this scenario drop to some 10.2 Gt per year by 2050 after accounting for CCUS. They are down by an average of about 400 million tons (Mt) per year during the 2020s and about 800 Mt per year between 2030 and 2050. Reaching zero by 2060 or 2070 without any support from negative emission technologies would require continued declines of more than 1 Gt per year for the 2060 target, and half that, i.e., about 500 Mt per year, for 2070. This might turn out to be difficult, especially since the remaining CO_2 emissions are concentrated in hard to abate sectors.

Assuming that BECCS, DAC etc. will play no role whatsoever in this timeframe could however be overly conservative. If we instead assume a global capacity to pull 4 Gt of CO_2 out of the air after 2050, the required emission reductions drop to 620 Mt per year in the "net zero by 2060" case and 310 Mt per year in the "net zero by 2070" case. The latter of these annual reductions is 60% smaller than what we already envisage for the 2030s and 2040s in *Rebalance*, and could conceivably be feasible. If it turns out to be possible to install more CCUS capacity than the 2 Gt assumed in *Rebalance* by 2050, the task would be somewhat less daunting.

World energy-related CO_2 emissions in Rebalance

Gt



Source: Equinor
Note: Extended to 2070 assuming a "net zero" definition allowing for 4Gt of emissions

Low growth economies

Asking the world's poorest countries to sacrifice economic growth for the sake of containing GHG is widely dismissed. Most of the UN's Sustainable Development Goals call for faster growth in these countries to ensure improvements in quality of life, reduce inequality and deliver sufficient means to focus on sustainability. This means that in a world prioritising sustainability the world's richer countries need to shoulder the bulk of adjustments. In *Rebalance*, industrialised countries' GDP growth is only marginally above population growth. Thus these regions are better off in GDP per capita terms at the end of the scenario period than today, but significantly less so than trend extrapolation would suggest.

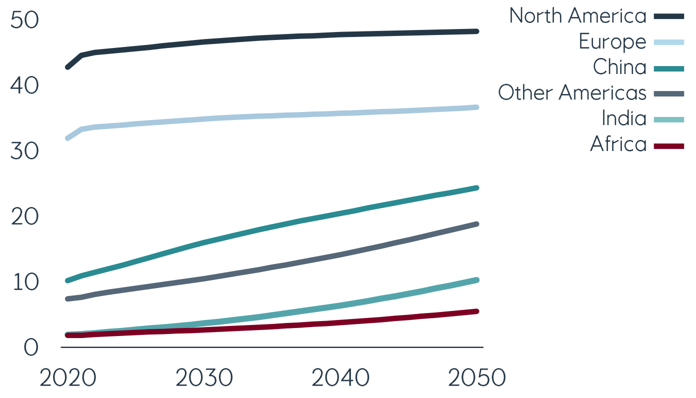
Low economic growth is not unheard of. Since the 1980s, some industrialised economies have experienced long periods of stagnation. In Italy, for instance, average real GDP per capita growth has been just above zero since the turn of the century. These set-backs have occurred not by design, but as results of challenging external and internal circumstances. And whether it is a sustainable situation, could be questioned. Subdued economic growth does not need, however, to be perceived as a disaster by those experiencing it. There are more aspects to wellbeing than booming material consumption.

Structural factors will dampen growth in the industrialised world irrespective of intentions. Demographics, with aging populations and urbanisation rates slowing, will play a role. Consumption is shifting from goods to services, and the scope for service sector productivity growth is limited. Global warming will probably cause droughts, floods and storms relevant to economic expansion. In *Rebalance* the transfer of resources from the richer to the poorer countries to combat, and manage the consequences of global warming, will shift growth impulses from the former to the latter regions. People in the industrialised regions may feel they are sufficiently prosperous and decide to reduce their working hours to spend more time on leisure activities. This might reduce consumption growth, but possibly also put strain on some recourses.

There are of course risks to this idealised pathway. Low growth in the economies may erode their capacity to innovate and sustain high levels of investment in energy efficiency and decarbonisation. It may also impact negatively through trade and investments on the emerging economies' prospects. As always, sustained global political support over a long period of time for an epically ambitious target may prove elusive. Time will tell.

Real GDP per capita by region in Rebalance

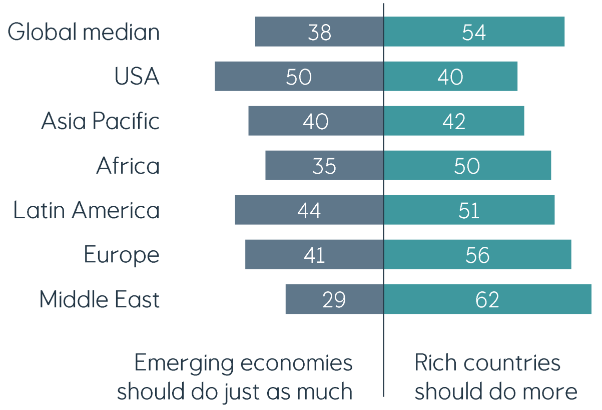
Real thousand USD at market exchange rates



Source: Equinor

Who should bear more of climate change cost?

Percentage



Source: Pew Research Center

How will costs and benefits of an energy transition be distributed?

Transforming global energy systems so that carbon emissions are reduced in line with the goals of the Paris agreement, will require shifting the relative attractiveness of different fuels away from fossil fuels towards low carbon alternatives, which are more expensive to produce. In that lies the need to tax or put fees on what is not wanted and/or put in place incentives or subsidy schemes on what is wanted.

When considering taxes and fees on carbon emissions, as well as incentives and subsidies for low carbon alternatives, recent events at a national level have shown that the burden sharing must be seen as fair, or just, by the public majority. Otherwise they are very difficult to find acceptance for, as shown by public reactions to:

- Fuel taxes in France, which served as a catalyst for the yellow-vest movement.
- Elimination of fuel subsidies in Equador and Iran.
- Norwegian subsidies for luxury electric vehicles and increased toll road fees for internal combustion engine cars.

In these examples the issue is not necessarily the tax or subsidy itself, but the fact that it hits the poorest hardest, or at least the ones that do not have an alternative to the activity that is inflicted with cost increases. This illustrates how politicians need to find a balanced approach, where an economic burden introduced for the purpose of reducing emissions must also be accompanied by policies handling the relative difference in burdens experienced by richer and poorer parts of society.

So far, there are few examples where this is the case. Policies that work, i.e. reduce emissions or bring about low carbon technologies, generally have a regressive impact. Very few governments in the world have a credible and visible plan for how to compensate the poorer parts of society for these regressive impacts. Hence, a just transition requires large-scale changes of most tax and transfer systems. Similarly, industries losing out in the transition and resultant job losses lead to discussions on difficult political trade-offs. The conclusion so far has been mainly exempting potentially losing industries, with little impact on CO_2 emissions as a consequence.

Similar challenges exist for what a just transition would entail in a global setting. Firstly, we have the issue that the problem at hand, carbon concentration in the atmosphere, has been overwhelmingly caused by the industrialised economies. So, who should be responsible for stabilising the concentration? Who should pay for the necessary change? Secondly, based on GDP per capita, a global approach to reducing carbon emissions would in relative terms entail much higher burdens on the emerging economies than on the industrialised nations. And at this level, we have the challenge that no global mechanisms exist to transfer costs and benefits between losers and winners. They must therefore be created. Thirdly, the need to justly assign the burden of handling already observed climate change effects poses an additional challenge, as many of the poorest nations will be most adversely affected.

The new *Rebalance* scenario is founded on some of these mechanisms coming into play to support a just transition at a global scale.

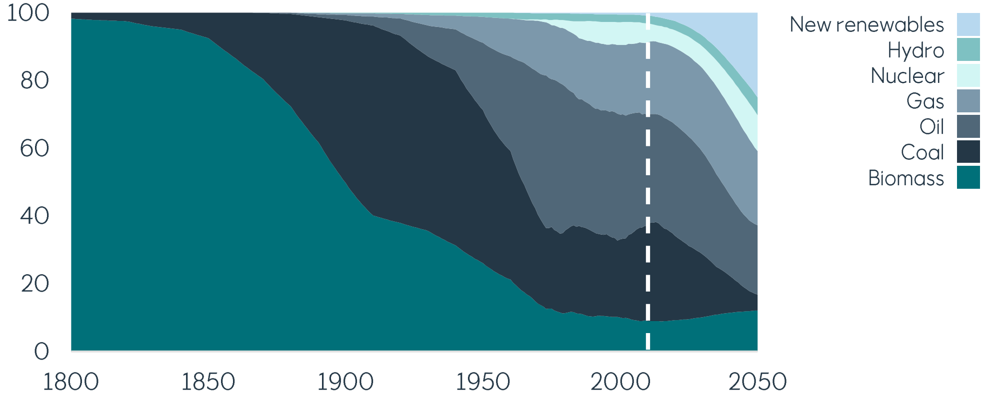
The energy transition in a historical context

The world has gone through energy transitions before, where the dominating source of energy has changed from one fuel to another. The late 19th century saw a transition from wood burning to coal, followed in the 1950s by a switch from coal to oil. Since the last energy transition, there has also been rapid growth in gas, significant increases for nuclear and hydro, and recently the emergence of new renewables. These changes in the fuel mix are clearly visible. However, when viewed in absolute demand terms, they are energy additions rather than transitions. The amount of coal burnt today would be unimaginable to those living through the industrial revolution, and oil demand has increased tenfold since 1950. The only consistent factor throughout these transitions is that energy demand has increased, and that humanity finds new ways to meet that demand. There has never been a period of declining energy demand for more than a handful of years, and no fuel has decreased significantly in absolute terms.

The requirement of the Paris Agreement, that fossil fuels will be phased out in absolute terms by renewable and low emissions fuels, is therefore without comparison in human history. *Rebalance* shows how a prolonged reduction in total energy demand is required, combined with extraordinarily rapid growth in new renewables, to push out first coal, and then oil and gas, from the fuel mix. Throughout all of this, global GDP and population continue to rise, implying an absolute decoupling of energy demand from the traditional drivers of demand growth. Though relative decoupling, where energy demand grows at an ever slower rate compared to GDP and population growth, has been observed, absolute decoupling is a new phenomenon and emphasises how profound the changes required to meet the Paris goals are. As demonstrated in *Rebalance*, the world must undergo unprecedented change, not just in the fuel mix, but in economic, technological, policy and behavioural terms, if global warming above 2° C is to be avoided by the end of the century.

Historic energy transitions and the Rebalance scenario

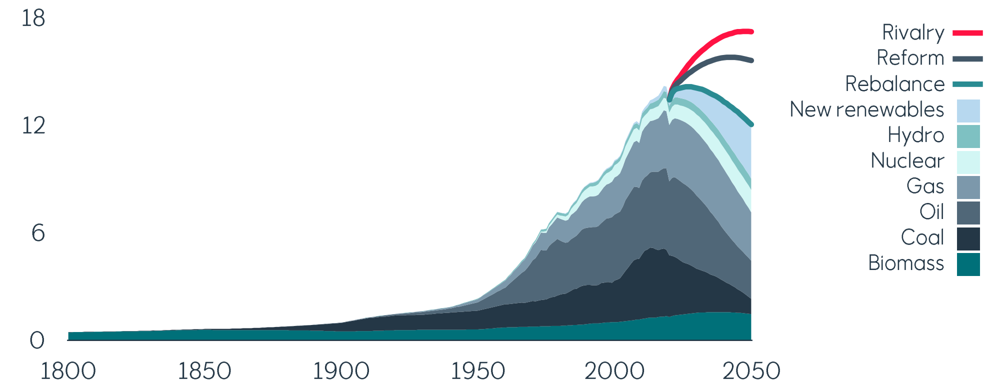
Fuel mix %



Source: Vaclav Smil (2017), BP, IEA, Equinor (projections)

Absolute primary energy demand

Billion toe



Source: Vaclav Smil (2017), BP, IEA, Equinor (projections)

Peak oil demand – and the pandemic's impact on when it may happen

Among the direct effects of Covid-19 are changes in new ways of working and interacting. In the industrialised world, working from home possibilities entails less need for commuting, although a higher share of it will be in private cars to ensure social distancing. Business meetings on screen are more frequent, reducing the need for air travel. Global supply chains may move from just-in-time to just-in-case, opening up for more goods produced domestically, with less demand for long-haul freight. That in turn could reduce demand growth in emerging economies, but it could also increase costs and reduce efficiency.

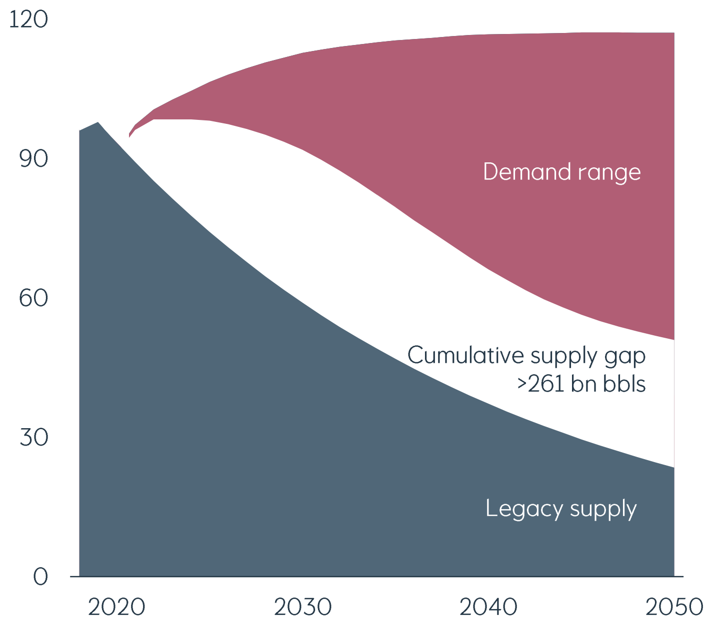
The ambition to "build back greener" might mean that future investments are directed more to renewable energy projects, driven by public sentiment and government policies. One driver is that electrification only has a positive climate effect if the electricity is renewable. And 1 kWh of electricity from solar or wind will replace 3 kWh worth of coal to a coal-fired power plant.

Covid-19 is likely to lead to slower demand growth for oil products, at least for a period. But it is also expected to influence oil supply. Oil production is an extractive industry and mature oil fields face declining output. Continuous investments are required just to keep output steady. As investments in fossil energy lose popularity, necessary funds might not be allocated. Low prices in 2020 have led to a 30% reduction in global oil and gas investments. Several producing countries have seen their oil revenues dwindle. The consequence may be that billions of barrels of oil that were earlier assumed to be recoverable will not be developed.

Natural decline from existing fields is seen at around 4-5 mbd per year. Even with current Opec+ production cuts ending, that would consume global spare production capacity in 2-3 years, including the return of Iranian production. Shale oil resources are huge, but require a substantially higher oil price to attract the necessary investments. Earlier assumptions for peak oil demand to happen around 2030 may be challenged. A decline in oil supply due to low investments could force that date 2-3 years earlier. After that, renewable energy must then cover for both the decline in oil supply, and the continuous growth in global energy demand. This means we need all the renewable energy that we can provide, but at a cost that debt-laden countries can afford.

Oil demand and supply from existing fields

Mbd



Source: IEA (history), Equinor (projections)

equinor

Hydrogen – the silver bullet?

Hydrogen (H_2) is at the moment the hottest topic in the global energy conversation, with energy consultancies churning out analyses. The EU and a string of other European and Asian countries have published H_2 strategies. Oil, gas and other energy companies plan to become H_2 suppliers. H_2 has been hot before, only to drop out of the conversation later. Costs have been too high, market interest limited and political support lukewarm or absent.

What has changed this time is mainly the political support. The bar for GHG emission reductions has been raised, with net zero by, or shortly after, 2050 overtaking less ambitious targets. Energy efficiency improvements, electrification and power sector decarbonisation will help, but not take the world all the way to net zero. A fuel option for sectors unable to decarbonise by means of electricity only is needed, and H_2 fits that bill. H_2 delivers high temperature heat, is lighter than batteries, does not give rise to emissions when consumed and does not need to give rise to emissions when produced either. Hence politicians' current fascination of the gas. H_2 is still expensive and future market interest is uncertain, but policy support has helped commercially unattractive options become attractive before and could do it again.

How important can H_2 become? With forecasters operating on highly uncertain assumptions on all drivers, the outcome space is wide. We have not for this edition of Energy Perspectives modeled H_2 supply and demand across regions and scenarios. If we had, it would again have been an illustrative exercise. Policy support remains a must for H_2. Without regulatory and financial backing, the volume growth required to lower costs, allowing growth to become self-sustaining, will not happen. But policy support remains also a big if. One may take all announced targets at face value, dismiss them or go for something in between. We have instead used different assumptions for the EU area to illustrate what it would take for H_2 to help the EU countries achieve their decarbonisation ambitions.

EU's reference energy and emission scenario from 2016, which is under revision, but still valid, shows a 50% decline in energy-related CO_2 emissions between 1990 and 2050, but the EU Commission's policy scenarios aim for carbon neutrality by 2050, i.e., an almost complete elimination of emissions. In *Reform* that target is missed by a wide margin. EU energy-related emissions are down 72% between 1990 and 2050. We assume however no H_2 for this scenario, in addition to little CCUS and no removal of emissions from land use changes.

How much could bringing H_2 into the fuel mix help? Emission reductions between 1990 and 2050 could increase 10 percentage points to 82%, if we assume:

- The H_2 share of EU's total final energy consumption (TFC) increasing to about 15% by 2050, with sector penetration rates varying from zero to some 30%, and with H_2 replacing oil in the transport sectors and mostly gas in the stationary sectors;
- H_2 production evolving from almost 100% "grey" (i.e. produced from gas without CCUS) today to 60-40% "green" (produced by electrolysis based on new renewable electricity) and "blue" (produced from gas with CCUS) by 2050, with 90% of CO_2 from the "blue" portion being captured and stored.

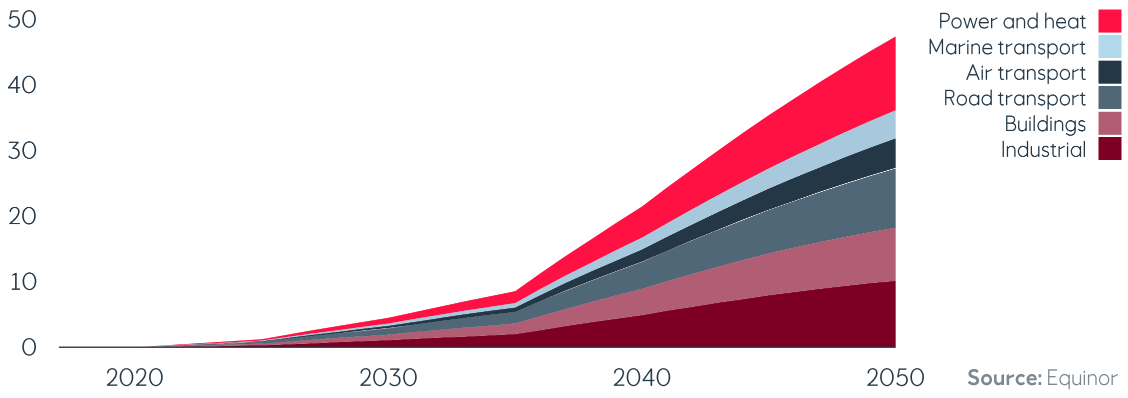
Wind and solar power generation by 2050 would need to be some 55% higher in this case than in *Reform*, to support the assumed production of "green" H_2. That could be a tall order, though many observers find such a growth in new renewables capacity within reach.

But, for H_2 to make a material dent in cumulative emissions to 2050, the pace of supply and demand growth would need to exceed expectations. A slow ramp-up with significant H_2 market capture only after 2030 might position H_2 as a key dampener of emission budget utilisation only in the longer term.

Hydrogen – the silver bullet?

EU H_2 use for energy, sensitivity on Reform

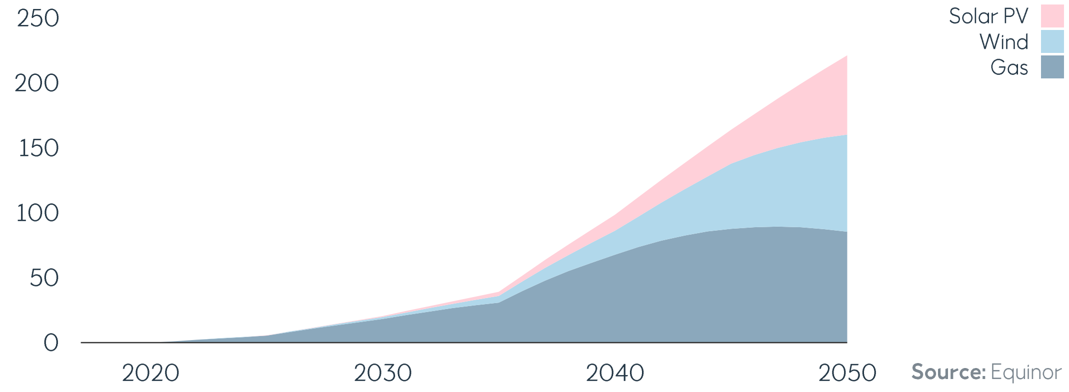
Mt



Source: Equinor

Primary energy requirements for H_2 production, sensitivity on Reform

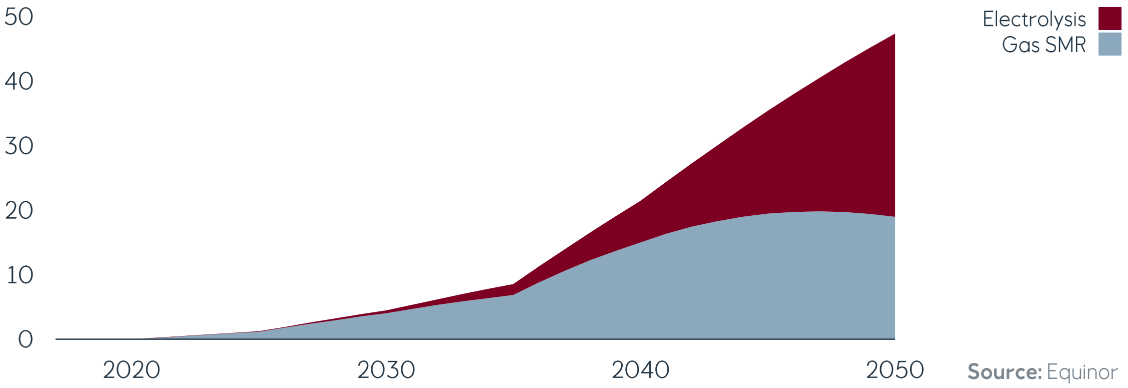
Mtoe



Source: Equinor

EU H_2 use for energy by technology, sensitivity on Reform

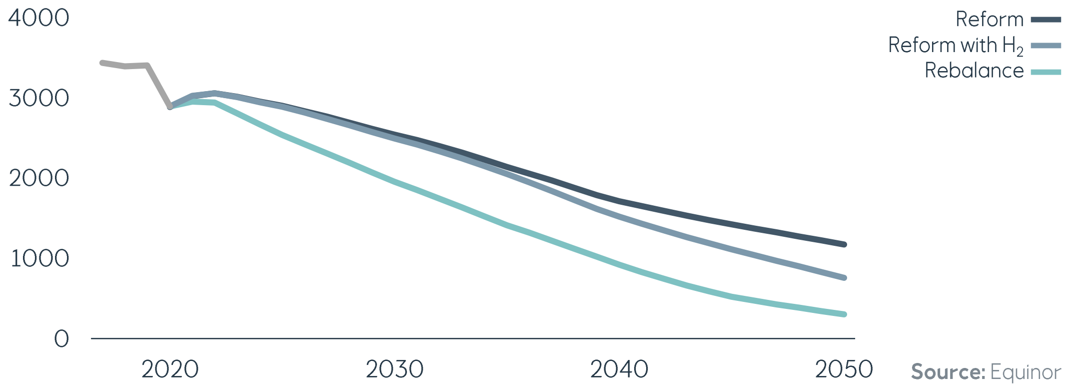
Mt



Source: Equinor

EU energy related CO_2 emissions

Mt



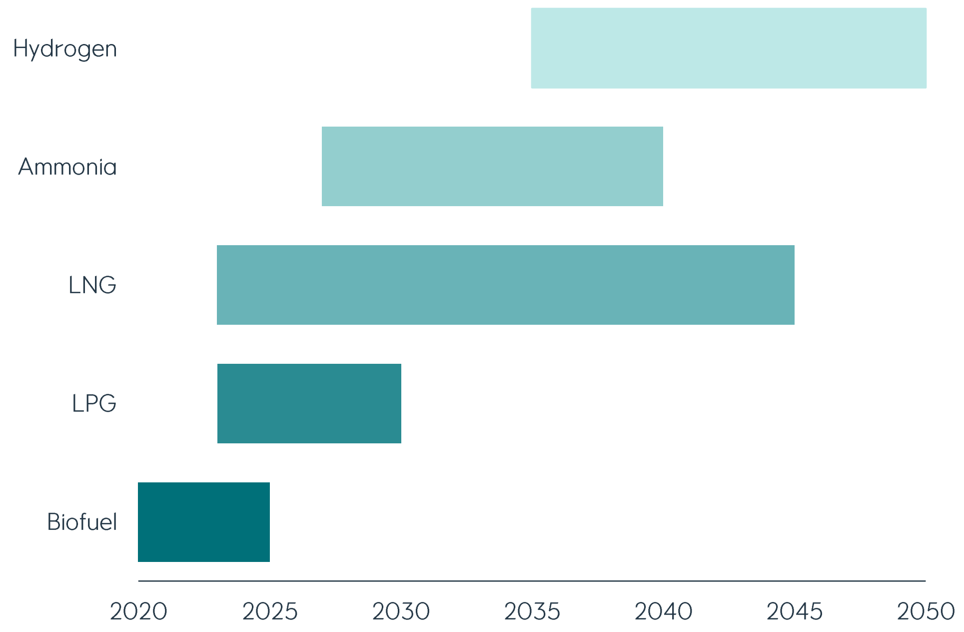
Source: Equinor

Alternative shipping fuels

The challenge for the shipping industry today is how to pursue the GHG reduction ambitions and stay competitive at the same time. In terms of fuel developments, the carbon-neutral choices such as biofuels, ammonia and hydrogen are in different stages of development. In a blooming LNG market, with industry and infrastructure already in place, LNG looks like a good solution for a short-term CO_2 emissions reduction. However, from a full LNG value chain perspective, LNG's GHG reduction is dependent on maintaining low methane emissions. A replacement of LNG with bio-LNG, which has almost the same chemical composition, is possible. However, as of now, an economically better solution to consider is the use of Hydrotreated Vegetable Oil (HVO) biodiesel in the dual-fuel marine engines. These engines are already widely adopted and do not require any modifications. Regardless of the chosen bio-alternative, both are dependent on the biomass availability and could therefore create a food security issue, unless they are produced from waste.

Ammonia is a likely alternative in the long term, when compared to other carbon-neutral choices in terms of production, storage capacity and stability of fuel supply. If ammonia is the most likely objective, then shipowners should take the most obvious solution for the short term, which is adopting fuel-flexible choices which can be easily upgraded in the future. For example, running vessels on LPG considering that the same engine after small modifications can be used to burn ammonia. However, the decision is not straight-forward as LPG lags behind in infrastructure, availability and costs when compared to its major competitor, LNG. Considering where we stand today, the way out of this fuel dilemma is for governments to support investments that aim at fully carbon neutral choices, share the risk with shipowners, and introduce more incentives for collaboration among key market players. Also, incentivising changes through carbon taxes is another option. The right technologies will hopefully gain momentum and the industry will be on its way to a cleaner future.

Indication of timing of marine fuel large-scale uptake



Source: DNV-GL, Lloyd's register, Equinor

How to regulate future electricity markets

Until the boom in renewables, most modern electricity markets were organised around a single price signal for electricity. The price discovery was based on a supply and demand equilibrium, where the last marginal megawatt (MW) necessary to clear the market sets the price for all the MW, also known as short-run marginal cost pricing (SMRC). That price was based on the variable costs, and that owners of technologies with lower marginal costs could recover their investments, returning a margin. The resulting system price for electrical energy was also intended to provide an investment or divestment signal to producers.

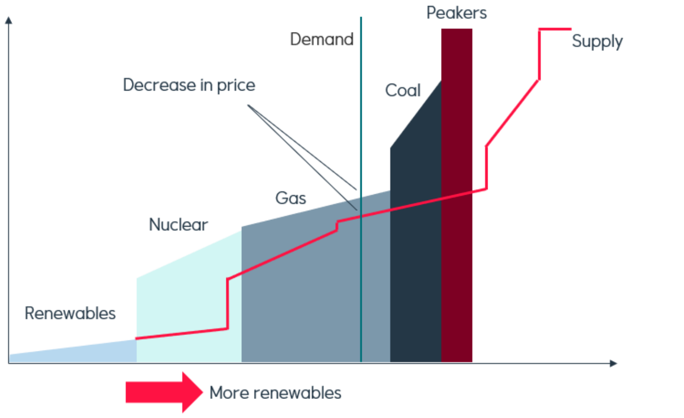
As the attention to environmental issues gained traction, policy makers in many modern electricity markets have provided both direct and indirect support to renewables. Such policy was aimed at helping the renewable industry in its infancy to grow and mature. As renewable penetration increased, the supply curve was displaced, driving wholesale prices down. This led to policy makers introducing measures to compensate the dispatchable capacity operators for the drop in prices, thus changing the market structure. These measures ensured enough flexibility and back-up on the system to cope with renewable intermittency through capacity auctions and other mechanisms. New technologies have been given support, while additional remuneration has been granted to flexible conventional generation. But regulators are now facing new objectives and challenges, requiring some radical thinking and probably a fundamental change in market design.

If renewables keep driving average wholesale prices down, the electricity market may eventually be unable to attract the investments required for a clean and stable electricity system, jeopardising the decarbonisation ambition of the regulators. Each region, country and market will address this fundamental challenge based on factors such as its resource base, trade relations and socioeconomic context. Markets require an investment signal for capacity investments, which is at odds with the current system where prices are based on volume of generation. This system made sense as long as electricity prices relied on fuel costs, which is no longer a factor in the case of renewables. A further move towards investment signals based on SRMC pricing principles is unlikely to address the fundamental challenge of ensuring both a decarbonised and robust electricity system. Change is needed.

equinor

Typical merit order of electricity's supply curve with more renewables

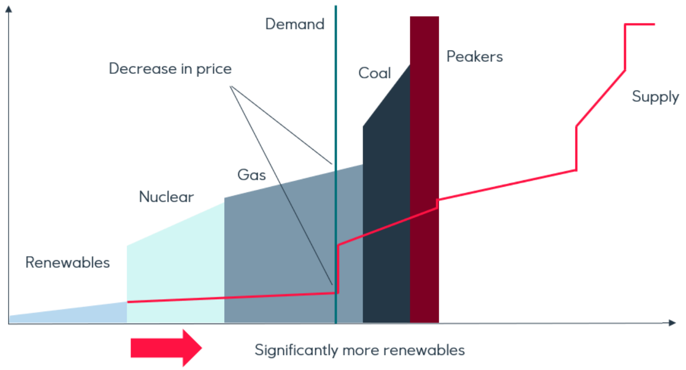
Price (vertical axis), MWh (horizontal axis)



Source: Equinor

Typical merit order of electricity's supply curve with significantly more renewables

Price (vertical axis), MWh (horizontal axis)



Source: Equinor

Key figures

	2018	2050			2018-50 growth per year (%), CAGR		
		Reform	Rebalance	Rivalry	Reform	Rebalance	Rivalry
Global GDP (trillion 2010-USD)	**82.4**	**159.8**	**156.8**	**146.2**	**2.1**	**2.0**	**1.8**
North America, Europe, Industrial Asia Pacific	52.5	75.8	60.6	73.3	1.2	0.4	1.0
China	11.1	33.2	26.7	29.3	3.5	2.8	3.1
Rest of World	18.8	50.8	69.5	43.7	3.2	4.2	2.7
Global energy intensity - Indexed to 2018	**100.0**	**56.7**	**44.5**	**68.4**	**-1.8**	**-2.5**	**-1.2**
Global population (billion)	**7.63**	**9.74**	**9.13**	**9.74**	**0.8**	**0.6**	**0.8**
Global energy demand (btoe)	**14.19**	**15.60**	**12.03**	**17.22**	**0.3**	**-0.5**	**0.6**
Coal	3.79	2.48	0.85	3.55	-1.3	-4.6	-0.2
Oil	4.48	3.86	2.13	5.17	-0.5	-2.3	0.5
Gas	3.23	3.96	2.69	3.93	0.6	-0.6	0.6
New renewables	0.30	2.07	3.02	1.37	6.3	7.5	4.9
Oil ex biofuels (mbd)	**96.1**	**84.1**	**47.2**	**112.5**	**-0.4**	**-2.2**	**0.5**
Gas (Bcm)	**3895**	**4766**	**3236**	**4727**	**0.6**	**-0.6**	**0.6**
Global energy related CO_2 emissions (billion tons)	**32.8**	**26.3**	**10.2**	**34.7**	**-0.7**	**-3.6**	**0.2**
North America	6.0	3.6	0.9	5.3	-1.6	-5,7	-0.4
Europe	3.9	1.5	0.4	2.5	-3.0	-7.0	-1.4
China	9.4	7.2	1.6	9.3	-0.8	-5.3	-0.1
India	2.3	3.1	1.9	4.0	0.9	-0.5	1.7
World CO_2 emissions from fossil fuel use removed by CCUS (mt)	**14**	**324**	**2000**	**53**	**10.3**	**16.8**	**4.2**
Global light duty vehicles (LDVs) fleet (million)	**1271**	**1491**	**1390**	**1823**	**0.5**	**0.3**	**1.1**
LDVs oil demand (mtoe)	**1126**	**610**	**173**	**1060**	**-1.9**	**-5.7**	**-0.2**
LDVs biofuel demand (mtoe)	**65**	**43**	**4**	**88**	**-1.3**	**-8.1**	**0.9**
LDVs electricity demand (mtoe)	**2**	**216**	**273**	**185**	**16.5**	**17.4**	**15.9**

Acknowledgements

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