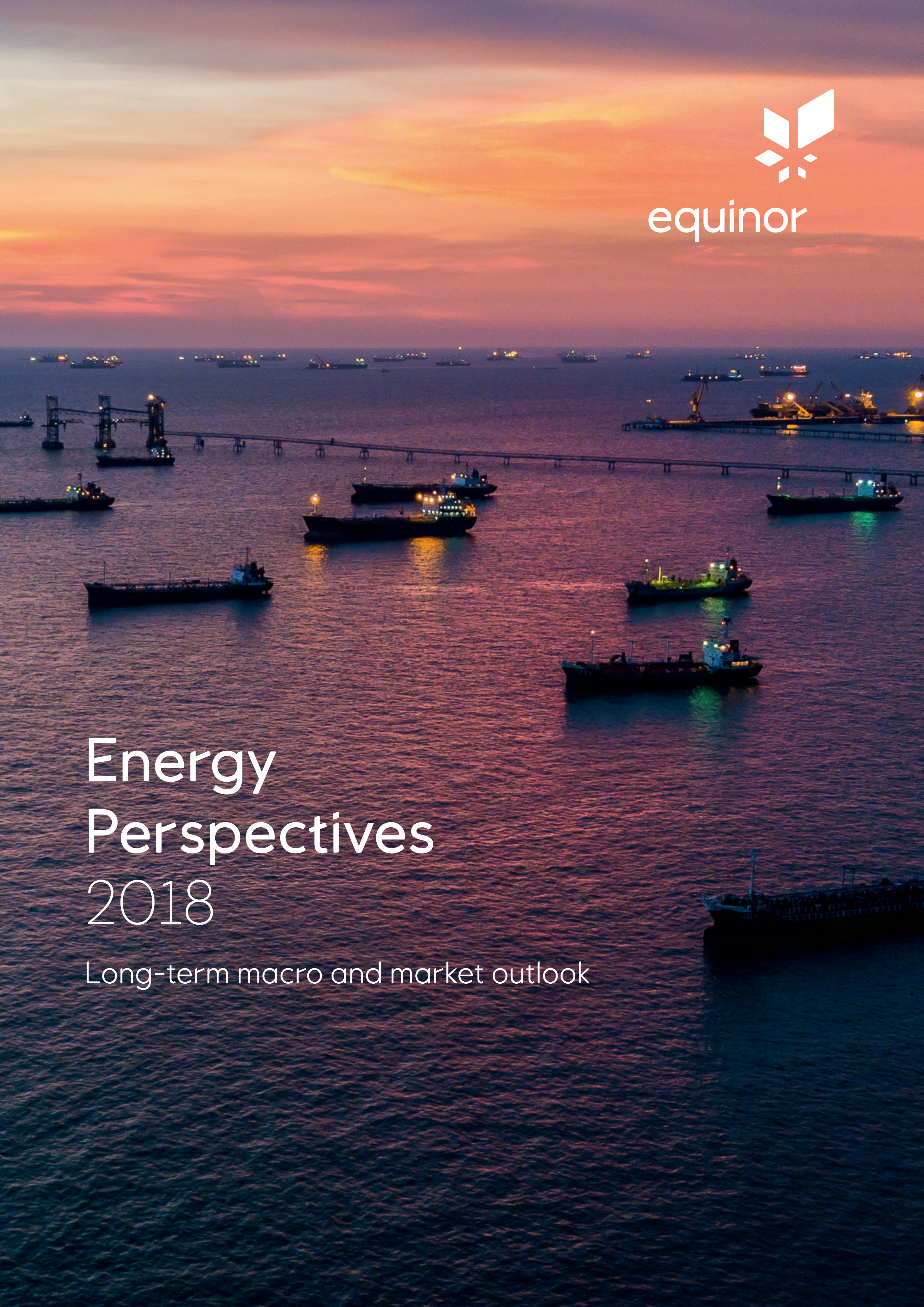

equinor

Energy Perspectives 2018

Long-term macro and market outlook

Welcome to Equinor's Energy Perspectives 2018

Equinor's vision is to shape the future of energy. Our strategy is: Always safe, High value and Low carbon. To succeed, we must have a balanced approach to opportunities and challenges we are faced with.

The future of energy is uncertain. It depends on developments in the global economy, technology, policy, resource availability and consumer preferences. At the same time, it seems certain that demand for goods, services and activities that require energy in their production or consumption will continue to grow, driven by increasing population and increasing wealth. The challenge for energy companies and society at large is to satisfy this growing demand while contributing to increased sustainability. For that to happen, we need an energy transition of enormous proportions. Fortunately, we see signs of this transition happening today, in the development of new renewable sources of electricity, in electrification of transport, in digital services, and elsewhere. However, demand for fossil fuels is still growing, greenhouse gas emissions are rising again, and technologies for capturing emissions hardly progress. The transition is simply too slow, and must speed up.

Uncertainties call for the use of scenarios, describing how policy, technology and market conditions can move development in different directions, both desired and undesired. That is what Equinor's Energy Perspectives 2018 describes. It shows that different drivers can move the development in vastly different directions over time. With one set of assumptions, the world will move in a sustainable direction in terms of continued economic development, access to affordable energy and lower emissions. With another set, energy efficiency will develop slowly, and the transition will be too slow.

The analysis in this report is important input to our strategic priorities, together with other analyses. Equinor wants the global energy mix to move in a sustainable direction, according to the goals set out in the Paris Agreement. That is the best for everyone living on this planet, as well as for our business. Our strategy; Always safe, High value, Low carbon; is designed to handle the uncertainties and contribute to a sustainable development, allowing Equinor to shape the future of energy in a balanced manner.

With this 8th edition of Energy Perspectives our analysts again contribute to discussion, highlight challenges and opportunities, and suggest shared beliefs on what will drive the development in global energy markets. In short: they provide insight.

I hope Energy Perspectives will provide useful input to your own work, regardless of your field of interest.

Eldar Sætre
President and CEO

Executive summary

Energy company executives, market analysts and the public seem to agree about three things: first, that a growing, richer global population will demand more goods, services and activities that require energy; secondly, that there is an energy transition going on; and thirdly, that large investments are needed to grow and improve the global energy system. This agreement is less visible in terms of the implications for energy demand, the speed and scope of the energy transition, and where in the energy system there is a need for large investments. In this 8th edition of Energy Perspectives, we intend to paint a holistic, aggregated picture of global energy markets towards 2050, analysing relevant energy sources, sectors and regions across three distinct scenarios.

The three scenarios in this report are constructed to embrace a wide range of possible future outcomes, building on different factors, trends and developments we observe today, but where there is considerable uncertainty about future development. Energy markets in *Reform* build on recent and current trends within market and technology development, rather than policy support, to be the main driver of change. *Renewal* represents a future trajectory, supported by strong, coordinated policy intervention, that delivers energy-related emission reductions consistent with the 2°-target on global warming. *Rivalry* describes a volatile world, where development and policy focus are determined mainly by geopolitics and other political priorities than climate change. While the important characteristics of the three scenarios remain the same compared to earlier years, certain scenario features are new in this year's report. We have supplemented *Renewal* with two sensitivities in addition to the main scenario projections to address two key uncertainties of low carbon emission scenarios; one where the role of carbon capture, utilisation and storage (CCUS) remains miniscule and is limited to currently operating and sanctioned projects; and another where climate policy action is delayed to 2025. This year's *Rivalry* contains cyclical economic growth with boom and bust periods, underlining the volatility of the scenario and allowing visualisation of the effects of cyclicality on energy demand. Additionally, oil demand has been split into oil products in each scenario, to better understand implications for crude oil quality and refinery crude slates.

Global population will grow to 9.8 bn people by 2050, and average global economic growth in the three scenarios ranges from 1.9% to 2.7% per year, yielding a global GDP in 2050 between 1.9 and 2.5 times that of the level in 2015. Improvements in energy intensity are larger than those seen between 1990 and 2015 in all scenarios, but vary significantly between 1.1% and 2.8% per year, resulting in total primary energy demand (TPED) in 2050 being 6% lower than in 2015 in *Renewal*, 25% higher in *Reform* and 30% higher in *Rivalry*. *Renewal* represents a tremendously challenging development aimed at achieving targeted emission reductions, with vast improvements in energy intensity, delivering on the first belief above without resulting in higher energy demand. Changes in the global energy mix provide a good indication for the speed and scope of the widely discussed energy transition. In 2015, fossil fuels – coal, oil and gas – accounted for 82% of TPED. Towards 2050, this share declines in all scenarios, but at vastly different rates; to 51% in *Renewal*, 70% in *Reform*, and 77% in *Rivalry*. The development in *Rivalry* thus questions the notion of a broad and swift energy transition. Oil demand in 2050 varies between 59 (*Renewal*) and 122 (*Rivalry*) million barrels per day (mbd), with *Reform* at 105 mbd. Peak oil demand arrives as early as 2020 in *Renewal*, around 2030 in *Reform*, while oil demand continues to grow through the entire time horizon in *Rivalry*. Gas demand in 2050 varies between 3,300 (*Renewal*) and 4,800 (*Reform*) billion cubic metres (Bcm), with gas demand in *Rivalry* a little lower than in *Reform*. There is a significant need for new investments in oil and gas in all scenarios, with *Reform* and *Rivalry* offering the widest opportunity set, while *Renewal* calls for the development of premium resources with competitive cost structure and low carbon footprint. Demand for coal, the most important contributor to global carbon emissions, develops in vastly different directions across the scenarios; in *Renewal*, the need to reduce CO_2 emissions drives coal demand down to 26% of the 2015 level. In *Rivalry*, where other forces dominate, demand is 111% of the 2015 level. Coal demand in *Reform* is 82% of the level in 2015. New renewable sources (New RES) of electricity generation, primarily solar and wind, increase their 2015 share in power generation from 5% to a substantial 24% to 49% in 2050, with average annual growth rates in solar and wind at 4.6% to 7.4%. This also calls for substantial investments to secure 3,600 to 8,300 gigawatts (GW) additional generation capacity compared to 2015. Global energy-related CO_2 emissions vary between 12.5 and 38 billion tons (Gt) in 2050, compared to 32 Gt in 2015.

Projecting development in global energy markets is a challenging, but important task. It is my hope that Energy Perspectives 2018 contributes to a fact-based discussion of possible energy futures.

Eirik Wærness
Senior vice president and Chief economist

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Acknowledgements

The analytical basis for this outlook is long-term research on macroeconomics and energy markets undertaken by the Equinor organisation during the winter of 2017 and the spring of 2018. The research process has been coordinated by Equinor's unit for Macroeconomics and Market Analysis, with crucial analytical input, support and comments from other parts of the company. Joint efforts and close cooperation in the company have been critical for the preparation of an integrated and consistent outlook for total energy demand and for the projections of future energy mix in different scenarios. We hereby extend our gratitude to everybody involved.

Editorial process concluded 30 May 2018.

Front page photo credit: iStock

Context and uncertainties

A transition fast or slow in the making?

The term "energy transition" is increasingly becoming commonplace in discussions of the global energy future. No clear definition or description of this transition exists, nor is it clear if we refer to a process or an end state. On the one hand, we see clear signals of increasing pace of change in different parts of the energy spectrum: in the costs of providing energy, oil, gas, renewables and battery capacity; in the costs of new end-user technologies; in geopolitical relations with relevance for energy markets; in the distribution of profits across the value chain for different energy sources; in the increasing linkage between energy and other services to end-users; in the rhetoric around the need for significant reductions in energy-related CO_2 emissions; and in the license to operate and public acceptance of companies involved in fossil fuel extraction. At the same time, the empirical proofs that an energy transition is taking place are currently difficult to find, since oil and gas demand keep growing, and coal demand is increasing again; CO_2 emissions have grown after three years of stagnation; sales of internal combustion engine vehicles (ICEVs) far outpace that of electric vehicles (EVs); electricity is below 20% of total final energy consumption (TFC); the future profitability in different parts of the value chain is uncertain; and the average global price of carbon emissions is close to zero.

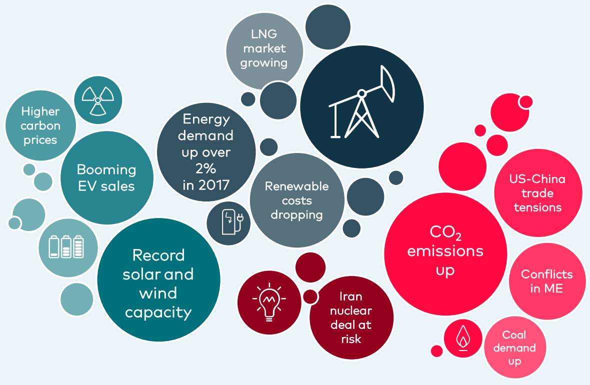
Energy transition in a changing, growing, integrating world

Any energy transition will take place in a world that is changing in many dimensions. Importantly, global population is growing, and the requirements for access to affordable, reliable and sustainable energy are also increasing in strength. Because of growing populations, capital accumulation, higher education and general technological progress, the size of the global economy will grow significantly over the next decades. Thus, demand for goods, services and activities that require energy will certainly increase. How this affects growth in energy demand depends on the development of global energy intensity, which is a key factor affecting our ability to ensure sustainable development going forward. In mature economies, there is reason to believe that energy demand could decline, both because populations do not grow, economic growth is moderate and energy access is already universal. In emerging economies, however, all these variables point towards higher energy demand. Since availability of energy sources is not distributed according to where energy demand will grow or shrink, future flows of energy exports and imports will change significantly over time, with Asia dominating imports of energy, and North America and Russia being key export regions.

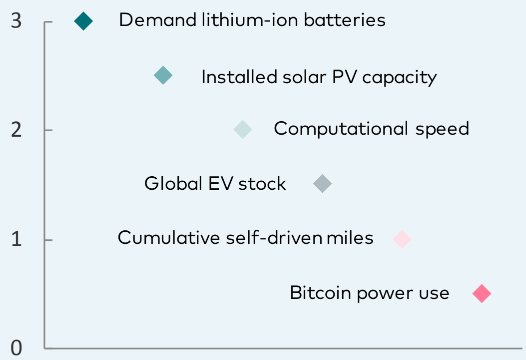
Geopolitics will be affected

The growing reliance on new renewables, as well as the corresponding decline in the importance of coal, oil and gas, combined with a shift away from centralised, large-scale, grid-dependent energy supplies, will impact geopolitics and the relative power between countries and regions. Energy balances will shift along with political inter-dependences. Some countries and regions will be losers in this transition, and may have to be compensated by the winners to ensure an efficient and peaceful transition. How this could take place, however, is not at all clear.

Recent signposts show diverging paths

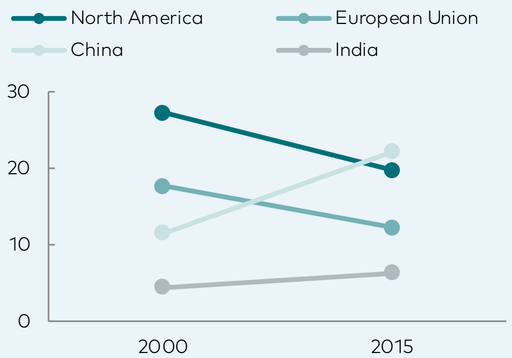


Most recent observed doubling time of key technologies
Years



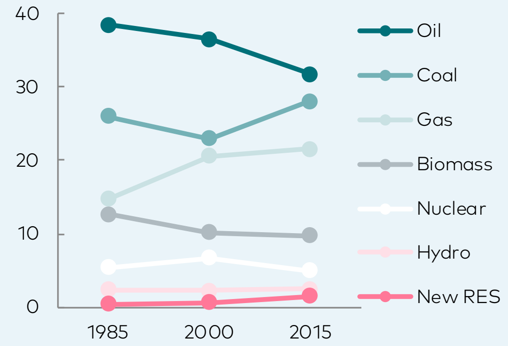
Source: Various sources, Equinor

Regional shares of global TPED
%



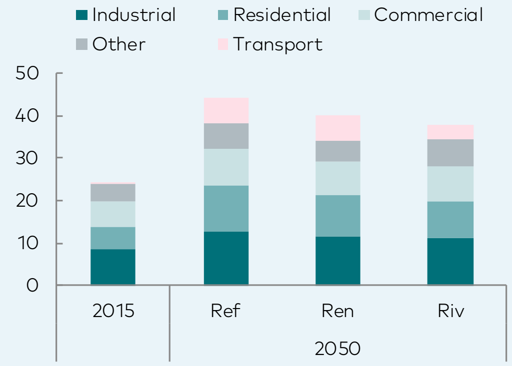
Source: IEA

Fuel mix in TPED, 1985-2015
%



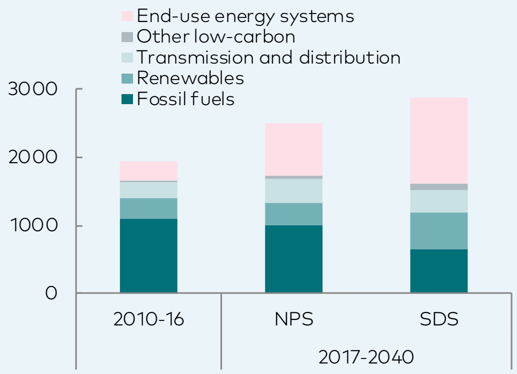
Source: IEA

Electricity demand by sector and scenario
Thousand TWh



Source: IEA (history), Equinor (projections)

Global energy investments
Bn USD, annual average



Source: IEA

A more electric world

It seems reasonable to assume that the share of electrification will increase. Electricity is an efficient, clean and silent source of energy for the end-user; and it is extremely versatile and flexible; so with economic growth, demand for electricity should grow. At the same time, the large cost improvements in new renewables entail that electricity becomes more easily available at low costs, and with no carbon emissions in the generation phase. Some sectors are clear candidates for increased electrification, such as certain transport segments. Other sectors could be more challenging, like heating and cooling in buildings. Increasingly, as electrification increases, costs of infrastructure, investments in electricity storage, balancing technologies, including the use of digitalisation to facilitate efficient balancing, will be a more important issue in addition to the investments in the supply capacity itself. This is particularly so as the share of weather-dependent, intermittent sources of electricity keeps growing. The issue of securing sufficiently high wholesale prices to stimulate investments will also grow in importance.

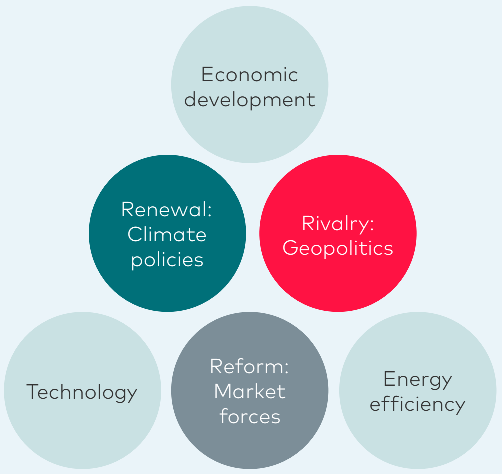
Enormous investment requirements

To ensure available energy supplies over the next decades, large investments in new capacity must be undertaken. IEA estimates cumulative investments in the 2015-40 period of USD 70-75 tn in fuel supply, electricity supply and end-user energy systems in their New Policies (NPS) and Sustainable Development (SDS) scenarios. Irrespective of forecasts for oil and gas demand, natural decline drives supply capacity down, below demand, and closing the gap requires large investments. As an example, in our *Renewal* scenario – with oil demand at only 59 mbd in 2050, a 6% annual decline implies a need to ensure deliveries of some 480 bn barrels of oil from new sources – 30% more than the total Opec supply over the last 35 years. Given the increasing difficulties of finding new resources and the increasingly tough environment in which the industry operates, it could be questioned whether the necessary investments will be undertaken. Similarly, growing demand for electricity all over the world, and the need to replace coal-fired and nuclear capacity, imply an enormous call for investments in new renewable electricity generation capacity as well. This needs to be supplemented by investments in local, regional and central electricity grids, backup capacity and storage. With the uncertainty around future electricity prices, business models and regulatory regimes, risks are high, impacting investments. In addition, cracking the CCUS code is necessary to deliver on climate ambitions and satisfy energy demand. This will also require investments, but with huge uncertainties about business models, regulatory regimes and profitability.

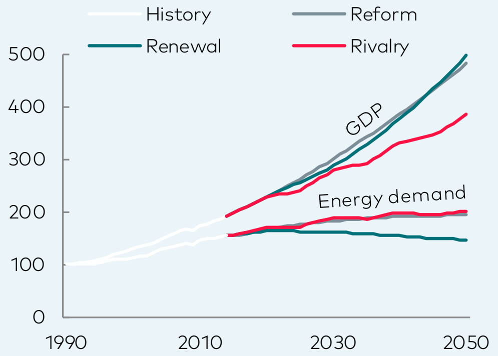
... in a digitalised setting

Finally, improved computational capacity and low costs of data storage and sensor technology facilitate a digital revolution. On the supply side, it will impact the way energy is delivered, through cost reductions, increased recovery rates, improved safety and increased efficiency. On the demand side, it will influence markets and future business models, and customers will increasingly see energy in combination with other digital services.

The three scenarios and main drivers

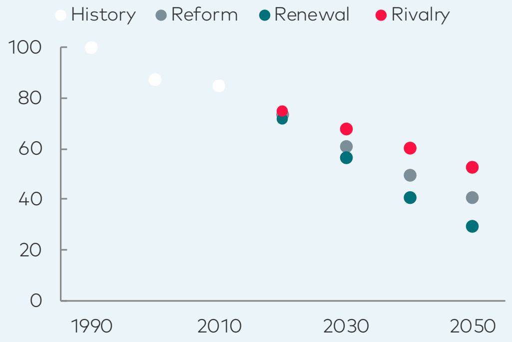


World GDP and energy demand by scenario
Index, 1990=100



Source: IEA (history), Equinor (projections)

Energy intensity by scenario
Index, 1990=100



Source: IEA (history), Equinor (projections)

The three scenarios

The future of energy is uncertain. Energy Perspectives therefore contains three scenarios that provide a wide outcome space for global energy market developments. There is no probability attached to the scenarios, but each scenario is technically achievable based on a distinct set of assumptions. The main scenario drivers can be summarised as economic development, climate policies, market forces, technology, energy efficiency and geopolitics, with the individual scenarios placing more emphasis on certain drivers. In *Reform*, market forces and technology developments take priority, while in *Renewal*, climate policies are driving the outlook. *Rivalry* is a scenario where geopolitics play centre stage. Energy market developments are kept similar in all three scenarios until 2020, at which point they start to diverge. The size of the global energy system and its inherent inertia entail that it will take some time before new development paths will become clear and visible. Out of the three scenarios, only *Renewal* represents a sustainable future from a climate perspective.

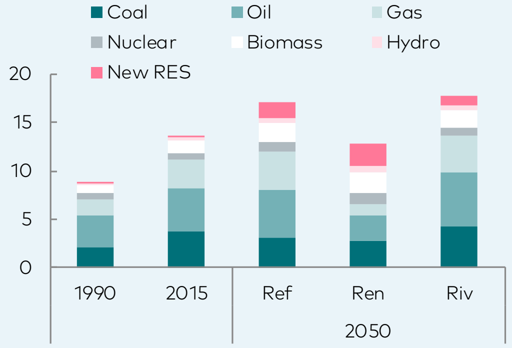
Reform: market forces and technology

In *Reform*, population growth and healthy economic development lead to continued growth in energy demand. Demand grows however at a slower pace than historically, as economies continuously strive to use energy more efficiently, leading to a sustained drop in energy intensity. Declining energy intensity is not a new trend; since 1990 the energy intensity of the global economy has dropped by almost a quarter. In *Reform*, energy intensity is projected to fall by almost 50% towards 2050. Annual energy-related CO_2 emissions increase from current levels of around 32 Gt to a peak of just below 35 Gt in the mid-2020s, before they gradually decline towards 31 Gt by 2050.

In terms of climate policy, the Nationally Determined Contributions (NDCs) from the 21st Conference of Parties in Paris in 2015 form the policy backbone in *Reform*. The guidance provided by the NDCs is however becoming more uncertain, as the existing NDCs are to be replaced and tightened by 2020 in the hope of putting the world on a more sustainable environmental trajectory. This can however not be taken for granted, and in the absence of strong climate policies and targets, *Reform* places more emphasis on market and technology developments. Energy prices provide important signals for how the market operates, and energy and technology costs shape long-term investment decisions. Energy prices gradually increase over time, as most regions introduce CO_2 prices, and energy subsidies are gradually phased out.

Market and technology developments in *Reform* largely build on recent and current trends. Technology improvements continue, but no "leap-frogging" technology break-throughs are assumed, and different technologies coexist over time. Policies can support new technologies at an early stage, but only technologies that become economical, or clearly show the potential to become economical, are sustained. The energy mix continues to change, but largely at the same pace that we have observed over the past. New renewables grow rapidly in the power sector and eventually take up a significant share of the electricity mix in all regions of the world. Battery cost reductions support the deployment of grid storage, as well as

Global TPED by fuel and scenario
Btoe

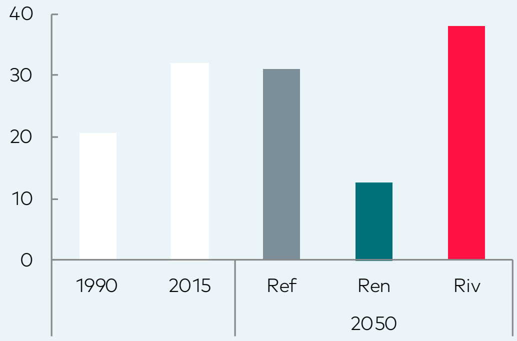


Source: IEA (history), Equinor (projections)

Solar thermal power stations with storage can provide baseload electricity

Source: iStock

Annual net energy-related CO_2 emissions by scenario
Gt



Source: IEA (history), Equinor (projections)

electrification of the transportation sector. The lack of a technology breakthrough however limits the ability of batteries to penetrate long-distance road transportation, aviation and maritime transportation.

Electrification continues in all sectors and the share of electricity in TFC continues to grow in line with historical trends. The industrial and residential sectors experience the largest growth in electricity demand, and residential electricity use almost doubles by 2050. Electricity demand for transportation grows the fastest and becomes a significant source of demand.

The share of fossil fuels in TPED declines gradually in *Reform* from almost 82% in 2015 to around 70% in 2050. Coal experiences the largest drop in share, oil loses market share marginally, while the share of gas increases. All low carbon fuels increase their presence in the energy mix, with new renewables gaining the most.

Renewal: a policy-driven 2° world

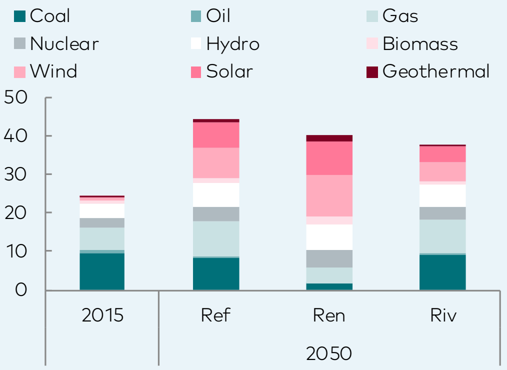
The *Renewal* scenario represents a future trajectory for the energy markets that is consistent with limiting global warming at below 2°. The scenario operates with a carbon budget that brings the cumulative energy-related emissions of CO_2 between 2016 and 2050 to around 816 Gt. The projections end in 2050, but is implicitly assumed that energy-related carbon emissions continue to fall further and fit to a carbon budget of around 250 Gt during the second half of the century.

Economic growth over the whole projection period is slightly higher in *Renewal* than in *Reform*. Up until around 2030, however, growth in *Renewal* is slightly suppressed due to lower capital efficiency related to the investments needed to transform the energy system. After 2030, the growth rates in *Renewal* eventually surpass *Reform*, as the economy benefits from the investments and technology development, and economic growth in *Reform* is hit by the increasing cost of climate change. Despite higher growth, energy demand is significantly lower in *Renewal* than in *Reform*, as the decline in energy intensity of the global economy is about two-thirds by 2050 compared to 2015. In fact, TPED in 2050 is 6% lower than in 2015.

Strong policy intervention is needed in energy markets in *Renewal* to force the necessary investments in low carbon technologies. This applies to renewables in the power sector, decarbonisation of the buildings sector, electrification of transportation, realisation of efficiency gains in industry and CCUS, in power generation and industry. A global approach is necessary and all regions must partake in this collective effort. Fossil fuel producer prices are lower compared to *Reform*, due to the lower level of supply, while end-user prices must be higher to contain demand, due to higher taxation of the related externalities. All regions implement CO_2 prices or taxes or a combination, and these tend to be significantly higher than in *Reform*.

Low carbon technologies get a strong push from policies in *Renewal*. The higher deployment of renewable power generation capacity, batteries and CCUS help driving efficiency, innovation and pushing down costs. In *Renewal*, we see broader technological shifts, such as

Global electricity generation by fuel and scenario
Thousand TWh

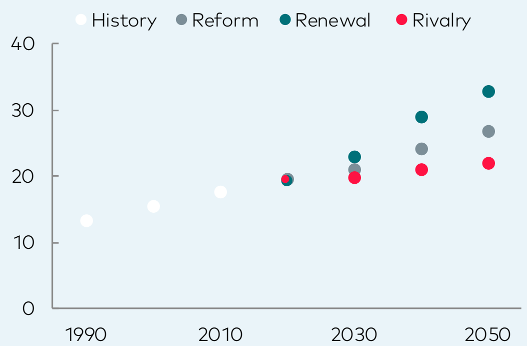


Source: IEA (history), Equinor (projections)

Coal remains an integral part of the electricity mix in Rivalry

Source: iStock

Electricity share of TFC by scenario
%



Source: IEA (history), Equinor (projections)

in passenger cars, where ICEVs are almost completely phased out in new car sales, and in power, where coal power generation almost disappears by 2050.

Renewal experiences the fastest rate of electrification of the three scenarios and delivers an acceleration compared to historical trends. The improvement in energy efficiency however leads to lower electricity demand in absolute terms relative to *Reform*.

The share of fossil fuels drops much faster in *Renewal* compared to *Reform*, declining to 50% by 2050. The sharpest fall is in coal, followed by oil, while gas ends up with a share in 2050 that is roughly the same as in 2015.

In this year's Energy Perspectives, we also introduce two sensitivities to the *Renewal* scenario. The first sensitivity explores how the carbon budget could be met if it is assumed that there is no more CCUS capacity installed compared to what is already built by 2020. The second sensitivity assumes that CO_2 emissions follow the same trajectory as in *Reform* until 2025, to illustrate what could happen if necessary further policy action is delayed. However, both sensitivities maintain their 2° character and comply with the carbon budget of 816 Gt allocated to 2016-2050.

Rivalry: a volatile geopolitical environment

In *Rivalry*, global economic growth is negatively impacted by a volatile geopolitical environment affecting trust, conflicts, trade, investments and consumption. In this scenario, we have also assumed cyclicality in economic growth, with periods of low growth and recessions followed by more positive periods when the global economy strengthens. Despite significantly lower economic growth relative to *Reform*, growth in energy consumption is higher. This is caused by less environmental regulation, slower or no phase-out of fuel subsidies and lower investments in energy efficiency. This in turn weighs on energy intensity improvements, which are significantly smaller than in the other two scenarios. Implementation of new technology is also slower, leading to slower cost reductions, less efficiency gains, lower ability to integrate variable renewables in the power system and less electrification of transport.

Indigenous sources of energy are favoured in *Rivalry*, and low cost and security of supply are more important concerns than being clean or low-carbon. The biggest winner in *Rivalry* is therefore coal. Coal is marginalised in *Renewal* and is in decline in *Reform*, but in *Rivalry* coal remains an important part of the energy mix. Renewables continue to grow in *Rivalry*, but at a slower pace compared to *Reform*. Renewables remain an attractive source of energy in most regions, but less supportive regulation and more restrictions on trade and technology exchange slow down capacity deployment. The situation for gas is more mixed. In *Rivalry*, gas loses out to coal due to higher cost and less focus on its environmental credentials. In addition, growth in LNG demand is hampered by security of supply concerns, protectionism and less global trade. Oil consumption is up relative to *Reform*, due to lower energy efficiency, less regulation, subsidised fuel prices and less electrification in the transport sector.

Cyber security, a new economic battleground

As we digitalise our lives and connect business operations through devices and applications, cyber security risks grow in probability and disruptive potential. The number of cyber attacks against businesses has almost doubled in the past five years, and the Ponemon Institute estimates that annual cyber threat related costs per company are on average USD 12 mn, increasing by 25% per year.

In 2017, so-called ransomware attack attempts represented two thirds of all malicious emails. Some were notoriously successful. WannaCry affected 300,000 computers in 150 countries; NotPetya is estimated to have cost USD 1.2 bn to the global economy. To confront this threat, the cyber security market is according to Zion Research expected to grow from USD 105 bn in 2015 to USD 180 bn by 2021.

The most common type of cyber-attacks happens when cyber criminals seek small and rapid profits through illegal gains of information, e.g., ransomware and credit card scams. The digital means used and information gained can lead to more severe cyber espionage through the acquisition of sensitive and confidential information. The energy sector is a target of attacks from both states and competitors seeking advantage, and criminals seeking potential revenues, from stolen information. Such information is also potentially used for cyber sabotage, creating entryways to compromise the integrity of systems.

The energy systems' supply, transportation and distribution assets are high-profile targets with potential for severe economic, safety and political implications. In 2015, hackers used a so-called trojan to shut down several Ukrainian power substations by attacking three power companies. In August 2017, Saudi Aramco was forced to shut down an industrial process as the Triton malware was attacking its safety system. In March 2018 the City of Atlanta was forced to shut down all its 8,000 employees' computers, halting many public services, as the SamSam group carried out a ransomware attack.

Increased digitalisation, the "Internet of Things" and the interconnection of legacy and new energy systems are introducing new vulnerabilities for the energy industry. The sophistication of the tools and attack vectors in the hands of small attack groups and individuals is increasing. Historically, tools that state actors could employ would take years to filter down to less organised groups. This timeline is shrinking, multiplying the threat sources. Governments, international institutions and industries are collaborating to prevent attacks, but preventive measures will always have to adapt to the changing nature of cyber threats. The human factor, awareness and behaviour, will remain critical as cyber defenders need to stay lucky all the time, whereas the attackers only have to be lucky once.

The rate of electrification is lowest in *Rivalry* and electricity demand growth is slowest, despite TPED being higher. Less focus on energy efficiency and decarbonisation favours direct use of fuels rather than electricity.

Overall, the share of fossil fuels remains relatively constant in *Rivalry* over time. By 2050, they still account for over 77% of total primary energy demand. Oil maintains its share, while gas and coal drop marginally.

The geopolitical backdrop in *Rivalry* is a fluid, volatile and conflict-ridden world, where the influence of global governance and multilateral institutions has diminished. Great power politics and shifting alliances signal the end of benign geopolitics. The lack of trust among global players leaves the international community unable to address effectively challenges associated with climate change, terrorism, cybercrime, as well as biological warfare and pandemics. Major powers impose their will on smaller countries through economic, and when deemed necessary, military means. The value proposition of democracy declines, with many parts of the world now ruled by dictators and autocrats, some of whom are intent on exporting their authoritarian political models. Other issues than climate dominate the energy policy agendas.

The rise of China as a global superpower and the demise of US influence on the global stage is accelerated in *Rivalry*. A weakened EU, meanwhile, driven by illiberalism in several member states and the continuous north-south divide, is unwilling and unable to assert itself globally. Despite economic and demographic challenges, Russian manoeuvres ensure that it remains an important international player, and, thus, a continuous thorn in the West's side. The US, meanwhile, is unable to reverse its relative global decline. The power vacuum that this inevitably leaves is quickly filled by regional actors much to the detriment of the rules-based global order. A direct consequence of disruptive geopolitics is weaker international trade and investment, which leads to economic stress across many parts of the world.

On the positive side, relative technological progress and productivity gains help improve standards of living across many regions over time, albeit at a slower pace than in *Reform* and *Renewal*. A significant portion of the 1.3 bn people living in extreme poverty in 2018 are better off, but poverty is far from eradicated. At the same time, the remaining poor are concentrated in a few populous countries in Africa, the Middle East, and Asia, thereby generating further instability in those regions and beyond.

In this world of diffusion and self-reliance, the global community proves unable to address many of the challenges that the modern world is confronted by. Conflict is now a constant, driven, as it is, by technology and mutual subversion. Most notably, the international community fails to meet its climate targets and *Rivalry* ends up being the least sustainable scenario in many ways. Annual global energy-related CO_2 emissions continue to grow until 2040, before they plateau at around 39 Gt.

Global population growth and energy demand

Global population growth is one of the fundamental assumptions supporting energy market forecasting, with powerful impact on results. Population projections build on the combination of four factors: fertility, mortality, migration and age distribution. The United Nations Population Division's 2017 Revision of the World Population Prospects is one of the most widely-referenced sources, where nine different standard projections are available. The Medium-Fertility Variant assumes a growth in the use of family planning that will result in reductions in fertility, the High-Fertility variant assumes that in each country the fertility rate is half a child more, while the Low-Fertility Variant assumes that in each country the fertility rate is half a child less. Population estimates and average growth rates for the three projections are shown in the table below. A Constant-Fertility projection further stretches these limits with 10.9 bn people projected in 2050, while other projections are within the range defined by the High and Low variants.

Projections	Population 2050	CAGR 2015-2050
Medium-Fertility	9.8 bn	0.8%
High-Fertility	10.8 bn	1.1%
Low-Fertility	8.8 bn	0.6%

Energy Perspectives uses the Medium-Fertility Variant projection across all scenarios, to simplify our approach to a complex discipline. Had this not been the case, the 0.3 %-point deviation between High and Low versus Medium global population growth rates alone would trigger a change of +/-9% in TFC by 2050 in *Reform*.

Not all forecasters share the same approach to population growth assumptions. The climate change research community has been working on a set of alternative pathways of future societal development, the so-called Shared Socioeconomic Pathways (SSPs), which are used in integrated assessment models to produce climate-relevant results. Interestingly, all the five SSPs are based on widely different population growth assumptions. Out of the five SSPs, three pathways rhyme well with our three scenarios: In the Middle of the Road pathway, which carries similarities to *Reform*, global population growth is moderate and levels off in the second half of the century, because of the demographic transition in high-income countries. Lack of satisfactory education investments in low-income countries, however, is not able to slow population growth in a similar manner. In the Sustainability – Taking the Green Road pathway, which shares narrative with *Renewal*, educational and health investments accelerate the demographic transition, freeing women from traditional gender norms and leading to relatively low population globally. Low fertility is also driven by the shift from agriculture to urban life, meaning less incentives for families to have children to work on farms, also reinforced by increasing costs of raising a child in urban environments. Fast income growth is an additional catalysator of low growth in high-fertility countries. Finally, in the Regional Rivalry – A Rocky Road pathway, which in many ways can be compared to *Rivalry*, demographics and urbanisation are poorly managed. Population growth is low in industrialised countries due to lack of migration, and high in developing countries due to slower improvements in education and income.

Energy policy and conflicts in Renewal

The *Renewal* scenario is assumed to play out in a benign political environment, where the whole world pulls in the same direction, leading to a coordinated and joint response to the threat of global warming. In *Renewal*, there are several factors that can potentially decrease conflict levels both on a domestic, regional and global level. There are less negative consequences of climate change over the longer term, local pollution is decreasing, energy production is decentralised and democratised, economic growth is solid, energy poverty is reduced, and access to energy is more widespread. Countries that today rely on fossil fuel imports, will become less vulnerable to supply disruptions and volatile import prices and experience improved energy security.

There are however many risks to this outlook, and new sources of conflict may arise, as the world goes through the transition to a low-carbon economy and energy system. This is a topic that is being examined by the Global Commission on the Geopolitics of Energy Transformation, established by the International Renewable Energy Agency and supported by the governments of the United Arab Emirates, Germany and Norway.

A key concern is what will happen in regions that today are highly dependent on oil and gas exports. The fall in export revenues in countries in the Middle East, North Africa and potentially Russia may lead to political instability and social unrest, which may jeopardise their participation in the energy transition, and potentially have negative geopolitical impact that could spread also outside the region. In *Renewal*, these income shifts are assumed to be handled and compensated in a benign manner.

The energy transition itself also brings up new risks. Increased deployment of renewables and battery storage puts pressure on the supply of critical raw materials. Countries that have restricted access to capital and new technology will be disadvantaged. Large-scale electricity transmission systems may need to be further expanded, creating new types of interdependencies between countries, that could be a source of strengthening ties, but also of conflict.

The big question is whether these risks endanger the energy transition and put the target of limiting global warming to 2° at risk. Today, the Middle East, North Africa and Russia account for around 13% of global energy-related CO_2 emissions. In *Renewal*, it is assumed that these emissions drop by around 35% by 2050, and continue to fall post-2050. A failure to do so will put more pressure on other regions to compensate and step up their efforts even further, which will be very challenging. If the lack of action spreads to other "disadvantaged" countries, where access to finance is limited, and ability to integrate new technology is low, it may prove to be an impossible task to put the world on a Paris-consistent 2° path.

Identity politics

As the post-Cold War era gives way to renewed geopolitical contest, identity politics, based on particular ethnic, social, cultural or religious identities, is re-emerging as an important factor in political mobilisation as well as in geopolitical rivalry between states. While not a new phenomenon – recall the Balkans and Rwanda in the 1990s – it is resurfacing with renewed relevance.

After World War 2 (WWII), the major powers saw it as crucial to build over-arching global institutions and treaties that created economic and political interdependencies between states, that ultimately would benefit all economically and stave off the attraction of nationalism and provincialism. However, while it has led to a global trading system that has driven global GDP growth across the world and hugely benefitted poor countries, inequalities within countries and societies have increased, both in industrialised and developing countries. This has led to an increasing sense of threat, victimisation and exclusion among the groups in society that have been "left behind".

The political consequences of this have emerged with ever greater clarity in the West, resulting in populist uprisings across established democracies, and producing a current that threatens to rip the political landscape of established democracies apart.

However, identity politics are also highly relevant in many other parts of the world. In a sense, identity politics never really went away, even if its importance has fluctuated over the years. Across the Middle East, political mobilisation around religious and ethnic identity has been a feature for decades, but now it is being skilfully managed by political regimes and non-state actors alike, contributing to growing instability, exemplified in the Sunni-Shia schism. In Asia, nationalism has been a prevalent feature since WWII, but today it is increasingly being used by current and rising powers to mobilise popular support in lieu of compelling ideological arguments and socio-economic progress.

In *Rivalry*, with the fracturing of international trade systems, increasing economic protectionism, and lower economic growth, and where conflict becomes a permanent feature, tensions within societies across the world continue to grow. Identity politics becomes easy to turn to both for leaders and political regimes as well as for groups that feel marginalised and under pressure. In some instances, this manifests itself as more traditional nationalism on behalf of the state; and in others, as a break-down of the party-political system. But in both cases, identity or identities are seized upon to create and amplify boundaries between groups of people, *us* and *them*.

Creating the conditions to be able to effectively combat nationalism in the geopolitical sphere, and communalism in domestic political spheres to achieve mutual trust, less inequality and more inclusion, will be exceedingly difficult in a *Rivalry* world, if not impossible.

If black swans fly

"Black swans" do appear on the horizon from time to time, but it is demanding to predict exactly where and when. Also known as "wild cards", "game changers" or "paradigm shifts", the term describes future developments with low probability, but high impact. They render most assumptions worthless and send planners back to the drawing board.

Looking ahead to 2050, it is more likely than not that black swan events will occur.

Conventional market analyses often think in terms of economy, policy and technology. Those categories are necessary, but far from sufficient. Also, politics, medicine, biotechnology, migration, environmental issues, and natural phenomena deserve attention. Profound changes here may ultimately hold more power to change the world. So here are three black swans for the reader's reflection that just might imply significant change for humanity over the next 32 years:

<u>Nuclear fusion</u>

The commercial breakthrough of this technology would be a blessing for the global community, but spells immense challenges for traditional energy producers. The ability to combine smaller atoms to release energy represents an energy source that is plentiful all over, safe, and green. This innovation fast renders irrelevant most traditional energy market ideas and is a paradigm shift for global energy politics. Apart from less affluent pockets of the world that are technologically disadvantaged and lack access to capital, the global electricity system moves on a path towards running almost exclusively on nuclear fusion.

<u>Blue Death</u>

New pandemics, the weaponization of disease and widespread antibiotics resistance leave millions of people vulnerable to lethal illnesses by natural contagion or human design. The most infamous case is Blue Death, a plague-like condition compared by medical researchers to the Black Death pestilence of the 14th century. In the 21st century world, it spreads fast and is almost impossible to contain. In economic and societal terms, it causes severe setbacks and a long-lasting economic depression. But it is also an equaliser, affecting rich and poor equally, and gives new population segments access to land, water and other resources. Fighting plague becomes the top political priority globally.

<u>Mars colonised</u>

The technology to melt subterranean ice on Mars, along with quantum leaps in oxygen condensation and space technology enable humankind to colonise the planet in a way imagined only in science fiction in the previous century. Driven by international rivalry, both China, the US, India and the EU have established permanent city clusters on Mars, on the "second planet". While they still depend on Earth for food and several staples, great progress has been made towards Mars' autonomy. There is still no agreement on how to rule the new world. But the day when human life can continue there, even if the Earth becomes uninhabitable, does not seem too far away.

The global economy

Current situation and outlook to 2025

The global economy is in an expansionary mode, with robust global growth and inflation trending upwards. Most leading economic sentiment indicators are up, signalling employment gains, higher private consumption, and an improvement in business activity. The US economy displays strong growth propelled by gains in the labour market, a loose monetary policy and fiscal stimulus. Eurozone progress remains solid, driven by job creation and ultra-loose monetary policy, but political uncertainty might damage business confidence. Japan has experienced a positive economic momentum, sustained by low unemployment and strong external demand. China's economy shows resilience in the transition from investments to a consumption driven-economy and the smooth leadership reshuffle late last year. Although growth in India has remained modest, improving business sentiment after the tax reform, and gradual resumption in bank lending, currently add support to the economy. Russia is helped by higher energy prices, and Brazil has recovered from its last recession. As of now, the global economy looks to grow by 3.2% in 2018, which is somewhat stronger than the year before. Geopolitical tensions, an excessive pace in monetary tightening, protectionism and rising debt levels in emerging markets are key downside risks. On the upside, the pickup in activity and easier financial conditions may underpin each other. Hence, risks to near-term growth appear broadly balanced.

Projecting economic development, our approach

Economic activity in the near term is shaped by demand for final goods and services. It is natural that economies fluctuate above or below the trend growth, with fiscal and monetary policy and reforms utilized actively by policy makers as steering tools. Our long-term approach shifts attention to the supply side and the production potential of economies. Our framework is based on modelling changes in input factors such as labour and capital, and a residual that reflects production efficiency, Total Factor Productivity (TFP). Convergence among economies is assumed, as developing countries will grow at faster rates than advanced countries.

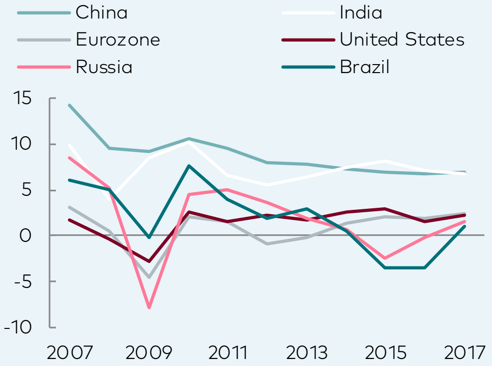
Outlook to 2025

For the 2018-20 period, global economic growth is expected to be stable at around 3.0% as a yearly average. This will be one of the stronger growth stages since the financial crisis of 2007-08. Emerging markets lead the development, but the cyclical upswing is also supported in mature economies. Geopolitical tensions and some protectionist measures will not arrest the economic momentum. To maintain and raise the pace of economic expansion, changes that encourage innovation and promote investment in productive capital will be important. The growth forecasts for our three scenarios start to deviate from year 2021 and are discussed below.

In *Reform*, the global economy during 2021-25 slows to an average growth of 2.8% per year. This is primarily due to a mild cyclical economic downturn in the US reinforced by a policy interest rate normalisation by the Federal Reserve. Still, healthy population growth and capital investments mostly in the energy sector contribute to expansion. Private consumption carries the US economy as it grows

GDP growth by region, 2007-2017

Real annual % change at market exchange rates



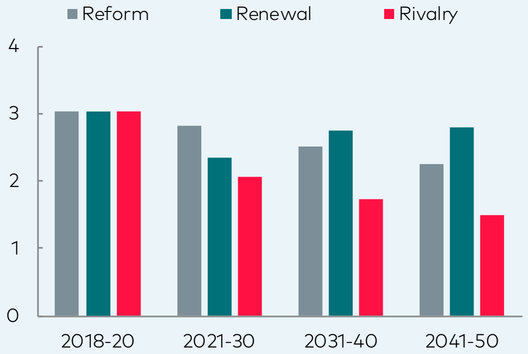
Source: IMF

Decrypting cryptocurrencies

Cryptocurrencies have rapidly gained ground over the last two years. Today, there are around 1,400 different digital currencies in use – led by Bitcoin – and the number is still growing. One of the new additions is the "Petro", which was launched by Venezuela in February 2018 to circumvent US financial sanctions and to help Venezuela's collapsing economy. Maduro's government claimed that the new currency is backed by the country's mineral reserves.

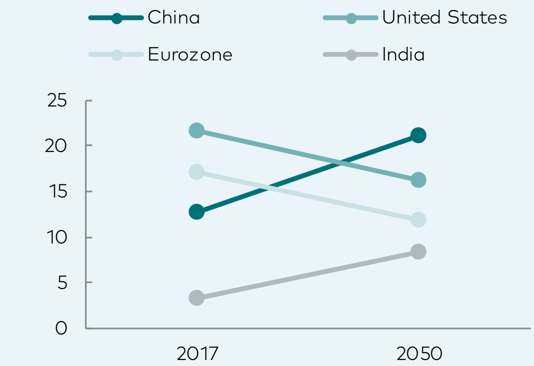
Some of the general benefits of cryptocurrencies are regarded to be no transaction fees, widespread access for users, limited risk for identity theft and immediate settlement. On the other hand, this digital payment vehicle has several weaknesses, such as not being accepted widely, being difficult to understand, lacking regulation, generally no guarantee by central banks, and the potential of being used in illegal financial activities. Due to the very nature of cryptocurrencies, the position and role of central banks will likely be challenged ahead, which is the biggest concern, as robust public institutions are one of the cornerstones of any country's economic development. Further, cryptocurrencies have been a very volatile asset class for investors and customers. High volatility in the valuation of cryptocurrencies may stress debt-funded market participants, which again could have negative ripple effects throughout the real economy. When it comes to energy use in the digital "printing" of some of the cryptocurrencies, Bitcoin's electricity consumption alone is huge and is estimated by Digiconomist to be just shy of 70 TWh/year (close to Austria's yearly electricity demand), and growing rapidly.

Global GDP growth by scenario
Real 2010 annual % change at market exchange rates



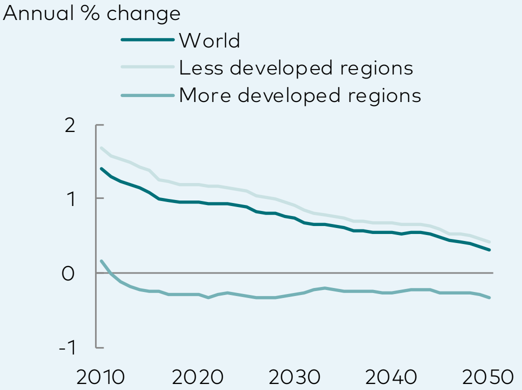
Source: Equinor

GDP by region, 2017 and 2050
% share of global GDP



Source: Equinor

Working-age population
Annual % change



Source: UN

at an average of 1.7% per year. In the Eurozone, core members pursue further integration, while fringe members are more reluctant. Some labour and product market reforms, coupled with investments in research and development filter through, as the area's economic performance reaches 1.5% per year on average – assuming a limited negative impact of Britain's EU-leave. Japan's robust industrial development and labour shortage lift real household income. Front-loaded purchases before the tax hike in 2019 and construction works in relation to the Tokyo 2020 Olympics sustain domestic activity. However, high public debt levels slow growth to 0.7% per year. China's economy continues to transform from industrial to services- and consumption-driven growth, with solid labour market conditions, robust digitalisation and an orderly soft landing of the housing market. A reduction in debt levels amongst companies and local government, the anti-pollution campaign, and supply side improvements will lead to a moderate GDP growth deceleration at 5.5% per year. India recovers from the twin policy shocks of demonetisation of large currency notes and the introduction of the Goods and Services Tax. Infrastructure development and structural reforms drive growth to a robust 6.8% per year over the period. Brazil's huge resource base, somewhat higher commodity prices, and favourable demographics result in an average expansion of 2.6% per year. In Russia, demanding demographics, slowing investments, low innovation and business diversification curb growth to an average of 1.5% per year.

The reallocation of investments towards the green economy in *Renewal* is driven by the need to reduce global CO_2 emissions and fulfil agreed targets, and is not aimed at the highest short-term economic return. Policy regulations materialise in the form of increased taxes on emissions, a gradual, but rapid phase-out of coal-fired power plants, and a curb in energy use. Initially, the transformation of the energy systems is costly and requires subsidies and investments with initially low returns. The economic growth in *Renewal* is 2.4% on average per year, which is 0.4 percentage points below *Reform's* growth rate. Europe and leading Asian countries are first movers with cost-efficient new solutions. The rest of the world will follow closely behind, as the political will for greening increases. However, it is difficult to cope with the energy transition in big fossil fuel producing regions and countries like the Middle East and Russia. The positive impacts of energy transition in the *Renewal* scenario come to the surface beyond 2025.

The economic development in *Rivalry* is highly cyclical. This is a feature in a world with escalated regional conflicts, sanctions and inefficient markets that dampen technology development. Political and economic resources are channelled to less productive purposes, such as security and defence spending. Further, lack of confidence between countries and focus on own interests, rather than solutions serving global interests, slows GDP growth significantly in *Rivalry* to only 1.1% per year through 2021-25. Pockets of outright economic recessions are seen in different regions. Economic activity is markedly poor first and foremost in the Middle East and North Africa (MENA). This assumes a continuation of the tumultuous geopolitical situation seen today in MENA, while other regions are slightly more sheltered. The US is about to abandon outdated regional alliances and costly

Technology driven slowdown in store?

Severe economic setbacks have historically often been caused by debt mismanagement, stock market crashes, imprudent economic policy or even very high oil prices. Some of this is likely to happen again, but what if a setback or stagnation will come from the "new technology rooted economy" itself? In the continuation we address three challenges that pose a risk to economic development going forward:

Challenge #1: The biggest new US technology companies listed on exchanges have surged in market value, and operate mostly in separate markets. An asymmetry has developed between these companies and their regulators (both domestic and foreign) in terms of resources. Further, some governments have raised the question of how to strengthen tax collection from these companies.

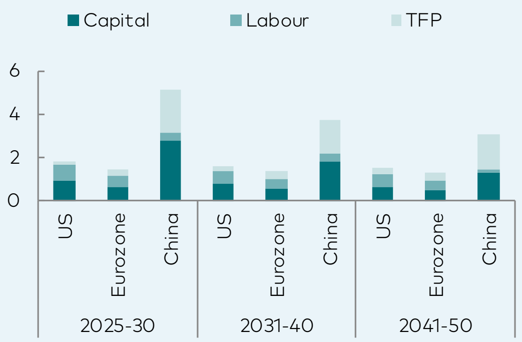
Challenge #2: Capital accumulation looks to benefit the few, leading to more inequality, and possibly binds up capital that otherwise could have been employed in the economy.

Challenge #3: Stronger automatisation, robotisation and innovation are expected to lead to welcome productivity gains in economies, but they may leave millions of people redundant. The market for goods and services may shrink as a consequence, leaving capital owners with less incentives to expand investments, creating a negative circle that slows down economies. A mixture of lower tax receipts and mass unemployment could thus threaten many welfare states.

The risk of all this to follow through is not seen as imminent, but in the short-term it may enlarge frictions between companies, labour unions and authorities. An escalation is likely to be gradual and stretch out in time – but it nevertheless bears the potential to cause substantial headwinds for economies and energy demand.

GDP growth by source, Reform

Real 2010 annual % change at market exchange rates



Source: Equinor

commitments, and pursues energy self-sufficiency. The EU is weakened, while China seeks to expand its geo-economic policies.

Outlook beyond 2025

The global population is set to increase through the forecasting period, but at a decelerating rate. According to the UN, the world's population is set to increase to 9.8 bn in 2050. All regions face aging issues at a varying degree, as workforces shrink due to retirement. A high labour market participation rate, improving educational system, and labour market flexibility are key elements for securing a competitive work force. Urbanisation is faster than ever, and megacities are at the heart of value creation. Countries continue to draw on their capital base of resources, machinery, transport equipment, infrastructure and building capital. As financial and credit markets mature, capital efficiency increases in emerging economies. Digitalisation, automatisation, and robotisation become important tools in combining labour and capital to enhance productivity, and to manage the aging issue. The service sector in the global economy grows. Beyond 2025 the three scenarios continue to develop in a multi-speed way, where *Reform* grows by an average of 2.5%, *Renewal* by 2.7%, and *Rivalry* by 1.9%. This means that by 2050, the global economy is 1.9 to 2.5 times as large as it was in 2015. In the long run, the world economy and its leaders have to deal with global imbalances in trade and budget deficits. Policy makers in the Western world also have to reduce and eventually end vast quantitative easing programs. Many governments must build or reinforce their social welfare systems, combat inequality through income and wealth distribution, revive productivity, and cope with migration.

Reform: a trend-based economy

The global growth in *Reform* is somewhat lower than the historical growth rate seen at 2.8% since 1990. This is primarily due to shrinking working-age population and a gradually diminishing catch-up potential in emerging markets. Overall, the world's energy and economic systems develop in line with previous decades and do not change as much as in *Renewal*. Most economies generally avoid enforcing excessively burdensome environmental regulations on their economies. The global economy stays market driven and operates efficiently. Traditional energy carriers dominate, although new renewables increase their market share. A slight negative environmental impact occurs from mid-2030s and lowers the economic pace somewhat. During the mid-2030s China surpasses the US as the world's biggest economy, measured at market exchange rates. Debt reduction and structural reforms towards a more consumption oriented welfare economy sustain China's growth. The economy grows on average by 3.6% per year, as financial and fiscal restructuring and investment in digital infrastructure enhance capital efficiency. Asia is expected to be the growth engine of the world by the mid-2030s with its favourable demographic dividends and attractive investment options. OECD economies grow at an annual average of 1.6% over the 2026-50 period, while progress in non-OECD economies averages 3.5%.

Renewal: a sustainable economy

Green investments gradually yield the highest return and are more attractive than traditional energy investments. The green shift is

China's shrinking labour force

China's total working-age population, or the number of people aged between 15 and 64, fell to 998 mn last year, its lowest level since 2009. A shrinking pool of workers presents a challenge to China's long term economic growth.

Japan has long experienced the working-age population decline with severe labour shortages, which threatens labour intensive construction and transportation sectors. Together with a rapidly ageing population, and the swelling spending on health and pensions, Japan has found it hard to rein in public debt and economic growth has plummeted since 1990.

Similarly, in China, the share of people over 65 years in 2017 increased to 11.4%, up from 10.8% in 2016. The rapidly ageing Chinese population has led to a growing shortfall in China's pension scheme which is often filled through transfers of central government funds. A pilot programme has been set up to transfer shares in state-owned firms to social security funds.

The working-age population decline in China has also a created a tighter labour market both in quantity and quality. In 2017, total Chinese urban employment increased by 10.3 mn, as more rural residents moved to cities, though the figure was less than the 13.5 mn new urban jobs being created. Further, there seems to be an insufficient pool of highly educated work force to satisfy the rapid upgrade of the economic structure. This has driven up labour cost and led to transfer of labour-intensive industries to other developing countries which have more competitive labour cost.

The shrinking potential labour force also led to a faster rise of per capita disposal income, which spurts a rapid transformation to a service-driven and consumption-based economy, that will be less dependent on labour-intensive industries. Nevertheless, one countervailing tendency in China mitigating wage increases has been the dramatic shift in the structure of labour demand. This is reflected in the collapse of employment in state-owned enterprises, especially in the manufacturing area as a result of structural reform to remove excess industrial capacity, and the growing role of employment in private enterprises and through self-employment.

Demand for labour in industry will decline further if China successfully implements its structural economic reform, and upgrades its manufacturing sector with more advanced labour-saving technology.

interlinked with a rapid digitalisation of the energy industry, which contributes to efficiency gains in the overall economy. Technology developments spread, helped by global arrangements that foster international relationships in areas important for green growth. Further, transition towards lighter industry and service based economy coincide with stricter energy efficiency and climate targets. Monitoring from space countries' emissions on an individual basis proves to be an efficient system for compliance with internationally agreed emission cuts. The phase-out of subsidies, and significantly higher global carbon costs help to fund new capital-intensive low-carbon electricity infrastructure and CCUS. Transforming the energy system is by nature labour-intensive, and new renewable energy capacity additions create local jobs which is welcomed by governments. Some of the new energy systems are de-centralised, meaning that households and companies generate their own electricity and sell excess electricity back to the grid. This directional shift in power from big electricity producing companies to consumers, in addition to the need for huge power capacity add-ons, raise the need for governments to be more active in energy infrastructure investments. Traditional fossil fuel producing regions are able to adjust to new reality in the long run. GDP growth in *Renewal* outpaces *Reform's* from the early 2030s. CO_2 emissions are kept within the 2°-consistent carbon budget, hence there is no or only a marginal negative environmental impact on economies.

Rivalry: a volatile economy

The meagre initial years of the 2020s are followed by a strong expansion phase from mid-2020s and for the remainder of the decade. Although the global growth rate hovers around 3% yearly during 2026-30, and outpacing both *Reform's* and *Renewal's* growth rates, the economic development is slow because of base effects. Cycles of economic growth continue during the 2030s and 2040s, alternating at 5-year bust periods of around 1% average yearly GDP growth and 5-year boom periods with around 3% average yearly growth. From the late 2020s, local pollution, global warming and their negative environmental consequences gradually filter through and escalate. This particularly hurts economic activity in less developed economies and countries closer to the Equator. Throughout the forecasting period, the Americas enjoy thriving inter-regional trade counteracting increased protectionism for the region and enabling relative prosperity. Europe is unable to compete effectively on the global scene and drifts into stagnation and protectionism. Russia's development in *Rivalry* is just shy of its development in *Reform*. Less emphasis is put on remodelling the economy, as the country harvests on its big petroleum resource base. China and Southeast Asian countries manage relatively well with a combination of large domestic markets and strong regional trade links. India emerges as a global manufacturing hub and maintains impressive growth. Economic activity in MENA is driven by oil and gas exports, but the instability across the region restricts trade within and between states, and also impacts economic expansion directly. Oil and gas production expansion is periodically hampered due to growing security threats. This, combined with increased domestic petroleum consumption and less availability for exports, make Middle East export countries see their financial resources shrinking.

Global climate policy and greenhouse gas emissions

Climate policy: a shift in global leadership

The US and China, the world's two largest carbon emitters, have revised their climate policy positions. In June 2017, President Trump announced that the US would withdraw from the Paris Agreement as soon as possible meaning November 2020. The Trump administration is also moving to roll back many of its predecessor's policies, such as the Clean Power Act, vehicle emission standards and curbs on power plants. Following the withdrawal announcement, the governors of several US states formed the United States Climate Alliance to continue advancing the objectives of the Paris Agreement.

China emerged as a cautious climate policy co-leader prior to the Paris conference, and is now – with the US no longer running for leadership – widely expected to assume an even more central role. China is however not in position to fill the void left by the US. Chinese leaders' rhetorical support for the Paris targets matters, but China cannot make good on the financial incentives the US had offered other nations. Rather than accepting to single-handedly defend the Paris accord, China is likely to enter a new coalition with the EU and Canada, replacing the US-China coalition. The EU has an ambition to be the world's climate leader, but internal tensions and Central-East European member states opposing the policy implications have made this difficult. However, the EU can take the role as facilitator for a China-EU-Canada coalition, and in that way play an important role in international climate negotiations.

EU's own climate policy is advancing, though with different member countries continuing to advocate different levels of ambition. Importantly, a post-2020 EU Emissions Trading System (ETS) reform plan has been agreed. The cap on aggregate emissions will be lowered at a faster pace, and more emission allowances will be injected into the Market Stability Reserve. The allowance price has responded by increasing from 4-5 EUR/t CO_2 in April 2017 to the 12-14 EUR/t range one year later. EU's 2030 climate and energy policy framework also includes an Effort Sharing Regulation (ESR) agreement to reduce emissions not covered by the ETS by 30% between 2005 and 2030, plus a renewables goal that could be 27% or 35% and an energy efficiency goal that could be 30% or 35%, depending on the outcome of discussions between EU institutions. While representing steps in the right direction, many feel the 2030 framework lacks in ambition as it falls short of putting the EU on track towards the "well below 2°" ambition, and the Council has given the Commission until 1st quarter 2019 to prepare a CO_2 emission reduction plan in line with this ambition.

Next steps for the Paris Agreement

The 21st Conference of the Parties (COP) in 2015 led to the Paris Agreement that sets out a common ambition to limit global warming to well below 2°, and to pursue efforts to limit it to 1.5°. The main mechanism to achieve this is the NDCs. A first set of NDCs covering the period up to 2025 or 2030 were submitted in 2015, and new or updated pledges are to be submitted every five years. At COP 24 in Katowice in Poland this year, the rules for how to measure, monitor and verify progress will have to be defined and agreed upon.

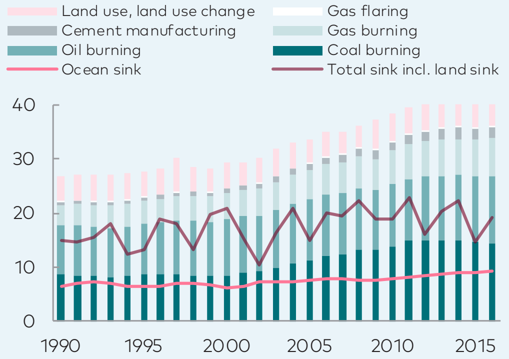
Climate-related financial disclosures

Mark Carney, the Governor of the Bank of England and Chairman of the G20's Financial Stability Board (FSB) has been the first high-profiled public official linking two issues: climate change and financial stability. His central idea and message has been that climate change could lead to financial crises and falling living standards, unless the world's leading countries do more to curb current and future carbon emissions. Carney suggests that doing too little, too late, may lead to a disruptive energy transition, which would likely have more severe economic and environmental impacts than a more gradual transition. Following his landmark speech "Breaking the tragedy of the horizon" in September 2015 and discussions at the November 2015 G20 meeting, the Task Force on Climate-related Financial Disclosures (TCFD) was established in December 2015 under the umbrella of the FSB. TCFD seeks to develop recommendations for voluntary climate-related financial disclosures that are consistent, comparable, reliable, clear and efficient, and provide decision-useful information to lenders, insurers, and investors. TCFD's Preparer Forum is tasked with identifying best practice and setting the direction for disclosures to be integrated in mainstream financial reporting. There is an expectation that the TCFD recommendations may evolve into regulatory requirements in some jurisdictions.

Financial risk associated with climate change comprises both physical and transition risks. Physical risk is the risk associated with the climate change itself, such as extreme weather, flooding, drought or sea level rise, and affects all sectors and regions. Transition risk is the risk of changes in policies, liabilities, technologies or consumer behaviour. The energy sector is thought to be most exposed for transition risk, but changes in energy consumption and mix have wide implications across many sectors. Both physical and transition risk can result in financial risk, such as production and operational disruptions, supply chain disruptions, physical damage to assets and consequent increase in insurance costs, changes in resource or input prices, such as water, energy or food, and changes in demand for and prices of products or services.

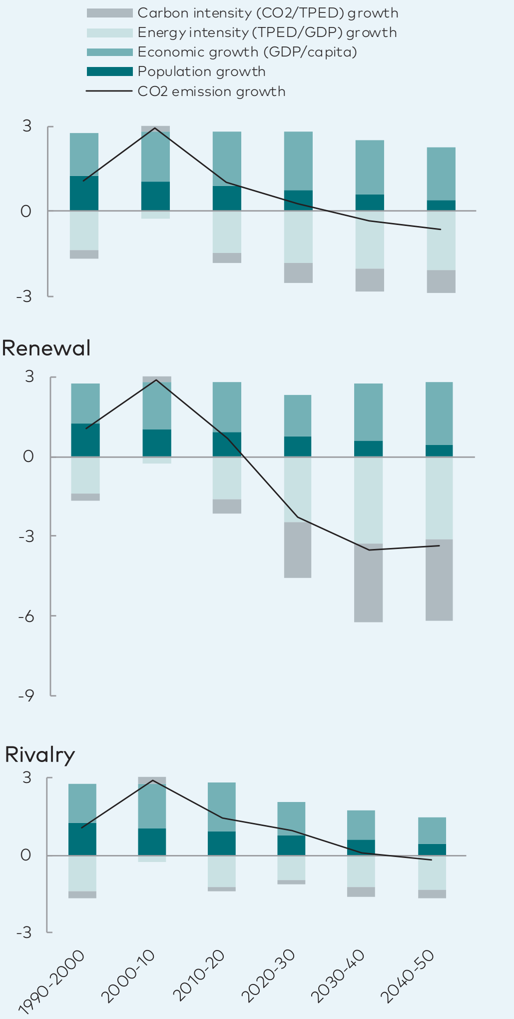
Interestingly, scenario analyses have been promoted as a useful tool in climate-related financial disclosures, to better inform the financial sector about the robustness of a company's business plans. CICERO, an independent non-profit climate research centre in Norway, recommends the use of consistent scenarios for a 2°, 3° and 4° future, to ease comparison across companies and industries. However, it is important that users of scenario analysis and stress testing are aware of the uncertainties and limitations of scenario analysis, apply the stress tests with due care, and do not misinterpret scenarios as predictions. In particular it is important to take note of the fact that future portfolios might be very different from current portfolios, if transition risks do in fact materialise.

Global CO_2 emissions and net CO_2 additions to the atmosphere
Gt



Source: Global Carbon Project

World energy-related CO2 emission growth and emission driver growth
%



Source: IEA (history), Equinor (projections)

The process will be challenging. Emission estimates are by their very nature uncertain. They need to encompass a variety of sources including fossil fuels, agriculture and deforestation. Individual country groups' relative emission reduction and financial responsibilities remain contested. Moreover, although the current NDCs are too weak to deliver the well below 2° target, pointing instead towards a warming in the 2.7-3.7° range, they have so far triggered an even weaker policy response with many countries failing to take adequate action. It is critical that the meeting in Katowice encourages greater urgency in raising the ambitions of the NDCs, to "move further faster", as the current UN slogan depicts. The new and updated pledges that are to be submitted in 2020, need to entail a significant tightening of policies if they are to bring the world back on track to limit global warming to well below 2°.

Global energy-related carbon emissions

IEA puts global energy-related CO_2 emissions in 2016 at 32.1 Gt. The Global Carbon Project estimates that fossil fuel use accounted for 82% of the total emissions, with land use changes contributing 12% and cement manufacturing 5%. Natural sinks – the world's forests and oceans – re-absorbed an estimated 47% of the emitted CO_2. Energy-related CO_2 emissions increased by around 60% between 2000 and 2015, but the curve flattened in 2016 and 2017, to the relief of everybody concerned with global warming. It seems however that they rebounded in 2017, by 1.5-2.0%, as energy demand growth picked up. OECD country emissions continued to decline, although marginally, but Chinese and Indian emissions were up.

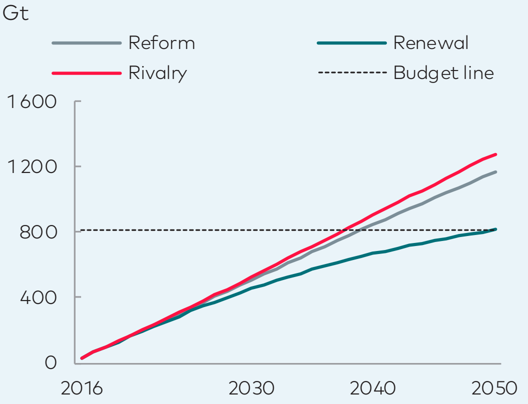
In *Reform*, global energy-related CO_2 emissions increase until the end of the 2020s – initially by about 1% per year, in line with apparent growth in 2017, later by rates falling to zero. Through the 2030s and 2040s emissions decline, yielding a total of 1,170 Gt over the full scenario period. In *Renewal*, emissions peak a couple of years from now and decline at an average of more than 3% per year between 2020 and 2050, so that the carbon budget underpinning this scenario is met. In *Rivalry*, emissions level out around 2030 at some 38.5 Gt, and fluctuate around this level for the rest of the scenario period. Cumulative emissions over the 2016-50 period are 1,280 Gt. The main *Renewal* scenario is as mentioned complemented with two sensitivities, one that caps CCUS capacity at current levels and another that assumes that policy tightening is delayed until 2025, and CO_2 emissions follow the same path as *Reform* up until this year. The key parameters for the scenario and the two sensitivities can be found in the table on the next page. The CCUS sensitivity is described further in the next section. If policy action is delayed until the mid-2020s, but the *Renewal* carbon budget is retained, more dramatic cuts will be needed in the following years. Whereas in *Renewal* global emissions never need to be depressed by more than some 4% per year, in the delayed action sensitivity they must be slashed by up to 6-7% per year. Consequently, global energy use will have to fall by an average of 1.3% per year from 2025. Combining this with the strong economic growth that is assumed in *Renewal* may not be technically feasible. Fossil fuel use has to be slashed further compared to the significant cuts already taking place in *Renewal*. To meet the carbon budget, coal is almost completely out of the mix by 2050 and gas and

Renewal sensitivity results

Year 2050	Renewal	No CCUS	Delay 2025
Gross CO_2 emissions - Gt	14	13	9
Annual growth TPED 2025-50	-0.5%	-0.5%	-1.3%
Oil demand - mbd	59	59	51
Gas demand - Bcm	3,300	3,100	3,000
Coal demand - mtoe	1,000	850	200
Total electricity generation - TWh	40,100	39,800	37,500
Solar/wind generation - TWh	19,600	21,300	21,300
Solar/wind share	49%	54%	57%

Source: Equinor

Cumulative CO_2 emissions, 2016-50 and assumed budget line to 2050



Source: Equinor

The vegetal system of Bosco Verticale gives many environmental benefits

Source: iStock

oil demand is respectively 9% and 14% lower than in *Renewal*. This sensitivity illustrates the urgency of starting emission reductions.

The role of CCUS

CCUS figures prominently in most 2° scenarios. The Inter-governmental Panel on Climate Change (IPCC) estimates that reaching the 2° target will be more than twice as expensive without CCUS as with. However, the disconnect between visions and actual project activity remains glaring. The World Bank reports that though a third of global carbon emissions are currently subject to some form of carbon pricing, prices are too low to incentivise the commercial implementation of CCUS in most regions.

There are now more than twenty large-scale CCUS projects operating or under construction throughout the world, in addition to more than one hundred smaller-scale projects. Most current projects are based in the US, and the CO_2 is as a rule being used for enhanced oil recovery (EOR). But EOR is not an option everywhere and the scope for other CO_2-based product lines remains unclear. This means that CCUS usually adds costs, but not revenues to projects, and may only fly if governments step in with subsidies or if companies are faced with carbon prices much higher than today's prices or both. Climate science suggests that governments should step in as the cost-benefit equation for CCUS looks different if the long-term benefits to society of reduced warming are considered, but there is not the same universal enthusiasm for this measure from governments or in green circles when compared to new renewable energy. CCUS on biomass use is widely counted on to remove already emitted CO_2 from the atmosphere beyond 2050, and is therefore outside the time horizon of this report.

In *Rivalry*, there is no progress beyond existing projects in operation or at advanced stages of preparation as of 2018. In *Reform*, many more projects go forward, and CCUS becomes a real – although comparatively small – contributor to global warming mitigation. *Renewal* sees significant growth, with capture increasing to approximately 1.5 Gt of CO_2 per year by 2050. This means the completion of almost 1,100 projects the size of the US Petra Nova CCUS project, the world's largest post-combustion CO_2 capture system in operation. Though CCUS plays an important role in all 2°-consistent scenarios, its implementation at scale is far from guaranteed, and recent policy developments have been underwhelming. To test the viability of a 2°-consistent scenario that does not include any new CCUS development, a sensitivity analysis was carried out on *Renewal*. To counter the lack of 1.5 Gt CO_2 being captured by 2050, a 9% increase in wind and solar capacity by 2050, as well as improvements in the energy efficiency of the industrial sector by a CAGR of 0.05%, would allow for the 2° carbon budget to be met. This further increase in wind and solar capacity represents over 800 GW of new capacity over that already required in the *Renewal* scenario.

Water supply, land use and energy supply in the world of climate change

Water, food and energy have always been crucial for human survival. A growing world population, climate change and a lack of incentives to coordinate utilisation across industries and national borders will increase the pressure on these basic resources. Although there are numerous international agreements and global initiatives aiming at distributing resources more fairly and eradicating hunger and deprivation, we see again and again that resources are used in geopolitical power struggles and even in wars. The result is maldistribution and inefficient use of resources, and serious damage to natural ecosystems.

To safeguard its population, ensure sustainable communities and provide for development and economic prosperity, a nation needs predictable, long-term access to basic natural resources. The importance of securing this lies at the base of all development planning. As we explore ways to combat and adapt to climate change, the interlinkages between land and water use and energy supply will become even more poignant, and potential conflicts involving food production will come into focus.

Global fresh water reserves are being depleted at an unprecedented rate. Agriculture accounts for 70% of global freshwater use. But also the energy industries are major users with oil and shale gas production, refining and the cooling of power stations being highly water intensive activities. OECD estimates that global demand for freshwater may increase by 55% between 2000 and 2050.

With most projections showing growth in both global food and global energy demand going forward, the competition for water and land resources will likely harden. If investment in biofuels farming picks up, that might aggravate the situation by causing large scale deforestation and displacement of land currently used for food production. Innovative deployment of sustainable renewables such as algae and waste would reduce the pressure on land and water. Only through clever combinations and utilisation of synergies will the world be able to meet the needs of the future, whilst also meeting the Paris Agreement ambitions and mitigating climate change.

In both *Rivalry* and *Reform*, energy demand is growing. In *Renewal*, total primary energy demand declines slightly from the mid-2020s, and coal and heavy oil use drops sharply. This also benefits water. Increased use of conventional biomass and biofuels in *Renewal* adds to the pressure on land and water. However, as *Renewal* is not a particularly biomass intensive scenario with a consumption by 2050 only marginally higher than that in *Reform*, this does not erode its preferability for an environmental point of view.

The scope for changes in life styles, food consumption and non-essential water use in a world with 9.8 bn people, a global GDP at 1.9-2.5 times that of 2015 and billions more middle-class consumers, is a key uncertainty going forward, irrespective of scenario.

Carbon value chains and CCUS, including CCUS in industrial applications

CCUS plays a significant role in most 2°-consistent scenarios. Providing for a roll out of CCUS at scale is therefore a key challenge for all regions of the world. The take up of the generally proven technologies involved in CCUS normally depends on their economic viability, with both technical and market factors playing roles. The utilisation aspect of CCUS is key to this, and although several opportunities are available, only EOR has been exploited and has made a substantial impact on project profitability. CO_2 has been used to enhance oil recovery from mature reservoirs in the US for decades, but elsewhere the adoption of CO_2-stimulated EOR as a storage option has been minimal. The amount of CO_2 that can be stored is determined by reservoir characteristics and miscibility, well design and number, operating decisions, and economic variables. Foremost of these variables are the prices the industry can obtain from oil production and for CO_2 storage. Pricing of CO_2 emissions could, if prices increase to levels significantly above those seen today, provide an important stimulus and encourage investment in developing new alternative technologies with lower emission profiles and costs. Other options available include investment tax and storage credits, tax exemptions, fuel economy and environmental standards, and carbon intensity limits.

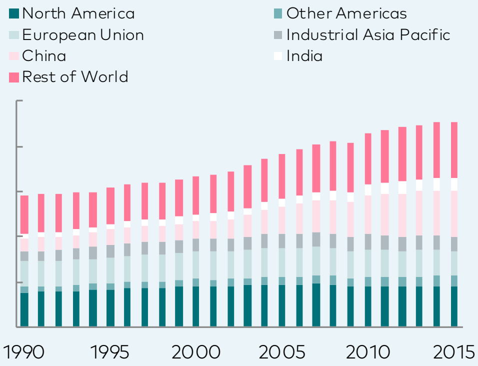
Currently, EOR projects use about 80 mn tonnes of CO_2 per year, almost all of which is permanently trapped in oil reservoirs. Though there is storage capacity both off- and onshore, the costs of utilising offshore reservoirs are much higher due to fewer injection wells and the requirement for subsea separation of the oil and CO_2. Offshore CCUS does however have potential for cost reductions, with research by Equinor showing that CO_2-stimulated EOR could be profitable on the Norwegian Continental Shelf given new technologies on material and sub-sea separation currently in development, of course helped by the high CO_2 tax in Norway.

The capture of CO_2 is the costliest part of CCUS value chains, and therefore projects involving the capture of high-purity CO_2 for industrial utilisation at source hold particular promise. Good examples are the industrial production of hydrogen, ethanol, natural gas and steel, as well as the use of ammonia and urea. Though outlooks for CCUS typically focus on the power sector, coal and gas burning power stations are low-concentration CO_2 sources for which CCUS is yet to prove cost-effective once the purification of the CO_2 is considered.

Stronger fiscal and regulatory incentives are required to facilitate the upscaling of advanced CO_2 storage through EOR around the globe. The development of a profitable CCUS industry also depends on capital investments for CO_2 capture and transportation infrastructure. Policy that is consistent and predictable, combined with targeted subsidies, are required to promote these investments.

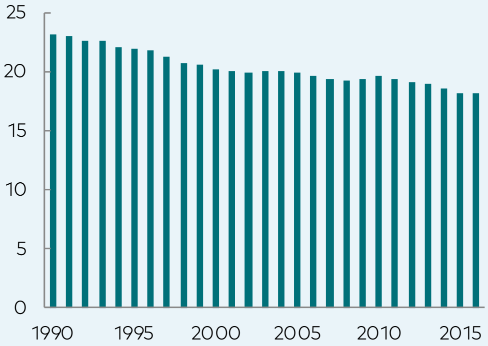
Renewal requires a CO_2 capture rate of approximately 1.5 Gt/year by 2050, a modest rate when compared to other climate-target consistent scenarios. The lack of policy support and economic viability in the short to medium term mean that it is unlikely CCUS will have a major uptake until the mid-2020s, particularly in the power market where low-cost new renewables are making up an ever-increasing share of supply.

World TPED by region
Btoe



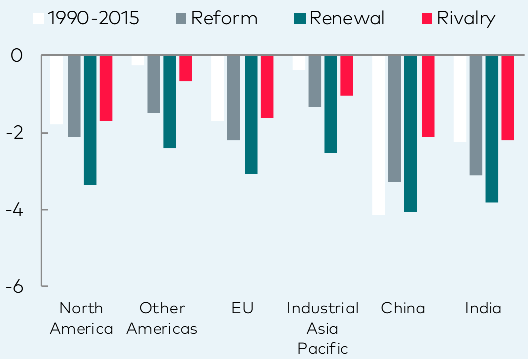
Source: IEA

Energy intensity of world economy
Toe/100,000, 2010 USD



Source: IEA

Average annual declines in regional energy intensities by scenario, 2015-50
%



Source: Equinor

Global energy developments

World TPED increased by an average of 1.8% per year between 1990 and 2017. Growth has fluctuated in response to economic cycles and fuel price ups and downs, as well as random factors, but has not displayed any clear trend. Since 1971, there have been three periods of declining energy demand growth, but after the first two, growth rebounded to the 3.0-3.5% range. Time will tell whether the third period which we are currently experiencing, proves more permanent. Energy intensity, meaning TPED per unit of global GDP, was down by an average of 1.0% per year between 1990 and 2015.

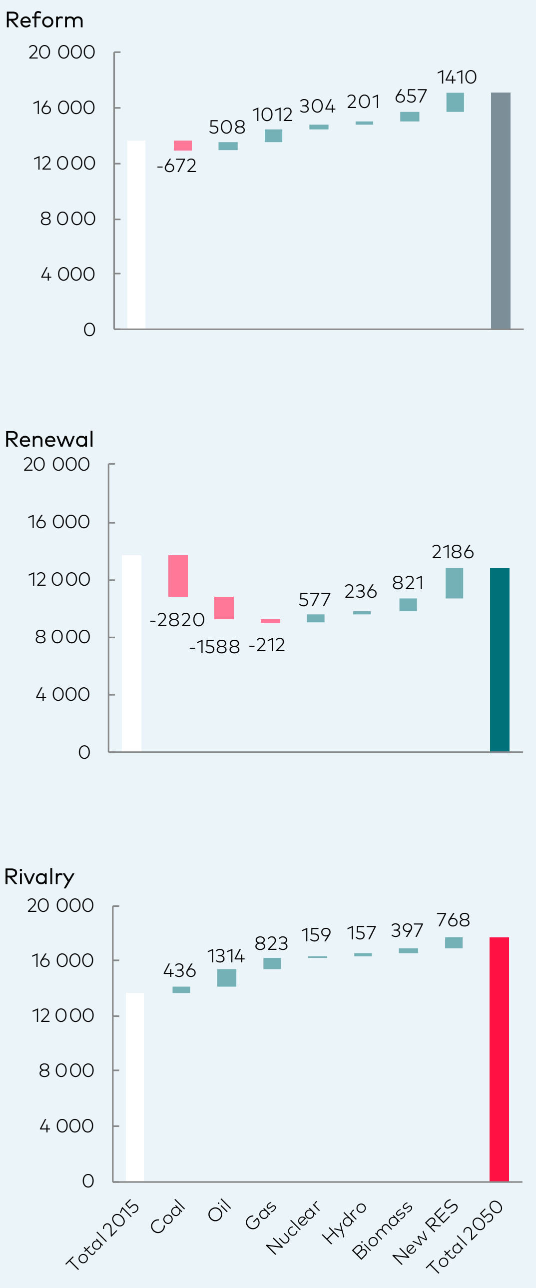
The energy intensity of an economy is determined by many factors. Energy efficiency improvements play a role, but do not always live up to expectations, and are seldom the only driver. Changes in economic structure, i.e., changes in the shares of individual industries in GDP, may affect energy use, as may the penetration of new technologies and fuels in energy end use and in electricity supply, and changes in consumer behaviour. Consumers' preparedness to accept more energy-light lifestyles have in the past proven transient, but changes like a turn towards car sharing or public transportation are factored into most green scenarios.

IEA, which monitors energy efficiency policy and energy intensity developments around the globe, is worried about recent developments. Global energy demand growth more than doubled – from 0.9% to 2.1% – from 2016 to 2017. The energy intensity of the global economy declined by about 1.7% in 2017, which represented a slow-down compared to the average of 2.3% for the period 2014-16. IEA puts the set-back down to a stand-still in energy efficiency policy coverage, stringency and enforcement, in addition to lower fuel prices.

Some observers consider that efforts to dampen or reverse energy demand growth by means of energy efficiency policy will always have mixed results due to the rebound effect. This effect refers to basic tenets in economic theory – that making the consumption of a good or service more efficient will lower its real price, and that as the good gets cheaper, consumers will want more of it. It is seen to work through various channels, via relative prices and by increasing consumers' spending power and encouraging them to buy more of everything, including the good that has become cheaper and other goods that use this good as input factor. The suggested result is that an initial policy-driven decline in the demand for the good that has become cheaper, like energy, over time will give way to renewed growth in demand, possibly to the point where the entire initial gain is wiped out.

In *Reform*, global TPED increases by an average of 0.6% per year between 2015 and 2050. Growth slows by two thirds compared to the 1.8% per year that was the average for the 1990-2015 period. The energy intensity of the world economy declines by an average of 1.9% per year. This is nearly double the rate which was typical for the 1990-2015 period. There are large interregional variations in energy demand growth and energy intensity decline rates, reflecting differences in economic growth, structural characteristics and policy emphasis on pushing energy efficiency improvements.

Global TPED by fuel and scenario
Change 2015-2050, mtoe



Source: IEA (history), Equinor (projections)

In *Renewal*, global TPED increases slowly for another 4-5 years, but then flattens and eventually goes into decline, resulting in a level by 2050 about 6% below today's level. The industrialised parts of the world use on balance 40% less primary energy by 2050 than in 2015. Most other regions need more energy by 2050 than today, but only India, Southeast Asia and Africa are still on rising demand curves by the end of the scenario period. The energy intensity of the world economy declines by an average of 2.8% per year, almost three times the rate of the 1990-2015 period. North America, Europe and industrialised Asia accomplish decline rates of 2.5-2.8% per year. China and India are in the lead with decline rates around 4% per year.

In *Rivalry*, global TPED increases by an average of 0.7% per year between 2015 and 2050, marginally faster than in *Reform* despite much slower economic growth. The rate fluctuates with periods of relatively rapid growth alternating with periods of zero or even negative growth in response to the violent economic cycles that characterise this scenario. Energy efficiency policy is not abandoned, but is pursued with less vigour and supported by less resources, especially in the regions most affected by instability. The energy intensity of the world economy declines by 1% per year, about as quickly as in the 1990-2015 period.

Fuel mix outlook

A country's fuel mix is heavily influenced by its resource endowments, vested interests in different fuels, inherited infrastructure, relative fuel prices and traditions for policy intervention motivated by supply security and/or social concerns. Hence there are huge variations in the shares of individual fuels in individual countries' energy use.

In recent years climate and other environmental concerns have prompted similar fuel mix policy adjustments across numerous countries. The global energy system is however a vast mechanism beset by technical and institutional rigidities, short-sightedness and temptations to free-ride, and turning it around is proving a monumental task.

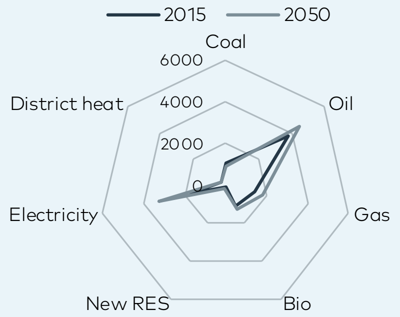
IEA data suggest that the fossil fuel share of global TPED has dropped from above 85% in the early 1970s, but has stagnated in a narrow 81-82% range. Within the fossil fuel category there have been changes, with the oil share declining from around 45% in the early 1970s to 32% in 2015 and the gas share going up from 16% to 22%. The coal share is higher today at around 28% than it was in the 1970s and 1980s. Outside the fossil fuel category, the nuclear share increased rapidly in the 1970s and early 1980s, but stagnated after Chernobyl and has declined since Fukushima. Hydro is stable in the 2.0-2.5% range.

The global fuel mix will likely see significantly larger changes in the future than in the past. There is broad agreement that attainment of the 2° target, not to mention an even more ambitious climate targets, will require rapid changes in fuel mix away from fossil fuels towards cleaner substitutes.

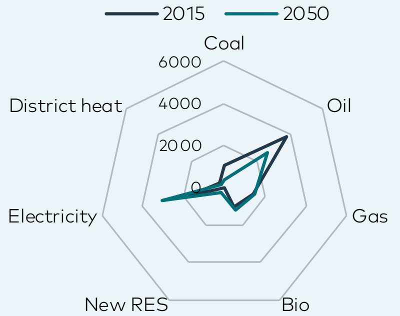
The power and transport sectors are key. Countless studies show decarbonisation of electricity supply in combination with accelerated

Global TFC by fuel, 2015 and 2050
Mtoe

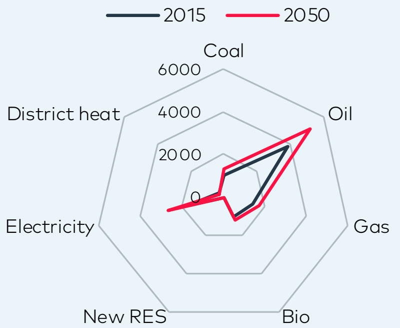
Reform



Renewal



Rivalry



Source: IEA (history), Equinor (projections)

electrification of energy end use to be the most feasible and cost efficient of global CO_2 emission reduction strategies. In the transport sector, interest in EVs has exploded, and in some regions hydrogen is being promoted as an alternative. Electricity and hydrogen, and evidently biofuels, could make inroads also in short-medium distance marine transportation and aviation, and LNG, biofuels and hydrogen are in scope for long distance non-road transport.

In *Reform*, the coal share of global TPED drops from 28% in 2015 to 19% by 2050. The oil share is down from 32% to 28% and the gas share edges up from 22% to 23%. The new renewables (mainly wind, solar, modern biomass and geothermal energy) share increases from about 1.5% to almost 10%. The latter score reflects however IEA's conventions for translating wind and solar power generation into contributions to TPED, which is controversial and arguably underplays the future importance of these renewables, see separate textbox. In *Renewal*, the coal and oil shares of global TPED drop further, to 8% and 21% respectively by 2050. Only gas holds up among fossil fuels with a market share of 21% by the end of the scenario period. New renewables contribute 19% to TPED by 2050. Also in *Rivalry*, coal is down, but only to 24%. Oil and gas are stable with shares of 32% and 21% at the end of the scenario period, respectively. New renewable energy supply increases by almost 5% per year, but its share of TPED by 2050 is still below 6%.

Power sector outlook

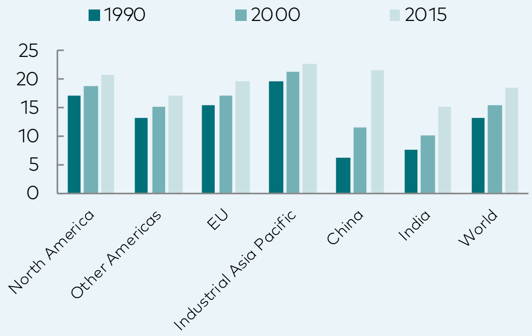
Global electricity consumption more than doubled between 1990 and 2015. Chinese demand increased more than 8-fold. Only one region, the Commonwealth of Independent States (CIS), experienced a decline in demand due to economic chaos in the 1990s that sharply reduced industrial production and energy demand including electricity use.

The electricity share of world TFC increased from 13% in 1990 to 19% in 2015. This share varies widely from region to region. Although more than 1 bn people still live without access to electricity, a vast number of communities have been connected to the grid and many more households have managed to put solar panels on their roofs to enable at least clean lighting and recharging of small appliances.

For technological, market and policy reasons, the electricity share of TFC is expected to continue increasing. Electricity use remains supply constrained in large parts of the world. Consumers everywhere want more appliances in their homes, and every year tens of millions of people pass the threshold where they can afford them. Demand growth will be strongest in the big emerging economies with hundreds of millions of citizens acquiring middle class status and celebrating by buying washing machines, fridges, freezers, air coolers, computers, gadgets, etc. Energy efficiency improvements will dampen growth in electricity demand, but not to the point of eliminating it any time soon.

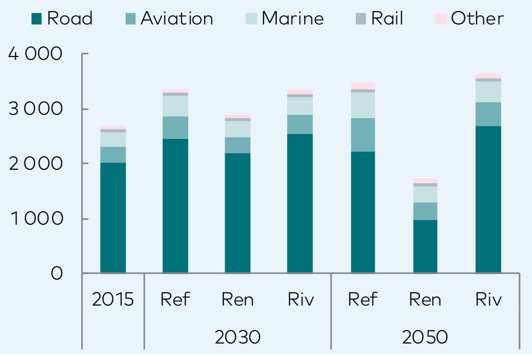
While the residential and services sectors will see further electrification from already high levels of electricity penetration, the transport sector is facing an upheaval in its fuel use, with electricity

Electricity share of TFC
%



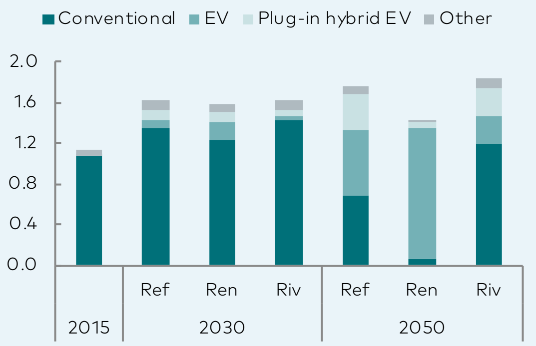
Source: IEA

TFC in the transport sector by mode and scenario
Mtoe



Source: IEA (history), Equinor (projections)

LDV fleet by scenario
Bn



Source: IEA (history), Equinor (projections)

likely to become the dominant fuel in road passenger transportation, capture major market share in road goods transportation and make inroads in marine and air transportation as well.

In *Reform*, global electricity demand increases by an average of 1.7% per year between 2015 and 2050, In *Renewal* and *Rivalry*, growth is 1.4% and 1.3% per year respectively. These electricity demand growth rates result in a 33% share of electricity on TFC in *Renewal*, a 27% share in *Reform* and a 22% share in *Rivalry*. Electricity use per capita varies by region, partly for natural and climatic reasons, but mostly due to economic inequalities. The gaps narrow in all scenarios, and some emerging countries and regions, like India and Southeast Asia, catch up well. But the poorest regions like Africa remain disfavoured.

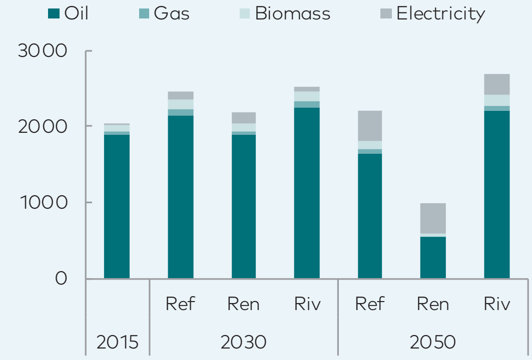
How is this electricity demand going to be supplied? In all scenarios coal loses market share in the power and heat sector. The pollution problems and weakening competitiveness on costs, which have led to numerous coal power plant closures, are not expected to reverse. The decline in coal market share is substantial even in *Rivalry*, from 39% in 2015 to 24% by 2050. But the decline is stronger in *Reform*, to 19% by 2050, and massive in *Renewal*, where coal accounts for only about 4% of global power and heat supply by the end of the scenario period. Only India and Southeast Asia derive noticeable shares of their power from coal by then. Chinese coal use for power and district heat generation is down by 96% in *Renewal*.

Gas to electricity increases in both *Reform* and *Rivalry*. Gas loses some market share in *Reform*, but electricity demand growth is more than strong enough to compensate for this. Gas to electricity falls in both absolute and relative terms in *Renewal*. All zero-carbon fuels gain market share and although electricity demand is up, it is not up sufficiently to bolster the standing of gas. Moderately green scenarios are good for gas, but in a 2°-consistent world, CO_2 emissions must hit "net zero" fairly shortly after the middle of the century, calling – unless CCUS comes to the rescue – for diminished roles for all fossil fuels, also gas, already by 2050.

Nuclear power is viewed with unease by the public and suffers from high investment costs partly related to post-Fukushima requirements for additional safety features. But it is an established zero-carbon option perfect for baseload power generation and remains relevant to regions struggling to meet CO_2 reduction commitments, while at the same time satisfying rapid electricity demand growth. Nuclear power generation increases by 1.1% per year in *Reform*, and by 1.8% per year in *Renewal*, but by only 0.6% in *Rivalry*, where cost and proliferation issues become even more serious hurdles than they are today. The world's leading emerging economies account for most of the assumed growth.

New renewable – mainly solar photovoltaics (PV) and wind – electricity generation expands by 7.6% per year in *Renewal*, 6.5% per year in *Reform* and 5.1% per year in *Rivalry*. It is difficult to see new renewable electricity stagnating in any scenario. Cost, supply security and local pollution concerns will sustain interest even if global warming policy loses momentum, or mitigation efforts are side-lined

Road transport demand by fuel and scenario
Mtoe

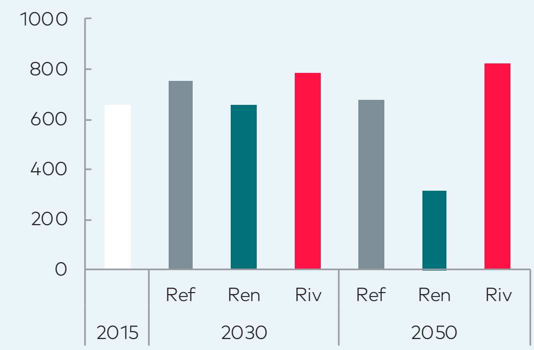


Source: IEA (history), Equinor (projections)

Major cities around the world aim to electrify their bus fleets by 2025

Source: proterra.com

Oil demand from trucks by scenario
Mtoe



Source: IEA (history), Equinor (projections)

by adaptation efforts. The issue is how quickly the power sector will decarbonise, not whether further decarbonisation will happen.

Energy demand in transport

As the world population and economy grow, demand for mobility increases, and open economies are built on trade in both goods and services. Globally, transport fuel demand makes up nearly 30% of TFC, up from 25% in 1990. Road transport is by far the biggest sub-sector, accounting for about 75% of total transport fuel demand, with air and marine transport contributing shares of 11% and 10% respectively. The rail share has dropped to about 2%.

Road transport

As an increasing share of the population reaches middle class, so does the ability to own a personal car. Growing car fleets are causing poor air quality and congestion, and are among the largest sources of CO_2 emissions. To combat these issues, stringent policy measures are being put in place. Future vehicle fleet developments, in terms of size and efficiency, will therefore likely be increasingly shaped by policies.

So far, results are seen mainly in improved passenger car fuel efficiencies. But more ambitious emission targets cannot be reached without more EVs on the road. Several countries are contemplating a ban on diesel and gasoline powered cars toward 2030-40, and other countries are setting targets for EV sales. Political support for battery development and EV engineering suggest that passenger car fleets will become largely electric in the long run. Bottlenecks related for instance to the availability of key minerals or to battery production capacity may arise, but will likely be resolved by market forces, given the right incentives.

Efforts to decarbonise road transportation have so far been limited to passenger cars. Increased globalisation and trade, uneven distribution of materials and large distances between production and consumer markets require transportation in all parts of the value chain. This has led to a massive growth in freight activity, particularly in Asia. Only a handful of countries have yet established rules to restrict or decarbonise heavy duty transport such as trucks, but with the light duty vehicles (LDV) segment being increasingly curbed, freight is most likely the next in line.

Buses also constitute a major potential for decarbonisation, and are attracting increasing attention, particularly due to the unparalleled development ongoing in China. 99% of the global electric bus fleet drive here. An additional 9,500 zero-emission buses, the equivalent of an entire London bus fleet, is put on the roads of China every five weeks, according to Bloomberg New Energy Finance (BNEF). The rest of the world is following; in 2017, the mayors of 12 major cities, including London, Paris, Los Angeles and Barcelona, made the commitment to buy only electric buses after 2025, and more cities will likely join in as technology advances.

In *Reform*, advances in battery technology and engineering continue, pushed by tightening regulations. Around the mid-2020s, the costs of purchasing and owning EVs break even with the costs of conventional cars. Buyers are able to choose from a wide selection of car models

Disruptions in the air and marine sectors?

Shipping and aviation have been considered bastions of oil demand. And whereas the road sub-sector is being electrified, there have been no viable alternatives to fuel oil for ships, and jet fuel for aircraft. This could change. Since most options remain technologically immature, alternative fuel supply sources and fuelling infrastructure must be developed and ships and aircraft have long lifetimes, overnight changes in these industries' fuel mix are unlikely. More gradual changes adding up to major shifts by 2050 are however possible. Policy makers are pushing both industries, for which no targets were set in the Paris agreement, to act.

The International Maritime Organization (IMO) in April 2018 reached agreement to cut CO_2 emissions from international shipping by at least 50% by 2050 relative to 2008. IMO will use five years to develop a plan for how to accomplish this, and revert with a strategy. For ferries and other vessels with frequent access to recharging points, electric propulsion is catching on. For international shipping, LNG – a fossil fuel with a smaller carbon footprint and less local pollution than fuel oil – biofuels, hydrogen and ammonia are possible alternatives. The world's first LNG powered container ships will be delivered in 2020-21. Biofuels is an easy solution from a technological point of view, but could face supply constraints and massive sustainability issues depending on the source.

The International Civil Aviation Organization (ICAO), the UN body for aviation, has published a plan for making the aviation industry carbon neutral from 2020, and an aspirational target to reduce CO_2 emissions by 50% by 2050 relative to 2005. This is to be achieved partly through energy efficiency improvements, but mainly by switching from jet fuel to biofuels. Observers acknowledge that the aviation industry should be first in line for biofuels supply since it has few other options, but point out that ICAO's vision presupposes a dramatic increase in biofuels availability, probably a break-through for 3rd generation biofuels of which there are few signs for the moment. On a different note, interest in electric aircraft is increasing, with major actors like Boeing, Airbus, Rolls Royce and Siemens funding development work with a view to start operating hybrid or battery powered aircraft on shorter regional routes in the 2030s or perhaps even in the late 2020s. The weight of batteries and electric engine cooling equipment is a hurdle, but possibly a surmountable one.

Whether any one of IMO's and ICAO's visions is feasible is a big if. Whether both are feasible within the same timeframe is an even bigger if, since they envisage to feed off the same limited biofuel resource pool and since electric flying on a significant scale remains a long shot. A fundamental challenge is also the underlying growth in demand for transport services following from population and economic growth. This does not mean, however, that continued confidence in steadily increasing oil demand from shipping and aviation should be part of any scenario.

from most major manufacturers. Combined with ample recharging opportunities this allows for mass adoption of EVs by the end of the 2020s, particularly in markets such as China and the EU. Supply of relevant metals and minerals for battery components expands in line with price signals, just like in *Renewal*. Trucks will also experience increasing electrification but likely in parallel with hydrogen and LNG, particularly for long haul, due to longer range potential. Electrification of the LDV fleet leads to a peak in oil demand past 2030, but demand from freight is sustained for longer.

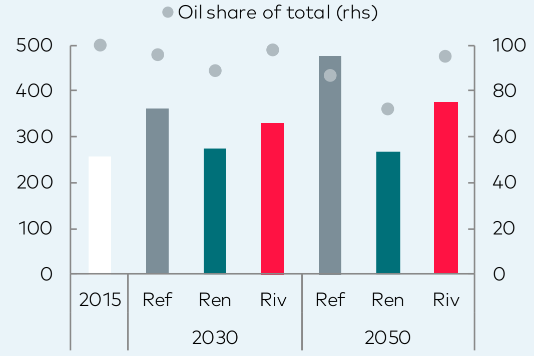
In *Renewal*, technological advances proceed at an even faster pace. Consumer preferences change, with a move away from privately owned cars to public transport. Non-motorised transport within smarter cities is also encouraged. EV sales increase, but more car sharing limits the growth in car fleets from the late 2020s. Truck manufacturers leverage the technology accomplishments of the car industry, and develop both hybrid and fully electric trucks. Truck owners also exploit opportunities to reduce their emissions without switching fuels. Optimisation of travel patterns and load factors enable fewer trucks to deliver the same amount of goods. Digital technology is adopted on a big scale. Combined with 3D printing and the introduction of drones for small deliveries, it eliminates millions of ton-kms from the roads. Combined with improvements in fuel efficiency, this results in energy demand from all segments of road transport declining significantly from the late 2020s.

In *Rivalry*, transport sector developments are less benign to the environment. Failure to reach a global consensus on climate issues weakens national decarbonisation policies. Less political cooperation and trust reduces ability for collectively smart solutions. Less global trade and cooperation hinder the dissemination of technological advances. The concentration of important battery resources such as cobalt in unstable regions increases costs of battery supply and discourages electrification. Freight activity is dampened by slower economic growth and less global trade, but less optimisation works in the opposite direction and delivers continued, though subdued, growth in freight demand. While LDV oil demand starts declining from 2040s, truck demand continues to grow in the developing regions.

Marine transport

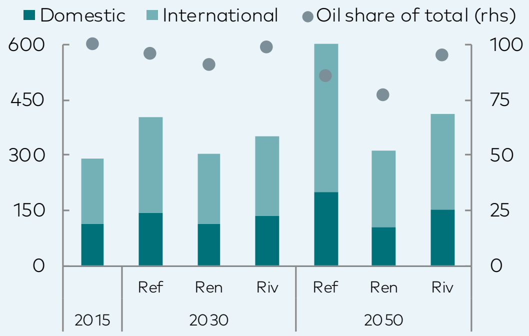
Shipping is a minor contributor to global passenger transportation, but handles the bulk of global freight transport activity measured in ton-km. Two ratios determine the sector's fuel use growth: The ratio of global marine freight transport activity growth to global economic growth, and the ratio of sector fuel use growth to sector activity growth. IEA data suggest that between 2000 and 2015 the former ratio averaged almost 1.4 and the latter 0.5. Seaborne freight transport grows faster than the global economy, but fuel efficiency is improving, so that fuel use growth is held in check. Baseline scenarios typically assume continued robust growth in global marine freight transportation. As for energy efficiency, OECD mentions possibilities for substitution to lighter materials, design improvements and friction reduction, and notes the potential gains from reducing speeds, increasing ship sizes and improving ship-port interfaces. In greener scenarios policy intervention is seen to drive

Global marine transport fuel use by scenario
Mtoe (lhs), % (rhs)



Source: IEA (history), Equinor (projections)

Aviation fuel use by scenario
Mtoe (lhs), % (rhs)



Source: IEA (history), Equinor (projections)

Norwegian Hurtigruten aims to be a leader in electric passenger shipping

Source: Hurtigruten

both accelerated efficiency improvements and changes in the sector's fuel mix.

In *Reform*, marine fuel use increases by 1.8% per year between 2015 and 2050 – slightly below the 2.2% growth recorded for the 1990-2015 period. Sector oil use increases by 1.4% per year, with LNG and to some extent biofuels entering the international long-distance segment, and electricity and biofuels making small inroads into the domestic shorter distance segment. In *Renewal*, marine fuel use peaks in the mid-2020s and declines to a level only some 5% above its current level by 2050. Sector oil use goes down, with the competing fuels – LNG, biofuels and electricity – capturing significant market shares. In *Rivalry*, sector fuel use increases by 1.1% per year, reflecting volatile economic growth and major hurdles to international trade, and very limited penetration of non-oil based fuels.

Air transport

The world's around 20,000 passenger and 1,600 cargo aircraft account for 12-13% of global passenger transport, but less than 1% of global freight transport. It is faster, but also more expensive, to fly goods around than shipping them. Air passenger transport activity increased by 5.3% per year between 2000 and 2015, faster than any other segment of the passenger transportation industry. Fuel use increased more slowly, by 1.7% per year, according to IEA. Air passenger transport is likely to continue growing faster than other forms of passenger transportation in response to further shifts in the modal structure of travelling. People – especially those residing in emerging economies – become richer, and international travel is not only a status marker, but also associated with higher quality of life. OECD assumes a passenger-km growth of 5.1% per year between 2015 and 2030 falling to 3.4% per year between 2030 and 2050. If realised, this means that the number of passenger-kms in 2050 will be more than four times that of 2015. Boeing's outlook for the 2017-36 period suggests a growth of 4.7% per year. Airbus forecasts 4.4% per year over the same period. In *Reform*, air transport fuel use increases by 2.1% per year, slightly above the average estimated for the 1990-2015 period. There is a continued mode shift to air, countered however by further aviation fuel efficiency improvements. Jet fuel retains its dominant position in the fuel mix, but biofuels make inroads of up to 10%. Electricity starts entering the market through short-distance intercity flights served by smaller aircraft towards the end of the period. In *Renewal*, sector fuel use increases by only 0.3% per year, with most of the growth taking place in the first decade of the scenario period. The pace of energy efficiency improvements is increased to the extent possible and the turnover of aircraft is accelerated. Non-essential flying is discouraged through policy and regulation. Aviation oil use goes into decline by the mid-2020s, with other fuels occupying some 23% of the fuel mix by 2050. In *Rivalry*, aviation fuel use increases at an uneven pace – averaging 1% per year – due to volatile and generally low GDP growth, and with some routes gaining and others losing popularity in response to shifting geopolitical tensions. Energy efficiency is improving, but slowly, and non-oil fuels make very small inroads.

Under-reporting of wind and solar in TPED?

TPED is the sum of the coal, oil, gas and biomass used directly by energy end users and the fuels that go into generating the electricity and district heat that end users rely on. Fossil fuel and biomass use is easily recorded and raise no problems for the TPED concept. Estimating the contributions from new renewable energy is more demanding. We know how much electricity we get out of the world's renewable power plants, but there are no exact records of the water, wind and sunshine used to generate this electricity, and it is this input, not the electricity output, we are interested in for TPED calculations.

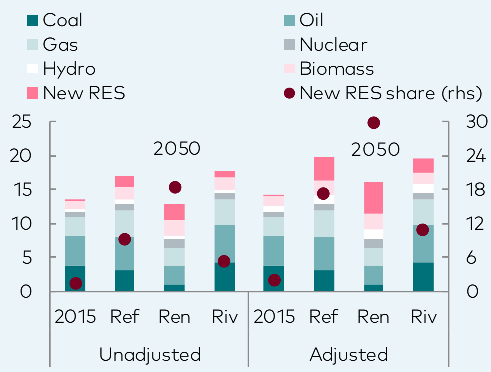
IEA assumes that one unit of hydro, wind and solar power out requires one unit of renewable energy in, assuming no inefficiencies in the conversion process. In comparison, 40-60% of the energy in coal and gas used in power plants ends up as "waste" energy. Thus, whereas a 10 TWh increment in solar power generation is seen to add 10 TWh of solar energy to TPED, the same increment in gas power generation is seen to add some 20 TWh of gas to TPED. Critics of IEA's approach dismiss the assumption of a conversion efficiency of 100% for renewable power generation, saying that high shares of the energy in running water, wind and sunshine are lost in the process. The critics conclude that IEA under-reports the renewable contributions relative to the fossil fuel contributions to TPED, and that IEA's reporting becomes more and more misleading, the bigger renewable energy becomes.

IEA is the world's leading provider of energy statistics. Nearly everybody following the energy markets rely on their numbers and thereby their definitions and book-keeping conventions. Energy Perspectives is no exception. In principle one could replace IEA's 100% efficiency assumption for wind, solar and hydro power generation with lower efficiency assumptions. Using instead 38%, which is the average for thermal power generation in the OECD area, and represents BP's practice, would – everything else equal – raise TPED and the shares of new renewable energy in the energy mix, as shown below. It is notable that the adjusted TPED increases in all scenarios, even in *Renewal*.

This edition of Energy Perspectives is like previous editions based on the practice that IEA has established. We may explore alternative approaches for future editions, though quick fixes to complex problems often backfire. Alternatively, one could stop emphasising TPED, which arguably makes more sense as a metric in a fossil fuel dominated energy landscape, with limited access to resources, than in a new renewables dominated landscape with unlimited access to wind and sun.

Global TPED and "adjusted" TPED

Btoe (lhs), new RES % share of TPED (rhs)



Source: IEA (history), Equinor (projections)

Accounting for electricity in total final consumption

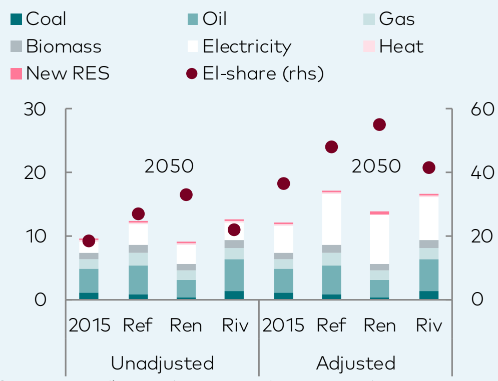
TFC measures how much energy is being used directly to provide various energy services. The shortcoming of this approach is that is does not show how much energy service is provided. Fuels, such as gas, coal, oil and biomass need to be burnt and the heat is used for several purposes. When gasoline or diesel are combusted to run an ICE, the energy efficiency can be in the range of 20% to 30%, meaning that 70% to 80% of the energy contained in the oil is lost. Other applications of fuels can have significantly higher efficiency, with high-efficiency heating systems having energy efficiency of over 90% while older, low-efficiency heating systems may have efficiency below 60%. Several of the same processes can be run on electricity with much higher efficiency. An electric engine has around 90% efficiency, i.e. it can be up to four times more efficient than an ICE. Heat pumps run on electricity and one unit of electricity in can give 3-4 units of heat out.

Considering that electricity can provide significantly more energy service per unit of energy compared to fuels, TFC arguably underrepresents the role of electricity. In 2015, electricity had a 18.5% share in TFC, but adjusting for the energy service level provided by electricity it would be significantly higher. Examples show that electricity can provide up to 4-5 times more energy services in some applications, but a conservative approach would be to multiply the contribution of electricity by 2.5 times in TFC. This gives a share of electricity in TFC of 36.2%. Accounting for electricity in this way provides a different perspective on energy demand. As electricity consumption grows, the role of electricity gets even larger and outcompetes fuels in the adjusted TFC. In *Reform*, TFC grows by 31% from 2015 to 2050 and the electricity share increases to 30%. If electricity is adjusted by a factor of 2.5, the adjusted TFC grows by 43% and the electricity share goes to 43%. *Renewal* does not show any longer a decline in adjusted TFC between 2015 and 2050.

It is important to keep in mind that electricity may not be suitable to replace fuel in all applications such as aviation and marine transport, district heating and high-heat processes in industry. Furthermore, fuels, or call it molecules, are needed in the non-energy sector where they are used as feedstock. On the other hand, it is important to recognise all the services that electricity provides, ranging from powering computers and mobile phones to keeping the lights on and electric machines and appliances running in homes, offices, schools, hospitals and more. The conventional calculation of the share of electricity in TFC may not reflect well how vital electricity is to our lives and to society.

Global TFC and "adjusted" TFC

Btoe (lhs), electricity % share of TFC (rhs)



Source: IEA (history), Equinor (projections)

Some implications of low-cost new renewable electricity supply

Renewable electricity has the potential to redefine the way we approach energy. First, solar and wind power has achieved prices in auctions around the world that up until recently were unimaginable. In the best locations and most competitive auctions, solar and wind power has been priced at 20 USD/MWh or below (Mexico and Saudi Arabia). The prospect of cheap and infinite electricity opens for new uses of electricity, such as production of hydrogen through electrolysis or the electrification of new sectors. When electricity becomes very cheap, it may be rational, i.e., better than the alternative, to build overcapacity even if this leads to curtailment and "wasted" energy.

Second, the zero short-run marginal cost nature of solar and wind power poses a challenge to investments in new power generation capacity, and puts stress on current market designs. In the marketplace, price is the main signal to balance and optimise supply and demand in the short term, and to attract necessary investments for the long term. Variable renewables do not respond to price signals. Up to now they have largely been remunerated outside of the market through power purchase agreements, and since they have zero short-run marginal cost, they will always produce, unless they are paid to curtail production or face negative prices. As the share of variable renewables increases, the price signal's ability to regulate the market breaks down and creates market failures and lack of investments.

There are several options for how to deal with this challenge, which involve either adapting existing market design, or creating a new system. Adapting the existing system could involve introducing capacity payments and improving balancing markets, an approach that is seen in several European markets currently. Another approach would be for regulators to gradually take more control of the market, and move in the direction of central planning and control of the system. This would however create concern about how efficiently the market regulators can control the market.

There are also several approaches that would mean a segregation of market segments, which could be divided along the type of electricity generation (flexible sources versus variable sources) and along time periods (short-term balancing versus long-term capacity markets). For instance, consumers could pay a low rate for variable renewable electricity when it is available, but if they need on-demand flexible electricity, the price would be higher. Or, consumers could make a fixed payment to cover the cost of installing certain capacity, and receive the produced electricity, as it is available. Changing the market structure will eventually not be an option for regulators, but an absolute necessity.

In all scenarios, the share of variable renewables in the power mix increases rapidly, reaching 24%, 32% and 49% by 2050 in *Rivalry*, *Reform* and *Renewal*, respectively. Typically, when the share moves closer to 20%, zero or negative wholesale electricity prices become more prevalent, calling for renewed market design to correct distortions in market signals and ensure sufficient incentives to invest.

Battery production capacity

The production of batteries is a huge industry in the making. If each light duty EV on average needs a 50-kWh battery at a cost of USD 5,000 per battery, the industry will have a revenue of USD 155 bn by 2030 in *Reform*, or USD 280 bn in *Renewal*. On top of this come batteries for other types of vehicles, consumer electronics, electricity storage and more.

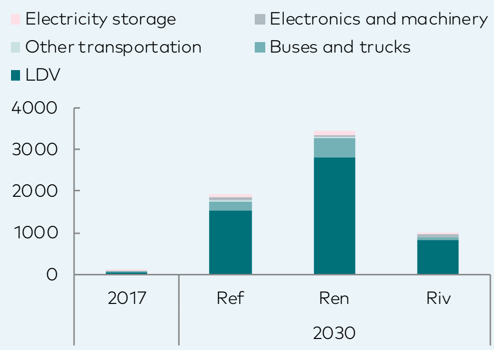
Today the industry is dominated by Asian companies. These include Panasonic from Japan, Samsung and LG Chem from Korea and the two Chinese companies BYD and CATL. There are more than 140 EV battery manufacturers in China.

Battery cell demand was estimated at around 100 GWh in 2017, a doubling from 2014. But this is just the beginning. The most famous battery plant that is being put into production is the Tesla Gigafactory in Nevada, which is currently in the process of ramping up its annual production capacity to 35 GWh, but there are many more. According to Benchmark Mineral Intelligence, there are 26 battery cell plants with a combined capacity of 344 GWh that will be in production by 2021. Almost half of this capacity is planned in China, one quarter in the EU and 15% in the US.

Capacity will have to continue to ramp up very quickly to meet growing demand. Cell demand for light duty EVs alone may approach 700 GWh by 2025 in *Reform* and 1,000 GWh in *Renewal*, growing further to 1,550 GWh and 2,800 GWh, respectively, in 2030. To meet this kind of demand, around five new gigafactories will need to be built every year in *Reform*, and 10 in *Renewal*. The Tesla Gigafactory is estimated to have a total investment cost of USD 5 bn, meaning that annual investments would be in the order of USD 25 to USD 50 bn per year.

Significant volumes of battery cells will also be needed by other types of vehicles such as buses and trucks. On top of that, demand for batteries from consumer electronics and machinery tools will grow, and batteries for electricity storage will become much more prevalent both on a distributed and grid level. In total, annual battery demand may approach 2,000 GWh by 2030 in *Renewal* and 3,500 GWh in *Reform*.

Global battery demand by scenario
GWh



Source: Various sources (history), Equinor (projections)

In the short-term it appears that the announced new capacity will be sufficient to meet quickly expanding demand, what is not clear is how the longer-term demand will be met and how the supply chain starting from metals and minerals will cope. The role of metals and minerals is discussed in more detail in a text box in the Renewable energy chapter.

Digital technological disruptions

Over the coming decades, digital technologies will make energy systems around the world more connected, intelligent, efficient, reliable and sustainable. Advances in data, analytics and connectivity are improving safety, increasing production/energy efficiency and oil and gas recovery, and reducing costs of renewable energy. IEA predicts that widespread use of existing digital technologies could lower oil and gas supply cost by between 10% and 20%, increase technically recoverable resources by 5%, while the power sector may save 5% of total annual power generation cost. Ambition and vision among entrepreneurs and governing bodies are vital for enabling a digital move towards a more sustainable energy future globally.

Artificial intelligence

Artificial intelligence (AI) and machine-learning can be among the most disruptive technologies during the next 10 years. AI is based on digital information from data driven software algorithms and includes reasoning, knowledge, planning, and learning. With increasing computational power, access to huge amounts of data, and open software packages, AI is becoming an enabler for e.g. autonomous vehicles, industrial robots, drones, personalised marketing and checkout-free shopping. Predictable routine-based tasks, repetitive physical activities, collection and processing of data may all be replaced by AI-based technologies. Transport, utilities, logistics, and the service sector all have great energy efficiency and cost reduction potential. The effect of AI on energy demand is uncertain as higher efficiency and reduced cost may increase availability, ultimately driving up energy consumption, also known as the rebound effect. So driverless cars could enable new car pooling business models which increase car seat-utilisation, while boosting transport volumes, as services become cheaper and more available. To the extent AI contributes to a net reduction in the number of paid jobs, it will impact private consumption and demand for different goods and services, as well as energy, negatively.

Digital platforms

The greatest transformational potential may be the ability to break down boundaries, increase flexibility, and enable integration across entire systems and energy sectors. Digital platforms are the fundamental data and software architecture for data access, software services and functionality, and end-user interaction. Connected sensors through the "Internet of Things", big data analytics, distributed ledgers, and even quantum computing represent digital paradigm shifts which enable innovation within the energy sector. Increased electrification and growth of decentralised power sources give a blurred distinction between supply and demand, as consumers can interact real time with balancing market demand. These "prosumers", who are both producers and consumers of energy at the same time, can deliver power from solar panels or home batteries if prices are high, and control appliances to use more power when prices are low. IEA estimates that this will provide 185 GW of system flexibility worldwide, and save USD 270 bn of investments in new electricity infrastructure to ensure security of supply.

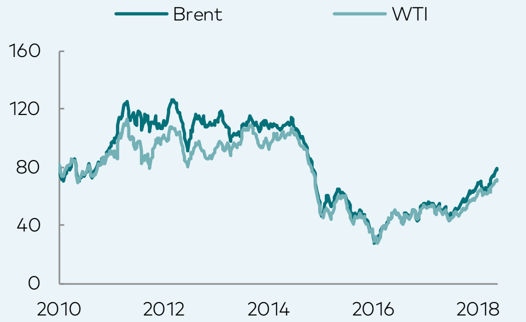
A distributed ledger, like Blockchain, is a database which is replicated, shared, and synchronised across different geographies. As a secure way of storing and sharing information, they can replace current systems in government regulated markets, like currency and power. Newer generations of distributed ledger technologies can form platforms for decentralised transactions and smart contracts for a variety of applications, including decentralised power production from renewable energy. Prosumer smart-houses can trade electricity automatically through smart contracts for securing transactions. New business models based on combining energy capacity and demand can threaten current utility companies. However, the effect of the use of distributed ledger technology on energy demand is unclear. Distributed ledger data security entails large amount of data processing, called "mining", which requires massive amounts of electricity. Bitcoin mining is the most visible example of extreme electricity demand for an activity that many would find completely useless. Still, the effect this technology may have on increasing the renewable energy share, improving energy efficiency, and promoting energy storage, may possibly compensate for the power required by mining over time.

Quantum computing represents a new platform of extensive computational power in the early days of development. Scaling with enough computational power is a great challenge, and the novel design of quantum computers presents innovative ways of feeding problems to the machine on a fundamental level. Overcoming these challenges could change information security, chemistry, material science and boost AI innovations. Industries likely affected are banking, defence, pharmaceuticals, and energy. The new paradigm in computational power can enable machines to crunch through currently unapproachable problems, involving complex simulations with many interacting variables and massive amounts of data. As for the energy sector, several areas may see significant impact; energy system modelling, improved seismic processing and reservoir modelling in oil and gas, and improved energy efficiency from e.g. design of stronger and lighter materials in cars or other machinery. Supported by academia, large digital players like Google, Microsoft and IBM are currently racing with start-ups to move quantum computing from pure science towards engineering.

AI and digital platforms enabling other disruptive technologies

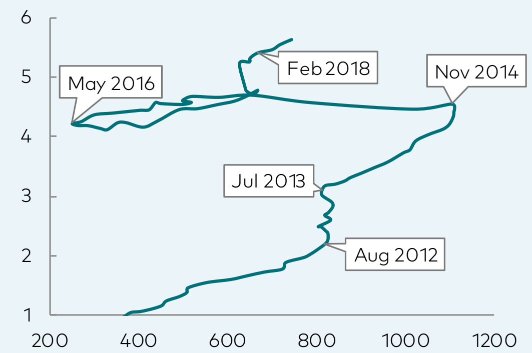
Other digital technologies like additive manufacturing, virtual and augmented reality, digital twins, deep learning and brain-computer interface technologies may also have disruptive effects on how the energy industry operates and change consumer patters, which will affect energy demand. AI and digital platform technology are key enablers for developing these technologies, and are therefore fundamental building blocks for digital technology disruptions.

Crude oil spot prices
USD/bbl



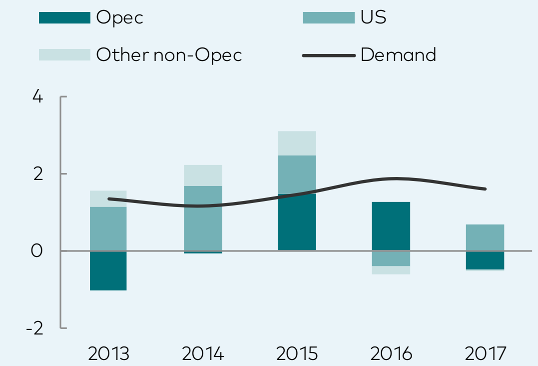
Source: Platts (Brent), Nymex (WTI)

US tight oil production vs rigs targeting tight formations
Mbd (vertical axis), number of rigs (horizontal axis)



Source: EIA

Global oil balance
Annual change, mbd



Source: IEA

The global oil market

Current situation and outlook to 2025

Between early 2015 and the end of 2016, the oil market was in a state of oversupply, initially because of too high oil prices prior to 2014, and partly due to Saudi Arabia's market share strategy. However, the historical agreement between Opec and Russia (and a smaller group of other non-Opec producers) at the end of 2016 to cut crude production gradually restored the market balance. Opec's goal of returning global storage levels to its 5-year average was reached in the spring of 2018. However, a potentially strong flow of new production coming on stream from non-Opec producers over the next years suggests that the Opec supply cuts must be extended beyond 2018, despite production declines in Venezuela and Iran. The sharp rise in oil prices in the spring of 2018 has been driven partly by the market rebalancing and partly by increased global geopolitical unrest. By March 2018, the production cuts were roughly 2.4 mbd, almost 700 kbd more than the target. Most of this was due to the sharp fall in Venezuelan production during the first half of 2018, driven by internal political unrest, financial hardship and sanctions imposed by the US. The main Opec countries and Russia have shown high quota compliance, while some countries have delivered cuts above target due to lack of investment or supply disruptions.

Higher oil prices spurred increased activity in the US, where the number of rigs targeting shale oil almost tripled from a low of 248 in May 2016 to more than 700 in the early spring of 2018. The increase in activity is expected to deliver an annual growth in US crude oil and condensate supplies of around 1.2 mbd in 2018. On top of that the output of NGLs is expected to increase by around 0.5 mbd, which is mainly ethane that is no longer reinjected into the gas stream.

More than three years of low crude oil prices together with an improving world economy have had a positive impact on oil demand, which has grown by 1.6 mbd on average per year (2014-2017), and is expected to grow by at least the same amount in 2018. Supply growth has been muted by the lower prices and averaged 1.2 mbd per year from 2015. However, the low oil prices in 2014-2016 forced the industry to find more efficient ways of developing new oil fields, and break-even prices in most regions have fallen by 40-50% since 2014. Prices returning to levels above 60 USD/bbl have spurred increased activity which, together with projects that started up prior to the price decline, will place significant new volumes in the market in the coming years. Oil supply growth in 2018 is estimated to be 2.0 mbd, of which 1.7 mbd will be from the US alone.

Medium-term supply will be driven by four main elements; the strength of oil demand under conditions of geopolitical vulnerability, price sensitive US shale oil production, recovery of conventional non-Opec production and ultimately Opec market management, including the participation of Russia. In *Reform* we assume healthy demand growth, the continuation of Opec management beyond 2018, moderate to strong US shale oil growth, and some growth also in other non-Opec production. Increasing unrest in the Middle East and Venezuela's struggling economy could lead to sudden supply disruptions altering the market balance. A termination of the cut agreement at the end of 2018 could however send prices down again.

2nd US shale revolution

The unprecedented growth in tight oil production over the last few years has been possible due to the continuous evolution in drilling and completion technologies, which have resulted in step changes in both productivity and efficiency.

In addition to pad drilling, which has enabled producers to drill multiple wells from one location to the next in an efficient manner, extended reach laterals and enhanced completions continue to progress, allowing operators to continuously increase recovery rates. In places like the Wolfcamp formation of the Permian Basin, producers have doubled the amount of proppant used since 2014 to around 3 tonnes per metre, while lateral lengths have increased by 20% to around 2,600 metres (m) with reports of some producers moving to 4,600 m. These improvements have allowed break-evens to fall from some 55 USD/bbl to around 45 USD/bbl in the region during this timeframe.

While the last few years have been marked by continued gains in productivity, the future is much less certain. Progressively tighter well spacing over multiple formations will test the reservoirs' productive capacity, with well interference becoming increasingly more common. Importantly, a 10% reduction in Estimated Ultimate Recovery equates approximately to a 3 USD/bbl increase in breakeven oil price, while a low-teens reduction in well costs is needed to maintain the same breakeven price.

Reductions in well productivity from high-density drilling also have negative implications for US oil production growth, which is supportive of a higher commodity price. Recent estimates show that a 10% reduction in Estimated Ultimate Recovery can have a 2-3% per year negative impact on US shale oil production.

Going forward, the Permian Basin will continue to displace the Bakken and Eagle Ford as the main engine of US oil supply growth. Unconventional Permian plays account for nearly half of new oil supply in 2017, a figure we expect will rise to 65% of the total growth by 2020. Capital spending will continue to be prioritised toward the Permian due to relatively favourable well economics, with operators ramping up development based activity following a flurry of acreage acquisitions. Six large oil companies alone, Chevron, ExxonMobil and Royal Dutch Shell, in addition to BHP, Pioneer and EnCana, expect to add over 800 kbd from the region by 2020.

Outlook to 2025

In *Reform*, US tight oil supply grows by an average of 0.5 mbd per year from now to 2025, reaching 9 mbd. To this, 0.3 mbd yearly growth of NGLs can be added with the giant Permian Basin, which is expected to more than double its tight oil and NGL supply to 4.4 mbd in 2025, as main contributor. Outside the US, the Vaca Muerta play in Argentina is attracting multinationals alongside YPF, the national oil company. Volumes are currently modest, but expectations are that tight oil production will surge and replace the already declining production from conventional fields. The pace of this development depends on the ability of the Argentine oil and gas sector to overcome challenges related to infrastructure, investment climate, political and economic stability, unions' demands, qualified local content, and crude oil price levels.

The impact of the surge in non-Opec investment levels prior to 2014 is not over yet. The 200 kbd Fort Hills oil sands mine in Canada has recently started operations, and the large Kashagan field in Kazakhstan, the Hebron fields in Canada and several fields in Russia are ramping up. In Brazil, the full field development of the Buzios offshore field is set to deliver 500 kbd in the early 2020s. The Iara field (also in Brazil), the Johan Sverdrup and Johan Castberg fields in Norway, and the recently sanctioned Liza field offshore Guyana will add supply towards 2025. The impact of low investment levels in the last years is yet to be felt. The recent prioritisation of brownfield investments, has temporarily slowed the decline in production from existing fields. Existing and sanctioned conventional non-Opec production is increasing by almost 2 mbd up to 2020 before slowly declining below current levels in 2025.

Opec must carefully balance the market in a price range that on the one hand does not encourage another wave of shale supplies, and on the other ensures needed oil revenues for Opec member economies. While Libya, Nigeria and Iraq are recovering from supply disruptions, new Venezuelan supply disruptions are emerging. In the Middle East there is still an ongoing strife between Saudi Arabia and Iran, and there are differing opinions on the right oil price level.

Expectations of a peak in oil demand and a wide range of opinions on long-term market growth may, if attractive short-cycle barrels continue to be available, change the supply dynamics in the oil market. Conventional non-Opec investment activity levels are increasing moderately going forward, but the question is whether investment levels will be sufficiently high to avoid a new upswing in oil prices.

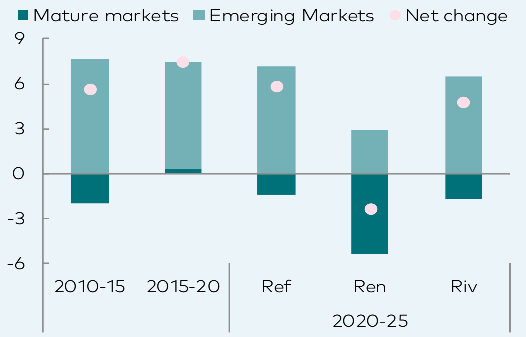
Regarding the demand for individual oil products, the IMO lowering of the cap on sulphur in bunker fuels used in international waters from 3.5% to 0.5% will be effective from 2020, and will strongly affect the fuel oil market. Refinery upgrades and desulphurisation capacity expansion are underway to reduce fuel oil supply and sulphur content, and exhaust gas scrubbers are being installed in vessels to allow the continued use of high sulphur fuel oil (HSFO). There will still probably be a surplus of HSFO in need of a new home. The power sector is a likely saviour, thus in *Reform* the decline in fuel oil used within the power and heat segment up to 2025 slows down

Changing dynamics – short vs long barrels

Short-cycle barrels are, as opposed to conventional long lead time developments, barrels that can be supplied with investments limited to a few mn USD within a short time horizon (six months to three years), whereas long-cycle barrels typically take from five to 10 years from exploration to supply, and require investments from 100+ mn to several bn USD. Short cycle barrels can be tight or shale oil, but they also encompass brownfield Improved or Enhanced Oil Recovery (water or gas injection; chemical or microbial injection and thermal methods) volumes from an existing reservoir/well. A possible future peak oil demand introduces some challenges to the traditional thinking around supply dynamics. Supplying a stagnant or declining market is, from an investor's point of view an entirely different activity than feeding a market with an everlasting growing demand. An oil market in potential decline increases the uncertainty the producers face, reduces their investment horizon, and increases the focus on short payback periods for investments. To shield themselves from the uncertainty, producers might want to diversify their long-cycle barrel portfolio by bringing in short-cycle barrels that allow them to change their output faster in response to changes in the market, while at the same time reducing both risk and capex.

Large international oil companies with robust balance sheets are the ones that probably will diversify first and the most, then operators or national oil companies with access to tight oil acreage or with conventional production with low recovery rates. Low-cost conventional producers with low decline rates are the ones that are least likely to diversify. However, as natural decline in existing production probably will be higher than the decline in oil demand, there will also be need for long-cycle barrels to replace the lost volumes even in *Renewal*. This change in supply dynamics will help to reduce price volatility in the market, but the increased uncertainty for suppliers must be balanced by price signals to avoid a supply crunch.

Global oil demand growth
Change, mbd



Source: IEA (history), Equinor (projections)

temporarily. Gasoil demand increases further, as vessels switch from fuel oil to gasoil to be compliant with the regulations.

In *Reform*, average oil demand growth is 1.6 mbd per year up to 2020, easing off to 1.1 mbd from 2021 to 2025, resulting in total oil demand of 108 mbd by 2025. The growth in demand is mainly driven by high economic growth in emerging markets like China, India and South-east Asia with more people moving into the middle class, thereby increasing demand for goods and services that ultimately require energy. LDV sales in China, which have quadrupled since 2008, are an important driver for the 30% growth in Chinese oil demand from 2017 to 2025. Middle East demand growth is also increasing, due to stronger economic growth on the back of higher oil prices. In most mature economies oil demand is stagnant or declining, but due to lower price levels and healthy economic growth, the pace of decline slows compared to the last 10 years. In North America, petrochemical demand grows by 50% to 2.9 mbd in 2025, with significant new ethane cracker capacity coming on stream, incentivised by easy and cheap access to ethane from US tight oil and gas production. This masks the decline in other sectors' demand and results in a 1.5-2% increase in North American oil demand between now and 2025.

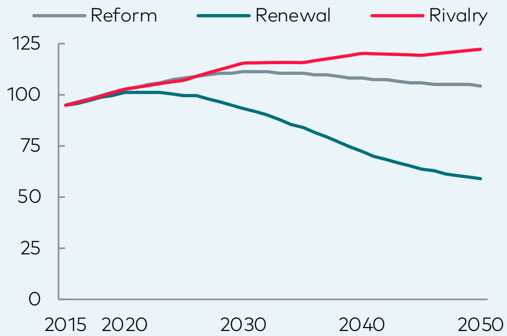
In *Renewal,* oil demand peaks in the early 2020s and then declines to 100 mbd in 2025. Oil demand in all sectors is lower than in *Reform* in 2025, apart from the non-energy sector, where the demand is robust due to need for additional feedstock in the petrochemical industry. In China and Southeast Asia, industrial oil demand is somewhat higher than in *Reform*, as oil replaces coal and increases its market share. Lower demand puts downward pressure on prices that decreases tight oil supply, increases decline rates and in isolation puts more strain on Opec member economies.

Oil demand in *Rivalry* follows *Reform* demand up to 2020, but an economic set-back moderately dampens growth in the early 2020s and results in total oil demand of 107 mbd in 2025. Non-energy sector demand is significantly down compared to *Reform,* due mainly to lower economic growth in key emerging economies. Road transport demand is up compared to *Reform*, but less use for aviation and maritime transport services results in a net lower demand of 0.8 mbd. The sum of industrial, residential, service sector and power sector oil demand is slightly higher compared to *Reform*, due to higher oil shares in the fuel mix. Opec supply suffers from political unrest and disruptions, while increased prices boost non-Opec production.

Outlook beyond 2025

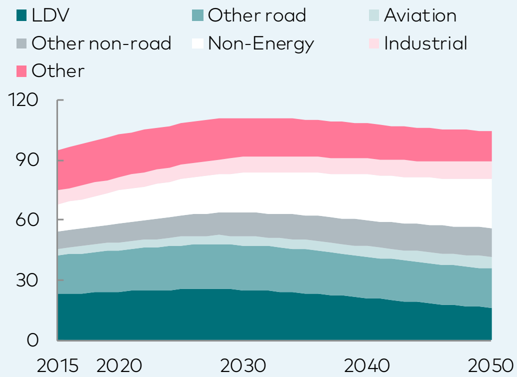
Oil demand by 2050 is highly uncertain, with our scenarios ranging from almost 60 mbd (*Renewal*) to around 120 mbd (*Rivalry*). Among the uncertainty drivers the pace of electrification in transport and other sectors, the pace of efficiency developments and the scope of different macroeconomic and behavioural pathways stand out. Drivers operating in the background include how forcefully climate and other environmental targets will be pursued, and how effectively vested interest, factionalism and geopolitical tensions will be managed.

Global oil demand by scenario
Mbd



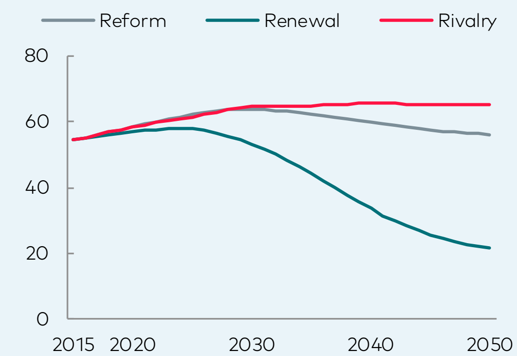
Source: IEA (history), Equinor (projections)

Global oil demand in Reform by sector
Mbd



Source: IEA (history), Equinor (projections)

Oil demand from transport by scenario
Mbd



Source: IEA (history), Equinor (projections)

Reform – peak demand around 2030

Oil demand, which grows robustly through the early 2020s, levels out in the second half of the decade and peaks at 111 mbd around 2030 before declining to 105 mbd by 2050. Electrification of road transport and other sectors and efficiency gains in all sectors offset the effect of continued growth in the petrochemical industry and aviation. In emerging economies, economic growth remains strong enough to sustain continued oil demand growth. Indian, Southeast Asian and African demand growth averages 1.3% per year between 2025 and 2050, while Chinese growth slows to 0.4% per year. Other emerging markets see even lower growth rates. In mature economies the downward pressure on oil due to electrification and efficiency gains is not outweighed by economic expansion, resulting in declining demand from 2030.

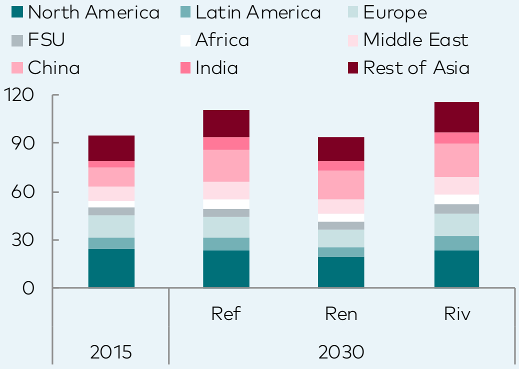
The penetration of electric light duty – and to a lesser extent heavy duty – vehicles erodes oil's dominant position in the transport sector, reducing road oil transportation demand by 12 mbd from 2025 to 47 mbd in 2050. Growth in aviation and marine oil demand continues after 2025, particularly in emerging markets, and partially compensate for the decline in road oil use, resulting in a total demand in the transport sector demand of 56 mbd in 2050.

The expansion of polymers into new applications seen over the last years continues. In *Reform*, polymers have revolutionised the design of car body exteriors, resulting in improved fuel efficiency, improving dent resistance, lower production costs, and more innovative concepts that otherwise would not have been possible. Polymers are also entering the construction industry where plastic composite materials can replace wood and to a smaller degree steel. A continuation of the plastic and other polymers revolution means that industry will be facing mounting pollution problems and threats to marine life caused by the disposal of plastic bags, bottles and other packaging material. Recycling is the obvious solution, but recycling of plastics is expensive and currently at a low level. In *Reform* recycling rates are comparatively lower than in *Renewal*. Overall annual growth in oil demand in the non-energy segment is 1.2%, mainly driven by increasing demand for goods in emerging economies.

Electrification and access to new renewables reduce the share of oil in other sectors. Residential and commercial oil use is in decline in most regions. However, in some emerging economies like India and Africa, LPG replaces biomass in cooking and heating, as less time spent searching for fuel, less soot, reduced deforestation and ease of transport make this an attractive fuel. Industrial oil demand increases in the emerging economies as their economies develop, but levels out and goes into decline in the mature economies where manufacturing stagnates. Power sector oil use starts declining at a faster pace after the moderation due to IMO regulation.

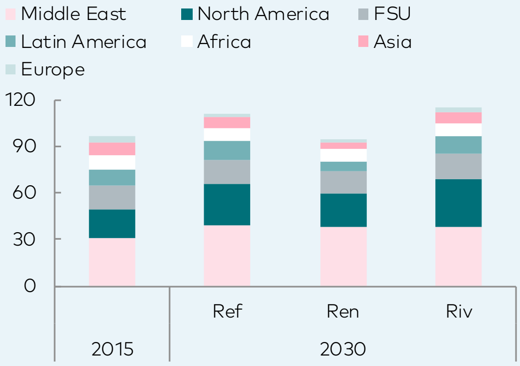
In emerging economies, the share of gasoline in oil demand decreases from 26% in 2015 to 20% in 2050 due to the electrification of road transport. Gasoil/diesel shows a more robust trend as it is also used outside the transport sector. Growth in the non-energy sector and in the residential sector results in LPG and naphtha increasing their share from 18% in 2015 to 27% in 2050. Also, the share of

Global oil demand by region and scenario
Mbd



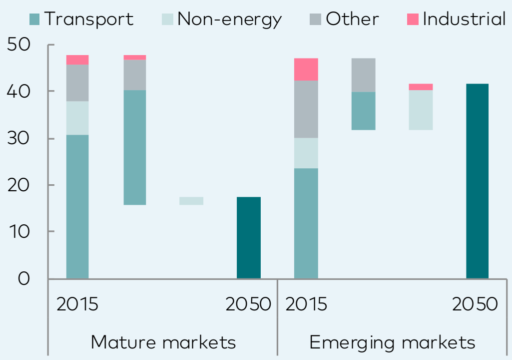
Source: IEA (history), Equinor (projections)

Global oil supply by region and scenario
Mbd



Source: IEA (history), Equinor (projections)

Oil demand in Renewal by sector
Change 2015-2050, mbd



Source: IEA (history), Equinor (projections)

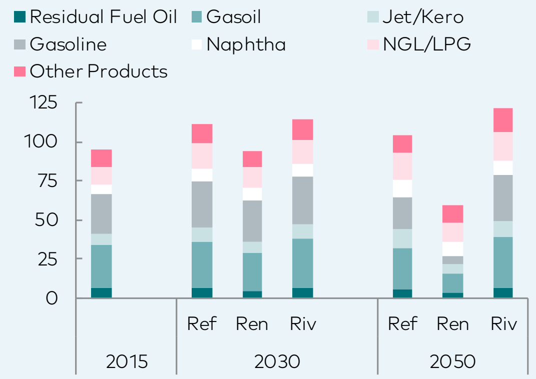
jet/kerosene goes up, driven by growth in aviation, while residual fuel oil continues losing its share. The shares of other products remain broadly stable. New refinery capacity is needed to replace aging refineries, and incremental refinery capacity is brought on stream in the main demand centres, especially in Asia. The change from gasoline production to distillates towards 2050 directionally favours investments in hydrocrackers, as they represent higher yields of jet/kerosene and gasoil/diesel. Growth in LPG supply fits with growing demand of lighter products. Investments in new complex refinery processes, like catalytic reformers, alkylation and catalytic crackers, which are geared towards gasoline production, lose momentum.

Significant investments are needed going forward to replace the 3-6% per year decline from conventional non-Opec supply and cover for the increased level of oil demand. Non-Opec supply peaks in the late 2020s, preceding the peak in demand, when the high growth period in US tight oil production comes to an end. Supply from new offshore fields in Brazil and other Latin American countries and Canadian oil sands continues to grow during the 2030s, but not enough to compensate for decline in other regions. Opec production grows steadily over the full period, approaching 50 mbd in 2050.

Renewal – demand in steady decline

All sectors need less oil in *Renewal* compared to *Reform*, leading to a global oil demand just below 60 mbd in 2050. Continued policy push, particularly prior to 2025, and faster battery technology development speed up the electrification in the transport sector relative to *Reform*. Road demand is further depressed by larger energy efficiency improvements and changes in consumer behaviour, with many more using public transport. *Renewal* also sees conscious policies to reduce the use of cars and develop efficient transport solutions in large cities. The consequence is a massive 72% reduction in oil demand for road transport to 2050, to a level by 2050 less than half of that in *Reform*. In aviation, oil demand is declining, due to energy efficiency and with biofuels and eventually electricity eating into the fuel mix. Biofuels and electricity are less important in maritime transport, but gas in the form of LNG takes almost 15% market share. Hydrogen and ammonia could make inroads instead of, or in addition to, the other non-oil based options. Demand for petrochemical products expands also in *Renewal*, driven mainly by the energy efficiency gains of switching from metals to lighter materials. But plastics do as noted raise other environmental issues which also receive more attention in *Renewal* than in *Reform*, dampening this growth. In other sectors quicker improvements in efficiency and faster electrification are the main drivers for lower oil demand. *Renewal* lacks the support from LPG in the household and commercial sectors in Africa and India seen in *Reform*, due to faster development of electricity grids and the use of new renewables like solar panels in combination with batteries.

Oil product demand by scenario



Source: IEA (history), Equinor (projections)

Oil supply change in Renewal and Rivalry vs Reform beyond 2030

Region	Renewal	Rivalry
North America	↓	↑
Latin America	↓	↑
Europe	→	→
CIS	↓	↑
Asia	↓	→
Opec	↓	↓
Rest of World	→	→

Source: Equinor

Vessels waiting outside of a trading hub in Asia

Source: iStock

In 2050, the share of gasoline in total oil demand in *Renewal* is only half of that in *Reform*. Gasoil demand is also declining, while the share of jet/kerosene and residual fuel oil stays like that in *Reform*. LPG and naphtha, on the other hand, increase their share in this scenario. Lower total demand for refined products reduces the need for refinery capacity by 40% in 2050, accelerating the shutdown of older refineries. Less complex refineries are more predominant, due to the higher share of LPG and naphtha instead of gasoline and distillates.

On the supply side, the main change compared to *Reform* comes from reduction in non-Opec volumes, especially the US and Brazil. Lower prices and low volumes increase the cost of maintaining infrastructure, accelerating decline rates and limiting investments in new production capacity. Opec production is stable up to the mid-2030s due to its low-cost position, before the effect of declining demand in *Renewal* starts to have significant impact on these volumes.

Rivalry – oil demand growth continues

Lower and volatile economic growth limits demand growth in *Rivalry*, particularly in the Middle East and Africa, but oil demand is still at 122 mbd in 2050, considerably higher in this scenario than in *Reform*. Less policy push, slower technology development and limited technology exchange lead to slower improvements in energy efficiency in all sectors and slower electrification in transport and elsewhere. Air and marine transport oil demand is also lower than in *Reform*, because of lower and more volatile economic growth and also because self-reliance in goods and services is valued, protectionist sentiment flourishes and barriers against international travel are erected. In the non-energy sector, where the potential for efficiency gains is more limited, lower economic growth results in lower oil demand compared to *Reform*. Slower efficiency gains and less electrification of road transport add 13 mbd road oil demand by 2050 compared to *Reform*. Other influencing factors are lack of trust in electricity grid stability and generally less developed grids, supporting the adoption of hybrid vehicles instead of EVs. Oil demand in other sectors is trending upwards, driven by cyclical economic growth, lower efficiency gains and slower electrification.

The total product mix in 2050 is relatively similar to today's shares. The trend towards lower fuel oil, gasoline and gasoil shares and higher LPG, naphtha and jet/kerosene shares is still visible, but to a smaller extent. Significant new refinery capacity with similar complexity as today is needed. Countries' concerns about self-sufficiency in final products imply a risk of overcapacity and less efficient trade flow patterns.

Higher geopolitical volatility in *Rivalry* hits Middle East and North Africa the hardest, leading to periods of supply disruptions and limited capacity growth from Opec producers. Increased non-Opec supply is required to compensate for the lower Opec output and meet the higher oil demand. Higher growth in tight oil production in the US and Canada, but also in Argentina and China, is helped by higher oil prices. Price levels and higher focus on exploration increase Brazilian oil production, while reduced environmental pressure lifts growth in Canadian oil sands.

Venezuela – on the brink of disaster

Venezuela has vast petroleum resources. The country's long tradition as key producer and member of Opec is facing enormous challenges, as an unprecedent political and economic crisis has accelerated production losses to levels not seen in decades. Once one of Latin America's wealthiest countries, it now has the highest inflation rate in the world, 2,600 % in 2017, and has battled with four years of consecutive economic contraction. With the advent of its former president Hugo Chavez's ascension to power in 1999, the Venezuelan oil and gas industry became highly politicised. After almost 20 years of dramatic political and social changes with strong focus on nationalisation of almost all sectors of the economy, hydrocarbons make up over 90% of the government's export revenues, compared with 19% in 1999. Several international oil companies left the country after 2006, and despite the arrival of a handful of new players, mainly Chinese and Russian companies, higher political uncertainty and increased internal turmoil have reduced Venezuela's ability to attract investments. Since 2014, oil revenues have waned as the country's economic crisis and lack of investments have steadily eroded production and deteriorated infrastructure, affecting oil companies' operations and restraining PDVSA's capex. Oil output has been halved from the 3.2 mbd peak in 1997, and the likelihood of further significant reductions is high.

The ability of Venezuela to meet financial and commercial obligations has also vanished. During 2017 the country experienced partial default, and it will face additional headwinds as more debt is due during 2018. Current president Nicolas Maduro's administration has received support from China and Russia in exchange for future oil deliveries and transfer of oil assets. However, the outstanding debt with China, significant default exposure and rising concerns about recognition of debt from future governments might decrease the likelihood of China to maintain financial aid. Russian willingness to lend has also decreased, demonstrated by tighter conditions and seizure of oil assets. The current crisis has left Maduro's administration facing almost daily protests, an increased migration and reactions from the international community, including introduction of sanctions from the US, the EU and neighbouring countries. More sanctions would force PDVSA to redirect its oil exports to Asian markets, both at a discount and with higher transport costs, squeezing cash flows even more and raising social discontent. Over time, the situation will most likely shift social and political dynamics.

If the current administration further isolates itself and the crisis deepens without a social explosion, the business environment will continue to deteriorate and become highly volatile. Oil supply will be more exposed to continuous decline, and operational expenses will increase along with cash flow problems. Additional sanctions will curb foreign investments and raise risk of additional production losses. In an alternative development where social dynamics worsen and the regime faces ruptures, more civil unrest and a potentially chaotic business environment could dominate short term, but this could also foster, in time, a positive long-term political, social and economic development. Most of the risk premium due to the current Venezuelan crisis has probably already been factored in to the current oil price. A fatal supply disruption is not likely to last long. In a more pragmatic and healthier business environment over the long term, one should expect increased oil supply.

Saudi Arabia – towards budget balance

Saudi Arabia's long-term Vision 2030, originally launched in 2016, with the aim of diversifying the economy and revitalising the private sector, still represents the main objective of the Saudi government, including the sale of a small share of Saudi Aramco. However, the transition from an oil dependent to a broader based economy is challenging – and takes time. The US shale revolution and the sharp reduction in crude oil prices have only made it more challenging. Since 2014, the Saudi government budget has been deeply in the red.

In theory, there is possibly an optimal macroeconomic path from the current position and structure and to the future, desired position. Given the government's expectations about a markedly lower price level, the main medium-term objective has been to adapt spending to the lower level of oil revenues, and bring the budget into balance by 2020. In 2015-2016, the government gave high priority to general belt-tightening, large cuts in construction activities and to raise non-oil revenues. However, the medicine was too strong, and the non-oil sector fell into stagnation.

The revised medium-term macroeconomic strategy is – at least for a while – to rely more on the oil sector; work closely with the rest of Opec and Russia to keep oil price and oil revenues at a higher and sustainable level, and thereby also stimulating the financial market's appetite for investing in Saudi Aramco.

In the 2018 budget, the government plans a strong rise in capital expenditure. Despite introduction of value added tax and reduced subsidies, a moderate recovery in the non-oil private sector is expected over the next few years. In total, the government's (lower) ambition is now to aim for budget balance by 2023. The government's financial reserves that fell sharply in 2015-2016, has in 2017 stabilized around USD 450 bn.

Based on the macroeconomic strategy briefly described above, our calculations suggest that a price of Brent in the 65-70 USD/bbl range is required to bring the government's budget back into balance.

The potential price recovery this year reduces the fiscal deficit to less than USD 100 bn, equivalent to -3% of total GDP. A price path around 65-70 USD/bbl allows for a moderate, steady rise in government expenditure over the medium term, which gives the government wider economic and political room for manoeuvre. However, in an oil market scenario where prices are fluctuating in the USD mid-50s, and other budget components are kept unchanged from the higher price scenario, the budget balance remains a challenge, and yields less funds for vitalising the non-oil sector. Thus, from a macroeconomic point of view, Saudi Arabia has strong incentives to aim for continued market cooperation with other Opec members and Russia, and seek a market where prices are sufficiently high, but not high enough to stimulate a too strong expansion in US shale production.

Long-term oil supply costs

Break-even prices and supply costs

The current level of oil supply costs, or the supply curve, for specific plays or regions is defined by the break-even prices (BEP) of current projects under development and evaluation. Such BEPs are ranked from the lowest cost to the higher cost or "the marginal" projects. While the volume side tells about the size and number of projects, the vertical dimension illustrates the cost level, including BEPs of average and marginal projects. Together with cyclical factors, the marginal projects of higher-cost regions are an important determinant of medium-term oil price formation.

Recalibration of recent cost levels

Driven by the shale revolution and price collapse (2014-2017), the oil industry's strategic reorientation to "value over volume" triggered new thinking about project development and work processes. Smarter, slimmed-down and better optimised projects, more efficient work processes and lower prices in supplier markets have all contributed to the sharp reduction of cost levels. BEP of higher-cost projects in most regions, widely seen well above 70 USD/bbl levels in the years up to 2014, have over the last three years come down to 45-55 USD/bbl. Several profiled projects in Norway, as well as larger, deep-water projects elsewhere have now lower BEPs, in the 20-40 USD/bbl range.

Driving forces behind long-term supply costs

Future projects, to be developed beyond 2025, define the long-term supply costs. As experienced during previous cycles, various drivers will determine project BEPs.

The resource factor points towards higher BEPs. The remaining recoverable oil resources are given, but highly uncertain. Over the longer term, the oil industry directionally needs to develop less productive shale oil formations and more distant and smaller reservoirs, that are costlier to develop and operate. Thus, cost curves of nearly all plays typically bend upwards. The relatively homogeneous Canadian oil sands formations represent an important exception. Utilisation of existing infrastructure could at least over the medium term have a dampening cost affect.

The oil industry's drive for efficiency combined with technology development is expected to continue. After steady deterioration in project efficiency during 2003-2014, but followed by the sharp improvements in 2014-2017, a period of diminishing returns drives the medium-term efficiency outlook. Beyond 2025, project efficiency is expected to accelerate again as a new wave of automatisation materialises. This should contribute to smarter concepts and improve the efficiency of most work processes, offering significant cost reduction potential.

Prices in most market segments stabilised in 2017 and moved higher in those segments that serve the expanding shale oil production. Relatively low capacity utilisation combined with outlook for further gains in project efficiency, which partially reduce the demand for services and materials, suggest that the price recovery in most offshore markets will be moderate over the medium term.

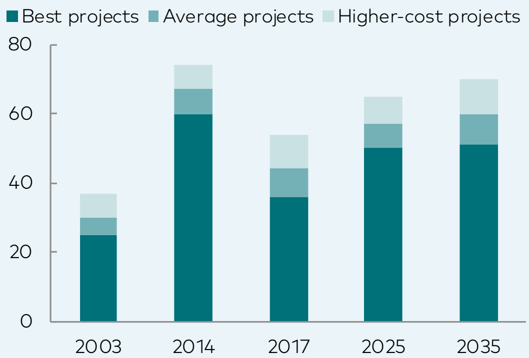
Governments/resource owners typically seek the balance between capturing a (high) oil rent and safeguarding other priorities, and on the other hand try to secure the competitive position of their resources. Thus, local content requirements, other protective measures and the tax regimes tend to shift over time, fundamentally driven by the intensity of the market and industry competition.

Supply costs vary with the scenarios

Based on these considerations and the general market tightness, the outlook for long-term supply costs typically varies by scenario. In *Reform*, the most likely outlook is for a continued race between the resource factor that drives costs upwards and steadily rising project efficiency. In *Renewal*, consistent with a lower level of oil prices, efficiency gains have the upper hand relative to the resource factor, while the pressure for efficiency improvements will be lower in *Rivalry*.

Oil supply costs in key non-Opec regions in Reform

Break-even prices in 2017, USD/bbl



Source: IEA (history), Equinor (projections)

The global gas market

Current situation and outlook to 2025

Global gas demand has been strong over the last two years and sufficiently strong to absorb new supplies from LNG plants in Australia and the US entering the market. According to CEDIGAZ's first estimate, global natural gas demand rose by 3.3% in 2017. The number compares to an average 1.5% annual growth over the last five years, hence supporting the current strength in market fundamentals. Chinese policy push for stricter air quality increased Chinese LNG imports during 2017. Despite gas shortages during winter, the policy of reducing pollution has been successful. Therefore, healthy Chinese LNG imports are expected going forward. Other big consumers of LNG in Asia in 2017 are South Korea, Japan and India. Due to extended nuclear maintenance, South Korea increased its imports to 53 Bcm. Japan's LNG import level remains largely flat, despite new nuclear reactors brought back on stream. Indian LNG imports increased slightly in 2017 to 25 Bcm, which gives a gas import dependency of around 45%.

The global LNG market has typically moved in so-called boom-and-bust cycles. Between 2009 and 2015 on average 30 Bcm per year (Bcma) of project capacity made final investment decision (FID). This dropped to 10 Bcm in 2016 and only 4 Bcm in 2017. So far in 2018 no project has been sanctioned. This slowdown in project sanctions could reverse relatively soon. It is expected that Qatar Petroleum and ExxonMobil make a FID on Golden Pass LNG in the US Gulf of Mexico on one or more trains in the second half of 2018. US independent Anadarko has been actively selling gas from its Mozambique LNG project (6.8 Bcma) and expects to reach FID in 2018 or 2019. Qatar has announced the construction of another three mega trains, each with a capacity of over 10 Bcma, and the Fortuna floating LNG project in Equatorial Guinea is also expected to be sanctioned this year.

Over the last three years European gas demand has increased by more than 70 Bcm, reaching 471 Bcm in 2017. An important component of European gas demand growth is the electricity sector, where gas generation is gaining ground at the expense of coal due to rising coal and CO_2 emission prices. On the supply side, European indigenous supply is in decline, while Norwegian and Russian pipeline flows reached record levels in 2017. The Groningen field continues to decline due to concerns over seismic activity, and the field's production permits will be reduced from 21.6 to 12 Bcma over the next 4-5 years. The Russian market share is currently around 35%, and it is expected to continue to grow in the future, as European domestic output continues its steep decline. LNG imports to Europe stood at 54 Bcm in 2017, up 16% from 2016.

The North American gas market continues to grow, driven by increasing domestic gas fired power generation and industrial demand for petrochemicals, in addition to increasing LNG and pipeline exports. LNG exports quadrupled in 2017, reaching 18 Bcm. The Cove Point LNG export facility started commercial operations in March 2018, and with two more liquefaction facilities due to come online, LNG exports will increase to 27 Bcm in 2018. Through 2020 natural gas output is expected to grow by 14% compared to current levels, while domestic demand will only grow by 8% over the same

China's seasonal peak gas demand and infrastructure constraints

The Chinese government's attempts to reduce air pollution by cutting consumption of coal in favour of natural gas are likely to be the most prominent drivers of Asia-Pacific gas consumption over the next years. China is pushing strongly to cut coal use under its 13th Five-year Plan. The government is targeting a 10% reduction in coal consumption by 2020 from 2015. At the opening of the annual meeting of the People's Congress in March 2018, the National Development and Reform Commission (NDRC) largely reiterated existing goals, underscoring China's years-long determination to reduce pollution, through shutting down outdated and non-efficient industries, re-prioritising fossil-fuel energy sources and cutting coal use in favour of cleaner energy.

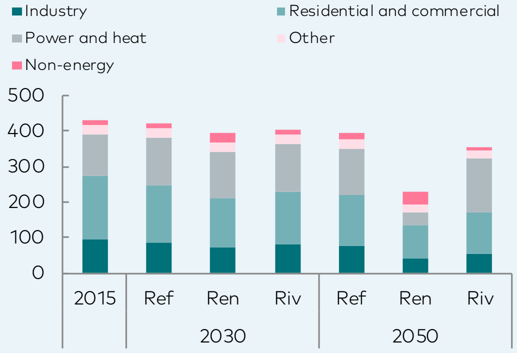
In 2017, the government ordered several million households and industrial plants in 28 northern Chinese cities to change from coal to gas heating as part of the country's fight against pollution, to defend the "blue of our skies". The policy is expected to continue as China has announced a more ambitious plan of switching heating systems in 4 mn households and industrial plants from coal to gas or electricity this year.

However, the jump in gas demand and inadequate storage and pipeline networks led to a supply crunch last winter. LNG import terminals in northern China operated at maximum capacity and authorities had to cut gas supplies to industrial users, as they prioritised residential demand for heating. According to NDRC Chairman He Lifeng, the government is working on several measures aimed at meeting power generation and heating needs during winters.

China has limited gas storage capacity relative to demand, and is planning to expand this with the start-up of the roughly 4 Bcm working capacity Wen 23 storage facility in Henan province this summer. This will increase total working gas capacity to above 10 Bcm during the winter of 2018/19. CNPC plans to increase its total working gas storage capacity to 15 Bcm by 2025, enough to meet 10% of China's peak seasonal demand. Similarly, plans to increase supply from Central Asia could be constrained without new capacity being built. The import capacity of the three existing West-to-East Pipelines is 55 Bcma, and in 2017 China imported 38 Bcm from central Asia. China is also seeking to increase its own production, through further exploration and development of tight and shale gas resources. China plans to raise shale gas output to 30 Bcm by 2020. But shale gas production missed the 10 Bcm 2017 target by 10% and still accounts only for a small share of the country's aggregate 2017 gas production of 148 Bcm.

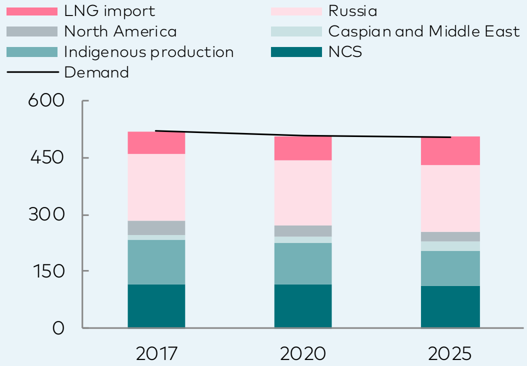
Given that gas makes up only 5.7% of the country's total fuel mix, compared with government's decision to raise China's gas consumption to 8-10% by 2020 – the shift from coal to gas is just the start of the energy reform in China.

EU gas demand by sector and scenario
Bcm



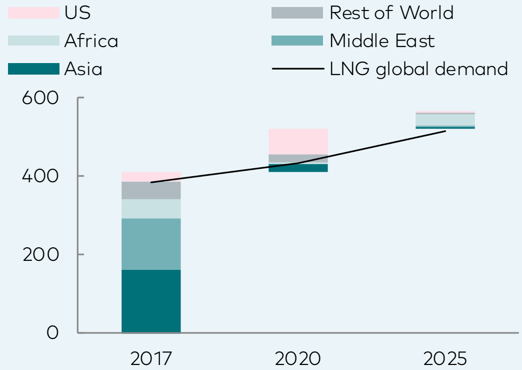
Source: IEA (history), Equinor (projections)

European gas balance in Reform
Bcm



NCS: Norwegian continental shelf
Source: Equinor

Global LNG balance to 2025 in Reform
Bcm



Source: Equinor

period. Thus, North America will face a period of supply led growth as gas flows make their way to the Gulf to satisfy industrial and export demand in the region.

Outlook to 2025

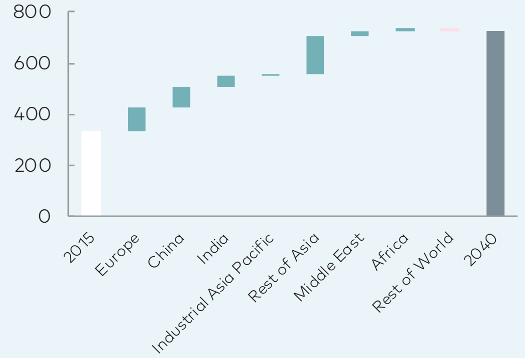
The medium-term global gas story is very much about to which degree global gas demand will keep pace with the current build-up in LNG supply. A significant slowdown in global gas demand growth in 2014 jeopardised the originally synchronised supply additions as foreseen by market players. Europe's spare LNG regasification capacity offers volume outlet, but not necessarily satisfactory economic rent for producers. Now, favourable natural gas pricing has spurred demand in emerging markets, but price elasticity might disappoint producers. In the following, we will address whether the supply and demand balance will change again.

Europe's need for imports is increasing, despite stable demand in *Reform*. Domestic supply in Denmark, the Netherlands and the UK continues to drop. Supply from the Caspian region arrives around 2020 and adds diversification to European gas imports. By 2025, new gas volumes become available for Europe, either from Middle East (Iraq) or from the Mediterranean region (Cyprus, Israel). *Renewal* and *Rivalry* fail to attract such volumes due to the significant value chain costs and due to political instability, respectively. North African exports to Europe are expected to gradually decline towards 2025, based on strong local demand combined with lower gas output.

In *Reform*, the market tightens during the mid-2020s, as global gas demand absorbs the additional LNG supply. The European import gap will again allow for Gazprom's exports to return to legacy market share in tandem with sizable LNG imports. The gas price recovers to levels allowing for adequate returns on investments in new supply. The alternative scenarios will during the mid-2020s both assume pathways for gas demand that are lower than in *Reform*. In *Renewal*, strong emphasis on low carbon and energy efficiency continue, whereas gas reliance is curbed in *Rivalry* due to lower economic growth, but also to reduce import dependency. Russian pipeline gas is and continues to be important for European gas supplies going forward irrespective of scenario, based on its low-cost base.

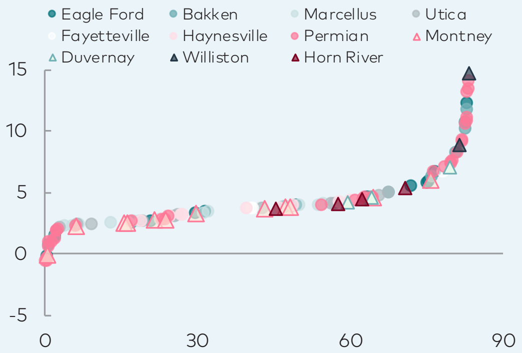
The Asian market will continue to grow after 2020, led by strong Chinese demand towards 2030 as the country aims for a natural gas's share of primary energy of 12% by 2030, up from 5.7% in 2015. In the same period coal's share is expected to fall from around two-thirds to less than 50% in 2030. Other countries like Bangladesh, India, Indonesia, Pakistan and Thailand will have a considerable call on LNG to make up for declining domestic supply and/or growing energy demand. The potential demand of these countries combined has the potential to exceed that of China, though, their ability to realise plans is more limited than China's. Infrastructure constraints, lack of funding and sensitivity to price represent dampening factors to LNG import growth, but soft medium-term prices will incentivise demand and tighten the global LNG balance.

Global LNG demand in Reform
Change 2015-2040, Bcm



Source: Equinor

North America resource availability
USD/MMBtu (vertical axis), Tcm (horizontal axis)



Source: ARI

Latin America gas export-import outlook to 2025

Source: Equinor

Some 110 Bcma LNG capacity is under construction globally and will reach the market between now and 2020. Some of this will originate from Australia and Russia, but the larger part will come from US LNG projects. Additional LNG beyond 2020 must come from LNG projects that have not made FID yet. Capex constraints during the start of the period is expected to drive efficiency and simplify concepts to ensure required cost competitiveness. This would typically be brownfield projects, i.e., new trains at existing plants, where most of the infrastructure is already in place, or LNG projects that include liquids-rich gas and where the profit from sale of liquids contributes positively to the economics of the project. The three new trains in Qatar with a combined capacity of 30 Bcma is a brownfield project where the feed gas is liquids-rich, and it is likely the most competitive project around. This project is planning for a FID in 2019, with first gas around 2023. Other projects that are likely to be developed in this period are brownfield projects in the US, Australia and Papua New Guinea.

Current resource assessments in North America show that there is roughly 25 years of production available at a cost of below 3 USD/MMBtu. This means that downwards price pressure will remain. In this context, the main challenge in the North American market will be to balance low-cost supply with additional demand from industrial use and gas fired power generation in addition to LNG and pipeline exports markets.

Natural gas supply in North America increases by 19% in *Reform* until 2025. Corresponding numbers are 12% in *Renewal* and 20% in *Rivalry*. Call from the domestic sectors is lower in *Renewal,* as demand grows only by 2%, mainly due to a significant reduction from the industrial and residential sectors. Domestic demand in *Rivalry* shows more resilience as cheap low-cost gas availability trumps incentives and efforts into energy efficiency and new renewable technology. In addition, *Rivalry* offers less export opportunities for US gas in overseas export markets.

Gas demand in Latin America is growing, based on economic growth and electricity sector demand. The continent is rich in gas resources, but price regulations have failed to provide investment incentives. This has hit supply and led to LNG import dependency. Both Brazil and Argentina are implementing energy frameworks to attract investments in supply and downstream infrastructure. Domestic supply is expected to reach some 180 Bcm in 2025, making the Latin American region close to self-sufficient. However, LNG is still expected to be key for balancing the market on a seasonable basis, defining the ceiling price for the region. The potential for market integration within the Southern Cone (defined by Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay) will add to gas market developments and efficient gas exchange between neighbouring markets, exploiting seasonal variations in demand and flexibility in supply.

Outlook beyond 2025

Our long-term energy market scenarios cover an outcome space defined by uncertainty in global energy and geopolitical develop-ments. Gas value chains are indeed political due to lead times, cross-

Gas demand in the EU heating market

Overall, heating and cooling demand forms the greatest proportion of all sectoral gas demand in Europe. In 2015, 40% of all demand was consumed in this sector. It is predicted to remain the largest sector for demand in most future scenarios. Given this, the European Commission has placed significant emphasis on this sector as a mechanism for reducing carbon emissions, and arguably import dependence.

The ability to improve efficiency in the heating sector relies on progression in two main areas; home efficiencies (heat retention) and heating equipment efficiencies, combined with consumer behaviour. The first of these, heat retention is difficult to drive in terms of economics. 40% of Europe's housing stock was built before 1960, when there was little focus on energy efficiency levels. Progression is possible via incentives for housing stock to increase insulation in lofts, walls, windows and doors. However, roughly 70% of the EU population lives in privately owned buildings and many have not undertaken renovation work due to a lack of awareness, advice or, most likely, financial incentives. To tackle the latter point, the European Structural and Investment Fund will allocate approximately EUR 19 bn for energy efficiency, and EUR 6 bn for renewables penetration in heating. Finally, the Commission's ambition for all new builds to be low in energy requirement and mostly powered by renewables (Nearly Zero Energy Buildings) by 2020 looks unlikely to be fully implemented. However, even partial implementation will reduce the demand increases from additional housing requirements.

With heating equipment, the focus is on boilers. Almost half of Europe's housing stock has a boiler that was installed before 1992, and therefore has an efficiency of about 60%. Furthermore, one third of the boilers are beyond their technical lifespan. To tackle this, the Ecodesign Directive came into effect in 2015 and banned the sale of inefficient heaters. Going forward, a wide number of replacement technologies are available to replace traditional gas boilers. Condensing boilers are a like for like replacement, and their use would increase efficiency levels by 20–30%. However, slight changes to technology can yield greater efficiency savings. Hybrid Heat Pumps can be integrated with condensing boilers as a transitionary solution towards full decarbonisation.

In *Reform*, we see only a marginal reduction in gas demand versus 2015 numbers – 7% by 2025. The penetration of new technologies and renovations relies on available technologies and natural lifecycles of equipment leading to a gradual reduction as efficiencies improve. The decline is more noted in *Renewal,* where increased focus on emission reductions and a greater co-ordinated approach from member states open the door for greater technological penetration with proactive retrofitting.

border infrastructure needs and link to energy policy measures and power market developments. History has proved Western Europe and Russia able and willing to overcome geopolitical conflicts, ensuring gas to flow uninterrupted during the cold war. Now, new political controversies are about to arise while some remain. Below, we outline possible interpretations for how the future global gas market can develop in *Reform*, in a more climate focused scenario – *Renewal*, and in a more political complex and protectionist scenario – *Rivalry*. In any case; gas market developments will relate to the given context.

Reform – global demand stays strong

Long-term gas demand increases by 32% to more than 4,700 Bcm in 2050. This corresponds to an annual growth rate of 0.8% over the total period and some 0.6% from 2025 to 2050. North American demand keeps growing based on growing low-cost resource availability, but Asia remains the main growth engine for global gas. Even if Europe's gas demand peaks around 2030, net imports continue to grow. As LNG's share of global gas supply increases, a gradual harmonisation of global gas prices is unfolding. Whether a global LNG price materialises, remains to be seen, still the share of uncontracted spot-based LNG contributes to the set direction.

The "fixed" factor in the long-term European supply stack is the sharp decline in the domestic contribution. European gas import dependency increases significantly from the current level of 55% to almost 80% by 2040-50. This calls in significant volumes of LNG as well as pipeline gas imports. The pipeline import potential from Russia, North Africa and Middle East is significant, but comes with various caveats. Overdependency on Russian piped gas is a concern, although European utilities together with Gazprom actively develop new supply routes to ensure long-term gas flows to the continent. Growing domestic demand in export countries such as Algeria limits the North African export potential. US LNG offers supply diversification, but at the same time anchors gas prices roughly at par with more expensive import regions in Asia. Demand side management is Brussel's tool to balance concerns about import dependency. Strategic responses to curb demand in the heating and cooling sectors address half of EU's energy demand. However, the lead time is extensive as building refurbishment, energy system replacements and newbuilds take time.

Asia delivers significant growth in gas demand, and large-scale imports are required to satisfy sustainable economic growth in urbanised areas and fuel diversification. As such the gas story in Asia continues its reliance on LNG market growth. Suppliers within the Pacific basin benefit from higher realised netbacks due to lower transport costs, whereas Atlantic basin suppliers benefit from flexibility to optimise between Europe and Asia. Regardless of location, project developers need adequate price signals to make new FIDs and commit the necessary capital. Unless the market over time allows for full cost coverage, new LNG capacity cannot be developed. The low-price environment as of the recent past has pushed costs down and called upon simplified concept developments. Continuation of this trend is required to strengthen competitiveness as resource

Rising dragon, hidden tigers?

China is on the rise as an importer of LNG, and the potential future LNG import requirements look truly large. Behind China, there are several Asian countries which in the future will have growing gas supply gaps. These countries' combined call on LNG could possibly exceed that of China, but currently their future demand for LNG comes in the shadow of the Chinese gas demand. What is the implication of this? The growth of the global LNG market will take place in Asia, and too much focus on China clouds a larger development across Asia.

2017 saw an additional 40 Bcm of LNG entering the market. This represented an 11% increase and brought the global LNG market to a size of 403 Bcm. Such an increase should have caused a comparatively loose market balance and weak associated prices. This, however, did not materialise, as several Asian countries absorbed much of the new LNG production. It was China that led the strong increase in LNG imports caused by policy to reduce local pollution by switching from coal to gas. This policy has been successful in reducing city smog, and it is likely that the importance of gas in the primary energy supply will grow. Another 110 Bcma of capacity is under construction, and this LNG is expected to enter the market between now and 2020. There is still a possibility that the global LNG market will see a period of abundant LNG supply, however, it will depend on the strength of Asian imports. China's target is to increase gas' share of primary energy demand to 8-10% by 2020 and to 12% by 2030. This will likely absorb a large part of the additional LNG that will be available on the market over the next couple of years.

Several other Asian countries have also increased their imports of LNG, and probable future LNG import from some of these countries could be large. Bangladesh, India, Indonesia, Pakistan and Thailand share a few common denominators. They have large populations, established gas markets, growing economies and increasing energy supply gaps. This group of countries could consume as much as 200 Bcma on top of today's demand. Whether such an upside scenario will play out in the future or not, will depend on gas` affordability in the primary energy mix compared to other energy commodities.

High population density in parts of Asia

Source: iStock

holders have seen the risk of missing the next window of opportunity to competing suppliers or technologies.

In *Reform*, North American natural gas supply is expected to grow 16% between 2025-2050. The market balance during the late 2020s builds on both domestic and global demand, incentivising new supply. Mexico's consolidated infrastructure is required to allow for US pipeline exports to the Mexican industry and electricity sectors. Domestic development of cleaner energy sources results in a balanced penetration of renewables, giving gas the opportunity to capture a share of the market despite a reduction of residential heating demand of 2%.

Renewal – global demand declines

As global demand peaks at around 4,000 Bcm in 2030 this materially impacts the global supply picture. *Reform* implicitly calls upon more LNG supply projects from 2025 and onwards. This is much less the case in *Renewal,* with the total market dropping to just below 3300 in 2050. Hence, supply competition could intensify for asset owners to avoid stranded assets. Mature markets are about to and will increasingly adapt new low carbon technologies. Such developments are initially driven by energy policies and global climate targets. As scale increases and costs are reduced, renewable energy sources provide a cost and climate efficient supply alternative to traditional fossil energy sources. Natural gas needs to gradually meet the challenge of getting green in absolute terms, not only being greener than alternative fuels, to sustain its long-term position in the energy mix.

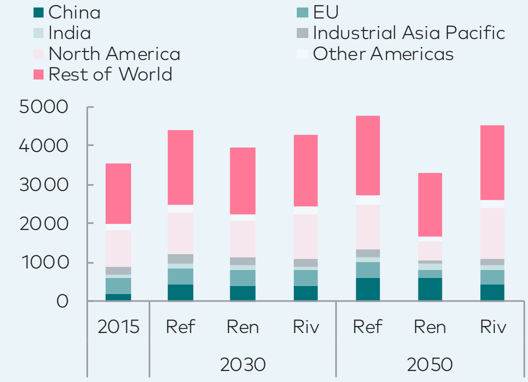
In Europe and North America, lower producer gas prices – a function of weakening demand during the medium term – cannot counter the strengthened supply competition from energy efficiency and renewable energy. The Russian market share in Europe increases throughout the period due to its competitive position and low supply cost. North African gas supply weakens due to absent investment signals and funding towards the latter end of our analysis horizon. In Asia, particularly in emerging markets, gas demand is more resilient throughout 2030-50 in *Renewal*. Low gas prices combine with climate regulation to play a significant role in driving gas to coal switching, and as a result, LNG finds a market in Asia. For instance, it is anticipated that Indian LNG import dependency increases from the current level of 45% to 70% by 2050.

Competitiveness of natural gas declines as end users face increasing cost from emitting CO_2. CCUS and hydrogen production are means to address this issue and ensure long-term competitiveness of gas in a low carbon context. However, the commercial scope of CCUS is limited to geographies close to production. Resource owners and partners will have to develop strategies to utilise infrastructure and reservoirs to avoid stranded assets. This is not a walk in the park.

Rivalry – global demand impacted by geopolitical instability

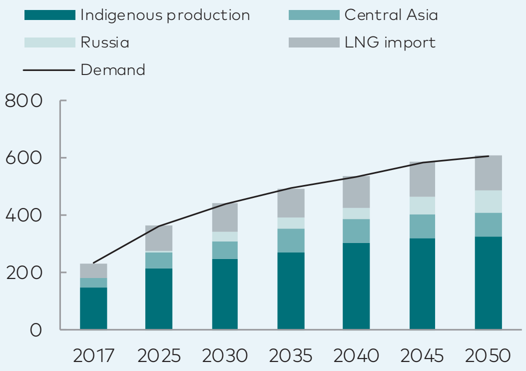
In *Rivalry,* the fundamentals for integrating regional gas markets are at risk as geopolitical and regional conflicts persist. Less focus on climate policies, slower phase-out of fuel subsidies and less incentives for energy efficiency counter the negative impact from lower

Global gas demand development by region and scenario
Bcm



Source: IEA (history), Equinor (projections)

China supply and demand balance in Reform
Bcm



Source: Equinor

Gas supply change in Renewal and Rivalry vs Reform beyond 2030

Region	Renewal	Rivalry
North America	↓	↑
Europe	→	→
China	→	→
India	→	→
Middle East	↓	↓
Africa	↓	→
CIS	↓	↑
Rest of Asia	↓	→

Source: Equinor

economic growth. Overall, gas loses terrain relative to coal as less climate focus and protectionism discourage new LNG investments. Preference for imported gas is lowered, reducing global demand in 2050 by almost 250 Bcm compared to *Reform*. Still, gas consumption increases in regions with abundant low-cost resources such as North America, where demand grows by 34% to 2050.

The Middle East contributes to limited gas demand growth in *Rivalry*, as progress in renewables and energy efficiency is slower. Continuous geopolitical instability in the region impacts the plans for developing new projects, which implies less gas available for export. The geopolitical context hampers the financial capabilities and as such the potential for new investments.

In Asia, gas demand is around 160 Bcm lower compared to *Reform* in 2050. Concerns about energy security mute gas imports, hence no new gas import pipeline is being developed beyond the Power of Siberia (38 Bcma capacity from Russia), which is currently under construction. In addition, China has three pipelines from Central Asia (total capacity of 55 Bcma) and the pipeline from Myanmar (13 Bcma capacity). LNG imports remain at the current level.

For Europe overall, gas demand is marginally lower compared to *Reform*. Lower LNG availability calls on higher gas prices to satisfy import needs. Indigenous energy tunes focus back on coal, whereas some countries improve their relationships and reliance on Russian gas.

Long-term supply challenges

IEA estimates global technically recoverable natural gas reserves at close to 800 trillion cubic metres (Tcm) and proven reserves at some 200 Tcm, which is comfortably sufficient to meet our estimated accumulated demand in *Renewal, Reform* and *Rivalry*, ranging from 135 to 158 Tcm. The main gas supply areas will remain the same: North America (US), Russia and Middle East (Iran, Qatar), which are also low-cost sources of gas. It is anticipated that China becomes one of the leading gas suppliers, however mainly serving domestic needs. The European indigenous gas supply projection shows significant reduction from 2025-30.

Reform requires new supply value chains to be built. The global LNG markets develop to supply both mature markets in Europe requesting more imports and emerging markets in Asian to facilitate growth. Continued efficiency gains, cost reductions, but also project improvements and tax credits should improve the competitive position of investment projects. This is all required as the competition intensifies further between energy carriers and projects. *Renewal* reinforces these perspectives for gas to maintain and defend its role into the low carbon context. *Rivalry* suffers from lack of trade and policy framework, in particular hurting affordability and demand in gas importing regions. Eventually, producers need firm price signals and credible gas market framework to defend new and robust investments in a more competitive energy landscape.

Shale gas developments in Argentina

Argentina has some of the largest unconventional gas resources in the world, but regulatory, political and market uncertainty have so far hampered development. After years of economic turmoil, Argentina is in the process of undertaking political and institutional steps towards economic and financial stability. The Macri government has worked actively to stabilise inflation and attract foreign investments, hoping to contribute to a positive economic outlook. The latest inflationary upsurge is handled through IMF involvement and banking regulations. The energy sector is critical to such developments, as energy subsidies weigh heavily on the government budget.

Argentina has the highest gas demand in South America. The market is connected to neighbouring markets, and supply dynamics in the area have changed several times, both due to changing supply availabilities and regional "geopolitics". Natural gas supplies about 50% of the country's energy needs, and demand is evenly distributed among the residential and commercial, industrial and power generation sectors. In addition, natural gas is extensively used in the transport sector. End user gas prices in Argentina have been kept artificially low and decoupled from international import prices. This has dramatically impacted incentives for gas suppliers, and from 2008 Argentina turned into a net importer of natural gas.

Government programs have been initiated to increase domestic gas supply. For new supply from the Neuquén area, gas suppliers are currently guaranteed a minimum price at the wellhead at 7.5 USD/MMBtu. The average realised gas price achieved in the market is approaching 4 USD/MMBtu, and the difference is covered by the government. This guaranteed price will stepwise be reduced to 6 USD/MMBtu in 2021. In parallel, the government has started to hike end user prices to allow for sound value chain economics. From 2021 onwards, end user gas prices are supposed to reach a level that allows suppliers to offer cost-based pricing without subsidies.

The ongoing commercialisation of new gas supplies from the Neuquén province's Vaca Muerta shale gas formation poses significant changes to the Argentine gas market. The volume potential is well proven and capital is flowing into operations, as international companies farm in to current and new projects. However, new infrastructure will be required to bring volumes to customers in and around the Buenos Aires region. The seasonal demand pattern from the heating sector adds to the infrastructure challenge, and so does the lack of supply flexibility and absence of storage. LNG or Bolivian contract volumes will probably be required for winter peaks, whereas Neuquén exports to neighbouring South American markets during summer is a likely option.

The local market exposure, including local infrastructure constraints, poses exposure to future regional gas prices. Still, the resource availability, industrial knowledge and political and economic direction point towards large-scale opportunities for Argentina.

Take-away capacity in the US – unleashing the North East and the mighty Permian

Much has changed in the US natural gas market over the past decade, and there is significant change yet to come. In 2007, North American natural gas supply was roughly 700 Bcm, the bulk of which was conventional gas emanating from Texas, the Gulf of Mexico and the Mid-Continent. Much of this gas flowed North and East to supply growing East Coast demand, as this region lacked sufficient indigenous supply.

By 2017, the US gas market had changed considerably. Unconventional gas from Appalachia had soared to 26% of North American supply, which was roughly 880 Bcm. In addition to growth in Appalachia, Permian associated gas has experienced significant growth, driven by increased exploitation of unconventional liquids. Over the next decade North American supply growth will be dominated by Appalachia and Texas, with Appalachia reaching 420 Bcma and Texas 340 Bcma, accounting for 35% and 28% of total North American supply, respectively.

These shifts in supply patterns are driving a rerouting of North American gas infrastructure and flows. Instead of importing gas, Appalachia is now exporting gas South and West, aided by reversal of gas flows in existing pipelines as well as through construction of new infrastructure. Increasingly, gas will flow to the US Gulf Coast to feed a growing base of LNG export and petrochemical facilities.

The evolution in North American gas infrastructure is influenced by a number of challenges. Northern Appalachia remains constrained, facing significant political, regulatory and cost hurdles for adding new capacity. As such, future pipeline capacity out of Northern Appalachia is expected to be limited. On the contrary, Southern Appalachia has benefitted and will continue to benefit from new infrastructure. Between now and 2022, Southern Appalachia will add 100 Bcma of gas pipeline capacity, while the North will add just 30 Bcma.

Suppliers and midstream companies in the Permian are currently engaged in a significant buildout of market-focused exit capacity, moving gas to the US Gulf Coast. Other projects will move gas to the Mid-Continent and to Mexico, which represents a growth market for Permian gas for use in power generation and industrial developments. While there are risks of short-term constraints moving gas out of the Permian, longer term projections show sufficient exit capacity from this region.

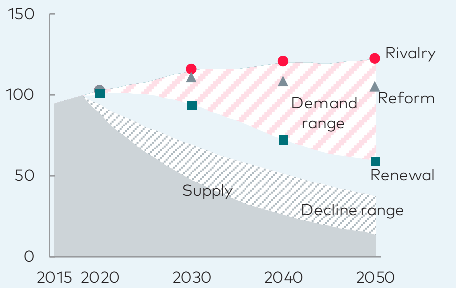
Once the current wave of pipeline construction is completed (around 2022), gas will be allowed to move more efficiently from supply regions to markets. This means that more Appalachian gas will flow North, West and South, while greater volumes of Permian gas will flow to Mexico and to the Gulf Coast. As Gulf Coast petrochemical capacity increases and as LNG and Mexico exports grow, the US gas market will become increasingly connected to global gas markets.

What is the need for new oil and gas supply capacity?

To answer this question, we compare demand scenarios for oil and gas with two supply curves representing future supply from existing fields that can be maintained going forward with only regular operations and maintenance costs incurred by operators. Determining the appropriate decline rate for existing supply is a complex task. An individual, mature conventional field is likely to display decline rates of 5-8% per year in the absence of EOR measures. Looking at bottom-up field supply profiles from Wood Mackenzie, in the full portfolio of older existing conventional fields in the Middle East, decline rates are predicted at only 0.5% per year, with EOR more often accounted for than not. A similar figure for older conventional supply elsewhere in the world is 5% per year. Younger fields, however, can not only avoid decline, but boost supply in the short run. Taking these factors into consideration, a range of 3-6% decline of existing supply per year has been assumed in the analysis.

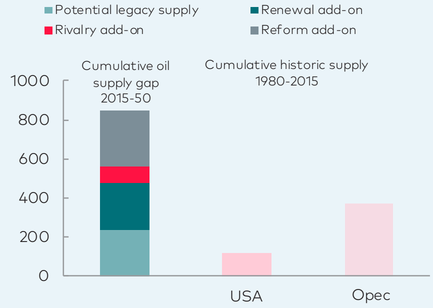
Global oil demand ranges from 59 mbd in *Renewal* to 122 mbd in *Rivalry* in 2050. The difference between oil demand and declining existing supply provides an indication of how much oil must be supplied to satisfy demand from brownfield developments, from greenfield project sanctions and from exploration. In *Renewal* in 2050, 22 to 45 mbd of oil must be made available for the market on top of remaining, existing supply. This delta corresponds roughly to 2-4 times Saudi Arabia's, the US' or Russia's current oil supply. In *Reform* and *Rivalry*, the gap measures up to 80-110 mbd in 2050. In cumulative terms, the need for new oil supply is between 240 bn bbls and 850 bn bbls, and is shown next to accumulated supply from the US and Opec over the period 1980-2015.

Oil demand and supply from existing fields
Mbd



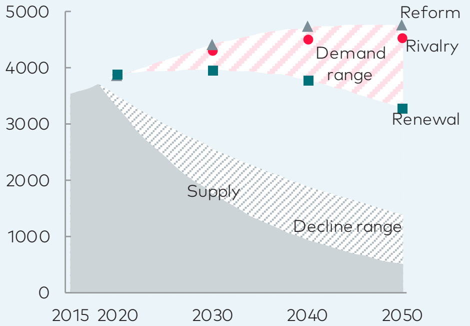
Source: BP and IEA (history), Equinor (projections)

Cumulative oil supply gap and historic supply
Bn bbl



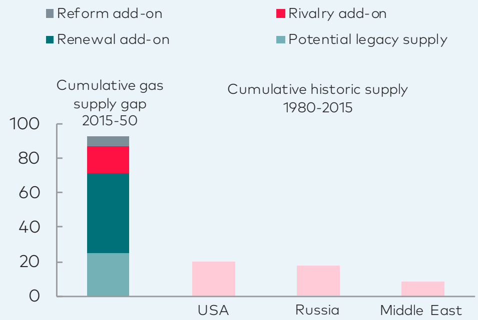
Global gas demand ranges from 3,300 Bcm in *Renewal* to 4,800 Bcm in *Reform* in 2050. In *Renewal*, 1,900 to 2,800 Bcm new gas will have to reach markets in 2050, corresponding to 2.5 to 4 times current US or Russian annual production. In *Rivalry* and *Reform*, the range increases to 3,200 to 4,200 Bcm, respectively.

Gas demand and supply from existing fields
Bcm



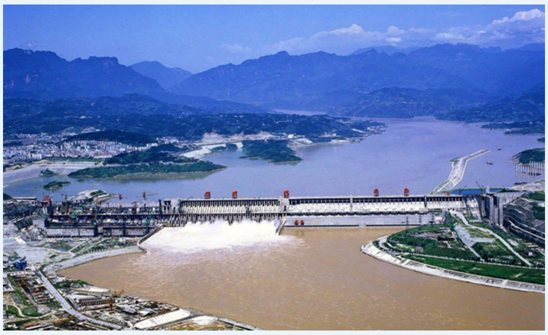
Source: BP and IEA (history), Equinor (projections)

Cumulative gas supply gap and historic supply
Tcm



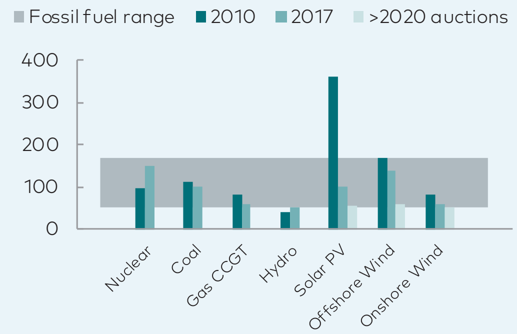
It also has some merit to compare reserves with the cumulative gaps described above. BP reports global proven oil reserves slightly above 1,700 bn bbls at the end of 2016 and the reserves to production (R/P) ratio at 51 years. This is 2-8 times the cumulative gap for oil, confirming that the world is not short of oil. As for gas, global proven gas reserves stood at almost 190 Tcm by end 2016 and the R/P ratio at 53 years. The relationship between proven reserves and the cumulative gap is 2-4. Knowing that last years' exploration expenditures and discoveries plummeted, and that some of the proven reserves are concentrated in geopolitically volatile areas or require high-cost technology to be developed, the future is still though reasonably bright for low-cost quality reserves and discoveries. Location in stable regulatory and political environments and low carbon footprint are additional requirements for success. However, as we are moving across scenarios from *Rivalry* and *Reform* to *Renewal*, the amount of necessary oil and gas investments is correspondingly less, such investments are increasingly short-cycled, producer prices are characteristically lower, and the competition for new quality resources is intensifying.

China's controversial Three Gorges dam, the world's largest hydroelectric plant



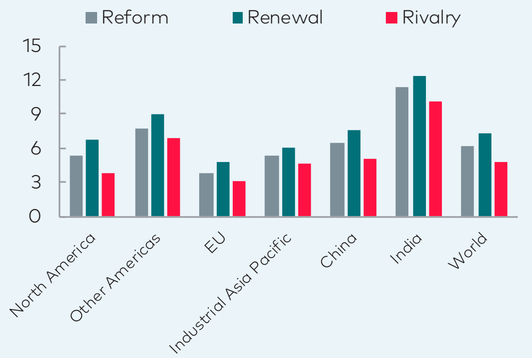
Source: china.org.cn

Global levelized costs of electricity, utility scale generation
USD/MWh



Source: IRENA, Lazard

Average annual growth in new renewable energy supply by scenario, 2015-50
%



Source: Equinor

Renewable energy

Hydro electricity: a mature technology

Renewable sources account for rapidly growing shares of power generation in ever larger parts of the world. Globally, running water is still the dominant renewable source of electricity in terms of generation, but the sum of solar PV and wind power could, according to some projections, grow past hydro power already in the late 2020s or early 2030s. Global hydro power generation increased by an average of 2.4% per year between 1990 and 2015. Growth was highly uneven across countries and regions. Whereas Chinese generation increased by more than 9% per year, OECD area generation was up by a mere 0.6% per year.

The world has an abundance of technical hydro power generation potential. One recent study suggests a resource-based scope for increasing generation from its 2015 level of 3,900 TWh to 52,000 TWh. Hydro also has the advantage of being dispatchable, i.e., adjustable to accommodate fluctuations in demand. In a global warming conscious world, hydro should therefore have a bright future. However, hydro generation has levelled out, and is expected to play only a supporting role in reducing greenhouse gas emissions, for three main reasons; the best resources close to demand centres have in many cases already been developed, hydro generation costs have not declined in line with other renewable generation costs, and finally, large-scale hydro power projects have become increasingly controversial due to their social and environmental impact.

In cost terms, large-scale hydro compares well. But whereas the costs of solar PV and wind have declined in recent years, those of hydro have gone up, eroding its lead on the competition. This development will likely continue. Learning curve analysis suggests that solar PV and offshore wind have significant remaining potential for cost reductions. Hydro is a mature technology with little such potential left in it. On the contrary, as hydro developers are forced towards lower quality resources further away from demand centres, unit costs may increase further.

Hydro power will not disappear. Existing facilities will not be abandoned, and hydro's strongpoints suggest that more facilities will be built. In *Reform*, hydro generation increases by an average of 1.4% between 2015 and 2050, with Southeast Asia and India seeing the highest growth rates. Hydro still loses global power market share. In *Renewal*, hydro increases only marginally faster, by 1.5% per year, but since total electricity demand growth is dampened by energy efficiency improvements, this means hydro gains market share. In *Rivalry*, hydro increases by 1.1% per year and loses some market share, but less than in *Reform*.

Wind and solar power: rapid growth

Wind and solar PV power have been the renewable energy growth stories "par excellence" in recent years. Global solar PV capacity was up from 14.6 GW in 2008 to 386 GW in 2017, implying an average growth of 44% per year. Nearly two thirds of total capacity is utility scale, with the rest made up of factory, office and residential rooftop panels. Global onshore wind capacity increased 116 GW in 2008 to 495 GW in 2017, implying an average growth of 18% per year. Global offshore wind is still, at 19.3 GW or 4% of total wind capacity, a small

Metals and minerals in the energy transition

With high expected growth in electricity shares, storage requirements and new renewable electricity, attention has been provided to the availability and sustainable production of necessary metals and minerals. Most published studies concentrate on incremental wind, solar and battery storage capacity to estimate increasing demand for metals and minerals; so does the World Bank in its 2017 "The Growing Role of Minerals and Metals for a Low Carbon Future" report. This choice is obvious, although it is recognised that other sectors and technologies will also contribute to demand for minerals, as new technologies become available.

Research shows that technologies critical to the energy transition are more material intensive than conventional fossil fuel based energy supply systems. It seems also obvious that 2° scenarios, like *Renewal*, trigger higher incremental demand than less strict climate scenarios. In wind power generation, analysis results show a 2.5-fold increase in the 2° scenario compared to a 6° trajectory by 2050, in terms of demand for aluminium, chromium, copper, iron, lead, manganese, molybdenum, neodymium, nickel and zinc. In solar power generation, a 3-fold increase is reported for all metals and minerals in the 2° scenario compared to the 6° trajectory, with indium and silver being new additions to the list. Such high incremental demand figures for some metals may seem intimidating, but compared to total demand for some of the same metals, they are relatively small. E.g., in the case of copper, other sectors than energy consume 85% of all copper. Automotive, grid-scale and decentralised energy storage through batteries shows the highest sensitivity to a 2° scenario; demand for relevant minerals including cobalt, lithium, and nickel can be as much as 13 times higher than in the 6° scenario.

The quadrupling of the price of lithium carbonate over the last three years and expectations of high incremental demand for battery components, underline the supply risk. BNEF forecasts some cobalt, lithium and nickel deficit by the 2020s, but also pinpoints that more mines and facilities will respond to price signals, and attract necessary investment. Current reserves to production ratio for lithium is estimated at 430 years. For cobalt, and nickel the ratio is only 60 and 30 years, respectively, and their scarcity could challenge EV adoption rates. However, recycling is expected to be encouraged and new technologies are emerging. It also needs to be noted that the overall impact on battery costs of even large price changes in minerals is small. Finally, it must be recognised that mineral resources are key to economic development in 81 countries, out of which 70% struggle with poverty, in Africa, Latin America and Asia. High dependence on cobalt production in the Democratic Republic of Congo is the best example of this trend and has already led to some substitution away from cobalt chemistries. This reality calls for local and international policy attention towards good governance in the sustainable development of these resources.

sibling in the family of renewable power technologies, but a growth of 33% per year between 2008 and 2017 suggests a potential for significant market capture. Solar PV and wind generation capacity account for 5.1% and 8.5%, respectively in global total generation capacity as of 2017.

The reasons for the rapid growth in wind and solar PV generation since 2010 are government support and falling costs. They are highly interconnected in that the support has stimulated technology development, allowed for economies of scale, attracted more actors to the playing field and boosted competition. Now governments are reassessing, modifying and in some cases winding down support arrangements. The feed-in tariffs, tax breaks and other incentives that are available have become fiscally burdensome, and in some cases created electricity supply-demand imbalances, calling for power system optimisation and better regulation, rather than continued propped-up growth in zero marginal cost electricity supply. The consequences for wind and solar PV remain to be seen, but few observers envisage long-term set-backs for either technology, rather a natural moderation of growth rates.

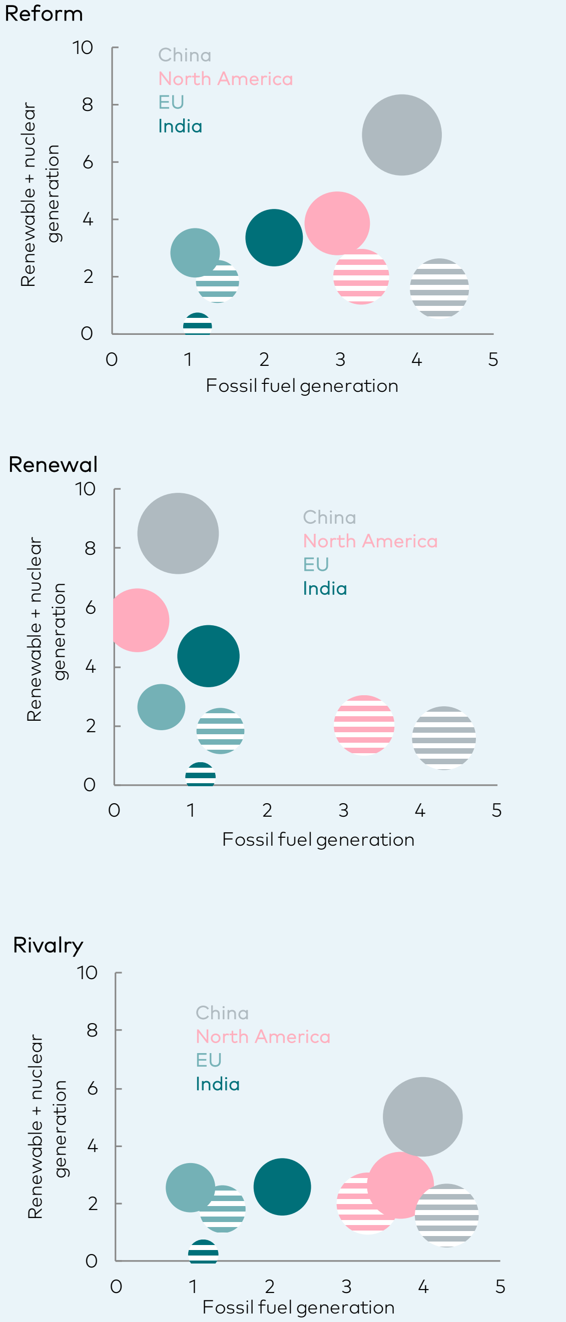
The standard metric for comparing power generation costs is the so-called levelized cost of electricity (LCOE), which means the sum of investment costs, operating and maintenance costs, fuel and carbon costs (if relevant) and financial costs over the lifetime of a power plant, divided by anticipated output and discounted to present day values. Competitiveness in LCOE terms is not the only variable relevant for investment decisions – there are cost items that are not captured by the LCOE, and some technologies have more flexibility to generate when prices are favourable than others. Relative LCOE developments are nevertheless key signposts to the future shape of the power sector.

The wind and solar PV LCOE reductions over the last decade or so, and expectations of more of the same, have turned outlooks for power sector decarbonisation even in the most fossil fuel reliant regions, which used to be outlier scenarios, into baseline forecasts.

LCOE estimates vary significantly, depending on underlying assumptions, and are typically presented as ranges to account for differences in national and site-specific cost drivers, but most recent overviews show well-located onshore wind power plants as the cheapest of all options, and utility-scale solar PV plants to be competitive with most new coal and gas plants. And whereas the capital and operational costs of fossil fuels are flat, and those of nuclear and large-scale hydro plants are up, those of new renewable electricity are still pointing down. The pace of cost declines has abated, but the learning curve rule of thumb, saying that costs drop by 20% for every doubling of capacity, suggests possibilities of additional declines in double digit territory, especially for solar PV.

Recent power auction prices convey the same message. Bid rounds have been won at prices below recent published average LCOE estimates, suggesting expectations of favourable electricity price, carbon price and/or cost developments between now and the time of commissioning, and probably that bidders consider they have exit

Fossil fuel generation vs zero carbon power generation by region
Thousand TWh, 2015 = stripes, 2050 = solid



Source: Equinor
Note: The size of the bubbles indicates the levels of total power generation in the individual countries/regions in the individual years, relative to each other.

options if these expectations are not met. Renewable power players' growing preparedness to take on "merchant" risk has been visible in recent offshore wind bid rounds. Offshore wind typically enjoys more stable wind conditions allowing for higher capacity factors, and represents an answer to the growing "Not In My Backyard" reservations against onshore wind.

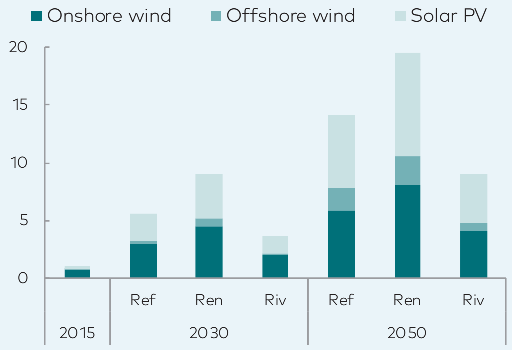
On a different note, the electricity price impacts of increasing shares of electricity available at zero marginal costs, in total supply, have prompted calls for regulatory reform and new power sector business models. There are fears of increased price volatility around depressed levels dis-incentivising investments in services that are crucial for uninterrupted supply. Unless the current mis-match between price signals, power plant dispatching principles and system long-term needs are handled, it could conceivably derail or at least slow the ongoing de-carbonization of electricity supply. In *Reform*, wind and solar PV power generation capacity increases to about 50% of total global power generation capacity by 2050. In *Renewal*, the share goes to 67% by 2050, and in *Rivalry* it is 40% by the end of the scenario period. The shares of wind and solar PV in actual power generation increases less due to remaining capacity factor constraints – to 32% in *Reform*, 49% in *Renewal* and 24% in *Rivalry*. In all scenarios solar PV is the biggest new renewable energy source by 2050, with shares varying from 23% in *Rivalry* to 38% in *Renewal*. The offshore wind share of total wind capacity increases from less than 3% in 2015 to 17-18% in both *Reform* and *Renewal* and 11% in *Rivalry*.

Modern biomass: unclear growth potential

Although solar and wind power are the most dynamic of the new renewable energy industries, biomass could play important roles both in energy end use and in power and heat generation going forward. Globally, biomass in 2015 made up some 10% of TPED, but as much as 26% of the buildings sector's TFC, reflecting developing country households' continued reliance on fuelwood and organic residue. Traditional biomass use is hoped to drop as it is unsustainable from all possible angles, but modern biomass use, which is seen to entail no net CO_2 emissions because of the balance between the CO_2 released in the incineration phase and the CO_2 stored in the prior growth phase, is supported. There are supply side and cost and competitiveness hurdles, but work is ongoing to lower them. Countries with many households relying on traditional biomass, and with millions of new households entering the market each year, face however major challenges in modernising existing energy demand and satisfying incremental energy demand in the same go.

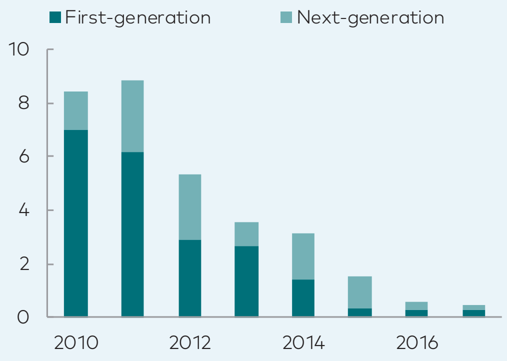
Opinions vary on the outlook for liquid biofuels in transportation. IEA projects growth rates for bio based gasoline, diesel and fuel oil substitutes between 4 and 7% per year depending on scenario. Outlooks tailored to the 2° target suggest the fastest growth. In IEA's Sustainable Development scenario, the share of biofuels in global transport sector fuel use goes to 14.5% by 2040. Others are less optimistic, pointing to the scepticism to 1st generation modern biofuels because of their land and water requirements and noting that the economics of 2nd generation, non-food crops and organic waste based biofuels are challenging. 3rd generation algae-based

Global wind and solar PV generation by scenario
Thousand TWh



Source: IEA (history), Equinor (projections)

Global biofuels investments
USD bn



Source: BNEF

World geothermal power plants

Source: Geothermal Education Office

biofuels remain experimental with no guarantees of commercial viability, and will in any event take time to scale up.

Biofuels used to be talked about mainly as an option for road transportation. This discussion has been partly silenced by the EV boom. There is still interest in bio-diesel for heavy-duty vehicles, but it has become clear that the sub-sectors in most critical need of biofuels to deliver on emission reductions are aviation and shipping. The world's airlines have put out a decarbonisation vision with a biofuels component exceeding current supply with a wide margin. Unfortunately for this and similar visions, investor interest in biofuels has declined and is currently at a fraction of where it was 8-10 years ago. It could recover, but only in response to strong price, cost or regulatory signals, and for the moment there are no signs of either.

Biomass is also an option for power and heat supply. Bio based power generation capacity in 2015 made up about 2% of global power generation capacity. This share is seen to increase, but only marginally on a global scale. Bio power is flexible, which is an advantage, but generation costs have not declined in recent years and are now on balance above those of onshore wind and solar PV generation. Considering the biomass supply uncertainties, there is no reason to expect this relationship to reverse. On a more positive note, some observers are optimistic about the direct use of biomass in industrial and transformation sector heat generation.

In *Reform*, global bio energy supply and demand increases by an average of 1.2% per year between 2015 and 2050. The bio energy share of TPED edges up from 9.7% in 2015 to 11.6% by 2050. Residential bio demand linked to the continued prevalence of primitive stoves in parts of the world declines. While road transport biofuels demand increases by less than 1% per year, non-road transport biofuels demand is up by 16% per year, though from a small starting point. In *Renewal*, bio energy increases by an average of 1.4% per year, translating into an increase in the bio share of global TPED to almost 17% by 2050. Biofuels are marginalised in road transportation – demand is almost 70% down as LDVs go all electric. In *Rivalry*, bio energy increases by slightly less than 1% per year, leaving the bio share of TPED unchanged at around 9.7%.

Geothermal power generation capacity totalled in 2017 around 13 GW corresponding to 0.6% of global renewable power capacity. A small number of countries – the US, Mexico, Indonesia, the Philippines, New Zealand, Turkey, Iceland, Italy and Kenya – dominate this comparatively small industry which has seen little growth in recent years. It does have potential in certain places, but requires a nearness to geothermal resources that suggests limited competitiveness in parts of the world. Technological progress may however widen the scope also for this option. The world's barely 5 GW of solar thermal power generation capacity makes up only 0.2% of total renewable capacity. Solar thermal power remains an expensive option but is attractive for its storability and is seen to have significant long-term potential in sunny places.

Financing of renewable energy

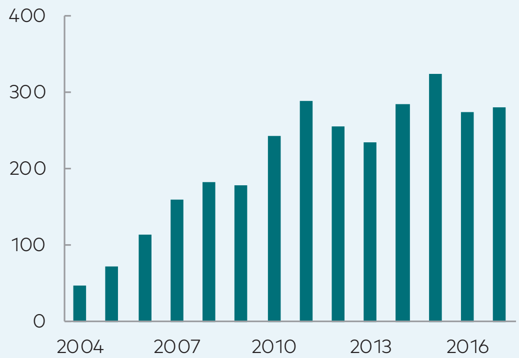
The capital allocated to the global renewable energy space increased considerably after the global financial crisis and has continued to receive a substantial inflow of funds thereafter. Total global investments into the sector went above USD 250 bn in 2011, and has since remained around this level.

With technology development, the costs of wind and solar coming down, and the increasing growth of renewables deployment, the sector initially became an attractive sector primarily for industrial developers. At the same time, low interest rates, narrowing credit spreads and quantitative easing in the aftermath of the financial crisis in 2008 made the sector increasingly attractive for financial investors. The result was an influx of financing and cheap capital to renewable energy.

Large industrials, small-cap developers, commercial banks, institutional investors and private entities have all increased capital allocations to the sector over the last decade. The types of instruments have also changed, with green bonds, project debt and funds having emerged as increasingly important sources of cheap capital. The leveraged renewables growth model (like YieldCos and other capital recycle models) also benefitted from the situation in global capital markets. In addition to the decreasing technology costs, this inflow of cheap capital has contributed further to the competitiveness of the sector.

If central banks continue to tighten monetary policy, this may represent a challenge for continued growth in the renewable energy sector. Commercial banks, institutional investors and project developers that have used highly leveraged growth models, could now face excessive exposure to financial conditions. Increasing interest rates would also present a challenge for the inflow of cheap capital to future debt-funded growth. In this respect, a changing monetary policy environment could also present a challenge to fund and meet the world's targets on emission reductions in the energy sector.

Annual renewable energy investments
USD bn



Source: UN, BNEF

Offshore wind from frontier to mature technology

Offshore wind power generation was until a few years ago considered an option for the longer term only. Different concepts were vying for attention, precluding standardisation and economies of scale. Offshore wind compared miserably in cost terms to the leading new renewable power generation technologies. This trend is changing. Although still more expensive than onshore wind and solar PV, and likely to remain a small sibling in the family of renewables technologies for some time, offshore wind is catching up.

According to IRENA, global offshore wind capacity was 19.3 GW by the end of 2017, with Northwest Europe accounting for 85% of the total and China for most of the remainder. Global capacity has increased by 34% per year since 2008. BNEF projects a 15% per year growth in capacity to a total of 115 GW by 2030. IRENA suggests in its Global Energy Transformation Roadmap to 2050 a global capacity of 521 GW by 2050. *Renewal* goes further, suggesting a global capacity of almost 690 GW this year. The wind industry's own economic resource estimates arrive at even bigger numbers, between 607 GW and 1,350 GW for Europe alone, though such estimates should not be confused with projections, as they take neither the demand side nor the competition, nor policy, fully into account.

Offshore wind LCOE estimates vary, with the US Department of Energy (DoE) and Lazard suggesting in their latest overviews USD 117 and USD 113 per MWh for the US, respectively. BNEF indicates a range of USD 100-175/MWh for Germany and the UK and a range of USD 74-100/GWh for China, and Energy Intelligence estimates a global average of USD 133/MWh. At the same time, in 2017 European offshore wind projects were awarded to bidders requiring expected market prices only and apparently operating on LCOEs in the USD 50-60/MWh range, barely above the range suggested by most sources for onshore wind and solar PV.

The apparent disconnect between recent offshore wind cost estimates and recent auction prices may be due to the bidders banking on further cost declines and electricity price increases between now and the time of commissioning. It is also possible, however, that costs are already below the levels assumed by forecasters mentioned above. Aurora Energy Research, a consultancy, points out that increased turbine sizes, innovation in operating and maintenance strategies, stream-lined supply chains and better financing arrangements have depressed offshore wind costs exceptionally quickly.

Aurora nevertheless believes that offshore wind will require a price guarantee that may not need to represent subsidisation, but will "de-risk" projects, to prosper before 2030. Aurora also considers that offshore wind should be included among the technologies allowed to participate in the capacity market and provide balancing and ancillary services. Thus, while variable energy normally is considered to be part of the balancing problem, offshore wind may also be part of the solution, thanks to its short ramp-up and ramp-down times, and "base-load characteristics" of more stable wind conditions offshore than onshore.

Hydrogen economy on the move?

Today approximately 60 mn tons of hydrogen are produced, which on an energy basis equals two times current Norwegian natural gas exports. As much as 95% of the hydrogen is directly used in industrial processes, such as producing ammonia and methanol, and used in refineries. Due to the nature of hydrogen it can provide the same energy flexibility and resilience as natural gas and other fossils fuels provide today, but without CO_2 emissions when it is used in these different processes. It could therefore play an important role in the transition towards a low-carbon society.

As a cross-sectoral energy carrier and fuel, hydrogen can play many different roles: 1) enable large-scale renewable energy integration, low carbon power generation and CCUS, 2) distribute energy across sectors and regions, 3) act as a buffer to increase energy system resilience, 4) decarbonise transportation, 5) decarbonise industrial energy use, 6) decarbonise building heat and power and 7) serve as feedstock for industry.

One of the key strengths of hydrogen is that it can be produced from almost all sources containing hydrogen atoms, for instance water, plastics, biomass and fossil fuels, and it can be combined with renewable energy. This enables regions and countries to use the method that provides most benefit for the local economy, and still meet the ambition of reducing CO_2 emissions. There are however two technologies that are expected to play the largest role in low carbon hydrogen production: water electrolysis and natural gas reforming with CCUS. Water electrolysis is based on splitting water into hydrogen and oxygen by way of electricity. When it is produced from renewable power it is called green hydrogen. Less than 5% of current global hydrogen production is based on electrolysis, primarily due to high electricity cost and efficiency losses in the process. 75% of total global hydrogen production today comes from natural gas (methane) reforming in a process where high-temperature steam is used to produce hydrogen. When adopting CCUS to natural gas based hydrogen production, it is called blue or clean hydrogen. Compared to electrolysis, reforming can be designed for much larger capacities and has higher energy efficiency. It is currently also seen as being more cost effective. On the other hand, the potential for cost reductions in electrolysis is probably higher and if it is scaled up and combined with cheap renewable power, green hydrogen can likely compete with clean hydrogen on price. Producing hydrogen from electricity will always be a detour and entail efficiency losses compared to using the electricity directly if the hydrogen is used to produce electricity again. What hydrogen in this case offers is a means of storing the electricity and an alternative to transport the electricity.

Hydrogen value chains come in various shapes and forms, some involve the direct use of hydrogen (power-to-gas), while others build on the conversion of hydrogen to fuel cells (power-to-power). Another variant is turning hydrogen into ammonia. Ammonia is a well-known compound for fertiliser production and can already today be transported as liquid in large volumes over long distances. Ammonia can be stored in large tanks and cracked back to hydrogen. The ammonia value chain is more capital intensive and requires more energy compared to hydrogen. However, due to transport flexibility, ammonia can be produced at locations with access to cheap renewables or natural gas, which makes ammonia an option with a similar role as LNG provides today in the gas market – just carbon free.

Several recent developments and initiatives are indicating that the momentum behind hydrogen may be picking up. In 2017, the Hydrogen Council released the report: Hydrogen Scaling Up – A Sustainable Pathway for the Global Energy Transition. The report showcases the potential of hydrogen to reduce CO_2 emissions and create economic growth by 2050. They expect that hydrogen could contribute to 18% of final energy demand and reduce CO_2 by 6 Gt per year equal to almost 20% of global CO_2 emissions. Hydrogen demand would increase by 10 times by 2050 compared to 2015.

Japan has been at the forefront in the move towards a hydrogen economy and in December 2017 the country launched its hydrogen vision for 2030 called Basic Strategy for Hydrogen. Some of the main targets are: 1) establishing a commercial-scale international hydrogen supply chain of 300,000 tons of hydrogen, 2) introducing 80,000 fuel cell vehicles (FCV) and 3) deploying 5.3 mn residential fuel cell units.

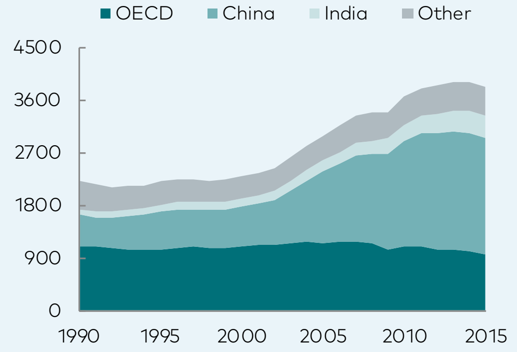
In the transportation sector, FCVs have been through a dramatic development in recent years, and the first cars have been sold commercially. The signs of hydrogen refuelling infrastructure for road transport are starting to materialise. Several hydrogen mobility initiatives on a global level have been started up. In Germany, car manufacturers, gas companies, and fuel retailers have committed to build 100 stations by the end of 2019, independent of the number of fuel cell cars sold in the country. The aim is to build another 300 by 2030 to provide full coverage of the country. Deployment of FCVs is however lagging far behind EVs and using batteries to store electricity has much lower losses compared to the combination of hydrogen (produced by electrolysis) and fuel cells.

In the UK, the H21 Leeds City Gate by Northern Gas Network (NGN) is aiming to demonstrate that a full conversion of the gas network from natural gas to hydrogen is feasible. For the UK, a full conversion from natural gas to hydrogen would equal 20% of current global hydrogen production. In the EU, the current gas distribution system consists of 1,600,000 km of pipelines, and is thus potentially an important asset for the future development of a hydrogen distribution system.

There are also initiatives considering converting gas power plants to run on hydrogen. As renewable power grows, the need for clean dispatchable power will increase and using green or clean hydrogen together with hydrogen storage provides such an opportunity. Despite the wide range of potential applications and ongoing initiatives it is important to keep in mind that the use of hydrogen outside of its traditional industrial applications is still in its infancy and there are several hurdles to be passed. Hydrogen will continue to rely on strong policy support and incentives and costs will have to come down significantly before hydrogen becomes an affordable, large-scale solution.

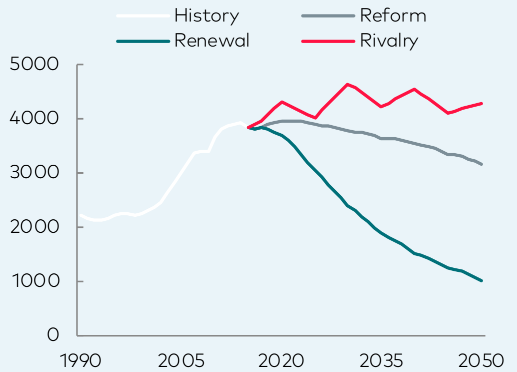
Other energy carriers

Coal demand by region
Mtoe



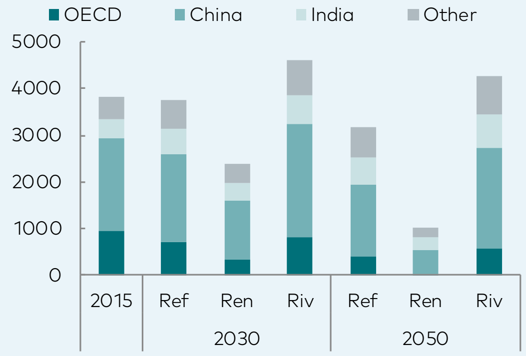
Source: IEA

Global coal demand by scenario
Mtoe



Source: IEA (history), Equinor (projections)

Coal demand by region and scenario
Mtoe



Source: IEA (history), Equinor (projections)

The coal market

Despite its reputation as the energy source with the most negative environmental impact, coal still covers over one quarter of global TPED. Global coal demand is roughly twice as high as in 2000. After a slight decline in global coal demand in 2015 and 2016, preliminary numbers for 2017 indicate an increase in coal use. The main driver is the increased power demand in Asia, sourced by a continued build-up of coal based power generation capacity. Seaborn demand in 2017 is estimated to have increased by around 5% to roughly 950 mn tons, with higher imports by China, South Korea and some Southeast Asian countries. There is a significant difference between the OECD countries on the one hand, that have experienced a continued decline in coal demand over the last 10 years, and increased use of coal in Asia on the other. The moderate reduction in OECD demand has been dwarfed and overcompensated by the enormous increase in China's demand, so that OECD countries' share of global demand has declined by 24%-points after 2000, while China's share has increased by 22%-points during the same time period.

China and India are expected to keep their dominance over the global coal market; currently they have a combined share of demand and production of more than 60% and 50% respectively. However, different economic and environmental policies will likely lead to different coal demand and import paths in the two countries. China's efforts to curb the negative environmental impact of coal use, and subsequent efforts to regulate domestic production and prices, will likely lead to reduced need for imported coal. However, the Chinese regulatory actions that will drive much of the market development can be difficult to project, and create volatility in import volumes and prices, with subsequent impact on demand in other markets. India's priority and challenge, on the other hand, is to meet increasing domestic coal demand, driven by a significant increase in electricity demand and industrial production. Despite efforts to increase domestic coal production, India is not expected to keep up with the demand increase, leading to higher imports.

In Europe, where several countries have announced policies that lead to declining coal burn, energy demand is expected to move away from coal.

On the supply side, China will continue as the largest global supplier. However, the largest exporters, Indonesia and Australia, are likely to solidify their position, given increased import requirements in India and other Asian countries. Russia, the third largest exporter, might see its position declining with lower European import needs. In the US, high-sulphur coal with heavy price discounts has started to make inroads into the European and Indian markets in particular.

The uncertainty in the global coal market development going forward is illustrated by the large differences in outcome between the three scenarios. In *Reform*, global coal demand peaks in the early 2020s and slowly declines to around 3.2 bn toe in 2050, from the current level of around 3.8 bn toe. *Rivalry* indicates a continued, however volatile increase to around 4.3 bn toe in 2050. In the low emission scenario, *Renewal*, coal use is declining significantly from now towards 2050, to only 1 bn toe.

Coal and nuclear in China and India

The possibilities and pathways to meeting the global CO_2 emissions reduction goals are dependent on the developments in China and India, since these two countries together currently are responsible for 36% of global CO_2 emissions, of which more than 40% is due to coal use in electricity generation. The build-up of generation capacities both in China and India is driven by an increasing demand for electricity in India, one fifth of the growing population still lacks access to electricity, and are dependent on old-fashion biomass. China's goal is to change the electricity mix to limit coal use and reduce emissions. Nuclear capacity could help in meeting the need for low-emission electricity going forward, and thereby help limiting carbon emissions. However, nuclear has its own challenges, for instance radioactive waste. Currently, coal is accounting for 64% and 73% of the power generation in China and India, respectively. With the carbon reduction pledges given by both countries in the Paris accord, China has pledged to increase the share of energy consumption from non-fossil sources to 20%, and India to 40%, by 2030. One of the realistic alternatives of meeting the growing electricity demand going forward is nuclear based power generation. Initiatives to limit coal use are visible both in China and India. The initiatives towards a lower coal share in China are anchored in the 13th Five-Year Plan. They involve stricter control of total capacity and emissions, and have resulted in cancelation and postponement of around 150 GW of new coal capacity until at least 2020, with retirement of older plants ongoing. In India, authorities have proposed closing nearly 50 GW of old coal capacity within 10 years, and finishing the 50 GW new coal plants already under construction.

Nuclear currently accounts for slightly below 2% of power generation capacity in China, and somewhat less in India. However, this share is expected to increase as China is responsible for more than one-third of the power plants under construction globally. Nuclear power generation in China is expected to more than quadruple towards 2050 in *Reform*, and reach a share of almost 10%. China is expected to overtake the US as the largest nuclear nation by 2030. Of India's 22 operating reactors, some are very old and partially disabled, and some are recommended to be permanently closed by the original supplier, representing a security risk. The Indian National Energy Plan calls for the anticipated doubling in electricity demand over the next decade, and in 2017 the cabinet approved 10 new pressurised heavy water reactors. In *Reform, we* anticipate a 5% nuclear share of their total power capacity in 2050. However, despite the investments in non-fossil power generation, the power and heat sector's CO_2 emissions in *Reform* from China and India in 2050 are still around 88% of today's emissions. The numbers for *Renewal* and *Rivalry* are 22% and 91%, respectively.

Nuclear power

The global nuclear industry has been in stagnation the last 10-15 years, and global electricity generation from nuclear power plants has declined from around 2,800 TWh in 2006 to around 2,650 TWh today, accounting for around 11% of the world's electricity generation, covering slightly below 2% total global energy demand.

This stagnant position for the nuclear industry has, to a large extent, been driven by safety concerns following the earthquake off the coast of Japan and the subsequent accident at the Fukushima nuclear plant in March 2011. This is not unlike the industry stagnation in the 1990s, which was due both to the Three Mile Island (1979) and Chernobyl (1986) events, and to delays and cost overruns at different nuclear projects. Lower fossil fuel prices also played a role.

Even though the Fukushima accident resulted in no direct deaths, the radioactive contamination lead to the evacuation of many thousand inhabitants. Most countries announced safety reviews of the reactors and revisions of their plans in the aftermath of the accident. Some countries (including Germany and Italy) have decided to eventually phase out nuclear power or abandon their nuclear projects.

However, currently we see a slight revival of investments in nuclear generation capacity, driven to a large extent by government pledges to reduce CO_2 emissions, in addition to energy security concerns. The nuclear power capacity worldwide is increasing, with 57 power reactors under construction by the end of 2017, in addition to the around 440 reactors now operating in 30 countries. All in all, about 160 power reactors are on order or planned, and over 300 are proposed. A major challenge for most projects is to keep costs under control. Nuclear power construction costs have been difficult to predict, with large variation in cost trends and across different countries, even with similar reactor technologies.

There are major uncertainties around future nuclear capacity. One is the possibility of lifetime extensions, where some countries (for instance France) are contemplating to increase reactor lifetimes out to 60 years from the original design life of 25 to 40 years, involving significant expenditure for maintenance and upgrading. Another is the strength of political and regulatory opposition to nuclear power, especially in the OECD area, that has led to reactor closures and shelving of construction plans.

These uncertainties are illustrated in our different scenarios. *Renewal* is characterised by an increased use of nuclear power generation by 1.8% per year from today's level to 4,750 TWh towards 2050. As with other energy carriers, most of this increase is expected in China and India, and with growth in other parts of Asia, the Middle East and in Africa. North America is expected to keep current nuclear levels, while Europe is expected to decrease nuclear use with on average 1.5% per year towards 2050.

An increase of nuclear power generation globally is also projected in the other two scenarios, by around 1.0% per year on average in *Reform*, and 0.5% in *Rivalry*.

Data appendix

Global GDP	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion 2010-USD		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	75.1	114.3	109.1	106.1	182.8	188.4	145.9	2.6	2.7	1.9

Energy intensity	2015	2030			2050			2015-50, growth per year (%), CAGR		
Indexed 2015, %		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
	100	77	72	87	51	38	67	-1.9	-2.8	-1.1

Global energy demand	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total primary energy demand	**13.6**	**16.1**	**14.2**	**16.7**	**17.1**	**12.8**	**17.7**	**0.6**	**-0.2**	**0.7**
Coal	3.8	3.8	2.4	4.6	3.2	1.0	4.3	-0.5	-3.7	0.3
Oil	4.3	5.1	4.3	5.3	4.8	2.8	5.7	0.3	-1.3	0.8
Gas	2.9	3.7	3.3	3.6	4.0	2.7	3.8	0.8	-0.2	0.7
Nuclear	0.7	0.8	0.9	0.7	1.0	1.2	0.8	1.1	1.8	0.6
Hydro	0.3	0.4	0.4	0.4	0.5	0.6	0.5	1.4	1.5	1.1
Biomass	1.3	1.6	1.7	1.6	2.0	2.1	1.7	1.2	1.4	0.8
New renewables	0.2	0.7	1.1	0.5	1.6	2.4	1.0	6.2	7.4	4.6
Oil (mbd)	*94.8*	*111.0*	*93.7*	*115.4*	*104.6*	*59.1*	*122.2*			
Gas (Bcm)	*3,547*	*4,422*	*3,967*	*4,303*	*4,758*	*3,288*	*4,536*			

Global energy mix	2015	2030			2050		
Shares, %		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Coal	28.1	23.4	16.9	24.1	18.5	7.9	24.1
Oil	31.8	31.8	30.3	32.0	28.4	21.4	32.0
Gas	21.6	22.8	23.2	21.3	23.2	21.3	21.3
Nuclear	4.9	4.8	6.6	4.7	5.7	9.7	4.7
Hydro	2.5	2.6	3.1	2.8	3.1	4.4	2.8
Biomass	9.7	10.2	12.1	9.7	11.6	16.7	9.7
New renewables	1.4	4.3	7.8	5.5	9.4	18.6	5.5

CO_2 emissions	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion tons		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**32.1**	**34.5**	**25.8**	**38.5**	**31.1**	**12.6**	**38.0**	**-0.1**	**-2.6**	**0.5**
North America	6.1	5.5	4.1	5.8	4.0	1.1	5.1	-1.2	-4.7	-0.5
Other Americas	1.3	1.4	1.2	1.6	1.5	0.7	1.8	0.4	-1.8	1.0
European Union	3.4	2.9	2.1	3.1	2.1	0.7	2.6	-1.4	-4.5	-0.8
Other Europe	0.5	0.5	0.4	0.6	0.5	0.2	0.6	-0.3	-3.0	0.6
CIS	2.2	2.3	1.9	2.5	2.0	1.2	2.5	-0.3	-1.8	0.4
Industrial Asia Pacific	2.4	2.1	1.4	2.1	1.7	0.5	1.7	-1.1	-4.7	-0.9
South East Asia	1.3	1.9	1.5	2.3	2.3	1.1	3.0	1.8	-0.4	2.5
Other Asia Pacific	0.6	0.7	0.5	0.6	0.7	0.3	0.6	0.4	-1.6	0.4
China	9.2	9.8	7.0	12.1	8.2	3.0	11.2	-0.3	-3.1	0.6
India	2.1	3.2	2.3	3.5	3.7	1.7	4.4	1.6	-0.6	2.1
Middle East	1.9	2.5	2.1	2.4	2.6	1.2	2.5	0.9	-1.3	0.7
Africa	1.2	1.7	1.4	1.6	1.9	1.0	1.9	1.4	-0.4	1.3
World CO_2 stripped by CCUS	0.03	0.12	0.47	0.04	0.35	1.52	0.04			

LDV sales	2015	2030			2050			2015-50, growth per year (%), CAGR		
Millions		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total sales	**86.6**	**112.9**	**102.7**	**112.9**	**106.0**	**78.6**	**117.0**	**0.6**	**-0.3**	**0.9**
Gasoline	63.0	59.4	35.1	74.1	26.1	0.0	60.6	-2.5	-	-0.1
Diesel	17.3	5.1	0.0	5.1	0.7	0.0	0.7	-8.8	-	-8.7
Hybrids	2.0	11.1	9.0	10.8	13.0	0.0	14.9	5.5	-	5.9
PHEV	0.2	14.8	15.8	10.6	20.7	0.4	17.3	14.7	2.3	14.1
EV	0.3	16.2	40.6	6.0	41.8	78.3	19.3	15.1	17.1	12.5
Others	3.9	6.3	2.2	6.3	3.8	0.0	4.3	-0.1	-	0.3

Fuel mix in LDV transport	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**1.11**	**1.31**	**1.17**	**1.36**	**1.08**	**0.32**	**1.40**	**-0.1**	**-3.5**	**0.7**
Oil	1.04	1.13	0.99	1.19	0.74	0.10	1.10	-1.0	-6.4	0.2
Gas	0.02	0.03	0.02	0.03	0.02	0.00	0.02	0.3	-8.3	0.5
Biofuels	0.05	0.09	0.08	0.10	0.06	0.00	0.09	0.4	-8.9	1.5
Electricity	0.00	0.06	0.08	0.04	0.26	0.22	0.18	19.8	19.2	18.6
Oil (mbd)	23.2	25.2	22.0	26.5	16.2	2.2	24.2			
Electricity (thousand TWh)	0.0	0.7	0.9	0.4	3.0	2.5	2.1			

Fuel mix in other transport	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**1.59**	**2.05**	**1.73**	**1.99**	**2.38**	**1.42**	**2.24**	**1.2**	**-0.3**	**1.0**
Oil	1.45	1.80	1.46	1.78	1.88	0.91	1.91	0.7	-1.3	0.8
Gas	0.08	0.11	0.10	0.10	0.14	0.12	0.13	1.6	1.3	1.4
Biofuels	0.02	0.06	0.07	0.05	0.11	0.10	0.07	4.9	4.4	3.5
Electricity	0.04	0.09	0.10	0.06	0.25	0.29	0.13	5.7	6.1	3.8
Oil (mbd)	31.3	38.5	31.3	38.2	40.0	19.4	40.9			

Fuel mix, power and heat	2015	2030			2050			2015-50, growth per year (%), CAGR		
Thousand TWh		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total generation	**28.0**	**36.8**	**35.3**	**36.0**	**47.9**	**43.3**	**41.6**	**1.5**	**1.3**	**1.1**
Coal	11.2	11.2	6.2	13.2	9.7	2.5	10.9	-0.4	-4.2	-0.1
Oil	1.2	0.9	0.6	0.9	0.5	0.1	0.5	-2.5	-6.3	-2.2
Gas	7.1	9.5	8.5	9.1	10.6	5.3	10.2	1.1	-0.8	1.0
Nuclear	2.6	3.0	3.6	2.9	3.8	4.8	3.2	1.1	1.8	0.6
Hydro	3.9	4.9	5.2	4.7	6.2	6.6	5.7	1.4	1.5	1.1
Biomass	0.8	1.2	1.5	1.0	1.8	2.5	1.4	2.5	3.3	1.7
Wind	0.8	3.2	5.2	2.2	7.8	10.6	4.8	6.6	7.5	5.1
Solar	0.3	2.3	3.8	1.5	6.4	9.0	4.2	9.6	10.7	8.3
Geothermal, others	0.2	0.5	0.7	0.4	1.1	1.8	0.7	4.9	6.4	3.4

Fuel mix other uses	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**5.80**	**6.76**	**5.99**	**7.31**	**7.15**	**5.75**	**8.11**	**0.6**	**0.0**	**1.0**
Coal	1.46	1.50	1.14	1.97	1.35	0.53	2.25	-0.2	-2.9	1.2
Oil	1.58	1.98	1.73	2.13	2.14	1.72	2.53	0.9	0.2	1.4
Gas	1.64	2.00	1.81	1.97	2.20	1.82	2.10	0.9	0.3	0.7
Biomass	1.08	1.19	1.18	1.18	1.28	1.35	1.17	0.5	0.6	0.2
New renewables	0.04	0.08	0.13	0.06	0.17	0.33	0.06	4.4	6.4	1.4

Global oil product mix	2015	2030			2050		
Shares, %		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Residual fuel oil	7.4	5.8	5.5	6.0	5.8	5.4	5.4
Gasoil	28.9	26.9	26.0	27.6	24.7	20.8	26.8
Gasoline	26.3	26.5	28.0	26.8	20.1	9.5	24.4
Jet/Kero	7.4	7.8	7.4	7.5	11.5	10.4	8.4
Naptha	6.6	7.6	8.3	7.2	9.9	15.2	8.2
NGL/LNG	11.5	14.3	13.8	13.5	16.5	20.9	14.9
Other products	12.0	11.1	11.0	11.4	11.5	17.9	12.0

Regional energy demand

North America	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**2.69**	**2.72**	**2.36**	**2.76**	**2.37**	**1.58**	**2.58**	**-0.4**	**-1.5**	**-0.1**
Coal	0.41	0.27	0.13	0.30	0.10	0.00	0.18	-4.0	-13.7	-2.3
Oil	1.02	0.99	0.81	1.01	0.71	0.34	0.84	-1.0	-3.1	-0.6
Gas	0.80	0.90	0.78	0.96	0.96	0.38	1.10	0.5	-2.1	0.9
Nuclear	0.25	0.22	0.25	0.21	0.17	0.26	0.14	-1.0	0.1	-1.6
Hydro	0.06	0.07	0.07	0.06	0.07	0.08	0.07	0.7	0.9	0.4
Biomass	0.12	0.14	0.15	0.14	0.14	0.15	0.12	0.3	0.6	0.0
New renewables	0.04	0.13	0.17	0.09	0.23	0.37	0.13	5.3	6.7	3.7
Oil (mbd)	*24.2*	*23.5*	*19.2*	*23.9*	*16.6*	*8.1*	*19.9*			
Gas (Bcm)	*960*	*1,085*	*942*	*1,152*	*1,153*	*457*	*1,318*			

Other Americas	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**0.69**	**0.83**	**0.74**	**0.88**	**0.96**	**0.71**	**1.01**	**1.0**	**0.1**	**1.1**
Coal	0.03	0.03	0.02	0.06	0.02	0.01	0.06	-2.1	-3.9	1.5
Oil	0.31	0.36	0.30	0.38	0.36	0.16	0.43	0.4	-1.8	1.0
Gas	0.14	0.17	0.14	0.16	0.20	0.13	0.18	1.0	-0.3	0.6
Nuclear	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.9	0.5	0.7
Hydro	0.06	0.07	0.07	0.07	0.09	0.08	0.08	1.1	0.8	1.0
Biomass	0.13	0.17	0.17	0.18	0.20	0.18	0.19	1.2	0.9	1.1
New renewables	0.01	0.03	0.05	0.02	0.09	0.14	0.06	7.7	9.0	6.4
Oil (mbd)	*6.9*	*7.9*	*6.7*	*8.6*	*7.9*	*3.6*	*9.7*			
Gas (Bcm)	*168*	*197*	*163*	*192*	*238*	*149*	*209*			

European Union	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**1.67**	**1.52**	**1.36**	**1.57**	**1.34**	**0.98**	**1.41**	**-0.6**	**-1.5**	**-0.5**
Coal	0.26	0.20	0.09	0.24	0.14	0.00	0.16	-1.8	-12.0	-1.3
Oil	0.61	0.52	0.44	0.57	0.40	0.21	0.53	-1.2	-3.0	-0.4
Gas	0.36	0.35	0.33	0.33	0.32	0.19	0.29	-0.3	-1.8	-0.6
Nuclear	0.22	0.18	0.18	0.17	0.13	0.13	0.13	-1.5	-1.5	-1.6
Hydro	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.8	0.8	0.6
Biomass	0.15	0.15	0.17	0.15	0.15	0.18	0.15	0.0	0.5	0.0
New renewables	0.04	0.09	0.13	0.07	0.16	0.22	0.12	3.8	4.8	2.9
Oil (mbd)	*13.0*	*11.1*	*9.4*	*12.1*	*8.4*	*4.5*	*11.3*			
Gas (Bcm)	*433*	*424*	*395*	*403*	*392*	*229*	*352*			

Industrial Asia Pacific	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**0.96**	**0.93**	**0.80**	**0.94**	**0.88**	**0.58**	**0.91**	**-0.2**	**-1.4**	**-0.1**
Coal	0.24	0.19	0.09	0.20	0.13	0.02	0.14	-1.8	-7.1	-1.5
Oil	0.43	0.40	0.32	0.41	0.34	0.19	0.38	-0.7	-2.3	-0.4
Gas	0.18	0.20	0.18	0.18	0.20	0.07	0.15	0.2	-2.7	-0.7
Nuclear	0.05	0.05	0.11	0.09	0.06	0.10	0.13	0.6	2.4	3.0
Hydro	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.7	1.2	0.4
Biomass	0.02	0.04	0.04	0.03	0.05	0.06	0.04	2.3	2.7	1.7
New renewables	0.01	0.04	0.06	0.03	0.08	0.11	0.06	5.3	6.1	4.4
Oil (mbd)	*9.1*	*8.4*	*6.7*	*8.6*	*7.1*	*4.0*	*7.9*			
Gas (Bcm)	*213*	*231*	*203*	*202*	*227*	*83*	*169*			

China	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**3.02**	**3.90**	**3.39**	**4.33**	**4.05**	**3.16**	**4.43**	**0.8**	**0.1**	**1.1**
Coal	1.99	1.89	1.28	2.44	1.54	0.50	2.16	-0.7	-3.9	0.2
Oil	0.57	0.93	0.83	0.99	0.87	0.64	1.10	1.2	0.3	1.9
Gas	0.16	0.38	0.35	0.33	0.52	0.50	0.38	3.4	3.3	2.5
Nuclear	0.04	0.18	0.21	0.15	0.27	0.34	0.19	5.3	6.0	4.2
Hydro	0.10	0.12	0.13	0.12	0.15	0.16	0.14	1.2	1.4	1.2
Biomass	0.11	0.18	0.23	0.16	0.30	0.43	0.21	2.8	3.9	1.8
New renewables	0.05	0.22	0.34	0.14	0.41	0.59	0.24	6.4	7.6	4.9
Oil (mbd)	*11.9*	*19.5*	*17.5*	*20.8*	*18.1*	*13.4*	*23.1*			
Gas (Bcm)	*190*	*442*	*413*	*391*	*609*	*585*	*449*			

India	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**0.86**	**1.36**	**1.18**	**1.37**	**1.92**	**1.60**	**1.93**	**2.3**	**1.8**	**2.4**
Coal	0.38	0.54	0.38	0.60	0.60	0.28	0.73	1.3	-0.9	1.9
Oil	0.21	0.37	0.30	0.38	0.48	0.29	0.54	2.3	0.9	2.7
Gas	0.04	0.10	0.10	0.08	0.11	0.15	0.10	2.7	3.6	2.4
Nuclear	0.01	0.03	0.05	0.02	0.15	0.19	0.11	8.1	8.8	7.3
Hydro	0.01	0.02	0.03	0.02	0.05	0.05	0.04	3.9	4.2	3.5
Biomass	0.20	0.24	0.24	0.23	0.33	0.35	0.28	1.5	1.6	1.1
New renewables	0.00	0.06	0.09	0.04	0.21	0.29	0.13	11.4	12.4	10.0
Oil (mbd)	*4.2*	*7.4*	*6.0*	*7.6*	*9.5*	*5.9*	*10.7*			
Gas (Bcm)	*50*	*111*	*114*	*95*	*128*	*175*	*117*			

Rest of World	2015	2030			2050			2015-50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**3.76**	**4.80**	**4.36**	**4.83**	**5.55**	**4.25**	**5.42**	**1.1**	**0.4**	**1.0**
Coal	0.52	0.63	0.42	0.78	0.65	0.20	0.84	0.6	-2.7	1.4
Oil	1.18	1.53	1.30	1.56	1.71	0.90	1.83	1.1	-0.8	1.3
Gas	1.25	1.58	1.42	1.53	1.65	1.32	1.57	0.8	0.1	0.6
Nuclear	0.10	0.12	0.13	0.11	0.18	0.22	0.13	1.8	2.4	0.8
Hydro	0.07	0.10	0.11	0.09	0.13	0.15	0.11	1.8	2.2	1.3
Biomass	0.59	0.72	0.72	0.69	0.81	0.80	0.72	0.9	0.9	0.6
New renewables	0.04	0.12	0.26	0.08	0.42	0.66	0.22	6.6	8.0	4.6
Oil (mbd)	*25.5*	*33.2*	*28.2*	*33.7*	*37.0*	*19.6*	*39.7*			
Gas (Bcm)	*1,533*	*1,931*	*1,736*	*1,869*	*2,011*	*1,609*	*1,923*			

Source: IEA (history), Equinor (projections)

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