Energy Perspectives 2017

Long-term macro and market outlook






Statoil

Acknowledgements

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We hereby extend our gratitude to everybody involved.

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Energy Perspectives 2017

Global energy markets are affected by several counteracting development trends. Population and income growth continue to boost energy demand, globally if not everywhere. The much-discussed energy transition is shaking up parts of the global energy system. In other parts, changes are however slow, indicating that it will take considerable time to align the energy intensity of the global economy and the global fuel mix with common sustainability criteria. The jury is still out on which factors will play the dominant role and have most impact on global energy in a few decades.

Developments in 2016 and thus far this year indicate that a long-term sustainable energy future by no means is a given. The rapid ratification of the Paris agreement under the UN Framework Convention on Climate Change signals a political willingness to ensure reductions in greenhouse gas emissions. Unfortunately, so far there is little to indicate that policies are in fact being adjusted to significantly increase the likelihood of reaching the "well below 2°" ambition in the agreement. Reaching global climate goals requires cooperation between countries on framework conditions, on technology development, and on income and burden sharing at levels beyond anything we have seen in global politics. Political developments during 2016 and 2017 are signposts that such cooperation could be difficult to establish. Populism, nationalism, protectionism, sanctions, terrorism, and threats of exiting international agreements could put our ability for rapid common action under pressure.

Sustainability means not only lower greenhouse gas emissions, but also higher standards of living for billions of people in emerging economies. Higher standards of living require, among other things, improved access to electricity and clean energy. The simultaneous pursuance of climate targets and welfare targets could, unless efforts are coordinated and shaped to minimize the risk of progress in one area driving set-backs in the other, lead to stalemate on both counts. In the developed regions of the world, the link between economic growth and energy demand growth appears to have been broken. Replicating this achievement on a global scale, and ensuring that remaining energy demand growth does not drive emission growth, are tremendous challenges.

Possible future outcomes for global energy demand and fuel mix therefore vary significantly, depending on many interacting and very uncertain factors. This is particularly true when we look beyond the near future towards 2050, as we do for the first time in this edition of Energy Perspectives. As before, we therefore present three significantly different tales of the future, or scenarios, from now and onwards. The scenarios rest on different assumptions about regional and global economic growth, technological developments, market behaviour, conflict levels and implications, and energy and climate policies. Since political and policy developments are unpredictable, we refrain from ascribing probabilities to the individual outlooks. All the scenarios are possible. We hope that they together provide a realistic impression of the very wide outcome space for developments in global energy.

The central scenario, *Reform*, proceeds from current macroeconomic and energy market trends and – in climate policy terms – from the Nationally Determined Contributions (NDCs) in the Paris agreement, with a gradually less prevalent role for market-correcting policies as market-based solutions drive and deliver energy efficient and low-carbon technologies. *Renewal* is as before a story about a technically possible, but very challenging pathway to energy-related CO_2 emissions consistent with the 2° target for global warming. It includes rapid and coordinated policy changes, accelerated energy efficiency improvements, and large changes in the global energy mix driven by revolutionary development in electricity generation and parts of the transport sector. *Rivalry* is a story about a multipolar world, characterised by mounting distrust in conventional politics and policy making, populism, protectionism and geopolitical conflict, and where focus on security of supply and other priorities overshadow global climate targets.

Average global economic growth ranges from 1.9% to 2.6% per year, with global GDP in 2050 at between 1.9 and 2.6 times that of the level in 2014. Improvements in energy efficiency are larger than the progress that was achieved between 1990 and 2014 in all scenarios, but vary significantly, resulting in total primary energy demand in 2050 being 6% lower (*Renewal*), 25% higher (*Reform*) or 30% higher (*Rivalry*) than in 2014. The challenge in *Renewal* is particularly daunting: Global GDP is 170% higher in 2050 than today, but demand for energy is 10% lower. The future global energy mix also varies significantly: Oil demand in 2050 varies between 63 and 123 million barrels per day, reflecting annual average growth rates between -1.1% and 0.8%, respectively. Gas demand in 2050 varies between 2,900 and 4,550 billion cubic metres (bcm), compared to 3,385 bcm in 2014. There is significant need for new investments in both oil and gas in all scenarios, since production from existing reserves cannot keep up with demand development. Coal demand is the most important key to global CO_2 emission levels in our scenarios – average annual growth rates vary between -3.1% and 0.4%, resulting in coal demand in 2050 between 30% and 110% of the 2014 level. New renewable sources of electricity, in particular solar and wind, will grow significantly in importance, delivering between 8 and 18 times more electricity in 2050 than in 2014. Global energy-related CO_2 emissions in 2050 vary enormously, between 13.5 and 39.5 billion tons, or 42-123% of the emission level in 2014. It is my hope that Energy Perspectives 2017 contributes to a fact-based discussion of multiple possible futures.

Eirik Wærness
Senior vice president and Chief economist

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Context and uncertainties

The future is uncertain, both short and long term. When trying to illustrate how global energy markets possibly might develop over the next 33 years, to 2050, it is important to realize that forecasting all the factors ultimately determining the outcome is impossible. This is one reason why this report contains illustrations of possible developments, scenarios, that rest on different assumptions for key drivers. This gives us a chance of being vaguely right and avoid being precisely wrong.

The three scenarios, stories of the future, that we have established – *Reform*, *Renewal* and *Rivalry* – are described in more detail in the next chapter. Both in assumptions and outcomes the scenarios are very different. However, we find signposts for all of them in recent developments. And many other possibilities also exist.

There is currently a lot of focus on energy transition in political and economic discussions. This is driven partly by the significant changes in market conditions experienced over the last years, partly by the significant step forward in global climate policy discussions, and partly by rapid technological developments holding the potential for significant change.

At the same time, it should be remembered that the global energy system is huge, complex, attached to capital equipment with long lifetimes, and affected by deeply rooted consumer behaviour patterns. Moreover, it is growing, as the global population and economy are growing. Large changes in something this big will inevitably take time.

Below is a list of the general factors that together will determine the features of the global energy market by 2050. In the rest of the report, we will make different assumptions on some of these to arrive at conclusions on energy demand and the energy mix in our three scenarios. Other assumptions would have given other results. Black swans, known and unknown unknowns, will ensure that the actual outcome will be different from our scenarios, but hopefully somewhere within the range of outcomes that our scenarios define.

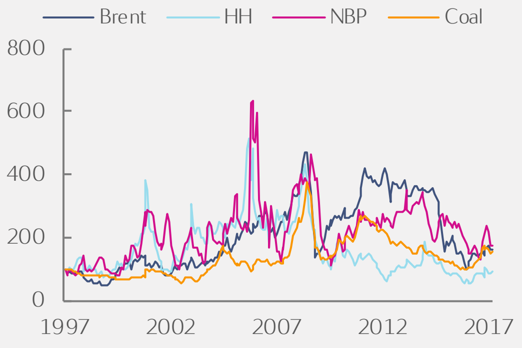
- *Economic growth*

  Population growth, development of labour force characteristics, investments in productive capital and our ability to combine labour and capital productively together determine economic development. These factors are in turn affected by things like education, gender (in)equality, income distribution, technology transfers and economic policy in different countries. In our scenarios, the average annual economic growth between 2014 and 2050 varies between 1.9 and 2.7%, respectively. One factor that makes it difficult to forecast long-term economic growth is the aging of the workforce in many countries. Another is digitalisation, a phenomenon carrying the potential for higher productivity development as well as for mass unemployment and income inequality.

- *Energy intensity*

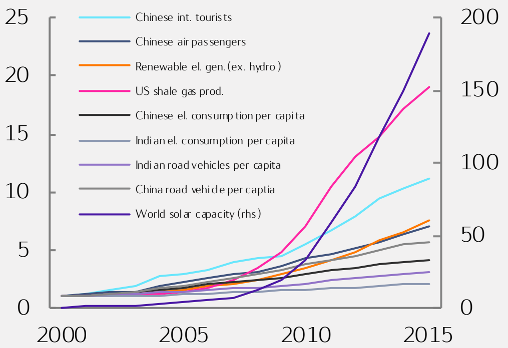
  Technology, market signals, energy policy and consumer behaviour interact to determine how much energy that goes into the production of a given amount of goods and services. Energy intensities vary across

Energy commodity prices
Index, Real April 2017, Feb 1997=100



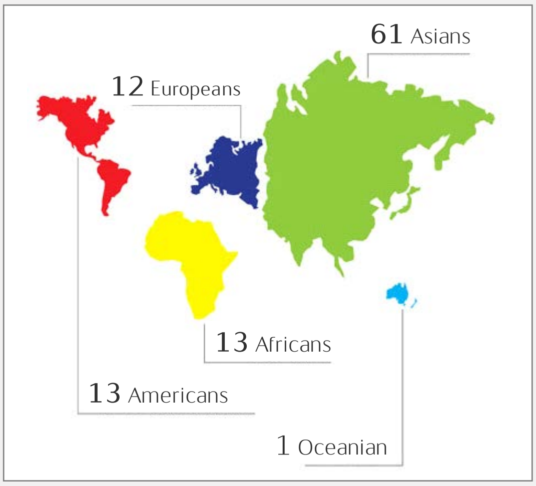
Source: Platts, ICIS Heren and World Bank

Development in selected energy supply and demand factors
2000=100



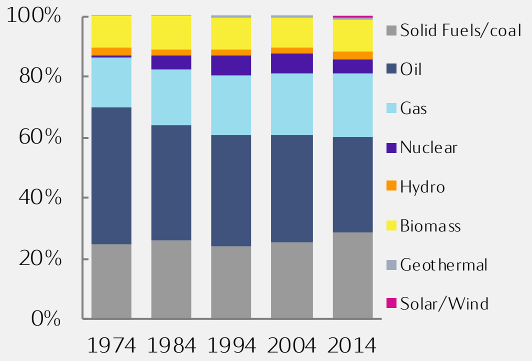
Source: World Bank, IEA, IRENA, EIA

The global population centre is Asia
If the world were a village of 100 people...



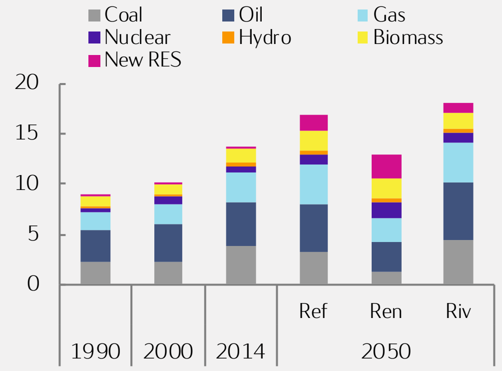
Source: Visualnews

Fuel mix in total primary energy supply 1974-2014



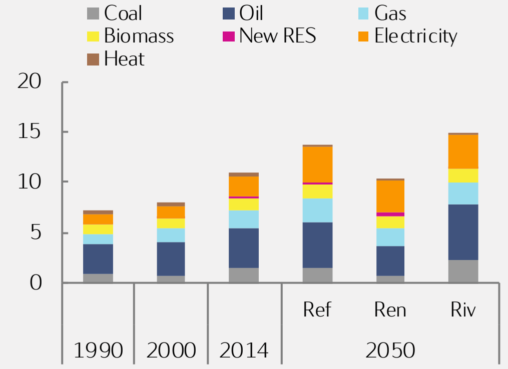
Source: IEA

Total primary energy demand in the three scenarios, by fuel
Btoe



Source: IEA (history), Statoil (projections)

Total final energy consumption in the three scenarios, by source
Btoe



Source: IEA (history), Statoil (projections)

sectors and countries and over time. Consumer choices sometimes reduce or even wipe out the demand reduction following from an energy efficiency improvement. Our scenarios aim to take such rebound effects into account. The energy intensity of the global economy nevertheless declines by between 1.1 and 2.8% per year on average. This is higher than the 0.9% per year average for the period 1990-2014, reflecting policy push and technological progress. The improvement in *Renewal* is key to delivering on the 2° target, but an enormous challenge.

- *Technological development on the supply and demand side*

Technology and subsidies have combined to sharply reduce the costs of new renewable electricity over the last decade. Battery costs have also come down, paving the way for rapid growth in electricity storage, although significant increases in the use of critical minerals may limit the potential. The oil and gas price collapse, producer responses and technology breakthroughs have driven significant cost reductions also in the petroleum industry, some of which are structural and lasting. Standards and technology have reduced the energy intensities of all end-use sectors. Digitalisation could allow for further cost reductions both on the supply and demand side. Ultimately, varying potential and success will affect the competitiveness and popularity of different fuels.

- *Energy and climate policies*

There is a lot of focus on policy targets. Targets are important, but do not deliver results. Energy and climate policy measures are what matters. Subsidies, taxes, quotas, standards, and requirements lead to outcomes different from those that would prevail in unregulated markets. In many cases, there is a need to improve markets to reduce negative external effects such as pollution and greenhouse gas emissions. A special challenge is the need for coordinated, international measures to address global problems that cannot be solved locally. The future development of energy and climate policies is very uncertain, partly because concerns for energy efficiency and climate change must compete with other valid concerns in many countries.

- *Geopolitics and regional conflicts*

Solving our common challenges requires cooperation, effective exchange of technology, good ideas and low-cost, low energy solutions, and trust. Geopolitical developments and regional conflicts might continue to hamper, rather than foster, such factors. In some dimensions, political developments the last year have reduced the likelihood of globally efficient solutions to common challenges. The future development in this area is crucial.

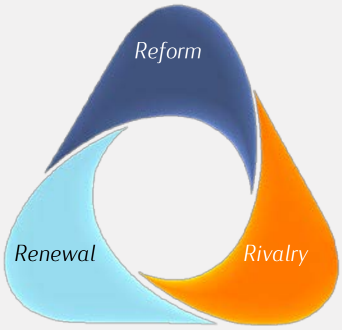
- *Black swans*

An important reminder is that we possibly will be surprised by events, developments and solutions that we do not know about and/or that have a low probability of occurring, but could have a large impact if and when they take place. One of the useful aspects of working with very different scenarios is that they could implicitly cater for some of these factors. To what extent this is the case for *Reform*, *Renewal* and *Rivalry* remains to be seen.

The three scenarios

This chapter provides a brief description of the three scenarios that form the basis of Energy Perspectives 2017. Energy Perspectives, which has been published since 2011, started featuring scenarios in 2014 as a response to the considerable uncertainty associated with long-term development in global energy markets. The three scenarios are all technically possible, and span a wide outcome range, but are not provided with specific probabilities indicating their likelihood of materializing. Each scenario is constructed from a distinct set of assumptions regarding the possible future development of the world economy and global energy markets. Further descriptions of the economic and energy-market specific implications of each scenario are presented in the following chapters.

Energy Perspectives 2017 scenarios



Source: Statoil

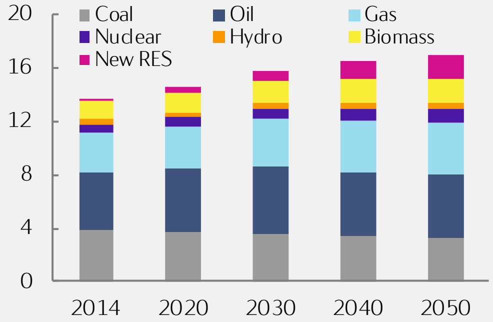
Reform: market forces coexist with climate policies

Last year's *Reform* scenario built on the NDCs pledged by nations around the world in the framework of the Paris Agreement from COP21. In this year's *Reform*, the NDCs still form the backbone of fundamental transformations in the energy industry, but it is assumed that only those changes that can be accomplished through market-optimal, non-subsidized investments are sustained. However, mandatory standards and regulations coexist with market forces in the scenario, both play a role in shaping consumers' decisions, and both contribute to innovation and technology developments. As technologies that meet demand for low-carbon energy become increasingly economical, market intervention becomes progressively less relevant than commercial drive. Therefore, only some tightening of emission targets and policies takes place during the late 2020s and beyond.

The *Reform* scenario

The geopolitical framework in *Reform* is characterised by national policy-making, reflecting national and private economic self-interest tempered by, but not subservient to, international policy-making. Regional geopolitical tensions play out without bringing major permanent disruptions: the US global leadership is called into question; local and regional conflicts continue to affect the Middle East; and Europe remains engrossed in domestic challenges precipitated by Brexit and resurgent fear of an EU breakup. The global roles of China and Russia are moderated by their respective and different internal challenges associated with demographic, economic, environmental and political development. Policy coherence is, to an extent, side-tracked by terrorist attacks and transnational challenges, such as migration. However, international institutions and order remain largely intact. In *Reform,* R&D and technology development are not hampered by geopolitical developments; as they are driven largely by commercial and national interests.

Global primary energy demand by fuel: *Reform*
Btoe



Source: IEA (history), Statoil (projections)

Economic growth in *Reform* is shaped strongly by demographic developments: increasing global population – with a decelerating growth rate out in time, and aging, particularly in the US, Europe and Japan. Productivity improvement, especially in the emerging economies continues to unleash their catch-up potential. Global GDP growth in *Reform* is foreseen to slow relative to the average for the last 25 years, and to be significantly lower than in the 5 years prior to the 2008 crisis.

Energy efficiency is key

Source: CrystalGraphics

Global warming and extreme weather events dent economic activity somewhat from the mid-30s, with an augmented impact during the 40s.

Lower prices of fossil fuels and varying degrees of commitment to the tightening of climate contribution targets translate into higher oil and gas demand early in the forecast period. The EU emissions trading system (EU ETS) and other national and regional carbon pricing schemes function, but prices remain mostly unlinked and below the levels needed to stimulate a large-scale roll-out of Carbon Capture and Storage (CCS). The relative lack of progress in CCS undermines its role as a major climate risk mitigation tool.

In *Reform* energy systems become significantly more efficient than they are today. Average annual improvement in energy intensity is 1.9%, more than double the improvement seen in the last 25 years. This is achieved through a combination of measures, including fuel efficiency standards for vehicles, as well as advances in technologies relevant to buildings, industry, power and the entire range of energy sub-sectors. The changes in the energy mix in *Reform* are primarily a result of a gradual, but important shift from carbon fuels to green energy technologies, notably in the electricity sector, and a technology shift for light duty vehicles that enables significant electrification of the global car fleet, once electric cars become cost-competitive. Regulatory incentives and subsidies that have helped wind and solar energy and electric vehicles gain traction in global energy markets are gradually phased out and leave space for profitable clean energy technologies.

Continued growth in global GDP in *Reform* outweighs the effects of a strong decline in energy intensity, so that projected energy demand continues to grow, albeit moderately. Fuel switching is too slow to stabilize and reduce energy-related CO_2 emissions significantly during the forecast period. Therefore, *Reform* is not a sustainable scenario in the long run, leaving a wide gap when compared to the ambitions of the Paris agreement.

The *Renewal* scenario

Renewal: a pathway to energy sustainability

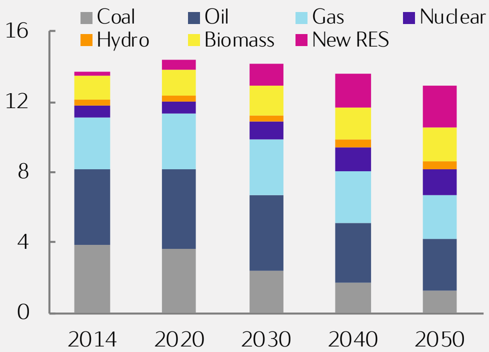
The *Renewal* scenario focuses on developments that combine to deliver an energy-related CO_2 trajectory that is consistent with a 50% probability of limiting global warming to 2°. As previously, *Renewal* is based on back-casting. This year, we have proceeded from a target of limiting cumulative global energy sector CO_2 emissions to slightly below the level by 2040 in IEA's 450 scenario, and then with the development extended to 2050.

Renewal plays out in a benign geopolitical environment where cooperation, not competition, drives policy. National policy agendas are shaped by a realization that the global warming threat calls for radical action, and that the severity of the required policies calls for a joint, coordinated response. The decision made in Paris to reconvene at five year intervals and tighten CO_2 emission reduction commitments with the 2° target in mind, is carried out. International institutions, legal frameworks and trade agreements remain in place, although with greater influence from emerging economies such as China, Brazil and India. Economic and energy diversification, with plans for moving beyond coal and oil dependence, makes real progress and boosts energy efficiency across developed and emerging economies. Investments and technology transfers rapidly generate greater buy-in for greener forms of energy.

Smart cities drive technology development

Source: SmartGridSpain

Global primary energy demand by fuel: *Renewal*
Btoe



Source: IEA (history), Statoil (projections)

The *Rivalry* scenario

The global economic growth performance in *Renewal*, at first, is slightly below *Reform*, since reallocation of investments towards the green economy are initially driven by the need to reduce global CO_2 emissions and fulfil agreed targets, and not by expectation of the highest short-term economic return. However, later in the outlook period, economic growth surges as green investments yield higher return. The reduction of CO_2 emissions in this scenario is sufficient to prevent an escalation of negative climate change impacts, hence, global GDP is expected to log an annual average growth slightly above *Reform* over the outlook period.

Lower demand for fossil fuels and carbon-conscious-producer attitudes leave the most expensive and CO_2 intensive assets in the ground. Fossil fuel subsidies to end users are phased out faster in *Renewal* than in *Reform*, and carbon prices in interlinked carbon markets are notably higher than in *Reform*. High carbon prices also incentivize the development and deployment of large-scale CCS. This enables continued use of fossil fuels – though at reduced levels – in sectors that do not have satisfactory options.

Renewal is characterised by a stable policy and regulatory framework effectively mobilizing investment in clean energy and efficient energy systems. A more consistent emphasis on green technology development and deployment ensures faster energy efficiency improvements, a deeper decarbonization of power generation and a radical electrification of key transport segments. The key climate policy tools in action are partly market based, partly interventionist, and partly oriented towards R&D. Key results include declining costs of renewable technologies and car batteries, widespread availability of charging points for electric vehicles (EVs), technical maturity and affordability of large-scale electricity storage, smart grids, a substantial strengthening of transmission networks and re-furbishing of a significant amount of homes and public building stocks.

The unprecedented pace of decline in energy intensity in *Renewal*, 3 times as high as the last 25 years, negates the impact of economic growth on global energy demand which is 6% below its 2014 level by 2050, despite the global economy being 2.6 times larger. Accelerated fuel switching on top of this revolutionary decline in energy use stabilizes and drastically reduce energy-related CO_2 emissions.

Rivalry: a multipolar world

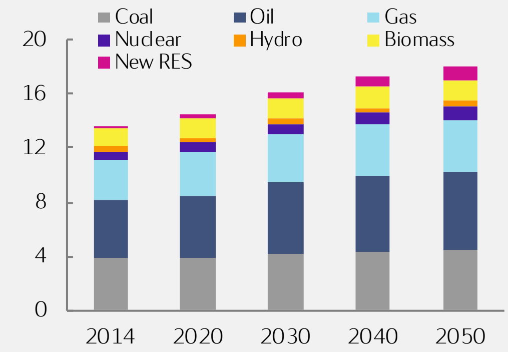
Rivalry portrays a multipolar world where populist, nationalist, inward-looking and short-term priorities direct policy making, where climate scepticism runs high and where disorder, conflict and power struggle apply at the expense of cooperation and trust. In *Reform*, self-interest is kept in check by a realization on the part of leaders that key issues do require restraint and cooperation. In *Rivalry,* there are fewer concerns for the common good beyond the interests of the family, the tribe or the nation.

The issues and tensions defining *Rivalry* are fluent by nature and affect different regions in different ways in different time periods. *Rivalry* consequently seeks to portray a world characterized by progress and set-backs and by regions making progress and regions falling behind, rather

Geopolitical challenges drive *Rivalry*

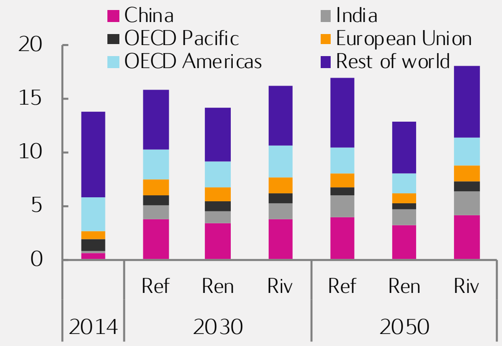
Source: Skanaar

Global primary energy demand by fuel: *Rivalry*
Btoe



Source: IEA (history), Statoil (projections)

Global primary energy demand by region
Btoe



Source: IEA (history), Statoil (projections)

than a world struggling uniformly and continuously throughout the entire outlook period.

The geopolitical scene in *Rivalry* is turbulent. Economic inequality within and between states erodes social and international cohesion. Conventional politics and principles are overrun by xenophobia and protectionism. Geopolitical rivalries remain elevated as state failures in exposed areas are not managed by established world powers, like the US, and as emerging powers like China and India do not fill the governance gap. Traditional institutions fail to mitigate the world's problems due to lack of support and funding. Physical walls and border controls spell the end of benign globalisation as it existed after the Cold War. Leaders rail against international institutions, trade agreements and economic blocs.

Challenging geopolitics hamper international trade and the deployment of new technology. Political and economic resources are channelled to less productive purposes. This leads to economic stress. Eventually there will also be negative environmental consequences of climate changes that unfold in this scenario. Therefore, global economic growth in *Rivalry* is curbed to a level well below that in *Reform* and *Renewal*.

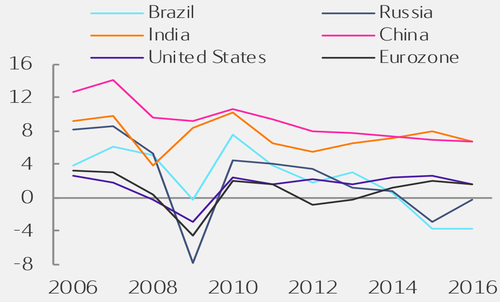
Long periods of underinvestment in new production capacity and higher demand for fossil fuels allow the development of higher cost assets, leading to higher energy prices and to volatility related to unrest in producing countries. Carbon pricing falls off policy agendas. Although existing schemes linger on, prices are never linked and never reach levels where they have material impact on fuel switching and investments. In this scenario, there is no economic incentive to support R&D in CCS technologies, so no projects beyond those existing or currently under implementation are considered.

Policy and regulatory attention to local environmental problems is sustained, but concerns for global issues are not. Global climate ambitions are nominally still in place, but are in practice ignored. A preoccupation with security of energy supply and periods of high prices spur interest in energy efficiency and indigenous new renewable energy, but above all a will to take advantage of domestic fossil fuel resources. Regions well-endowed with coal, oil or gas continue to rely on these fuels regardless of their climate implications. The electrification of the global car fleet is much slower in *Rivalry* than in *Renewal* and *Reform*.

As projected and energy-related CO_2 emissions by 2050 are higher in *Rivalry* than in *Reform*, despite substantially lower GDP, this scenario is clearly unsustainable also from a climate perspective.

GDP growth 2006-2016 by region

Real annual % change at market exchange rates



Source: The International Monetary Fund

Protectionism - a threat to world growth?

Global economic development since the 1990s has been characterized by a strong increase in international trade underpinning economic growth. Economies have blossomed, confirming the comparative advantage theorem when a given country produces goods and services at a lower opportunity cost than other countries, and where trade allows for utilizing this. However, on the negative side, the working class in several developed countries increasingly feel excluded from the gains created by international trade, resulting in populist arguments against globalization. Protectionist leanings are e.g. observed in the US, in Britain by the EU leave vote, and France where the election was coloured by economic nationalism. Anti-globalization is of concern for small open economies and for developing export-oriented economies.

Economists have noted that the increased imports of goods and the constrained development in the manufacturing industry in developed countries is not a cause-effect relationship, but an effect of individual company decisions. Stolper and Samuelson[1] explains how international trade influences the return on input factors. Return on labour, in a sector competing with imports, will become lower as importing companies increase their profit. This is consistent with the increasing inequality in income and wealth distribution. There is hence a risk for developed economies to experience continued stagnation in manufacturing.

The incoming US administration has put emphasis on trying to change the US position towards international trade. The withdrawal from the TPP trade agreement, efforts to renegotiate the NAFTA and the idea of a "border adjustment tax" have been introduced. The background for these policies is that US for many years has had a trade deficit. High US imports (in absolute terms) are caused by consumers' high consumption rate and low savings. Another cause is that 43% of the imports is intermediate goods imported by US firms. US protectionist measures will be challenging for US multinationals and the situation will become further complicated if other countries implement tariffs on US exports.

[1]Stolper, W. F./Samuelson, P A: "Protection and Real Wages", The Review Of Economic Studies, November 1941.

The global economy

Current situation and outlook to 2020

The global economy is in a mild pick-up mode confirmed by solid economic development in many parts of the world. Most leading sentiment indicators are positive and signal continued job creation, healthy consumer spending and business activity. The recovery in commodity prices and the ongoing greening of economies lead to more investments. Monetary policy is still accommodative, although the US Federal Reserve has started to increase the interest rate. Inflation in advanced economies is moderate, but has picked up lately. Consumer spending in the US is robust and policy efforts are being made to spur the expansion. Economic growth in Europe is decent, and the same goes for Japan, lifted by an export recovery. In emerging market economies inflation is slowing down as the effect of past exchange rate depreciations diminishes. China's economy has stabilized, helped by policy stimulus and credit growth. India is also holding up well, despite the recent withdrawal of large currency notes that is dampening domestic demand. Russia looks set to expand, while the Brazilian economy is still weak. However, the global economic momentum is fragile due to geopolitical tensions, Euroscepticism, and the risk of protectionism. To maintain and raise the pace of economic expansion, reforms that encourage innovation, promote investment in productive capital, and counteract the negative impetus from an aging population will be important. The growth forecasts for the three scenarios are discussed below.

Forecasting economic development, our approach

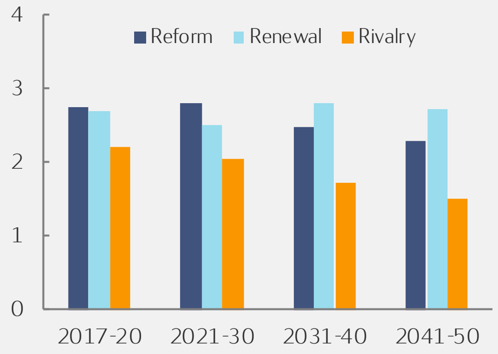
Economic activity in the near term is shaped by demand for final goods and services. It is natural that the economies fluctuate above or below the trend growth, with fiscal and monetary policy and reforms as steering tools for authorities. The long-term approach shifts attention to the supply side, and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

Outlook to 2020

In *Reform*, the global economy during 2017-20 grows by an average of 2.7% per year. Emerging markets lead the acceleration, but under the conditions of a growth slowdown in China, increasing commodity prices and a loose monetary policy by most central banks.

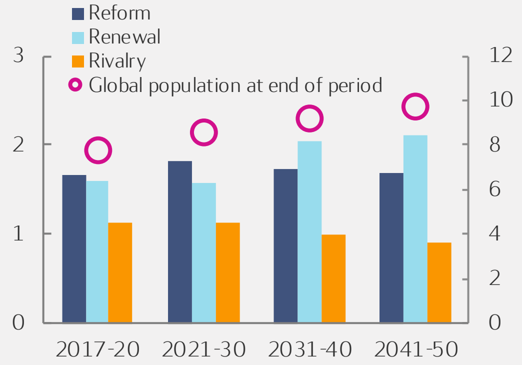
The US economy is carried by solid consumer spending at the back of a relatively tight labour market. Expected growth enhancing tax changes, business deregulation and increased public infrastructure spending are also supportive. Continued weak labour productivity development and a prolonged drag from net exports lead to an average GDP growth of 2.1% per year. In the Eurozone, domestic demand is the main growth driver as politicians are coping with Brexit and prevailing Euroscepticism. The positive effect of low energy prices fades, and although there are less fiscal headwinds, the region develops in a multi-speed way. Reform fatigue continues and policy focuses more on equality to defeat the rise of populism. An average GDP progress of 1.5% per year is achieved over the period. In Japan, improved exports due to a weak yen lift business

Global GDP growth
% change, (CAGR), real



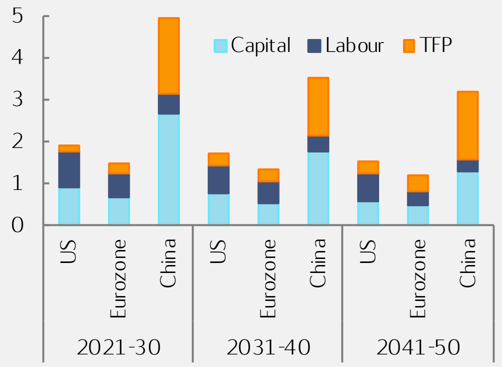
Source: Statoil

GDP per capita growth and population development
Real annual % change, billion people (rhs)



Source: Statoil, United Nations

GDP growth by source, *Reform* scenario
Real % annual change (CAGR)



Source: Statoil

conditions despite a cautious corporate sentiment towards capital expenditures and the global economic outlook. Labour shortage and lower tax revenues due to deteriorating demographics limit the effectiveness of fiscal stimulus. Growth is expected to average around 0.6% in 2017-2020 as the consumption tax hike kicks in. China's economy has been stabilised by monetary easing, infrastructure investment and property sales. However, asset price overheating, industrial overcapacity reduction, and reforms of its state-owned enterprises and financial markets are posing challenges. Growth is expected to remain on a moderate deceleration path to averaging 5.9% yearly. India's demonetization policy has dampened industry recovery. Despite this, tax reform, fiscal stimulus and streamlining of foreign investment approval will boost growth to 7.3% annually over the period. Brazil and Russia will recover from recession, but underperform due to the commodity cycle and political issues.

The economic performance in *Renewal* is similar to the development in *Reform* at 2.7% per year. Investments in new low-carbon energy systems are gradually expected based on stricter climate targets and the application of strong policy regulations. However, green investments and climate initiatives are scaled up only gradually and will start to make a difference from 2020. Reallocation of investments towards the green economy are initially driven by the need to reduce global CO_2 emissions and fulfil agreed targets, and not by aiming for the highest short-term economic return. A world with a lower energy demand also contributes to somewhat less economic progress.

The economic development in *Rivalry* at 2.2% per year through 2017-20 is significantly weaker than in both *Reform* and *Renewal*. This lower growth path reflects increased protectionism, and the result of political and economic resources being channelled to less productive purposes. This filters through on a broad basis, with the exemption of Russia that capitalizes on its energy resource base and defence industry. Economic activity is significantly weaker 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. Global expansion is nevertheless reasonable, as energy demand is sustained due to less improvement in energy efficiency. Lower renewable investments call for higher fossil fuel value chain growth than in *Reform* and *Renewal*.

Outlook 2020s

Reform: robust growth driven by emerging economies

In the US, a healthy population growth secures a sound basis for the economy, although the labour force shrinks and the old-age dependency ratio rises. Capital investments contribute to expansion, partly helped by the energy sector. Being a mature economy, the TFP component in the US is moderate, and the economy grows at an average of 1.9% per year. The Eurozone stays integrated, and dividends from labour and product market reforms coupled with investments in research and development, materialize during the 2020s. The Eurozone economic performance reaches 1.5% per year on average. Japan's growth continues to be constrained by its shrinking population, which exerts downward pressure on spending, housing demand and government expenditure. Nevertheless,

Disruptive socio-demographic trends

Demographic trends will shape how the world changes politically, economically and socially. According to the UN, the world's population is set to increase by 2.4 billion, reaching 9.7 billion in 2050. Africa is accounting for more than half of the total growth, while some OECD countries' populations will shrink. The number of people aged 60 and above will more than double. Over 3 billion people will join the middle class through 2030, pushing its size to nearly 5 billion of the world's population. The rise in the middle class will be concentrated in emerging economies. As people become richer, 75% of global consumption growth between 2015-30 will be attributable to increases in per capita spending and 25% will be driven by population growth, according to McKinsey Global Institute.

The world's population will be urbanizing faster than ever. A billion more people will move to urban areas by 2030, and almost 2/3 of the world's population will be urbanized by 2050, creating new megacities. Therefore, a massive urban development will be needed to cope with this movement. By 2030, 12 new megacities (above 10 million people) will have emerged, 10 of them in Asia and Africa. The World Economic Forum has identified water shortages as the biggest threat on the planet in the next 10 years. It is expected that nearly half the world's population will live in areas with severe water stress by 2050. Fragile states in Africa and the Middle East run the highest risk of experiencing food and water shortages. Migration is another trend where the speed is accelerating, fuelled by refugees from poor and politically instable nations.

The areas of significant change are not limited to the size and structure of the population. Notable changes are happening in people's behaviour. Supported by technological advances, young generations are more connected and share goods, services and their respective benefits and costs. Equally important, youth aspirations are evolving. In the US, "millennials" have relatively fewer driving licenses, and in China electric vehicle purchases have been dominated by the "millennials". This pattern will possibly expand to other emerging economies, but much later and at slower pace as, in many of these countries, the priority of young people remains job security and welfare gains.

Major population changes along with urbanization will create lasting socio-economic and geopolitical challenges. The sustainability of the current energy system within the context of growing population, along with rapid urbanization, will constitute major areas of concern worldwide. Ending energy poverty and ensuring universal access to clean, affordable and modern energy by 2030 as targeted by the UN will prove extremely challenging for societies. According to the IEA, today over 2.5 billion people still lack access to clean energy. Mounting socio-demographic, environmental and economic pressures are forcing urban planners to rethink and transform the way they have been building and organizing cities, and the way people live, interact and consume. These transformations will not only alter people's lives, but will also constantly challenge corporations' business models. The way energy and energy-related companies have been doing business is increasingly under disruptive threat.

robust investment in digital infrastructure and increasing female participation in the labour force help alleviate severe labour shortage. The Japanese economy grows on average by 0.7% per year in the 2020s driven by higher capital efficiency.

Debt reduction and reform towards a more market-based and consumption oriented economy will sustain China's decent growth. The Chinese economy grows on average by 4.9% per year as financial reforms and investment in digital infrastructure enhance capital efficiency. India's bold reforms to remove economic constraints and electricity shortage are key to its healthy long-term development driven by strong demographics. Financial and tax reforms along with land reforms and policies to reduce bureaucracy ensure growth at an average of 6.3% in 2020s, with a rapidly rising middle class. Policy paralysis ends in Brazil and economic bottlenecks are removed, and in combination with its huge resource base and favourable demographics, an average expansion of 2.7% per year comes through. In Russia, demanding demographics, slowing investments, low innovation and business diversification curb growth to an average of 1.5% per year.

OECD economies grow at an annual average of 1.8% over the 2021-30 period, while progress in non-OECD economies averages a robust 4.3%. Thus, global growth over the 2020s is close to the average after 2000.

Renewal: economy driven by radical energy transformation

Investments in new renewables and related infrastructure, efficiency improvements, and a gradual removal of fossil fuel subsidies take place on a large scale in *Renewal*. The greening of the global economy is labour intensive and has a positive impact on employment. The new energy systems are nurtured by rapid technology development and much higher global carbon costs. 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. Technology developments are spreading, helped by global arrangements that foster international relationships in areas important for green growth. In China, technology upgrades boost productivity, the overcapacity of the heavy industry is scaled back, and the industry is retrofitted with cleaner equipment. In India, smart cities and industrial corridors develop, benefitting from modern infrastructure. The average economic growth rate in *Renewal* during the 2020s is nevertheless 0.3 percentage points below *Reform*'s 2.8%, as some momentum is lost during the investment-heavy transition phase.

Rivalry: economic isolationism prevails

Isolationist policies have become the norm for consecutive US administrations and hamper economic growth and productivity development, with negative spill-over effects globally due to constraints on trade and technology exchange. International trade develops towards bilateral enterprises. Countries on all continents follow the American example and introduce new customs barriers to prevent undesirable competition and imports. Under a protectionist paradigm value chains across the Americas are disrupted. Several member countries decide to leave the Eurozone after strong immigration pressures and popular discontent. Europe is unable to compete effectively on the global scene and drifts into stagnation. Despite of a large domestic market, China is also

The 4th industrial revolution and society

The 3rd industrial revolution began its era in the 1980s with the development of the digital technology we see today. Now the world finds itself at the start of an unprecedented period of technological breakthroughs within connectivity, automatization, big data management, the "Internet of things", artificial intelligence, genetics, etc. under the notion "the 4th industrial revolution". Technological progress is not a new phenomenon, and ever since the 18th century engineering has fostered growth both in the global population and in the number of jobs. New technology enables higher wealth creation, lower costs and increased efficiency – which will benefit all. Also, safety improvements and the phasing out of heavy and repetitive manual work is positive.

A key priority for governments is to secure employment for their inhabitants. It is easy to see, and fear, that not only manual jobs within manufacturing and transport will disappear due to automatization, it will also affect high-education-level occupations in the service sector. Further, a higher share of wealth creation may fall into the hands of capital owners, yielding greater inequality. This can already be seen in many countries with high unemployment rates despite growing economies – a "jobless" growth. Solving the issue of income distribution and wealth looks to become more important than ever, both to secure governments' funding and consumers' purchasing power. If this is not resolved, markets will shrink and capital owners will not have sufficient incentives to expand investments, creating a negative circle that slows down economies.

Source: shutterstock.com

At the same time, new jobs will be needed and created in the new economy and many people will find themselves in jobs that we do not yet know of. If the amount of work done by humans decreases, this may be balanced out with more time for leisure and reduced working hours. After capital expenditures are done, many goods and services will be offered close to the marginal cost, as this will be aided by the nature of new technologies. This will be good for consumers, and many companies must change and adapt their business models to stay competitive. Orchestrated in a sound way, the 4th industrial revolution should result in better lives and more interesting jobs, like previous industrial revolutions. Economic growth will be underpinned by increased demand for services, moving the world towards a more environmentally sustainable path. However, given the speed of transition that potentially is taking place, medium-term challenges with unemployment and increased inequality could cause serious friction.

negatively affected as geopolitical crises occur more frequently. India emerges as a manufacturing hub, and with its growing middle class it is more sheltered from the downturn. Economies in MENA take the hardest hit as governments are unsuccessful at weaning populations off heavy energy consumption but, simultaneously, unable to fund still high energy subsidies. Global growth in *Rivalry* tracks significantly below both *Reform* and *Renewal* at 2.1% per year.

Outlook beyond 2030

The global population is set to increase through the forecasting period, but at a decelerating rate. The world will also face aging issues as workforces shrink due to retirement, increasing states' old-age dependency burdens and constraining development. Many governments must build or reinforce their social welfare systems, which entails trade-offs among today's allocations. In developing countries, large numbers of young people enter the workforce, and this requires millions of new jobs to fully utilize the human capital component. A high labour market participation rate, improving educational system, and labour market flexibility are key elements for securing a competitive work force. Inequality gains attention and is partly dealt with through income and wealth distribution, which might require some sort of global cooperation.

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. Labour forces shrink, and investments slow somewhat due to a dwindling customer base. Digitalisation and automatization become important tools in combining labour and capital to enhance productivity, and to manage the aging issue. The service sector in the global economy continues to grow.

Beyond 2030 an increasing difference materializes between the scenarios, where *Renewal* grows by an average of 2.8% per year, *Reform* by 2.4%, and *Rivalry* by 1.6%. The main characteristics in the three scenarios are:

- *Reform*

Traditional energy carriers dominate, although new renewables increase their market share. A slight negative environmental impact occurs and lowers the economic pace somewhat. The world's energy and economic systems develop in line with previous decades and do not change as much as in *Renewal*.

- *Renewal*

A green transformation takes effect, enabling the world to harvest on investments made during the 2020s. Green investments yield the highest return and are more attractive than fossil energy investments. As CO_2 emissions are kept within the 2° trajectory, there is no or only a marginal negative environmental impact on economies. Output increases in the service sector based on improvements in the wider economy.

- *Rivalry*

The world is in a tumultuous state dominated by trade barriers and sanctions. Global warming and its negative environmental consequences, and local pollution, gradually filter through and escalate. This particularly hurts economic activity in less developed economies and countries closer to the Equator.

Greenhouse gas emissions and global climate policy

IEA puts global CO_2 emissions related to coal, oil and gas consumption in 2014 at 32.2 Gt. Emissions increased by an average of 1.9% per year between 1990 and 2014. They have since been stable despite worldwide economic growth and non-OECD energy demand growth.

Around two thirds of greenhouse gas (GHG) emissions stem from the burning of fossil fuels. The last third includes both CO_2 and methane, nitrous oxide and fluorinated gases, and come from land use changes, agriculture, certain energy sector operations and a variety of industrial processes. Climate policy making must take this variety of GHG emission sources and a matching variety of mitigation possibilities into account. However, the weight of fossil fuel related emissions calls for a focus on dampening energy demand growth on the one hand, and reducing the carbon intensity of energy supply on the other.

The UN Paris climate agreement signed in December 2015 was ratified in November 2016. Discussions on how to measure progress and scale up emission reduction ambitions, and how to raise finance for adaptation and mitigation, are ongoing. The signatories will reconvene in 2018.

The planned fleshing out of the agreement will take place in a changed political landscape. US President Trump in March 2017 signed an executive order to rewrite the Clean Power Plan, a linchpin of President Obama's climate policies. The current administration seeks to reverse other environmental legislation as well. President Trump campaigned on a promise to pull the US out of the Paris agreement, but at the time of writing it remains unclear whether that will happen.

In contrast to the current US administration, Chinese President Xi Jinping has acclaimed the Paris Agreement "a hard-won achievement" and encouraged all signatories to stick to it. China has made climate actions the core of its economic and political agenda and may become a climate leader on the international scene.

Climate policies are still high on the European Union's political agenda. The Commission is trying to reform the EU ETS and submitted in late 2016 a new energy and climate policy framework for the period 2021 to 2030, focusing on further supporting the role of renewable energy sources in the European economy and raising the union's energy efficiency ambition. While high-level targets for 2050 already exist, detailed policy proposals will be presented in 2019.

India has pledged a 35% reduction in the carbon intensity of its economy from 2005 to 2030, and an increase in the share of renewable power generation capacity in total power generation capacity to 40% by 2030. Last year India raised its renewable capacity target to 175 GW – including 100 GW of solar power by 2022. The country will however need to significantly ramp up the pace of solar capacity additions, from 4.4 GW last year to 15+ GW per year, to meet this target.

Status and outlook for the EU ETS

The EU emissions trading system (EU ETS) is the world's first and so far largest single carbon market. It was implemented as a key tool in EU's policy to fight climate change, and is based on a 'cap and trade' principle; a cap is set on the total amount of certain greenhouse gases that can be emitted by power plants, large industry and airlines. Within the cap, which is lowered every year, companies receive, buy or trade emission allowances. A company must surrender enough allowances to cover all its emissions, or pay heavy fines.

The system has gone through different phases with different rules since its launch in 2005. The key features of the current third phase (2013-2020) is that there is a single, EU-wide emissions cap. Auctioning is the default method of allowance allocation. Renewable technologies and CCS are to be supported by sales of 300 million emissions allowances from a New Entrants' Reserve (NER300).

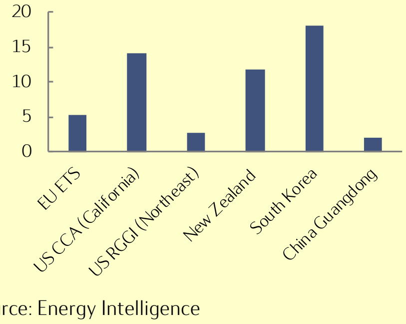
The balance is set up to secure that the emissions from sectors covered by the system (accounting for around 45% of EUs total emissions) by 2020 will be 21% lower than in 2005.

The discussions around the market reforms for Phase IV (2021-2030) are expected to be finalized in the Autumn of 2017. The European Parliament and the European Council both adopted their positions in February, and will meet with the European Commission to shape the final legislative framework. The proposals look to strengthen the EU ETS somewhat, especially the proposed increase in the Market Stability Reserve (MSR) injection rate from 12% to 24% in the 2019-2022 period, securing a lower supply of allowances.

The allowance price has traded in the 4-6 USD/ton range the last 1½ year which is below the current US West Coast, Korean and New Zealand prices, and lower than needed to incentivize coal to gas switching, let alone investments in CCS. Low growth in electricity demand and growth in wind and solar power have reduced demand for allowances.

Going forward, we do not expect any noteworthy price change during this year and next. However, assuming implementation of the expected Phase IV reforms mentioned above, we expect a stronger price from 2019. There is however much uncertainty related to energy demand and policies that impact the EU carbon price.

Global carbon emission allowance prices
USD/ton (as of 9th May 2017)

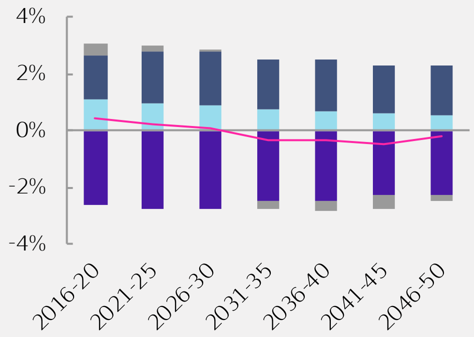


Source: Energy Intelligence

Global energy-related CO_2 emission growth and emission driver growth

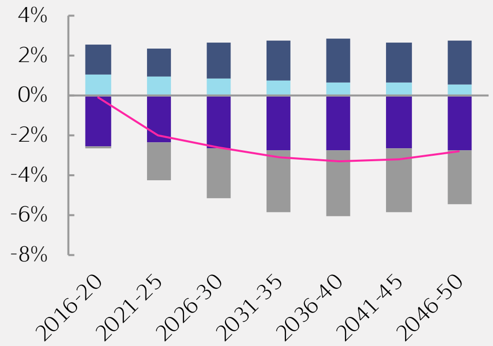
Population growth / GDP/capita growth / TPED/GDP growth / Carbon/TPED growth / CO2 growth

Reform scenario
2015 - 2050



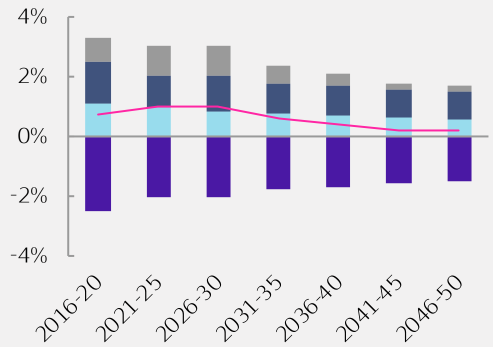
Source: Statoil

Renewal scenario
2015 - 2050



Source: Statoil

Rivalry scenario
2015 - 2050



Source: Statoil

Scenario impacts

In *Reform*, economic self-interest, technological innovation and local environmental challenges shape investment and consumption decisions as much as grand cooperative schemes. However, the Paris agreement does play a role. Most countries deliver on their unconditional Paris commitments. US federal climate policy loses momentum, and this in turn prompts some other countries to delay action, but cost fundamentals and state and grassroots initiatives sustain progress. The EU ETS recovers and other national and regional carbon pricing schemes are becoming factors for fuel mix decisions, but prices remain mostly uncoupled and below the levels needed to stimulate a large-scale roll-out of CCS. The plan to make 100 billion USD per year available for global warming risk mitigation and adaptation in poor countries is only partially fulfilled, hence some conditional commitments are postponed or ignored. Some tightening of commitments during the 2020s and beyond takes place, but the revised targets and policies fail to deliver CO_2 emission declines consistent with long-term targets. Global energy-related CO_2 emissions rise gently to some 33 Gt in the late 2020s, before going into an equally slow decline to around 31 Gt by 2050.

The so-called Kaya identity is a handy mental map for examining the different factors driving CO_2 emissions. The Kaya identity observes that a country's CO_2 emissions are the product of population level, GDP per capita, energy consumption per unit of GDP and CO_2 emissions per unit of energy supplied, so that the change in CO_2 emissions in any given period is the sum of the changes in each of these factors in that period:

CO_2 emission growth =
Population growth + GDP per capita growth + energy intensity growth + carbon intensity growth

CO_2 emissions decline if the driver growth rates sum to a negative number. In most countries population growth is positive, and while GDP per capita can suffer set-backs, it is expected to trend up. Hence the focus in the climate policy debate is on the third and fourth drivers – energy efficiency improvements, and the replacement of high carbon with low or zero carbon fuels (including coal or gas equipped with CCS).

In the 1990s and early 2000s, rapid growth in the carbon intensity of global primary energy supply – due mainly to the switch to coal in Asia – on top of economic growth and population growth drove increases in global CO_2 emissions of up to 3-4% per year. Energy intensity declined but not fast enough to compensate for the positive values of the other drivers. In the 2011-15 period the carbon intensity of energy supply stabilized and CO_2 emission growth fell to an average of 1% per year, moving towards zero at the end of the period. In *Reform*, major energy efficiency improvements and small reductions in the carbon intensity of energy supply in the 2030s and 2040s more than compensate for population and economic growth and secure annual declines in CO_2 emissions in the 0-0.5% range. In *Renewal*, the Paris agreement, including its longer-term ambitions, takes centre stage. A period of confusion, frustration, and delayed action is overcome, and at around 2020 an unprecedented global effort to come to grips with global warming commences. Carbon markets multiply and tighten with high and interlinked prices, and governments go

Modelling a 1.5° scenario?

The commitments made in Paris in 2015 indicate a levelling out of global warming at some 3° above pre-industrial level. This was as far as countries were prepared to go. However, it was agreed to reconvene and tighten commitments at 5-year intervals with a view to further suppress GHG emissions and lower the warming outlook. As for how much it should be lowered, most delegates came to Paris with a 2° ceiling in mind, but an alliance of vulnerable countries argued that they might still be deprived of their means of existence in a 2° world, and their call for a 1.5° ceiling has since gained considerable traction.

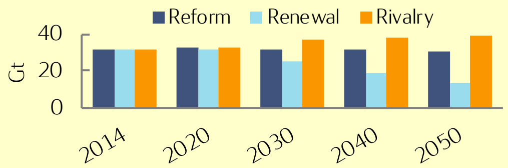
Analysts continue to build sustainable energy demand scenarios based on the 2° target. For the moment, there are no benchmark scenarios delivering the 1.5° target with a high probability, and little science that addresses this target at all. IPCC is compiling input to a report on the subject for release in 2018.

Awaiting better characterizations of a 1.5° world, IEA and IRENA have put out energy scenarios generating less emissions and therefore having a higher chance of success in meeting the 2° target than today's benchmark 2° scenarios. Probabilities are crucial in climate science. How much uncertainty that is permitted determines how much fossil fuels that can be left in the fuel mix.

On present indications, a 1.5° target seems an extremely tough proposition. All easy options – and many difficult ones – will need to be exploited to hold warming at 2°. The last half degree will likely cost much more than the distance between the two targets might indicate. The 2° target offers some flexibility with respect to timing and combination of measures, a 1.5° limit offers none. The world would likely need to achieve net zero carbon emissions between 2045 and 2055, 15-20 years earlier than under a 2° cap, implying that governments that are still working out how to deliver on their Paris targets would have to take more radical action.

Reducing net carbon emissions to zero would mean terminating all fossil fuel based power generation not equipped with CCS, converting all road and as much air and marine transportation as possible to zero carbon fuels, eliminate fossil fuel use in the buildings sectors and almost eliminate it in industry, and probably implement negative emissions on a big scale to compensate for excessive emissions in the past. Many of the technologies needed to accomplish these changes remain untested at scale, and unsupported by any known business models. It will also be absolutely critical to address the 1/3 of emissions that are not energy-related.

Global energy-related CO_2 emissions



Source: IEA (2014), Statoil

all in to accelerate the pace of energy efficiency improvement and zero carbon technology deployment through mandates and standards.

Technology and market forces exert stronger downward pressure on emissions in *Renewal,* since they are key mechanisms for achieving the target towards global warming reduction, and directed to prioritize accordingly. Today's system constraints on the share of intermittent electricity generation in total electricity supply become less binding in response to break-throughs for large scale electricity storage, a strengthening of transmission networks and more widespread demand side management. Unconventional cars and trucks which capture big market shares in *Reform* become ubiquitous in *Renewal*. Buildings are retrofitted or replaced ahead of "natural" time. Financial support for green investments is available from budgets financed in turn from carbon taxes and/or savings on conventional fuel expenses.

Towards 2020, global energy-related CO_2 emissions remain at today's level before going into rapid decline. By 2040 they total some 18.5 billion tons (Gt). By 2050 they are between 13 and 14 Gt. This is below the level suggested by the IEA as consistent with a 50% probability of limiting global warming to 2°C in its 450 scenario, although above the level recommended for a 66% probability of achieving the same result in its scenario associated with the "Well-below 2°" ambition of the Paris agreement.

The biggest difference in driver terms between *Renewal* and *Reform* is a much bigger contribution from decarbonization of energy supply, due in part to CCS, but also to more wind, solar, biomass and nuclear.

In *Rivalry*, a sceptical stance towards climate science becomes commonplace. This happens partly because a rejection of science based and globally coordinated approaches sits well with the inward looking, populist politics underpinning *Rivalry*. It happens also because leaders are distracted by challenges such as international tensions breeding security threats, inter-religious tensions triggering terrorism, immigration pressure stoking local and national unrest, and investor pessimism prolonging and aggravating unemployment problems. Neglect of the global warming drivers feeds back on, and reinforces, many of these distractions.

Most countries deliver partially on their Paris commitments, but no tightening takes place, and the agreement gradually loses its relevance. The EU ETS lingers on, but plays no meaningful role. The other existing regional emission allowance trading systems stall. CCS does not progress beyond the handful of projects in operation or at advanced stages of implementation. This does not mean that interest in energy efficiency and renewable energy evaporates. Investments limiting fossil fuel import dependence are encouraged, and local pollution problems remain sources of public discontent. But a softer focus on, and a scarcity of funds for these issues slow the transition to lighter, greener energy systems. Global energy related CO_2 emissions increase throughout the period and are by 2050 almost 40 Gt per year. In *Rivalry*, growth in the carbon intensity of energy

Carbon budgets in the GHG policy debate

Global CO_2 emission decline targets are typically based on estimates of the so-called global carbon budget. This concept reflects the near linear, but wide, relationship that seems to exist between cumulative man-made CO_2 emissions and the average global surface temperature. It enables the translation of any agreed limit on global warming into a limit on cumulative CO_2 emissions since pre-industrial times. Deduction from this total of historical emissions gives the remaining budget. Deduction from this sub-total of likely emissions from industrial processes and land use changes gives the remaining budget for fossil fuel related emissions. Budgets are typically set for emissions between now and 2100. Energy scenarios tailored to meet them typically suggest that they will be used up well before 2100, and overshot. This implies that net emissions from some point will need to become not only zero, but negative, to compensate for the earlier overshooting and for remaining emissions from sectors that cannot be fully decarbonized.

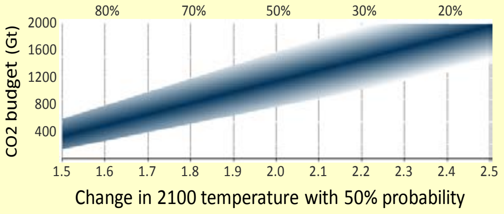
Although the cause-and-effect relationship between cumulative CO_2 emissions and global warming is well established, it can be quantified only in a probabilistic way. Thus, if the world requires a 66% probability of global warming levelling out at some given level, emissions must be squeezed more – i.e., the budget must be smaller – than if the requirement is a 50% probability.

IEA's 450 scenario is based on a 1080 Gt fossil fuel related CO_2 budget for the 2015-2100 period. However, it comes with a 50% probability of achieving the 2º target. IEA's and IRENA's joint scenario released earlier this year is based on a much lower 790 Gt budget – but in return indicates a 66% chance of delivery on the 2º target.

Conceivably, land use changes and industrial processes could do with smaller CO_2 emission budgets, leaving a bigger slot for fossil fuel related emissions. But these emission sources are expected to play minor roles as it is. Stepping up efforts to reduce other GHG emissions could take pressure off the CO_2 budget, but measures to reduce CH_4, SO_2, NO_x and black carbon emissions are already factored into most CO_2 budget calculations.

The exact size of the carbon budget is subject to considerable uncertainty and sensitive to assumption values, as indicated by the IEA/IRENA:

Carbon budget associated with temperature scenarios



Source: IEA/IRENA

We continue to base our *Renewal* scenario on a CO_2 budget for the 2015-2100 period broadly in line with the 1080 Gt budget assumed for IEA's 450 scenario. This budget line is crossed during the 2040s in *Reform* and *Rivalry*, but is less than 80% exploited by 2050 in *Renewal*.

supply is net positive all the way to 2050, and the sum of this factor and population and economic growth trumps energy efficiency improvements and ensures positive, though slowing, growth in emissions throughout the scenario period.

Carbon capture and storage

CCS features in most 2° and "Well-below 2°" scenarios. The Intergovernmental Panel on Climate Change (IPCC) estimates that reaching the 2° target will be more than twice as expensive without CCS as with CCS. In IEA's 66% 2° scenario CCS increases towards 3 Gt of CO_2 per year by 2050. Beyond 2050, CCS on biomass use is widely counted on to remove already emitted CO_2 from the atmosphere.

CCS continues to edge forward. Last November a project to capture and store 0.8 mt of CO_2 per year from an iron and steel plant – the first of its kind – was launched in Abu Dhabi. In December, the US Petra Nova project designed to capture 1.4 mt of CO_2 per year from an existing coal power plant started operations. In March the first of several planned Chinese CCS projects targeting CO_2 from syngas plants received final investment decision, and in April the US Illinois Industrial CCS plant began operations. This project is ground-breaking because it is tied into a biofuels projects, capturing CO_2 from the processing of corn into methanol.

The Global CCS Institute estimates that in 2017 a total of 40.3 million tons (mt) of CO_2 will be captured and stored. This is up from 22.1 mt in 2012. CCS has however a long way to go to reach the levels foreseen for 2040 and 2050 in 2º scenarios – and the Global CCS Institute expects little growth in captured volumes over the next five years; the pipeline of projects nearing completion is short. The institute observes that the projects starting operations now were decided several years ago under more favourable policy conditions than those prevalent today.

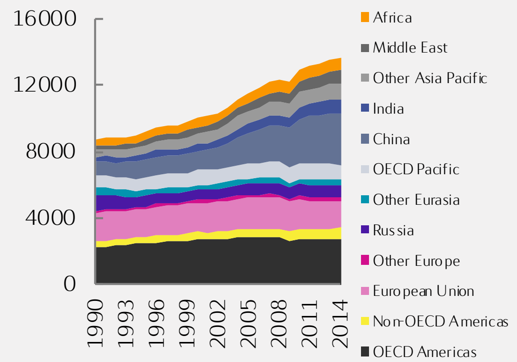
CCS remains without viable business models, apart from selling the CO_2 to nearby oil fields relying on EOR, and that is not an option everywhere. CCS also lacks the popular and policy support that has boosted wind and solar power, and the carbon market support counted on in the 2000s – CO_2 prices remain way too low to make CCS competitive, and too low to provide adequate funds for project subsidization.

Some see CCU – carbon capture and utilization – as the solution, and there are underexploited usages for CO_2. But there is also research suggesting that CO_2 utilization can only be a small supplement to CO_2 storage.

Our assumptions on CCS for Energy Perspectives are that there will be:

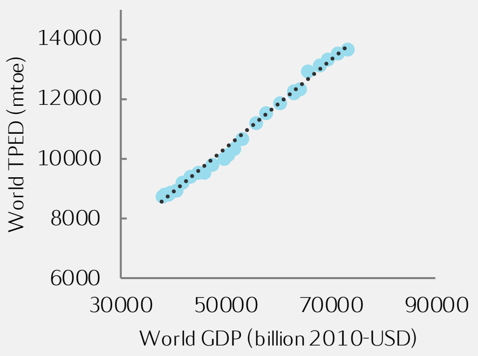
- No progress in *Rivalry* beyond the handful of projects in operation or at advanced stages of preparation as of 2017.
- Many successful projects in *Reform*, but no scale-up making CCS an important contributor to global warming mitigation.
- Significant growth in *Renewal*, though only to about half the level assumed by IEA for its 66% 2º scenario, and with minimal use before 2050 of CCS on biofuels to enable negative emissions.

World primary energy demand net of international bunkers, 1990-2014
Mtoe



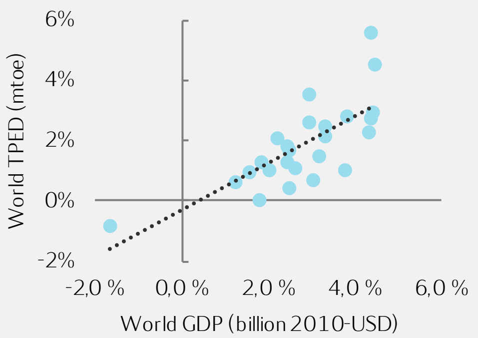
Source: IEA

World primary energy demand and world GDP
1990-2014



Source: IEA

World primary energy demand growth vs economic growth, 1990-2014



Source: IEA

Energy demand outlook

Energy demand scenarios are the starting point for individual fuel demand scenarios and for the fuel supply, fuel price and GHG emission scenarios linked to each of them.

Energy demand is driven by economic growth, changes in individual sectors' contributions to this growth, technology developments and investor and consumer decisions. These decisions are in turn influenced by market signals, lifestyle and other broad societal trends, and policy. In market economies investors and consumers have the last say on their purchases, but policy makers can to an extent steer technology developments and constrain choices by setting energy efficiency and other standards, and by introducing taxes and subsidies.

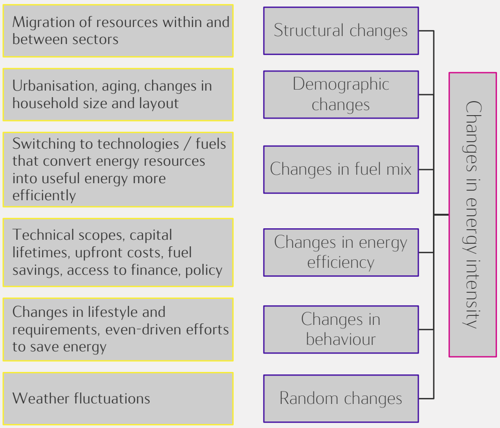
The technical scope for energy savings is normally estimated bottom up by comparing the quantities of energy required to produce given goods and services in given amounts with standard equipment, with how much would be required when using the most energy efficient equipment on the market. The estimated gaps between energy use today and energy use if all standard equipment is replaced by best available equipment indicate how much energy demand can be reduced without loss of welfare. Actual energy savings are however further shaped by real-life circumstances. Superior equipment is often more expensive so that only a portion of technical replacement possibilities makes economic sense to investors, and replacement decisions are normally bound by equipment lifetimes. Also, investors may not be aware of all their options. Energy efficiency policies are thus very much about leading investors towards best available technologies by means of carrots in the form of information and financial support, and sticks in the form of mandates and standards.

History shows that energy consumption *is* becoming more efficient, but also suggests that it is not easy to politically push the pace of improvements. Research on the impacts of existing energy efficiency policies is inconclusive. There are examples of energy intensities declining as a direct result of policy intervention. But there are also examples of energy demand failing to respond to policy incentives, or bouncing back after temporary improvements.

Globally, energy demand has grown in a fairly stable relationship to GDP. IEA data suggests a ratio of global primary energy demand growth to global GDP growth of 0.70 for the 1972-2014 period. Dividing the world into the OECD countries on the one hand and all other countries on the other, and focusing on the shorter, more recent 1990-2014 period, shows a ratio of 0.32 for the former countries and a ratio of 0.62 for the latter. As economies mature, they become more service and high-tech industry based and require less energy to sustain growth.

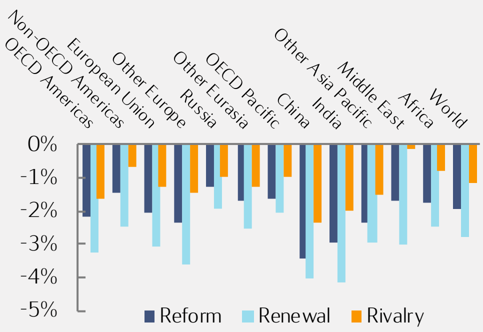
OECD area primary energy consumption seems to have levelled out. IEA data suggest that between 2009 and 2014 a 1.8% per year increase in GDP generated a mere 0.1%/y increase in energy demand. Outside the OECD area, however, a 5.5%/y growth in GDP drove a 3.8%/y growth in energy use. The non-OECD share of world energy demand increased from 48% in 1990 to 62% in 2015, and continues to increase.

Energy intensity drivers



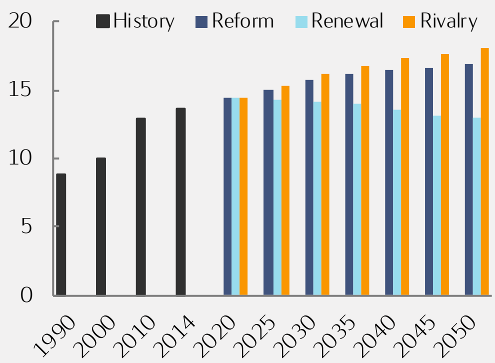
Source: Statoil

Average annual changes in energy intensity (TPED/GDP), 2014-2050



Source: Statoil

World primary energy demand in the EP17 scenarios
Btoe



Source: IEA (history), Statoil (projections)

That OECD energy demand has peaked for good and will fluctuate around a gently declining trend over the next 30-40 years, is part of the current consensus. Stagnant and aging populations, expectations of only moderate economic growth, plenty of opportunities based on well-known technology to reduce energy intensities, and strong interest in smart cities, smart grids, electric vehicles, carpooling, etc., constitute the basis for this view.

Non-OECD energy demand is however bound to continue increasing because of much higher population growth rates and more dynamic economies, and since narrowing today's living standard gaps – a universally accepted goal – will not be possible without giving billion of people better access to modern lighting, heating, appliances and transportation.

The deployment of energy efficient technology and systems to the non-OECD world needs to be fast-tracked if energy efficiency is to help with emission target attainment. The challenges are to design and build confidence in other and more sustainable ways to do this than those that have brought the OECD countries to prosperity.

One non-OECD country – China – is standing out as a contributor to the recent flattening of global energy demand. Economic liberalization and rapid growth left the Chinese economy some 23 times bigger in 2010 than in 1980. In the beginning, growth was labour intensive, and energy demand did not increase as fast as the economy. But the 2000s saw a ramp-up of investments in infrastructure, buildings and heavy industry, and energy demand shot up by nearly 9% a year. However, set-backs for Chinese exports and mounting local environmental problems triggered a rethink of this model. Recently economic growth rates in the 6.5-7% range have given rise to energy demand growth rates of only 2-4%, declining in 2015 to 1-1.5%. The 13th Five-Year Plan covering the 2016-20 period promises more of the same – real GDP growth is to be kept at 6.5% per year and energy demand growth is to be capped at 3-3.1% per year. Chinese authorities aim for a decline in the energy intensity of the Chinese economy of 3.2% per year or 15% in total.

Indian leaders have not given the same priority to nation-wide energy intensity targets as Chinese leaders. The Modi administration is striving to modernize the energy sector, but has concentrated on upstream reforms, pricing reforms, electrification – 240 million Indians had by 2015 no grid access – and paving the way for new renewable power supply, especially solar PV generation. Thus, while Chinese energy demand has flattened, Indian demand has not – the country used 5-6% more energy in 2015 than in 2014. India's energy demand is still less than a third of China's demand, but could increase to half of Chinese demand by 2050.

Scenario impacts

In *Reform*, global primary energy demand increases by 24% or by an average of 0.6% per year between 2014 and 2050, with the energy intensity of the global economy declining by some 50% or by an average of 1.9%/y. The improvement in energy intensity is more than double of what we experienced between 1990 and 2014. While OECD area energy demand declines by a total of 14% between 2014 and 2050, non-OECD demand grows by 49%. Most non-OECD regions apart from non-OECD Europe and Russia are still on rising energy demand curves by 2050,

The energy intensity-carbon intensity trade-off space

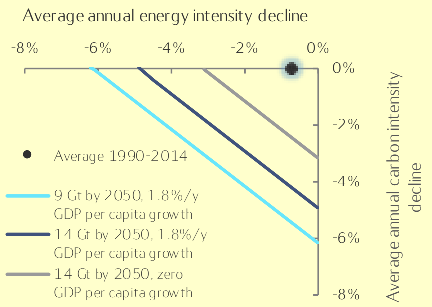
Economic development, technological progress and market signals have driven reductions in both energy intensity and carbon intensity. The market is however not delivering these changes fast enough. This puts governments in a central position. There is a need for policies slowing energy demand growth and further decarbonizing energy supply.

The sum of policies needs in the first place to eliminate the emission increases resulting from population growth and economic growth, and then to deliver declines consistent with climate and emission level targets. The below chart illustrates the trade-off space.

If the emission target for 2050 is set at below 9 Gt, and if global GDP and population growth rates are assumed to be 3.1%/y and 0.8%/y respectively, in line with IEA's and IRENA's so-called 66% 2º Scenario, then combinations of energy intensity and carbon intensity decline targets must be sought along the red budget line. In the extreme (and hypothetical) cases of no change in either energy efficiency or carbon intensity, a decline of 6.6% a year in the other metric will be necessary. If the emission target is set at some 16 Gt in line with IEA's 450 scenario, and again with GDP per capita growing at 2.3% per year, the budget line shifts inward to the blue line connecting extreme values of -4.6%/y. Statoil's *Renewal* scenario which delivers some 14 Gt/y of emissions by 2050 is represented by the green line. Finally, in the undesirable and unlikely event of zero GDP per capita growth over the entire scenario period, a 14 Gt emission target would call for energy intensity and carbon intensity decline rate combinations along the orange budget line with 3% per year reductions in each metric as extreme values.

Historically the world has not been close to any of these trade-off lines. Between 1990 and 2014 the energy intensity of the world economy declined by an average of 0.9% per year with the carbon intensity of the world economy not changing at all. In recent years, carbon intensity has also started to come down, and there is more policy focus on these issues now than in the past. Still the world has some way to go to get on track towards long-term energy sustainability.

Energy Intensity reduction – Carbon intensity budget line



Source: IEA/Statoil

although growth slows in the 2030s and even more so in the 2040s. As a rule, energy intensities drop faster in the future than in the past, although for different reasons in different regions. In the OECD area and in some non-OECD regions, technological innovation and policy play key roles. In other non-OECD regions, structural changes matter more.

In *Renewal* world energy demand drops by a total of 6%, reflecting a 2.8% per year decline in the energy intensity of the global economy, 3 times that of the 1990-2014 period. The OECD regions' energy use drops by a total of 37% with the non-OECD regions combined demand increasing by a total of 16%. However, around 2040 also non-OECD demand levels out and goes into decline, with only Africa, India and non-OECD Asia net of China and India continuing to grow their energy consumption.

In *Rivalry* world energy demand increases by 32% – although slower economic growth dampens energy growth, a paltry 1.1% decline in the energy intensity of the global economy pushes demand growth above the level in *Reform*. OECD demand declines also in *Rivalry*, but only by 3.5%, and non-OECD demand grows by 55%. Energy efficiency is valued also in *Rivalry*, as one way to mitigate energy security risk and environmental degradation. However, inward looking leaders favour energy supply side rather than energy demand side measures. Funds for investments in energy efficiency are in short supply especially in the hardest hit non-OECD regions, and protectionism slows the dissemination of ideas and technology. Also, the tensions ebbing and flowing in *Rivalry* drive shifts in investments from energy light consumer oriented services towards defence and other energy heavy sectors.

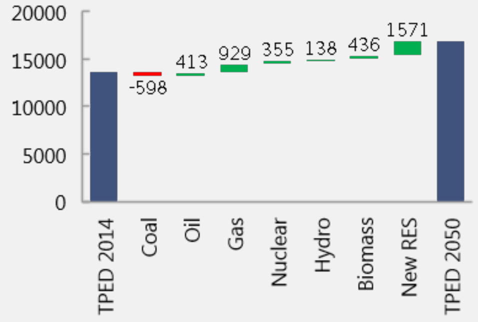
Fuel mix outlook

The global fuel mix is changing, though not as quickly as the attention paid to wind and solar power suggests – or as it should from a global warming mitigation point of view.

In 1990 fossil fuels, net of international marine and aviation bunkers, made up 85.5% of global total primary energy consumption. In 2014 fossil fuels were down to 82.6%. The oil share of this total has dropped significantly, from 36.9% to 31.3%. But the gas share has increased, from 19.0% to 21.2%, and so has the coal share – from 25.2% to 28.6%. As for the non-fossil shares of energy consumption, biomass and hydro were about as important in relative terms in 2014 as in 1990. Nuclear has declined in both absolute and relative terms. New renewable energy including mainly wind, solar and geothermal energy increased its share from 0.4% in 1990 to 1.4% in 2014.

Oil has lost market share as cars have become more energy efficient and as oil has been marginalized as a power sector fuel everywhere but in the Middle East. Gas has gained market share largely because of its growing popularity – for cost, environmental and supply side reasons – as a power sector fuel. Coal has risen mainly because of Asia's rapid economic and electricity demand growth. Nuclear has declined in response to the Chernobyl and Fukushima disasters which triggered strong NIMBY – not in my backyard – attitudes, and a focus on safety provisions that has sent development costs skyrocketing at a time when other generation options

Changes in global TPED in *Reform* 2014-2050
Mtoe



Source: Statoil

Changes in global TPED in *Renewal* 2014-2050
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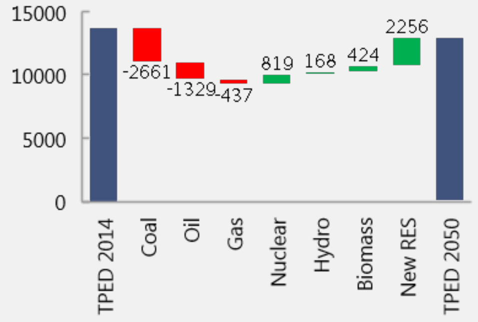
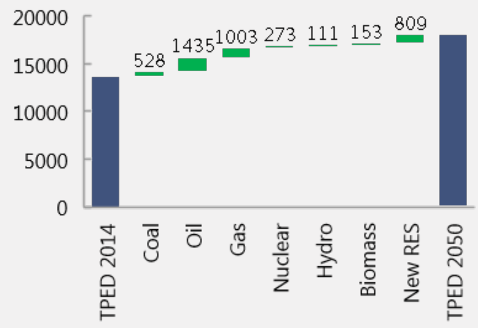


Source: Statoil

Changes in global TPED in *Rivalry* 2014-2050
Mtoe



Source: Statoil

have become cheaper. Wind and solar power generation has grown based on political support, but increasingly also because of improving economics.

Fuel mix developments since 2010 indicate that the global mix could be in for major changes. Two trends stand out: Coal is losing market share, and new renewable power is growing at a pace making the "small starting points" argument for not paying attention, increasingly unsustainable.

World coal demand as a share of world total primary energy demand peaked in 2011 at 29% and has since edged downward. The coal share of OECD energy consumption started to decline around 2008 due mainly to the North American shale gas revolution. Promises of restoring the role of coal in the US are dismissed by most observers as implausible. EU coal use has faced less direct competition from gas but was still 17-18% lower in 2015 than in peak year 2003.

Important as the OECD regions' turning away from coal is, China's recently subdued appetite for solid fuels could matter more. Chinese coal demand increased by an average of 7.5% per year between 2003 and 2013, and by 15% as recently as in 2011, but declined by 3-4% per year in 2014 and 2015 in response to slower growth, structural shifts in the economy and competition from other, environmentally preferable fuels. Chinese coal use could still bounce back, but if that happens the rebound will likely be weak and temporary. The 13th five-year plan foresees a reduction in the share of coal in total primary energy consumption from 65% in 2014 to 58% by 2020, an increase in the share of gas from 5% to 10% and an increase in the share of non-fossil fuels from 12% to 15%. For India and South-East Asia further growth in coal use should be expected, and this will moderate the pace of decline in the coal share of global energy demand. But also these countries aim to reduce their reliance on solid fuels.

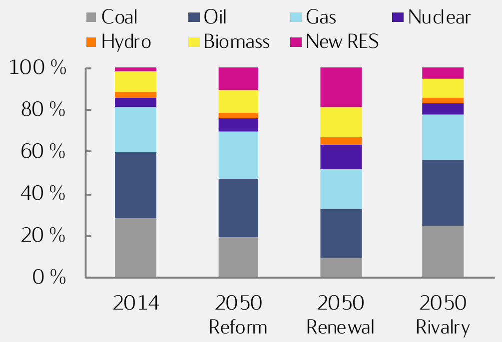
The other main trend in the global fuel mix is the relentless growth in new renewable power – mainly wind and solar PV – generation capacity. Also, this trend is expected to continue.

Scenario impacts

In *Reform*, the coal share of global TPED, which was 29% in 2014, declines to 20% in 2050. Barring either geopolitical developments suspending energy trade and technology exchange and forcing key countries to live within their energy resource means, or a decisive breakthrough for CCS, it is difficult to see a world-level renaissance for solid fuels. In *Renewal,* the coal share develops much as it does in *Reform* up to 2020, but then it drops at an accelerating pace to only 10% by 2050. In *Rivalry*, governments and investors rally behind coal for a lack of more secure alternatives, with only a minor decline in the share of fossil fuels in TPED to 25% by 2050 as a result.

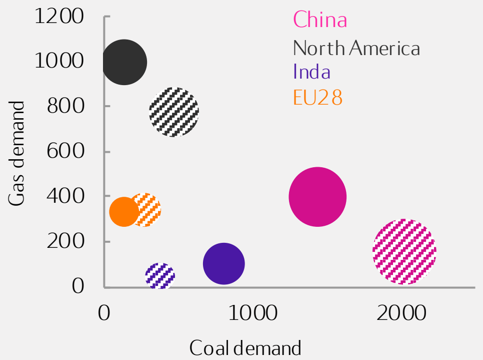
The future oil and gas shares of world primary energy demand are also subject to uncertainty. The oil share is expected to continue to decline as the world's car fleets go electric, with biofuels, CNG and possibly hydrogen playing supportive roles in select markets. There are however many views on how quickly and to what extent unconventional vehicles will side-line

Global primary energy mix
2014 and 2050



Source: IEA (2014), Statoil

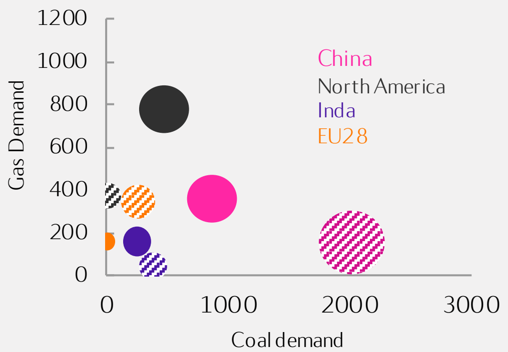
Coal and gas demand in four key regions in *Reform*, 2014 and 2050 (mtoe)
2014 = stripes, 2050 = solid



Source: IEA (2014), Statoil

Note: size of circle indicates total primary energy demand

Coal and gas demand in four key regions in *Reform*, 2014 and 2050 (mtoe)
2014 = stripes, 2050 = solid



Source: IEA (2014), Statoil

Note: size of circle indicates total primary energy demand

gasoline and diesel vehicles. OECD industrial and residential oil use dropped by 40% between 1990 and 2014, and there are no signs of a rebound in demand. The chemical and petrochemical industry will require more naphtha and light fuel oil as feedstock, but this will only partly compensate for the decline in other demand.

Driven by low prices the oil share of global TPED increases in the short term in all scenarios, but it peaks by 2020 in *Renewal* and in the mid-2020s in *Reform* as electric cars become fully competitive, and to varying degrees also because of energy efficiency and fuel substitution policies. The share is down from 31% in 2014 to 28% by 2050 in *Reform* and to 22% in *Renewal*. In *Rivalry*, the oil share levels out because of subdued economic growth and security of oil supply concerns, and it is still 32% by 2050, reflecting less emphasis on energy efficiency, less electrification of road transportation, and the fact that other fuels are hit harder by the political hardships that define this scenario.

The gas share increases in some regional markets, but declines in others. Gas is widely welcomed as a solution to a range of emission problems. Gas is also in more ample supply at lower costs than assumed a decade ago. The gas share of world TPED increases gently from 21% in 2014 to 23% in 2050 in *Reform* and to 22% in *Rivalr*y, but declines to 19% in *Renewal*; in 2° scenarios all fossil fuels need to be suppressed, barring a massive roll-out of CCS. In the OECD regions, the gas share declines sharply after 2030 but in China, India and other non-OECD Asia where coal remains significant and local pollution problems receive top priority, it keeps growing, albeit slowly.

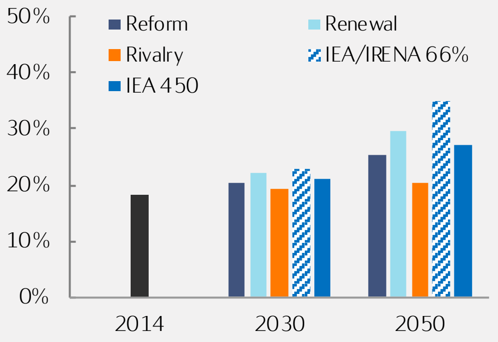
Until the early 2020s the nuclear share of world TPED does not change much in any scenario, and it remains in the 5-6% range in both *Reform* and *Rivalry*. In *Renewal*, however, many governments come to see nuclear as an indispensable source of zero carbon, dispatchable power supply, pushing the share up to 11.5% by 2050.

Hydroelectricity increases its share of global primary energy supply, though only marginally in *Reform* and *Rivalry*. Biomass consumption is subject to two opposing drivers – the need to reduce traditional biomass use and an ambition to increase modern biomass use. In *Renewal*, the latter driver ensures a growing biomass share of world TPED. Wind and solar power generation expands in absolute and relative terms across scenarios, though most rapidly in *Renewal*. See separate chapter for details.

Power sector outlook

The electricity share of global final energy consumption (TFC) is expected to increase, for technology, market and policy reasons. The appliances underpinning modern lifestyles are with few exceptions electric. The IT revolution is particularly electricity intensive. As for policy, the targeted decarbonization of the global economy is widely perceived as a two-step process, with the first involving (apart from energy efficiency improvements) the conversion of as much fuel use to electricity use as possible, and the second involving the decarbonization of electricity supply. The electricity share of world TFC increases from 18% to 25% by 2050 in *Reform*, 20% in *Rivalry* and 30% in *Renewal*.

Electricity share of total final energy consumption



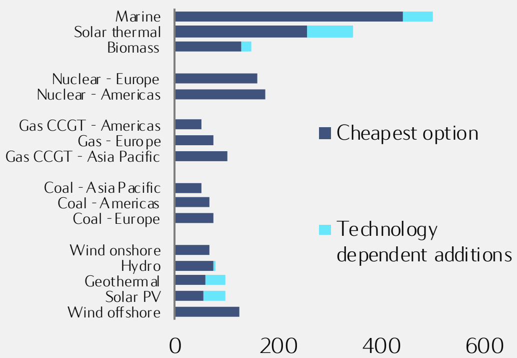
Source: IEA (2014), Statoil

Power plant competitiveness concepts

There are two common metrics for assessing the competitiveness of individual power generation options. Generators base their short-term existing conventional capacity dispatching decisions on so-called spark spread – dark spread comparisons, and their long-term new capacity investment decisions on so-called levelised cost of electricity (LCOE) comparisons. The latter concept is the most relevant for long-term energy scenario analysis.

The LCOE of a power project is the electricity price the owner needs to break even on his capital, financial, operating and maintenance and fuel costs, and make a standard return on his investment, over the lifetime of the project. LCOE estimates rest on multiple assumptions and are correspondingly uncertain. Most recent estimates indicate however that further growth in renewable power is a done deal regardless of support levels.

LCOE estimates, 1st half 2017
USD/MWh



Source: Bloomberg New Energy Finance (BNEF)

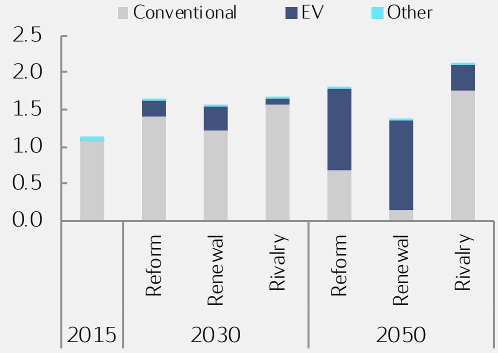
Coal is still by far the biggest source of electricity supply, accounting in 2014 for 41% of global power generation. Coal power generation is however increasingly becoming an Asian emerging economy play. In the OECD regions, the coal share of power generation peaked at 43% in 1983 and was by 2015 down to 30%. These conflicting trends reflect developing Asia's rapidly growing electricity demand and natural resort to indigenous, cheap fuels, and the OECD regions stagnant electricity demand and widening range of alternatives to coal power with nuclear, gas and recently wind and solar entering the supply picture.

Gas accounted for 22% of total global electricity generation in 2014. Growth took off in the early 1990s when certain countries that had considered gas too valuable for the power sector changed their minds. There have been signs of stagnation since 2010 with utilities responding to fuel price signals by switching from gas to coal, and to policy signals by bringing new renewable capacity online. Gas to power is still seen to have a future in countries with ample indigenous gas resources and/or major coal related emission challenges.

In *Reform*, the coal share of global power supply drops from 41% in 2014 to 27% in 2030 and 19% in 2050. In the OECD regions, governments act on their Paris commitments and local emission concerns, investors act on technology and cost signals favouring options other than solid fuels, and the coal lobbies weaken, with drops in the coal power shares to the 10-12% range as a result. In China, India and other non-OECD Asia coal remains important, but shares decline to 27% in China and 40-45% in the other regions. The global gas share increases slightly to 24% by 2030, but falls back to between 20 and 21% by 2050 because of pressure from new renewables.

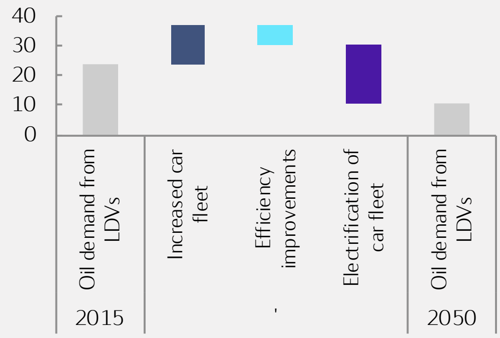
In *Renewal*, coal to power is almost eradicated – only China, India and to an extent other non-OECD Asia retain coal power industries on a scale that matters. Globally the share of coal in total electricity generation is slightly above 5% by 2050. The share of gas is also sharply down, to 8%. In *Rivalry*, coal retains higher market share than in *Reform*, but still declines to 26% by 2050. Coal is subject to less climate policy pressure, but remains unpopular for local pollution reasons, and faces increasing competition on cost from new renewables. The gas power share holds up better and ends at between 24 and 25%. In some regions where gas can capitalize on its availability and low costs, the use of gas in electricity generation fares better in *Rivalry* than in *Reform*. Nuclear suffers mildly – as a high cost option it is not favoured by the macroeconomics of *Rivalry*, but as an indigenous option to regions with secure access to uranium it is favoured by the emphasis on supply security.

Global LDV fleet
Billions



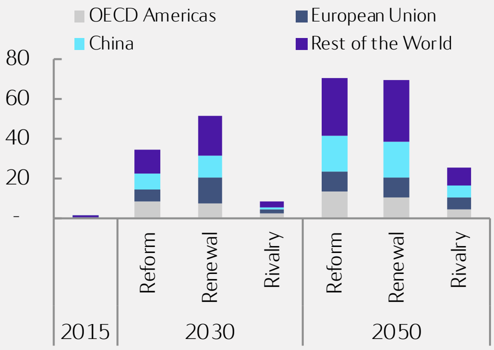
Source: Statoil

Oil demand from LDVs in *Reform*
Mbd



Source: Statoil

Global EV sales
Millions



Source: Statoil

Energy demand in transport

Global demand for mobility is increasing as population and wealth grow. Growing prosperity in emerging economies helps lift their citizens from poverty into middle class and with it comes an increased demand for energy. The transport sector represented more than half (56%) of global oil demand in 2016, growing by an annual average of 1.5% over the last decade. Three quarters of this demand came from road transport and more than half (56%) was demand from cars and motorcycles (LDVs). The growth in demand has been driven by a growing road vehicle fleet, including heavy vehicles and motorcycles, which has more than doubled since 2000, from 1.1bn to 2.3bn road vehicles in 2015. Most of this growth has been motorcycles. The importance of the transport sector's part of total global oil demand is obvious. With new trends and technologies emerging rapidly there are clear indications that the transport sector is changing and that mobility in the future will be of a different kind, composition and size than it is today.

Push from policy

The emerging green shift in transport is now driven forward by regulations and incentives in many countries around the world, much due to increased focus on environmental issues and the COP21 Paris agreement. Leading up to and following the ratification of the agreement, several countries have set clear targets for road transport emissions and actions to reduce CO_2 emissions and local pollution, which is an increasing problem accompanying congestion in urban areas. Electrification of the global car fleet has been identified as one of the key actions that will make a significant impact. The multi-governmental forum "Electric Vehicles Initiative" (EVI), consisting of 15 countries such as China, India, US, France and Germany, is working to promote road transport electrification through collaboration and has set an ambitious target of 20 million EVs by 2020. Although the target may be out of reach in the short timeframe, it sets a clear direction for the future development of road transport. Several countries are already debating banning internal combustion engine vehicles (ICEVs) by the end of the 2020s, some even sooner. The push from policy and stricter regulation on emissions has forced car producers to develop and expand their fleet portfolios with low- and zero-emission vehicles. This will lower the total portfolio CO_2 emissions and continue to allow producers to manufacture and sell ICEVs with large engines and accompanying large emissions. Many of the large car producers have announced a release of a new electric/hybrid fleet portfolio around 2020. Biofuel content in transport fuel is expected to increase in both the road and non-road sectors due to stricter regulation, and would be a way to reach the targets. Non-road transport will probably increase with the focus on reducing congestion and local pollution and lead to a shift from road to rail, as the need for mobility is increasing rapidly and the preferred solution from an environmental and a governmental point of view is public transport, above and below ground. Furthermore, expectations are for rapid growth in air transport as global and regional mobility increases with higher income levels.

Pull from technology and consumers

Partly because of the push from policymakers there is also an emerging

Autonomous cars – impact on miles driven

The thought of getting into a vehicle and be transported with little or no interaction with the vehicle has fascinated and enticed consumers for a long time. Autonomous cars already exist, and chances are that if you own a relatively new vehicle it is autonomous at level 1 or 2, be it cruise control with automatic distance control, self-parking features or emergency breaking systems or similar. The autonomy scale ranges up to 5 where the vehicle operates independently of any driver. In a world of almost full autonomy, which is probably not feasible in the next 20 - 30 years, car ownership as we know it today could be a thing of the past. Car sharing services, carpooling solutions and personally owned vehicles will roam the streets of urban settlements. The car fleet is consequently expected to decline/grow less, but higher utilization will lead to higher turnover and offset some of the decline in new car sales. Less cars would imply less vehicle miles travelled (VMT), higher utilization of each vehicle would counter this and possibly lead to increased VMT. Full autonomy introduces several factors that could both reduce and increase VMT for cars. It will increase mobility options for groups of citizens that are underserved, such as elderly, disabled, youths and those without a driver's license. A connected and automated vehicle (CAV) could reduce the time spent driving around looking for parking as it would know where the available spaces are and could park itself, thus reducing VMT. However, the vehicle could also drive around on its own while waiting for you, drive your kids to school, run errands or refuel and thus run up more miles. Easier travel, potentially less congestion and lower cost per mile allowing for longer travel from home to work could increase VMT.

Research in the US on the potential effects of vehicle autonomy on light duty vehicle VMT with scenarios ranging from no to full autonomy, with and without car sharing, show VMT growth estimates ranging from a decrease of half a trillion miles up to an increase of 6 trillion miles. Higher VMT can be counteracted by higher efficiency, optimized and smoother driving, less braking and accelerating, reduced aerodynamic drag due to platooning (two or more vehicles following each other in close proximity and thereby reducing the aerodynamic drag for the entire platoon).

An autonomous car is often thought of as an EV, a common conjunction fallacy, that because a car is connected and controlled by computers it is probably electric. For a product to replace an existing one it would have to be vastly superior with only a modest capital outlay. There is no reason to believe that EVs will check these boxes any time soon, so if autonomy takes off, it will, due to stint of market share, be adopted by ICEVs.

The impact of autonomy in road vehicles on oil demand is a multi-facetted and complex matter. The primary factor will not be technology, infrastructure or legislation. These are speed bumps and hurdles to navigate along the path. The main factor of impact is likely to be the rate of adoption by consumers, how quickly they will and can adapt to letting go of control and how much more they will travel as cost comes down and ease of travel increases.

pull for electrification of the car fleet from technology development and consumers. The increased efforts from car producers to bring to the market a low emission fleet adds scale to production and allows for new technology to be tested and implemented faster. Apart from Tesla and a select few others, who have built EVs from the bottom up, most large car producers have taken conventional vehicles in their portfolio and put batteries and electric engines into them. To enable sufficient scale, car producers are setting up custom made production lines optimized to build electric and hybrid vehicles. Battery technology development is rapidly improving energy density, driving range and lifetime of car batteries and scale of production is helping to bring cost per kwh down. Lithium-ion battery costs per kwh has, according to Bloomberg New Energy Finance, dropped by 73% since 2010. This average annual decline of 19% indicates that if continued, an EV would be competitively priced against an ICEV around 2025. Level 4-5 autonomous vehicles (see textbox for details) could have an impact on number of miles driven and ownership of cars and thus impact oil demand. Incentives and benefits have increased end users' appetite for EVs. The proposition of converting to a full or partially electric vehicle has become more appealing as the gap in price, driving range, convenience of use (access to charging infrastructure) and comfort features have been reduced compared to ICEVs. Access to electricity will help in this transition.

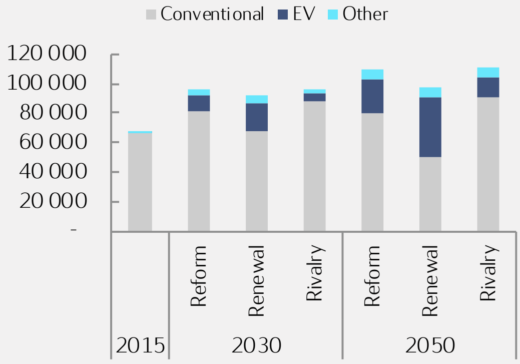
Digitalisation will change the ways of transport

The Internet of Things, smartphones, connectivity and autonomy will contribute in changing the way people and cargo are transported in the future. The growing global demand for mobility and continued urbanization trends represent a challenge. The need to develop more efficient ways of organizing public transport in dense urban areas is already obvious. Digitalisation enables direct contact between supplier of transport services and the consumer. Car sharing services and autonomous vehicles may be enablers to alleviate the pressure from congestion and do not necessarily pose a threat to conventional public transport. First- and last-mile assistance to and from train and transit stations provided by autonomous vehicles would increase accessibility and potentially increase the use of public transport.

Transport represents more than 50% of total oil demand in 2030 in all scenarios

The three scenarios have different assumptions for drivers and trends that will impact the transport sector, while the common features are weighted differently in each scenario. In *Reform,* development continues along the current pathway, with focus on reducing emissions and local pollution, based on the expectation that market rationale will pull in the desired direction assisted by regulations and incentives. The momentum of EV penetration is growing, and economy of scale and total cost of ownership will make EVs more competitive compared to ICEVs. The aviation fleet size increases and the amount of air travel is expected to double over the next 15-20 years, pulling oil demand up, despite higher efficiency requirements and biofuel additions. Continued healthy economic growth supports global trading and thereby further growth in oil demand from shipping and trucking, although more efficient engines and use of gas and biofuels also have an impact. In *Renewal*, strong coordinated global climate effort drives

Global truck fleet composition
Number of trucks

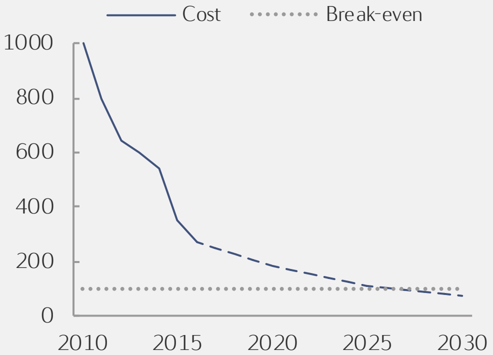


Source: Statoil

Connected autonomous vehicles

Source: iStock

Battery pack costs
USD/kWh



Source: Bloomberg New Energy Finance

decline in energy intensity forward and enables a radical electrification of the road transport sector, and LDVs in particular. Strong support to research and technology development leads to breakthroughs and focus on environment increases the speed of consumer adaptation to EVs regardless of incentives. Consumer behaviour is a vital component in this scenario, and it assumes that consumption per capita decreases on a global level; that we acquire less goods, reuse and mend things that are broken and travel less in a joint effort to reduce the strain on the global environment. In *Rivalry*, a world of increased tension and protectionism, the focus on environmental challenges fades as geopolitical unrest persists and capital investments reflect the trend. The consequence is slower technological development and more diversified driveline technologies, leading to a significantly slower electrification of the road fleet compared to *Reform* and *Renewal*.

In *Reform*, global oil demand from road transport continues to grow towards the end of the 2020s, although with large differences between regions. The EU and other OECD countries will typically see a continuation of the downward trend, while emerging economies will grow into the early 2030s and even towards 2040 in some regions. By 2020 the amount of full electric and plug-in hybrid electric cars is expected to reach around 16 million, 1.2% of the global fleet, missing the 20-by-20 target set by EVI. A pivoting point is reached around 2025 when EVs will gain a competitive advantage over ICEVs and the impact on global oil demand will become evident, no longer only in mature economies. By 2030 the EV share of the global fleet has grown to around 12% and oil demand from transport is almost 5 mbd lower than in *Rivalry*. Through the 2030s the effects of changes in transport patterns, digitalisation and electrification strengthen, and light-duty diesel cars become an insignificant portion of new car sales. The electricity share of the global bus and truck fleet will have grown from almost nothing in 2017 to around 10% in 2030. The growth of electrification is lower in this fleet segment due to slower turnover and the continued challenge that weight and size of the batteries represent. The global trucking fleet is expected to increase in all scenarios, driven by increasing population and economic growth. Potential trends of slowing and declining car density as regulations and incentives push towards increased use of public transport, add demand for transport of goods. Even in a *Renewal* world with less consumption, there will still be growth in demand for road freight. However, the demand for oil in trucking in this scenario is expected to decline due to fuel switching and improved energy efficiency.

Up until the early 2020s the three scenarios follow the same development before parting ways and ending up at very different endpoints by the end of the forecast period. By 2050 oil demand in transport ranges from 26 mbd to 68 mbd, with road transport capturing from 60% to 75% of total oil demand in transport. The level of electrification in road transport accounts for the major portion of the differences between the three scenarios, where electricity demand in the transport sector multiplies from the current level of ~400 TWh by 5 to 20 times, ranging from 2200 TWh to almost 6000 TWh.

3D printing

The Additive Manufacturing (AM) industry, known as 3D Printing and defined as "the process of joining materials to make parts from 3D data, usually layer upon layer, as opposed to subtractive manufacturing technologies", is booming. It reportedly grew by nearly 26% in 2015 to reach USD 5.2 bn. That is slightly down from the 33.8% CAGR observed for the last three years, yet still extremely promising. For instance, sales of desktop 3D printers almost doubled between 2014 and 2015.

The US is the largest producer of 3D items in the world, followed by China, Japan and Germany. Several major players involved in aerospace, motor vehicles and consumer products are generating value from its applications. Within the oil and gas industry AM is still immature, but some of the big suppliers are now moving parts of key products from the development to the manufacturing phase. Notable examples are critical turbine parts manufactured by GE and Siemens, which are expected to improve efficiency and performance.

One key advantage of 3D Printing is that it offers superior design freedom. Internal structures may be created for performance optimization and the number of parts in an assembly may be dramatically reduced. In some cases, the entire assembly can be printed as one part. Another important advantage is that material consumption can be reduced as most unused building material may be recycled. As the metal AM technology is still young, industry standards are immature and key alloys for critical components in the oil and gas industry are not yet available. More research will be carried out in the coming years to develop and benchmark the properties of these materials.

AM will have the capacity to disrupt the traditional manufacturing industry as technology matures and product prices fall. It will encourage the innovation of new products and may change completely the way industrial manufacturing is done. Traditional manufacturers who choose to ignore 3D printing may fall prey to new competitors who embrace it.

The transport sector will come under threat as the number of parts required to be shipped from different locations to create a product will diminish. A component previously made from many separate parts from a variety of raw materials at different locations can be made as one component using one material. A good example is GE's jet fuel nozzles. These used to require 18 separate parts and are now printed as one component with just a single alloy.

According to a PwC estimate from 2015, as much as 41% of the air cargo business and 37% of the ocean container business is at risk because of 3D printing. Roughly a quarter of the trucking freight business is also vulnerable due to the potential decline in goods that begin their journeys as air cargo or as containers on ships and ultimately need some form of overland transport. Transport of raw materials to printing location will partly compensate.

Source: General Electric

A bright outlook for hydrogen?

Hydrogen has been promoted for many years as an alternative to fossil fuels and an answer to problems ranging from the assumed peak in oil supply to – more recently – CO_2 driven global warming. Hydrogen has many industrial applications and is used as a rocket fuel, but for the moment it attracts interest mainly for its potential to replace gasoline and diesel and save transport sector CO_2 emissions.

Hydrogen vehicles are essentially electric vehicles carrying their own power plants in the form of fuel cells. A fuel cell generates electricity by combining hydrogen and oxygen atoms. Car manufacturers started to pay attention in the 1960s and build demonstration vehicles with the mass market in mind in the 1990s. They have struggled to see their visions through, however, partly for cost reasons and partly for chicken-and-egg reasons.

Hydrogen is not found by itself in nature – it exists bonded to carbon in hydrocarbons or oxygen in water, and needs to be produced, at a cost, from either of these elements. Moreover, hydrogen utilization requires dedicated distribution channels, storage tanks and engines that also drive costs. Hydrogen cars are less expensive to build today than 1-2 decades ago, but manufacturers have some way to go to match the competition on costs.

The chicken-and-egg problem refers to the fact that until a hydrogen refuelling infrastructure is up and running, customers will hesitate to buy, and manufacturers will be reluctant to produce, hydrogen cars. However, until the potential users of a hydrogen station network reach critical mass, fuel companies will hesitate to build it.

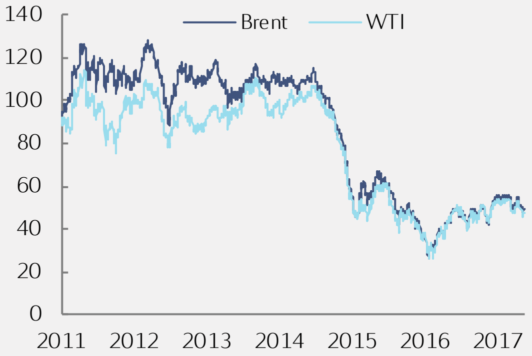
The climate credentials of hydrogen depend on how it is produced. Today the dominant method is steam methane reforming, i.e., separating the hydrogen from the carbon atoms in methane (CH_4). This process results in CO_2 which must be captured and stored if the hydrogen is to qualify as a zero-carbon fuel. An alternative, more expensive, method is to use electricity to split hydrogen from water through electrolysis. If the electricity is renewable, the hydrogen is genuinely zero-carbon. Thus, hydrogen holds some promise as a new outlet for gas, but could become a competitor to gas as well.

If hydrogen can be produced sustainably, the outlook for hydrogen vehicles will depend mainly on their future competitiveness with electric cars and biofuels powered trucks and buses. Hydrogen cars currently outperform EVs on driving range and refuelling time, and does not have the issues plaguing 1st generation biofuels, but struggle on costs and, as noted, on access to refuelling.

Hydrogen has other possible uses that could secure a break-through at last. In periods of excess wind or solar power generation, the surplus electricity generated can be converted to hydrogen through electrolysis for storage and later use as a source of back-up power or for sales to other sectors. As a high density and highly transportable fuel, hydrogen from renewable power also sits well with visions of increased international trade in clean energy.

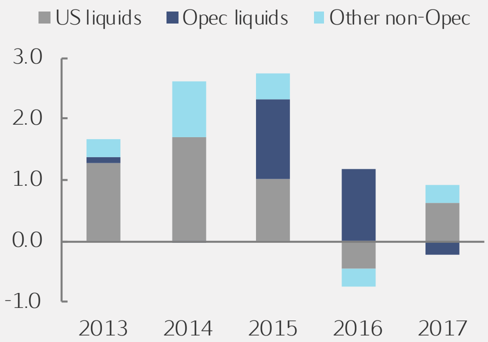
This year's Energy Perspectives does not propose precise market shares for hydrogen. Interest in this fuel which has ebbed and flowed is currently flowing, but the believers in hydrogen vehicles could still find that they are too far behind the competition – mainly electric cars – to secure a major foothold for themselves, at least for a long period.

Crude oil spot prices
USD/bbl



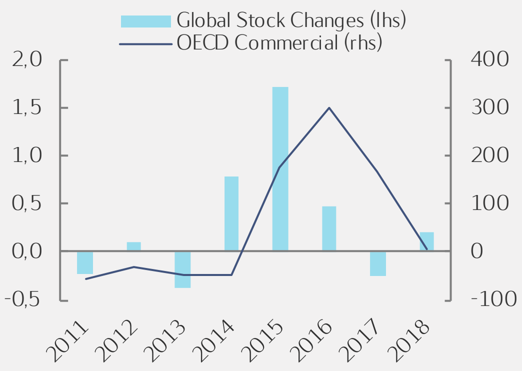
Source: Platts (Dated Brent), Nymex (WTI)

Global oil supply
Growth, y-o-y, mbd



Source: IEA (history), Statoil (projections)

Change in oil stocks
Change in oil stocks, mbd (lhs),
Excess OECD commercial oil* stocks, mb (rhs)



Source: Pira (history), Statoil (projections)

*OECD commercial stocks (annual average) vs. rolling 5-year average (e.g. 2011 vs average 2006-2010)

The global oil market

Current situation and outlook to 2020

Towards a more balanced market

In 2014, Opec abandoned its strategy of price defence and announced increased production to defend market share. This was primarily a response from Saudi Arabia to the accelerating US shale output and outlook of recovering Iranian and Iraqi production. The expansions in Iraqi and Saudi oil output, resilient US shale production and continued rise in non-Opec supplies outside the US pushed supply higher and kept the market in consistent oversupply up until the autumn of 2016. In January 2016, the Brent and Opec reference basket prices reached their lowest level at below 30 USD/bbl and 22 USD/bbl, respectively.

Opec's strategy was perceived to start working as US production went into significant decline, the build-up in inventories decelerated and upstream capital investments sharply declined from 2015 into 2016. The rebalancing was well supported by strong demand growth mainly due to low energy prices. However, the process of removing surplus inventories progressed very slowly and in November 2016, Opec and 11 producers outside of the cartel, including Russia, reached the first deal to cut production after the financial crisis. The deal called Opec members to reduce crude production by 1.2 mbd for 6 months if the other partners outside the cartel committed to contribute with further 0.6 mbd of production cuts. Prices immediately responded and settled in a narrow range around 55 USD/bbl up to February 2017.

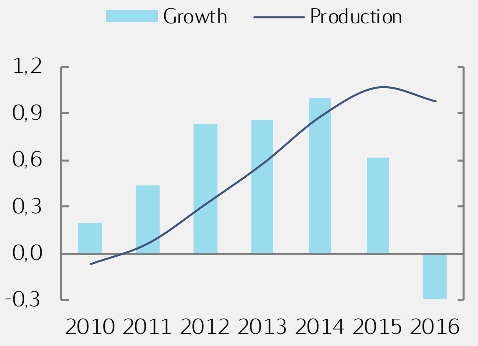
Despite a strong quota compliance by most Opec countries and signals from Russia that the promised cuts would be delivered during the spring months of 2017, the stubbornly high OECD oil stocks and signs that US oil production was in a process of picking up, changed the market sentiment towards the end of 1Q 2017. Financial players were optimistic at the start of the year about how fast the excess oil stocks could be brought back to normal levels. However, the outlook for stronger price-driven US shale recovery dampened the optimism and led to liquidation of long positions in the oil market. This change in sentiment pushed prices back to the 50 USD/bbl level.

The Opec meeting in May 2017, where the Opec cut agreement was prolonged with additional 9 months, confirmed Opec's and its partners' determination of bringing the global oil stocks down to levels around the 5-year average. However, the growth in US shale production could make this challenging.

Towards 2020; a battle between Opec and resurgent supply

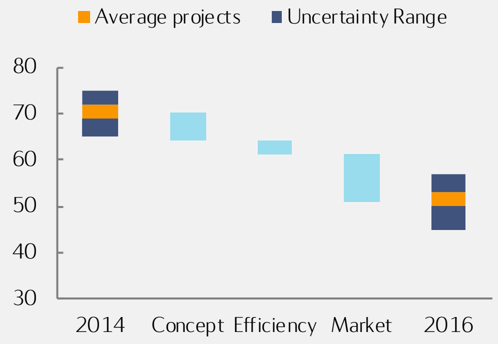
Given the still unclear medium-term effect of the industry capex cuts; uncertain US shale oil dynamics; and on top of that the risk for major supply disruptions, there are certainly a wide range of plausible market outcomes in this period. Opec must carefully balance the market into a price range, that on the one hand does not encourage another wave of US shale supplies, and on the other ensures badly needed oil revenues into Opec member economies. As US shale oil production expectations are updated, the market in both 2018 and 2019 risks being oversupplied again, unless Opec continues and delivers on its production cut strategy. With crude oil

US shale oil production
Growth y-o-y (lhs), production (rhs), mbd



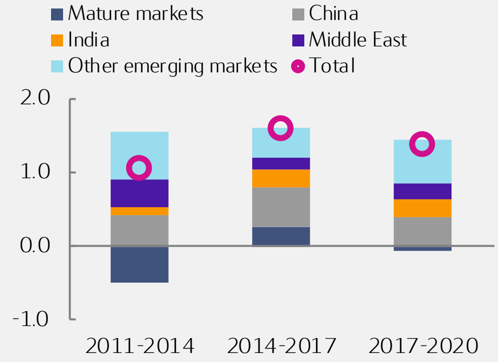
Source: Source: Drillinginfo.com

Break-even prices in US GoM
Breakdown of cost reduction, nominal USD/bbl



Source: Company information, Statoil

Global oil demand growth
Annual average change, mbd



Source: IEA (history), Statoil (projections)

prices strengthening and rig counts rising, tight oil production is expected to rise going forward. Further increases in other non-Opec production capacity between 2017 and 2019 are also expected, as the record 2011-2013 capex commitments result in added production, increasing total non-Opec production by 1.3 mbd per year on average from 2016 to 2020. The main growth in non-Opec supply in addition to US shale is seen in Canada, Brazil, Russia and Kazakhstan. The completion of two large oil sand mines in 2017 and the subsequent ramp-up of production will increase Canadian production by 0.5 mbd by 2020. The two other sources of growth in Canada are the liquids-rich section of the Montney and Duvernay plays and the Canadian offshore with the start-up of the Hebron field in 2017 and connection of Hibernia to the new fields. Growth in Brazil is explained by ramp-up of production from Lula-Iracema and Búzios, two pre-salt fields in the Santos basin. In Russia, increased focus on infill drilling and pipeline connections established to more remote Siberian upstream projects have enabled ramp-up of new fields. Kazakh oil production will increase due to the ramp-up of Kashagan, the super-giant field that started production in 2016.

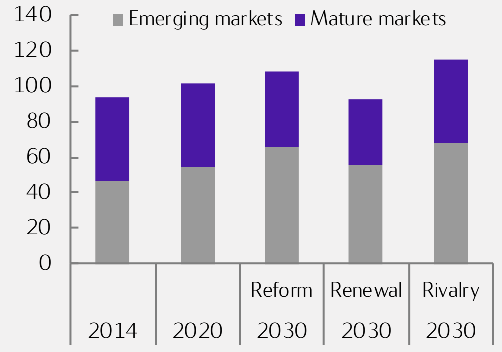
Project break-even cost levels have been reduced

During 2015-2017, the industry responded powerfully in different ways to adapt to a lower price environment, following the 2014-2015 price collapse. Corporate reorganization and downsizing reduced corporate costs and, together with reduced investment activity, improved corporate cash-flow. Lower activity levels have forced oil companies to prioritize stricter between the projects in their portfolios. Through shifting concepts, high-grading, moving from high-cost ultra-deep water to more moderate-cost deep water plays, capex budgets have shrunk. Combined with shifts in strategic focus towards utilizing existing infrastructure rather than developing new stand-alone projects with infrastructure investments, the large oil producers have managed to reduce their project break-even costs substantially. On an individual project level, simplification and efficiency in all elements of the project design and concept changes have improved project economics. Examples of concept optimization and efficiency improvements are moving from a spar buoy to a semi-submersible,
higher drilling efficiency, simplification, weight reductions, operator contract cooperation including (potential) standardisation of operations and equipment. These actions have also led to reductions of (unit) prices in the supplier market of about 30% at the global level (2014-2016), and even more in the US/North American market. All in all, the above-mentioned activities have led to a 20-30 USD/bbl reduction in the average project break-even costs, down to 50-55 USD/bbl.

Strong oil demand growth up to 2020

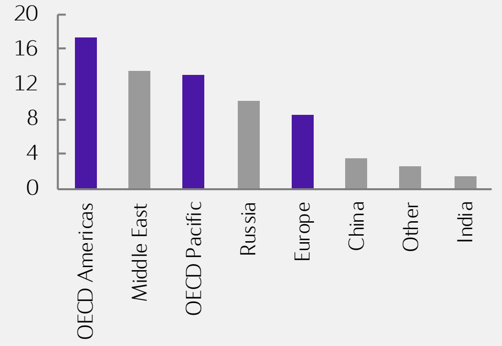
The advent of a low-price environment has accelerated the demand for consumer products like gasoline, naphtha, LPG and jet fuel. Lower pump prices have encouraged more discretionary driving, while cheaper jet fuel prices have been passed through to lower flight ticket prices. The petrochemical sector, that typically tracks GDP growth, has seen a wave of new propane-based petrochemical plant investments and contributed to the boom in Asian LPG demand. Overall, global oil demand growth is expected to average ~1.4 mbd per annum in the period from 2016 to 2020, and to pass 100 mbd in 2019. Towards 2020, continued growth in Asia is expected, and the Middle East will steadily add to their petrochemical capacity. In addition, the US is building capacity to capitalise

Oil demand in mature vs emerging markets
Mbd



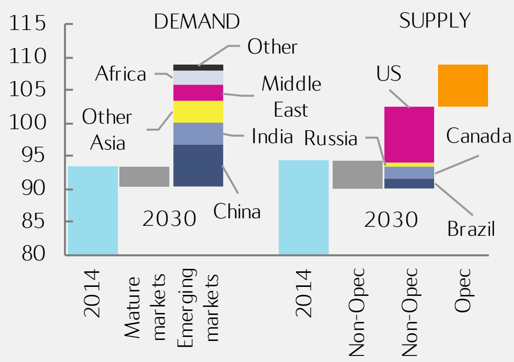
Source: IEA (history), Statoil (projections)

Annual oil demand per capita in 2020
Bbl/capita



Source: Statoil (demand), United Nations (population)

Change in oil supply and demand in *Reform*
Mbd



Source: IEA (history), Statoil (projections)

on large ethane volumes coming from shale gas production. Overall, the transport sector is expected to continue its growth driven by increasing GDP in emerging markets, while the mature markets are expected to be stagnant mainly due to increased oil prices. EVs will have very limited impact in the short-term outlook. Demand for oil in the manufacturing and oil burning for electricity are expected to be stagnant at today's level. The growth will be strongest in emerging markets, while the mature markets seem set for stable or declining oil demand. The only exception is OECD Americas due to the growth in demand from petrochemicals.

Outlook 2020s - Towards slowing demand growth

The main factors impacting the long-term development of oil demand are global GDP growth and increased demand for commodity transport, electrification of the road transport sector and increase in air traffic, growth in the petrochemical sector and efficiency gains in all sectors. These drivers have significantly different impacts in the three scenarios, resulting in corresponding differences in oil demand by 2030. Throughout the 2020s the transport sector represents more than 50% of oil demand, while non-energy demand is taking market share from the other sectors, in all three scenarios.

Oil demand growth mainly from emerging markets

On average one person in the mature markets demands the same amount of oil as four persons in emerging markets in 2020. Within the emerging markets there are large differences as large oil producing countries have significantly higher consumption per capita. During the 2020s more people in emerging markets will move into the middle class, increasing the demand for goods and services that require energy. The combination of efficiency gains, electrification and other substitutions on the one hand, and higher demand growth in emerging markets on the other, will reduce the abovementioned ratio from 4.0 to 3.3 in 2030 in *Rivalry* and *Renewal* and to 3.4 in *Reform*. The main explanation is a reduction in per capita oil demand in the mature markets. In the 2020s demand grows by 0.4%-2.3% in emerging markets, while demand in the mature markets declines by 0.2%-2.3%, depending on scenario.

Transport sector – EVs eating into oil's position

In *Reform*, EVs become competitive during the mid-2020s. This is largely driven by a push from policy and pull from market via commercialization and technology. However, even with growing EV share in new car sales, the impact on demand by 2030 is limited as it takes time to replace the conventional car fleet, and the fleet is growing. On the other hand, non-LDV transport continues its strong growth. Demand in the transport sector is 61 mbd in 2030, 4 mbd higher compared to 2020.

In *Renewal*, global climate policy efforts and increased support to research and technological development accelerate the penetration of EVs and shift demand from road to mass public transport, lowering the growth in the car fleet. Higher energy efficiency and lower GDP growth also add downwards pressure, resulting in a demand of 52 mbd in 2030, 9 mbd lower than in *Reform*, and 5 mbd below 2020. By 2030 transport oil demand in *Rivalry* is 65 mbd, 4 mbd higher than in *Reform*, mainly driven by slower EV penetration and less efficiency gains due to waning focus on policy. These drivers together dominate the impact of lower GDP growth.

Increased focus on sulphur

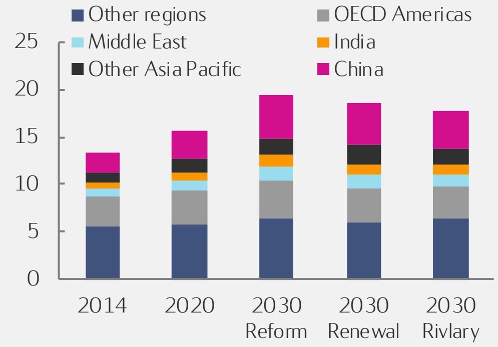
In October 2010, the International Maritime Organization (IMO) ratified a regulation reducing the maximum sulphur content of bunker fuels used in international waters from 3.5% sulphur (S) to 0.5% S. The consequence is that following the implementation of this regulation, from 1 Jan 2020 vessels will not be able to use high sulphur fuel oils unless they have exhaust gas scrubbers (EGS) installed.

The penetration of scrubbers is currently very low, but expected to accelerate towards and beyond the 2020 implementation date. Nevertheless, come 2020, a main market for high sulphur fuel oil is expected to disappear, replaced by low sulphur fuel oils and distillates. Other options such as LNG will also find a more favourable market in the marine sector.

Several market observers expect insufficient desulphurization capacity in refineries combined with the erosion of the high sulphur fuel oil market to result in stranded high sulphur fuel and a resulting collapse in the prices of the high sulphur fuel oils. The relatively short lead time until implementation of the new regulations supports the view of large price movements. The market balance will be restored over time as this drives investments into scrubbers.

The impact of the marine bunker regulation is important as it will bring the sulphur economics in stronger focus throughout the oil industry value chain.

Oil demand in the non-energy sector
Mbd



Source: IEA (history), Statoil (projections)

Continued support from petrochemical demand

An average person living in Western Europe or North America uses 100 kg of plastic annually, mostly in the form of packaging. In China and India, demand is still only 52 kg/year and 9 kg/year, respectively. Economic growth and a larger middle class, especially in Asia, is expected to add to this number rapidly, contributing to a continued strong growth in non-energy oil (and gas) demand up to 2030. The main driver for the difference between the scenarios is GDP growth as efficiency gains are expected to be small, leading to somewhat lower demand from non-energy in *Renewal* and *Rivalry* than in *Reform*, due to lower GDP growth estimates in this period.

Other sectors face competition

In *Reform,* demand for oil in commercial and public services, which is the main contributor of the residential and commercial sectors, loses market share to electricity in the mature markets. In emerging markets, a similar trend is seen, but to a lesser extent, due to substitution from biomass to LPG particularly in Africa and India. Here, the benefits of using LPG for household purposes; less time spent collecting firewood, less soot, improved air quality, and higher energy content; will prevail over burning of biomass as distribution and logistics improve and prices become competitive. Oil demand in 2030 is therefore expected to be slightly lower than in 2020. The historical decline in the market share of oil in the power and heat sector continues, while demand in the industrial sector increases slightly, resulting in a total decrease in demand for oil in other sectors from ~29mbd to ~28mbd by 2030.

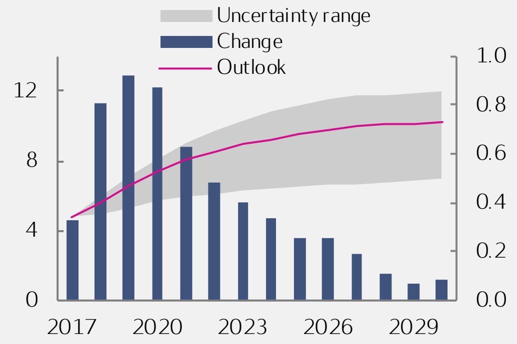
In *Renewal,* increased focus on climate policy, increasing efficiency gains and lower GDP growth together push demand down. In China phase-out of coal increases demand for oil in the industry sector compared to *Reform*. Lower efficiency gains due to less technology sharing increase oil demand in *Rivalry*. Energy security prevails over environmental concerns for oil producing countries, while increased focus on sulphur content in the marine sector spurs the use of high sulphur fuel oil in power plants for a period.

Break-even cost of the next generation projects

The driving forces for the reduction in break-even costs seen the last years are partly structural and partly cyclical. The tendency of a well-supplied market towards 2020 will continue to give strong signals to the industry to seek lean and cost effective development projects and strive for further efficiency gains. This market climate will create incentives for wider industry cooperation and contribute to the standardization of processes and equipment. However, the overall price index of supplier markets is expected to move higher, especially over the next five years. Thus, it is expected that project break-even costs will increase going forward. It is also important to note that break-even cost levels will be much lower than equilibrium long-term oil prices, since they do not consider corporate costs, exploration costs and pre-decision development costs.

US tight oil production

Production and uncertainty, mbd (lhs), change (rhs)



Source: Statoil

Decline rates

While the global oil market is currently well supplied, the abundance of oil is not going to last forever. As we are in the third consecutive year of low oil prices, concerns of a supply shortfall towards the end of this decade are being voiced. In this context, decline rates are coming more into focus since the global rate of decline strongly defines the required production from new developments and increased oil recovery from existing fields to satisfy growing global oil demand.

The term individual decline rate refers to the annual reduction in the rate of production from an individual field or a group of fields, after a peak in production has been reached. Aggregate decline rate is defined as the annual change in rate of production from all fields in a region or group of fields. Decline rate should not be mistaken with the term depletion rate, which refers to the rate at which oil is produced in a field or region expressed as a fraction of the remaining reserves.

Decline rates can vary significantly across wells, fields, geological areas, producing countries and individual companies, which is why an average aggregate decline rate for the entire global production is a matter of debate. Many factors will affect the decline rate of an individual field; reservoir dynamics, operational aspects, incidents, cessation of activities. Current consensus, however, implies that a decline of 5-8% per year is applicable for individual fields after reaching peak production. Global average aggregate decline rates are lower and depend on assumptions of production ramp-up and production plateau length from newer developments.

Generally, one can say that larger fields have lower decline rates than smaller fields, which can be attributed to various reasons. Large fields are often developed in phases, so the whole field is not producing at the same time. Another reason is that operators tend to invest money to arrest decline in a larger, more productive field than a smaller field because more production is at stake. It is also important to note that offshore fields often decline faster than onshore fields. There are several methods which can be used to arrest the production decline of mature conventional oilfields, including careful management of production, infill drilling, workovers and concrete projects to increase recovery.

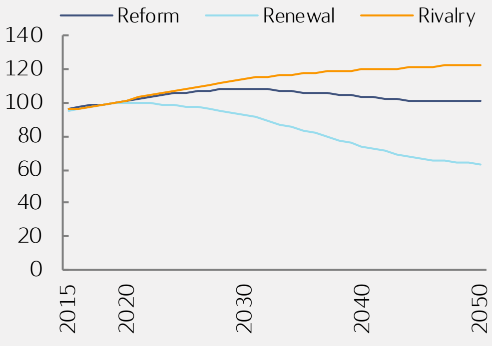
Increased appetite for short-cycle investment combined with continued advancements in productivity is expected to allow tight oil to retain the lion's share of non-Opec capital investment for the next decade, resulting in US shale oil production more than doubling from ~4 mbd in 2016 to ~10 mbd in 2030 in *Reform*, and potentially higher in *Rivalry*. Growth is led by the Permian, followed by Eagle Ford, and Bakken. Emerging plays, such as Scoop/Stack in the mid-continent and Niobrara in the Rockies, are also seen as contributing ~1 mbd over the next ten years. However, as these basins mature and core regions become exhausted, rigs will be directed towards less productive and costlier areas. Concurrent with this development, production growth will slow as incremental growth becomes more difficult due to the inherently higher legacy decline rate. At this stage of the life cycle, other non-Opec supply sources will become relatively more competitive and begin to attract capital at the expense of shale. It is this dynamic rather than the outright depletion of the resource base that is expected to drive the ultimate peak in tight oil around the 2030 timeframe in *Reform* and *Rivalry*. Uncertainty in technology development and inflationary pressure on sand or water logistics could further decrease the competitiveness of shale and limit growth. Environmental concerns on fracking, water contamination and earthquakes could have a dampening effect on shale expansion and lead to increased need for supply from other sources. In *Renewal*, the growth in shale will be much less, due to lower demand growth and the Middle East being in a position to supply a larger share of the overall balance at moderate costs.

Increasing investments in conventional non-Opec production

In *Reform*, supply must grow by 16 mbd until 2030 to cover demand growth. Opec and shale oil production provide most of this growth. Based on a global average aggregate decline rate of 3% for existing and sanctioned fields, other non-Opec production declines by around 20 mbd, which must be replaced by 2030. Outside the US shale industry, a three to five-year time lag between final investment decision (FID) and production start is typical. There is also a lag from the time of production start until the fields reach their maximum production level. Thus, production from the fields currently under development have a peak in 2025. Hence the FIDs the next 5 years will decide much of the conventional non-Opec production in the 2020s. A supressed oil price at current levels of ~50-55 USD/bbl could lead to further postponement of project investments as IOCs continue to revisit their portfolio in search for further cost reductions. The increasing demand uncertainty into the next decade will be another important factor for the level of investments in the near term. In combination, these drivers lead to a slow increase in investments, resulting in a tightening market in *Reform*.

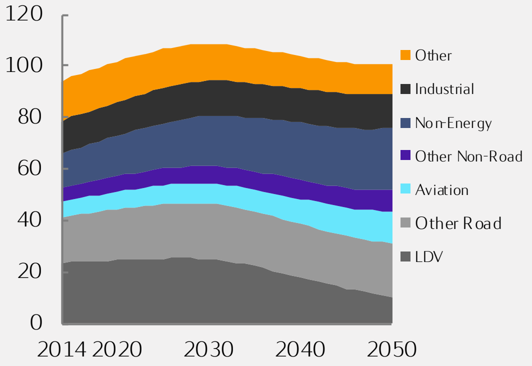
In *Rivalry*, increased demand requires even more supply, and the challenge is further increased as growing geopolitical tensions lead to higher risk of supply disruptions, adding to the tightening of the market. Even with the lower demand in *Renewal*, there is still a need for significant investments from non-Opec producers to counter the natural decline in production.

Global oil demand in the three scenarios
Mbd



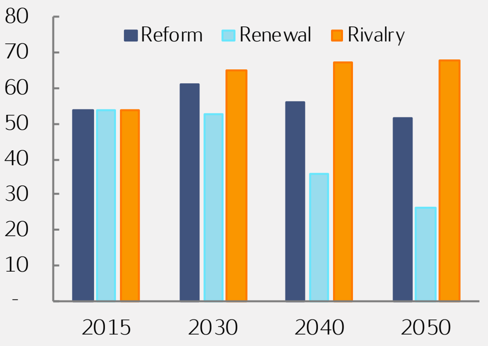
Source: Statoil

Oil demand in *Reform*
Mbd



Source: IEA (history), Statoil (projections)

Oil demand in the transport sector
Mbd



Source: Statoil

Demand beyond 2030: towards 60, 100 or 120 mbd?

Differences in macroeconomic drivers, energy efficiency development, electrification in the transport sector and other sectors result in oil demand ranging from 63 mbd to 123 mbd in 2050 across the scenarios. Demand in the non-energy/petrochemical sector remains a key growth component in all scenarios.

Reform

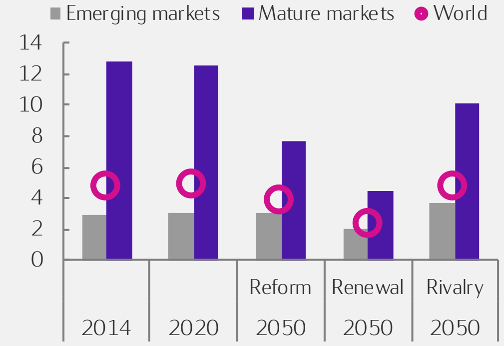
In *Reform,* demand peaks around 2030 at 109 mbd and decreases towards 100 mbd by 2050. The main drivers are increased efficiency combined with growing electrification both in transport and other sectors. These drivers are stronger in mature markets, where car density etc. has peaked, leading to further reduction in differences in oil demand per capita between regions. However, in 2050 one person in the mature economies still demands the same amount of oil as 2.5 persons in emerging markets.

After 2030 the EV share of new car sales starts making a serious impact on the vehicle fleet composition, contributing to a significant decrease in oil demand from the transport sector towards 2050, despite growing demand for goods and non-road transport. Continued strong efficiency gains are also important, as producers of cars, airplanes, ships and locomotives strive to bring to market more efficient and low emission vehicles, and governments are pushing for stricter fuel standards. The efficiency gains are however lower in the marine and aviation sectors due to the higher technical lifetime of transport equipment.

The use of plastics has expanded to new applications over some years. Plastics have revolutionized the design of auto body exteriors giving cars better gas mileage, lowering production costs, improving dent resistance and allowing more freedom to create innovative concepts that otherwise would never be possible. In addition to parts for cars and airplanes, a potential segment of future demand is the construction industry where use of plastic composites competes with concrete and contributes significantly towards a more sustainable construction industry. Plastic composite materials continue to replace wood in construction and to a smaller degree, steel. As the demand for oil in other sectors is under siege from other energy sources, and as use of oil in the petrochemical sector has a lower carbon intensity compared to other sectors, this sector could be an opportunity for the oil companies to secure outlet for production. Even though the environmental concerns related to plastic pollution continue, the increasing trend of oil use per capita continues in this sector, both in mature and emerging markets.

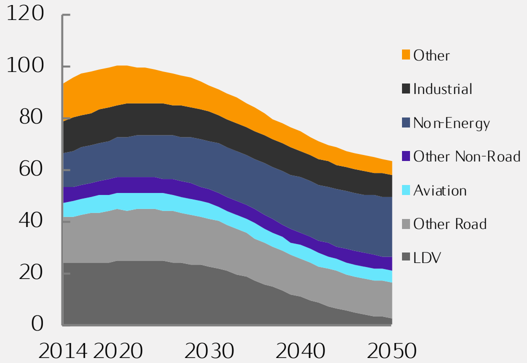
In other sectors, oil demand loses market share due to growing electrification and increasing use of new renewables. Driven by global GDP growth, the total volume of oil used in the manufacturing sector increases through the last two decades of the outlook, although with regional differences. As the global economic centre moves eastwards, oil demand from manufacturing moves with it. Emerging economies grow their GDP through expanding their domestic industries and serve regional markets. Lower GDP growth and higher efficiency gains in the OECD regions lead to a stagnant or slowly declining oil demand. Oil demand from the residential sector loses market share in almost all regions, apart from Africa where substitution from biomass to LPG continues. Biomass retains about

Oil demand per capita
Bbl/capita



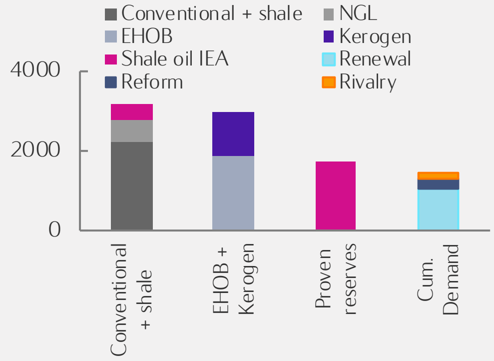
Source: IEA (history), Statoil (projections), United Nations (population)

Oil demand in *Renewal*
Mbd



Source: IEA (history), Statoil (projections)

Recoverable oil resources, compared with cumulative demand
Billion barrels (bn bbl)



Source: IEA, USGS, OGJ, BP, BGR, EIA, Statoil
Notes: EHOB denotes Extra Heavy Oil and Bitumen

one third of the energy mix in the residential sector globally with Africa and China together making up 60% of demand. The decline in the power and heat sector is particularly strong in the Middle East, as crude oil producers prefer to export crude and rather use other sources of energy such as gas, new renewables and nuclear for electricity generation and heating/cooling. Oil demand in total from this sector is currently around 6 mbd and is expected to fall by around 50% until 2050, generally replaced by new renewables in almost all regions of the world.

Through further capacity expansions in the Middle East and steady increase in US shale oil output the need for high-cost non-Opec supply is reduced.

Renewal

In *Renewal*, the decline in demand seen in the 2020s is accelerating during the 2030s, before decline slows down and yields a demand a little above 60 mbd in 2050. The main factors behind the lower demand compared to *Reform* are more rapid electrification, larger efficiency gains and changing consumer preferences. Strong push from policy and pull from technology lead to major shifts in the transport sector, contributing to lower oil demand. Environmental awareness leads to more consumers avoiding travel and acquiring less goods, generally consuming less and recycling more.

Continued Middle East expansions and growth from US shale plays lowers the need for oil supply from all other regions.

Rivalry

Oil demand continues to grow through the forecast period in *Rivalry*, increasing demand to a little above 120 mbd in 2050. The main driver is slower electrification, less improvement in efficiency gains and waning and inconsistent focus on climate policy.

Oil demand from the transport sector continues to grow as it takes longer time before EVs are competitive due to reduced push from policy. Even though EVs eventually become competitive, reliance on unstable electricity grids is a challenge in some regions, resulting in more use of hybrid cars. Lower focus on climate policy also results in increased number of cars, higher number of miles travelled and reduced use of public transportation compared to *Reform* and *Renewal*. Lower efficiency gains drive increased oil demand in other sectors as there is less technology exchange and therefore the best technology is not always available. In the non-energy sector, demand growth is lower compared to *Reform*, driven by lower GDP growth, higher oil prices and reduced need for oil producers to find niche markets for oil.

Low capacity growth in the Middle East and significant supply disruptions lead to need for large contributions from higher-cost non-Opec producers to balance the market.

Technically recoverable resources are sufficient

The amount of reserves needed to meet demand in *Reform* up to 2050 is 1300 billion barrels (bn bbl). In *Renewal* and *Rivalry*, the requirement is 1000 bn bbl and 1400 bn bbl, respectively. IEA estimates remaining

Environmental concerns around production and use of plastics

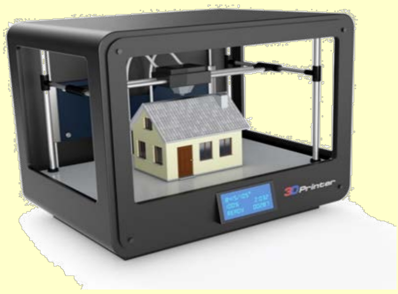
Plastic waste and its impact on the environment is a growing concern, and the drivers behind it look set to continue. Every year, more than 8 million tonnes of plastics end up in the world's oceans. Most ocean pollution starts out on land and is carried by wind and rain to the sea. Once in the water, there is a near-continuous accumulation of waste, since plastic is so durable that the US EPA reports "every bit of plastic ever made still exists."

In the developing world people work hard to climb into welfare levels where they can access plastic goods and gadgets. It is in the emerging economies that we can expect the highest growth in plastics demand, tightly linked with economic development and population growth. However, with growing environmental concerns, some developing countries have been frontrunners in banning the use of lightweight plastic bags, like Bangladesh and Rwanda. India is experimenting with incorporation of recycled plastics in road construction.

While plastics help to reduce food waste by keeping products fresh longer, there is increasing public awareness on the need for sustainable production and use. This has encouraged local authorities to organize collection of recyclables, encouraged some manufacturers to develop products with recycled content, which could reduce total plastics demand.

Furthermore, new uses of plastics are emerging, like construction components and car and airplane parts. The technology of 3D printing brings new aspects to the use of plastics. Printing goods on-site instead of producing in low-cost countries and transporting long-distance can save large amounts of packaging, in addition to energy in transport. With 3D printing, there is potential for building products from within in a manner that cannot be punched or cast in moulds. We have not yet a full overview of the potential here. Within 3D printing biologic materials and aluminium are also starting to be used.

The long-term potential for 3D printing

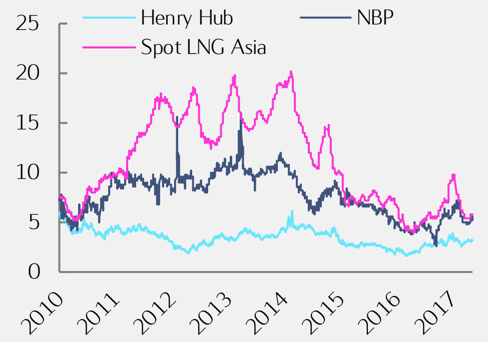


Source: iStock

technical recoverable oil resources to be 6118 bn bbl, while proven reserves are estimated to be 1700 bn bbl. Note that booked reserves in oil companies are much lower. Even if a cautious estimate is applied for reserve growth and yet-to-find, the remaining technically recoverable resources globally are sufficient to cover the accumulated demand in all three scenarios. However, the amount of ultimately economically recoverable resources depends on technological improvements, oil quality issues, other cost drivers, tax regimes and the level of oil prices. Recent exploration results have disappointed and could indicate that the larger share of future oil demand must be satisfied by economically and environmentally challenging oil resources.

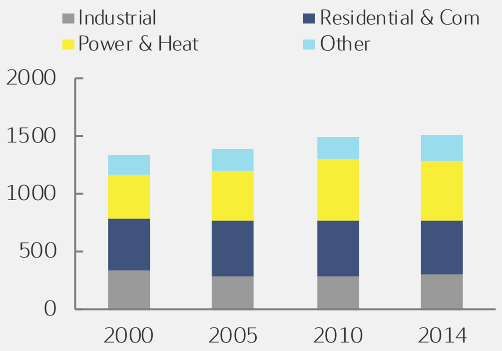
The global gas market

Regional gas price markers
USD/MMBtu



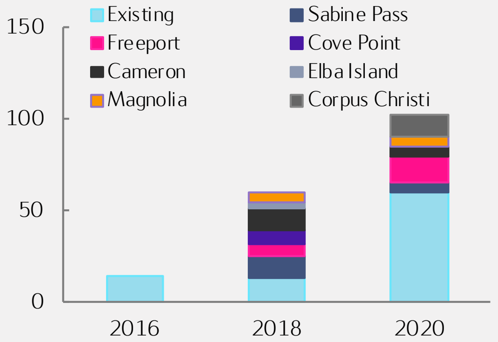
Source: Platts; ICIS Heren; NYMEX

OECD gas demand development per sector
Bcm



Source: IEA

US liquefaction capacity build up by 2020
Bcm



Source: IHS, company information, Statoil

Current situation and outlook to 2020

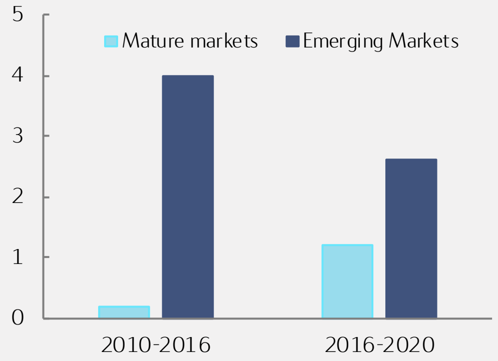
The global gas markets are still struggling with the aftermath of the global commodity price fall in 2014, but low gas prices spur competitiveness and provide market opportunities, portraying a positive outlook for demand, particularly for price sensitive emerging markets. CEDIGAZ estimates global gas consumption growth at 1.6% for 2016 in line with 2015. Demand grew in Europe, North America, the Middle East, India and China, and fell in the rest of Asia and Latin America.

The start-up of US LNG exports from Sabine Pass has been watched with interest as Europe could serve as a fall-back destination for flexible volumes. New LNG liquefaction capacity entering the market will alter global supply dynamics as Asia struggle to absorb additional volumes. Increased LNG availability for Europe will create further supply competition from other import sources. Domestic supply is in decline, pushing up imports. The structure of supply contracts is evolving as sellers move away from oil indexation towards more gas hub pricing mechanisms and increased selling at national hubs.

Demand is in transition too, as Europe starts its journey towards decarbonisation. This progression is currently focused on the power sector, where the drive to reduce coal fired production has led to some increases in gas for electricity generation. Future nuclear phase-out could also boost gas to power demand. European demand was driven up by the electricity sector in 2016, as the 40% climb in coal prices brought the most efficient Combined Cycle Gas Turbine (CCGT) plants into competition with older coal plants. In the UK, the carbon floor price made this competition even more pronounced. Furthermore, a spate of outages at nuclear sites and a drought hampering hydroelectric production in Western Europe influenced the increase in gas to power as much as policy. Project delays and outages left LNG deliveries to Europe lower than anticipated; this, together with incremental LNG demand in Asia and the Middle East left Europe with a modest 4 bcm increase over 2015. Pipeline imports were strong, as Russian exports to Europe (including Turkey) reached 180 bcm. Even if Groningen production continues to be restricted due to concerns over the link to seismic activity, the loose global LNG balance represents an oversupply risk to the market until 2020.

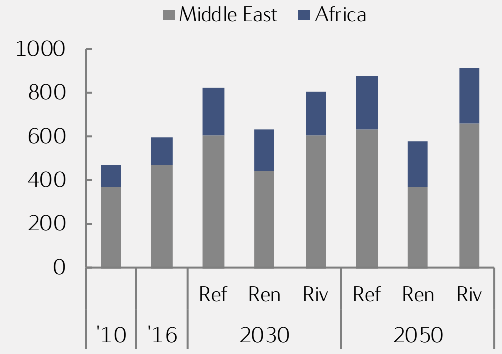
Through 2020, the North American market is expected to rebalance to reflect the new reality of abundant supply. After decades of demand exceeding supply and net imports from the rest of the world, North America and the US shift to net exports. For the US, volumes from Canada are more than offset by increasing pipeline exports to Mexico and to the rest of the world via LNG. Demand growth in this market is substantial, but faster supply growth, based on production from shale and tight gas formations, would possibly crash the continental market if it were not for the option to send the gas overseas. One LNG project is already in operation, and a second location is likely to be running by the end of 2017. By 2020 over 70 bcm of exports are expected from five locations, four in the Gulf of Mexico, and one on the East Coast. The low cost of gas encourages industrial gas demand growth and the displacement of coal by natural gas in electricity generation. The starting point for this shift is a market recovering from cyclically low prices in 2016. Rising prices have encouraged increased drilling activity, but signs of improved supply have not come just yet. The needs of rising domestic demand and export

Global gas demand growth
Bcm



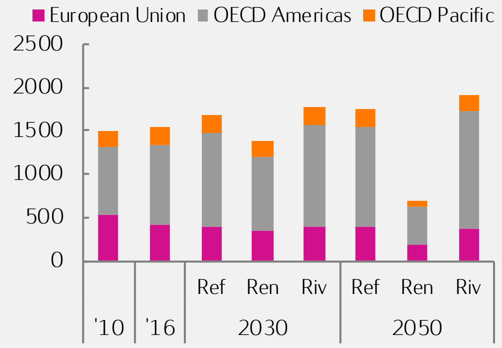
Source: IEA (history), Statoil (projections)

Gas demand in Middle East and Africa
Bcm



Source: IEA (history), Statoil (projections)

Gas demand in mature markets
Bcm



Source: IEA (history), Statoil (projections)

projects suggest a period of tighter fundamentals until supply growth catches up with market wants.

Low prices support Asian gas demand. Chinese gas demand gained some 9% in 2016 vs. 2015, mainly driven by the government's anti-pollution activities supporting a switch from coal to gas, bringing total gas demand above 200 bcm. The domestic market remains oversupplied, leaving LNG imports below contracted levels. Indigenous gas production growth has been slowing, hence import dependency reached a record 36% last year. There are clear trends for continued Chinese gas demand growth based on strong supply competition and environmental policies. The deadline for implementation of a series of actions on air pollution prevention published in 2013 are set for the end of 2017, which is expected to push aggressive coal to gas switching over the next few years. In parallel, India showed year-on-year gas demand growth of around 11% in 2016. Lower priced LNG imports and short-term subsidy policies increased consumption in the fertilizer and power sectors. However, continued and sustainable demand growth needs to deal with fundamental gas pricing and infrastructure issues. Still, the short-term factors created new policy momentum for gas: a gas price policy was announced to stimulate new gas production and an official target aims to increase the share of gas in India's primary energy mix from 6.5% currently, to around 15% within 3-5 years through doubling LNG imports and shifting India towards a gas-based economy.

Outlook for the 2020s

World gas demand increases in all three scenarios through the 2020s, even if growth in *Renewal* is marginal. In *Reform* and *Rivalry,* the size of the global gas market increases by some 400 bcm (11-12%) over the 2020s, whereas *Renewal* sees only little growth in demand in the same period. The growth is concentrated in China, India, the Middle East and Africa. Depending on the scenario, the Asia Pacific basin remains the target demand area for new LNG as well as large scale pipeline projects through the medium-term period.

Through our medium-term horizon, the global gas market is supplied by four main regions with excess supply: Russia, Australia, the Middle East, and the US, with important implications for global price formation and regional price spreads. Gas demand and relative competitiveness vary between our scenarios, due to drivers like geopolitics, regulatory framework, prices, as well as environmental regulations and carbon taxes. The uncertainty poses significant challenges to producers chasing FID for new gas projects, both in regions such as North America and East Africa. Still, energy hungry markets require energy; but price matters.

Transformation of structured LNG trade into a global market

LNG is expected to account for about half of globally traded gas by 2035, compared to some 30% in 2015, as gas markets structurally integrate and supply from sea-borne dependent exporters increases. The US will gradually provide a price anchor for global gas prices, as its sourcing flexibility and hub indexed LNG supply becomes the provider of marginal supply between the Pacific and Atlantic basins. Henry Hub based US cargoes will contribute to the maturing of the Asian LNG market.

Floating Storage and Regasification Units (FSRU)

Since the first Floating storage and regasification unit was delivered in 2005, the FSRU fleet has grown significantly and now counts 21 operational units. Total capacity is around 100 bcm per year (bcma). Another 60 bcma of FSRU capacity is either under construction or development, with a further 180 bcma proposed.

The energy consultancy IHS states that as much as 272 bcma of FSRU capacity could be operational by 2020.

Whilst the operational cost of running an FSRU compared with a land based regasification terminal is higher, the added flexibility that a floating unit offers is attractive for many prospective LNG importers.

One benefit this solution has over a land based terminal is that the capital expense is lower. A second benefit is that importers can unwind their investments and infrastructure if the country no longer needs LNG as FSRUs usually are rented out on time charters. A third benefit is the speed with which an FSRU can be installed and put in to operation. If gas infrastructure is already in place an FSRU can be installed in less than a year. This enables LNG to be a quick stop gap solution for countries with large energy deficits.

Egypt and Pakistan use LNG to fill a large energy supply gap. For Egypt, the use of FSRUs will also serve as a bridging solution until its new giant Zhor gas field comes into operation later this decade. For Pakistan, installing the first FSRU was a step in dealing with a supply deficit. Indonesia is an archipelago with wide spread settlements which could benefit from getting gas to feed power plants. The country has plans for 64 smaller scale LNG regasification terminals, many of which will likely be implemented by renting an FSRU.

The leading companies providing FSRUs are American Excelerate (7 FSRUs including ships held in partnership with other ship-owners), and Norwegians Golar LNG (7 FSRUs) and Hoegh LNG (6 FSRUs including ships held in partnership with other ship-owners).

FSRUs facilitate access to LNG

Source: hoeghlng.com

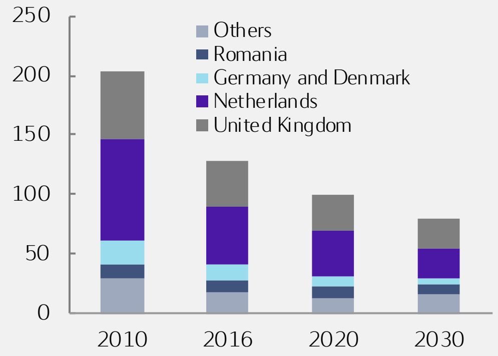
Low global gas prices are supporting demand, but not allowing LNG producers to cover full cost. That creates large uncertainties for potential investments into new LNG projects. Gas balances in *Reform* signal a need for new LNG capacity, and thus, up to 100 bcm of new LNG capacity is forecasted to support underlying demand growth during the second half of the 2020s. However, there is a risk that low oil and gas prices, uncertain demand and cost levels (still regarded as unsustainably high) risk delaying FIDs for new green field development projects. Restructuring of contractual terms that ensure that project developers', sellers' and buyers' concerns for financial robustness and operational flexibility is required, as capital costs have fallen less than LNG prices. The projects with lower costs and most likely smaller sizes will be prioritized as will project expansion to the existing LNG producing facilities. Low-cost supply is what the market needs, whereas recent new mega projects are struggling at the opposite end of the supply cost curve. Qatar's repositioning with respect to the Northern Field Moratorium is a sign of a strategic return to ensure its medium-term market position. US is well positioned with cheap feed gas, but new projects must provide for return on full capital investments and not only the variable costs.

Finally, ability to pay for new gas in the growing non-OECD areas of the world is the ultimate test criterion for LNG developers through the 2020s. Rethinking of project concepts and risk taking will be needed to avoid project delays affecting both demand and prices. The *Renewal* scenario sees limited growth in gas demand after 2020 with embedded implications for global gas supply. Over-capacity would underpin gas demand temporarily, but imply major transfers of value from producers to consumers. Non-OECD Asia is likely to exploit this opportunity to speed up low carbon transition of its energy mix at the expense of coal.

Can energy policy curb Europe's growing import needs?

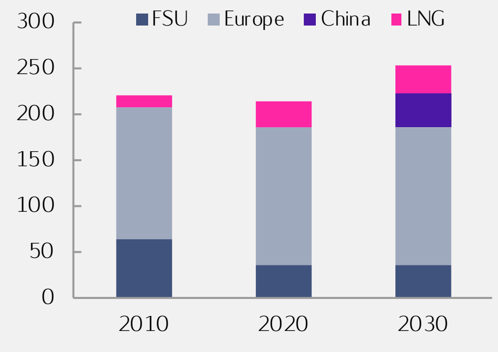
During 2016 the European Union reinforced its position towards the 2030 energy transition. The European Commission emphasises modernization of the economy and includes ambitious targets of reduced carbon emissions, increased energy efficiency, and growth in renewable energy. Being on track to reach its 2020 targets, policy implementation to deliver on these targets will be high on Brussel's political agenda through the next decade. Streamlining the internal arena will however be far from smooth sailing as the national opinions and prioritizations so far have differed. Gas demand might be affected if EU's heating and cooling strategy aiming at reducing the use of gas in the heating sector materializes. Sharply falling domestic production is putting attention to energy security. In 2015, 50% of European gas demand was met by domestic production, including the Norwegian Continental Shelf. In *Reform,* we expect this to fall to 35% by 2030. The Netherlands, Europe's second largest regional producer and exporter after Norway, continues to undertake fundamental supply assessments of its legacy Groningen production area due to health and safety fears over seismic activity. Curtailing output from Groningen hits base supply, but also means a loss of flexibility, as the field has historically provided swing production to meet seasonal demand.

EU domestic gas production in *Reform*
Bcm



Source: Statoil compiled from CEDIGAZ and others

Russian pipeline gas and LNG exports in *Reform*
Bcm



Source: Statoil compiled from OIES, CEDIGAZ and others

Curbing long-term gas demand in some respects serves as a risk mitigating approach compared to continued exposure to imported energy. In 2015, electricity generation from renewable sources contributed 29% to EU-28 total gross electricity generation, an increase by 4% compared to the year before. Hydro produced less, whereas wind generation added the most to renewable growth. Heating sector reforms are slow to implement due to the incentive to keep existing heating systems to the end of their long economic lifetimes. Standards restricting energy consumption in new buildings will come into effect in the 2020s, but implications for the heating sector are unlikely to become material before 2030.

Global gas availability is growing and Europe benefits from widespread regasification capacity. Russian gas is the backbone for European supply, however competitive global LNG will gain market share in a Europe with growing imports. Security of supply was always key to gas supply and infrastructure build. The absence of long-term contractual dependencies between gas buyers and sellers adds flexibility and (in theory) efficiency. Still, in a liberalized Continental gas market context, gas' role in the power sector is about competitive pricing. The rising cost of emitting carbon in isolation supports gas burn for electricity generation at the expense of coal through the 2020s, but increases the competition from new renewables, which in addition imply structurally lower power prices and higher volatility. In total, therefore the future role of gas in electricity is complicated and uncertain.

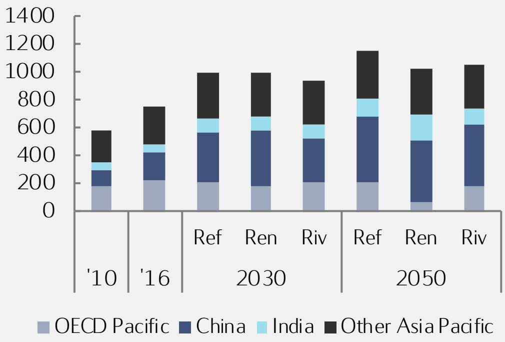
In *Reform,* gas use in the European electricity sector keeps growing through the entire planning period. The scenario is built on an assumption of growing political willingness to restrict the use of hard coal and lignite in North-West Europe by tightening climate regulations and policies. In addition, firm decisions to phase out nuclear capacity add to the need for more gas fired capacity. In *Renewal,* continued strong growth in new renewable power generation across the Continent limits gas' role into being back-up for intermittent solar and wind generation. In *Rivalry,* on the one hand security of supply concerns limit gas demand, while on the other hand less new renewable electricity leaves more space for gas in electricity generation. The combined effect is a gas demand similar to *Reform* by 2030.

Central Asia and Russia – heading west or east?

Gas is already the most important component in Russia's fuel mix, representing more than 50% of domestic primary energy demand. A huge energy savings potential and slow economic growth leaves limited room for domestic gas demand growth, causing declines in both *Reform* and *Renewal.* In *Rivalry,* gas demand is slightly higher than the current level based on an assumption of increased domestic gas-to-power use, as depressed economic growth in Europe and elsewhere, and protectionism, constrain the scope for gas exports.

During the 2000s Gazprom built up supply capacity as a response to European concerns about Russia's ability to bring sufficient volumes to Europe. Accompanied by independent gas producers' output, reduced FSU demand, and changing European market conditions, Russian gas is facing oversupply. EU policy statements are now explicitly motivated by the need to reduce dependency on Russian gas, possibly altering the legacy supply routes of trunk line gas flows into Europe. This would leave Russia and

Asian gas demand
Bcm

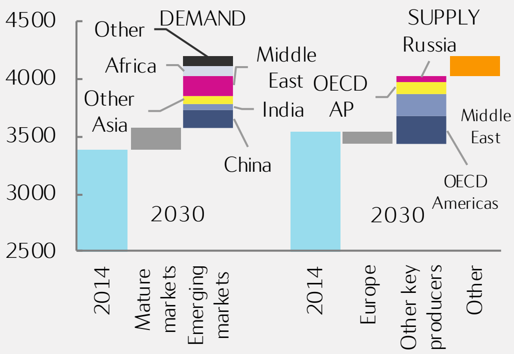


Source: IEA (history), Statoil (projections)

Air quality challenges characterize several large Asian cities

Source: Civilsdaily

Change in gas supply and demand in *Reform*
Bcm



Source: IEA (history), Statoil (projections)

Central Asian gas exporters to rethink supply options and relationships to ensure the long-term offtake of proven resources.

Russia's gas market share in Europe ranges between 27-32% for the scenarios over the period 2020-2030, reflecting the varying combination of LNG availability and gas demand projections for Europe. New export routes, such as the Power of Siberia pipeline materialize, proving to be more politically than economically driven and giving the possibility to export gas to Asia. Start-up is expected between 2020-2025. Altay, the second pipeline project discussed with China, is still only at the stage of a signed MoU. Distance to consuming market implies a high cost for gas, hence policy or *Rivalry's* geopolitical context would be required to see the project materialize.

In China's main gas consumption regions of the coastal provinces, Central Asian pipeline gas is less competitive compared to LNG imports. Currently three lines with a total capacity of 55 bcm are installed, with utilization rates around 65%. Global geopolitical tension as in *Rivalry* could call upon further expansion of the Central Asian pipeline to be discussed with China, and a possible fourth line might be added to bring the total capacity up to 85 bcm.

What about Asian gas demand?

Asia consumed around 700 bcm in 2016 and the region continues to add growth to global gas demand. In 2030 we forecast demand to reach around 1000 bcm in all three scenarios; a quarter of total world demand. Still, the favourable development depends upon sustainable prices from a buyer perspective as both legacy coal and emerging renewable energy are arguing their case. OECD Pacific demand is mature and offers flat level demand at best in *Reform* and *Rivalry*, but decreases by 30 bcm (14%) in *Renewal* compared to 2016. China, India and other non-OECD Asian markets continue to develop gas value chains to fuel the growing need for energy following strong population growth, economic growth and urbanization. In *Reform*, gas gains priority, and both indigenous production and regional imports grow in importance. In *Renewal*, low import prices support gas demand as does awareness of urban air quality and commitments to curb growing carbon emissions. A low gas price environment creates no incentives to invest into developing expensive indigenous production, hence import is prioritized. In *Rivalry*, heightened regional instability increases the impetus for firm energy relations, reinforcing support for Central Asia and Russian piped gas supplies.

The non-OECD Asia region is in the process of big changes in their energy demand in all scenarios, and most profoundly in *Renewal*. Driven by economic growth, demographic change and urbanization, electricity demand increases significantly. Since the 2000s growth has been based on available low cost coal. Gas production has stagnated, and even countries like Indonesia, historically an LNG exporter, has started to import gas. Governments' efforts to meet electricity needs and gradual implementation of environmental policies see gas consumption growing in all three scenarios. Gas demand rises significantly in *Renewal* due to flexibility needs in combination with growing variable renewable power production, whereas *Rivalry* sees less gas consumption caused by higher prices and constrained availability.

Brazil's gas potential - opportunities beyond the challenges

Brazil is the largest economy in South America and the 5th largest country on Earth by land area. It borders every country in South America except Chile and Ecuador. Over the last decades, Brazil's economic and social progress has lifted 30 million people out of poverty. However, since 2015 the economic crisis led real GDP growth rates to drop, and Brazil entered recession. At the same time, increased political instability and corruption scandals affecting Petrobras, the national oil company, created increased disturbance in the economy. While the short-term outlook is muted, long-term prospects for the Brazilian economy remain relatively positive with GDP growth expected from 2018 onwards.

Changing regulatory gas framework, together with Petrobras' divestment program, is expected to transform the local gas market into becoming more transparent, competitive and investor friendly.

Gas penetration in Brazil is limited, with gas representing a minor share compared to hydro, biomass and oil. The current gas market in Brazil is still in an immature state. Gas infrastructure is limited and predominantly located in the coastal regions. However, there is a strong pressure from the Brazilian government to increase gas penetration.

Brazil's natural gas supply is currently either domestically produced, imported from Bolivia, or imported through LNG spot cargoes. Historically, domestic gas production has been modest and large volumes of associated gas have either been re-injected or flared. Domestic gas production has doubled since 2006, as production from inflexible pre-salt fields ramped up. This situation is expected to continue, replacing the decline of traditional post-salt fields.

Gas demand is concentrated in Southeast Brazil (currently around 60% of total), which is also closer to the main supply areas and includes the large metropolitan areas of Rio de Janeiro and São Paulo. Industry has historically been the largest gas consumer, with around 60% of total demand. The electricity market is hydropower based, and gas to power demand can significantly differ depending on hydrological conditions. However, in the last years due to climate changes and the restriction of flooding of large areas, the new hydro projects are run of river without storage facility. New big capacity additions through major hydro projects are no longer expected and new capacity additions will be of smaller scale resulting in an expected lower share of hydro in the power generation mix and increased role for new renewables and gas.

The significant amount of associated gas expected to come to the market later this decade must find and develop new outlets for gas consumption in a competitive setting.

Steadily growing North American production

The abundance of supply in North America enables the growth of the gas market in the 2020s. Current resource assessments suggest that North America has a very flat supply curve. There are known resources which could provide rising gas supply in North America through the 2020s without significantly raising costs.

Rising domestic demand – the energy sector in Canada, industrial and power growth in Mexico and the US – captures much of the growing gas supply. North American natural gas demand continues to grow through the 2020s in all scenarios except in the *Renewal* scenario, where gas demand begins to wane. Gas is not likely to play a major role in the transformation of the transport sector, and changes in the residential and commercial markets are expected in later decades. However, the difference between the three scenarios primarily plays out mostly in the electricity market, with new renewables growing their market shares significantly relative to gas in *Renewal*, and gas keeping its market share in *Reform* and *Rivalry*.

In the OECD Americas in the 2020s, coal declines while renewables grow in all three scenarios. Market competition favours gas over coal in North America in all scenarios. Carbon policy also affects the gas versus coal competition – stricter policies mean a bigger impact on coal. In *Renewal*, coal demand shrinks by over 70% in one decade, while inaction on greenhouse gas emissions in *Rivalry* implies a 25% loss of demand. Solar and wind power grow significantly this decade: by at least 40% in *Rivalry* and more than doubling in *Renewal*. This limits fossil fuel use and the upside available to gas. Gas plays the role of the marginal energy source, filling in the gap left by other sources.

The residential and commercial space heating and cooling markets are likely to start to change in this decade. Policies to improve housing and commercial building energy efficiency begin to play a role, while homeowners and building managers increasingly invest in more efficient designs. This process begins to bear fruit in the 2020s.

For the OECD Americas in the 2020s, gas demand is highest under *Rivalry*, lowest under *Renewal*. The loss of power sector market share to renewables under a strong carbon regime pushes gas from growth to decline in *Renewal*. *Rivalry*, by comparison, allows gas to gain at the expense of coal, and gas faces little competition from solar and wind just yet.

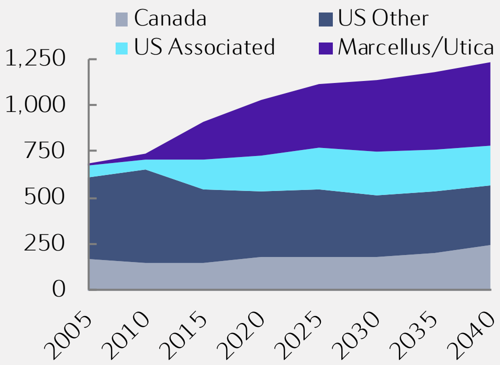
Outlook beyond 2030

Long-term gas demand differs significantly across the scenarios as do supply implications. Global gas demand is forecast to grow by 0.8% per year on average, from 3500 bcm today up to 4500 bcm in 2050 in both *Reform* and *Rivalry*, with gradually lower growth rates as we approach 2050. *Renewal* sees stable gas demand up to 2030, but requires radical transformation of global energy systems to limit and eventually reduce emissions by implementing new technologies and targeted policies. *Renewal* is thus characterized by falling demand after 2030, so that global gas demand in 2050 is around 14% lower than in 2014. Despite the lower carbon footprint from gas use compared to both coal and oil, it is only India that increases its gas consumption in *Renewal* compared to *Reform*. In the other regions, decarbonization of generally much more energy efficient economies results in lower gas demand. By 2050 in *Renewal*, demand for

H21 Leeds city gate project – hydrogen replacing methane?

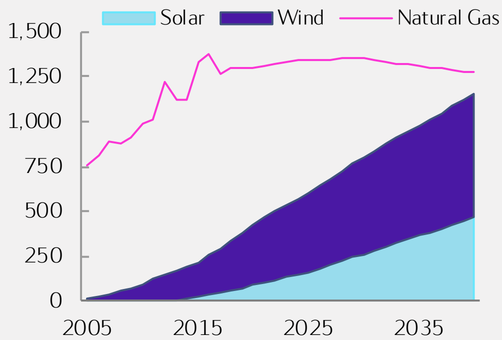
Source: Northern Gas Networks, H21 roadmap

OECD Americas gas supply in *Reform*
Bcm



Source: EIA, IHS (history), Statoil (projections)

Low carbon power generation in the US
GWh



Source: EIA (history), Statoil (projection)

gas in the OECD has been reduced by more than 50% compared to 2014 levels.

In *Rivalry*, gas import regions are negatively impacted, resulting in lower demand, changing trade patterns and increasing domestic supply where possible. Supply regions like Russia and North America demand more at home. Russia's relations with Central Asian countries to the east are also partly reinforced in this scenario, supporting Chinese diversification interests.

A decarbonized Europe - what are the alternatives?

The profound long-term challenge for the European gas market relates to the long-term security of competitive supply. Europe is dependent on imports and has a continued requirement for Russian pipeline volumes. Geopolitics distort the picture and hamper confidence, especially in *Rivalry*, even if history proves Russian and other supplies to be reliable. Both *Reform* and *Rivalry* see gas demand plateau and gradually decrease towards 460 and 425 bcm respectively after 2030.

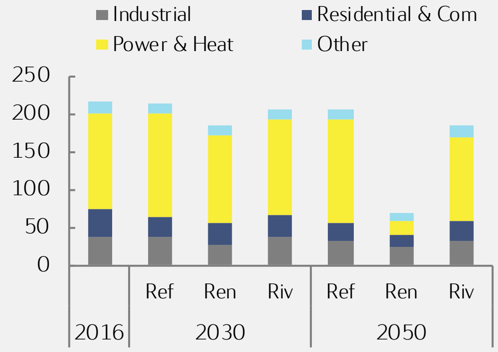
Renewal means dramatically less energy consumed per unit of GDP output. Supply competition will intensify as the regulated and economically driven process of phasing out coal in the electricity sector has run its course and cost reduction in renewables is expected to continue. Gas' role in the future electricity mix must resolve the challenge of low carbon. Efforts into CCS seem to be limited to consumption areas close to production, due to the required infrastructure and costs. Bio-gas supply and conversion to hydrogen value chains are possible low carbon options ensuring continued use of existing infrastructure.

The heating and cooling sector in buildings and industry is exposed to major changes as it is the predominant consuming sector, contributing to close to half of EU's energy consumption. Further gas intensity reductions in this sector respond to the supply challenge. The Netherlands, once the most gas-friendly country in Europe, increasingly seeks energy efficiency and alternative energy sources such as renewables in response to faster than expected losses in indigenous production. In a country where 98% of households are connected to the gas network, the progressive disconnection of residential customers from the gas grid by 2050 is a dramatic evolution. The fundamental question is which investment signals Europe provides. In the absence of firm commitments from Brussels new gas value chains could fail to materialize. Total European gas demand in *Renewal* nearly halves from 400 bcm in 2030 to 220 bcm in 2050 due to the radical transformation of both electricity and heat generation.

North America

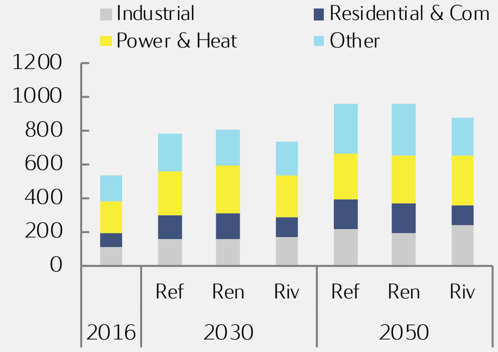
From 2030 onward, growth of gas demand can no longer be assured in the OECD Americas. Demand begins to decline in the 2020s under *Renewal*, in the 2040s in *Reform*, and presumably after 2050 in *Rivalry*. In the drive to reduce carbon emissions, carbon-free renewable energy sources stand as the most sustainable long-term alternatives to fossil fuels and in this time-frame we anticipate that gas faces more competition from renewables than from fossil fuels. Gas looks like a preferable alternative

OECD Asia Pacific demand by sector
Bcm



Source: Statoil

Non-OECD Asia demand by sector
Bcm



Source: Statoil

when coal is still prevalent in *Rivalry*. But when coal has been squeezed out in *Renewal*, gas has less of a market to capture. Technology for renewables continues to improve. The cost of manufacturing and installing solar and wind is falling – a trend that is expected to continue for decades. By the 2030s renewables become competitive with natural gas in more locations and gain more market share.

In the *Renewal* world, gas is pushed into a backup role. Providing power when the wind does not blow or the sun does not shine is an increasingly important reason to turn to gas, but requires less volume. Gas logistics become more important as gas acts as backup fuel.

Other sectors are expected to turn to declines for the most part. Industrial demand is not expected to maintain growth, once the early wave of investment in the 2010s and 2020s is completed. Residential and commercial demand softens with more efficient building designs. The small market for gas in transportation – LNG trucks and bunker fuel mostly stagnates.

Asia

By 2050, gas gains importance in Asia in all scenarios, with demand reaching 1160 bcma in *Reform*. Environmental policy, combined with fuel diversification supports gas usage in all sectors. Strong energy demand growth in China drives domestic production, and pipeline and LNG imports. In *Renewal*, high demand growth builds on steady economic development, abundant supply, and competitive pricing. India's increased gas demand implies reliance on imports as they reach more than 60% of gas demand in *Reform*, and even higher levels in *Renewal*.

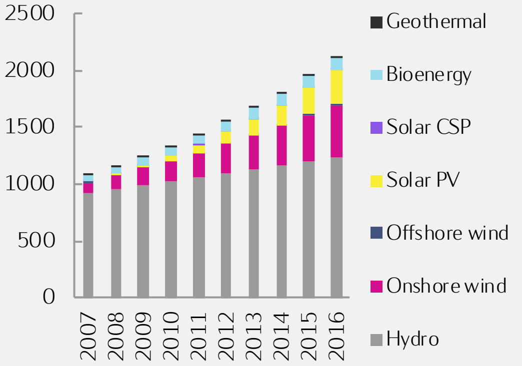
The emerging Asian markets grow in importance over the long term. LNG imports compensate the decline of mature fields. However, the question of affordability of LNG has significant impact for new developments. In OECD Pacific countries like Japan and Korea, governments plan a strong growth in nuclear and renewables which cuts into the market share of fossil fuels, in particular gas, in power generation, resulting in more than a 60% reduction in gas demand in *Renewal* compared to *Reform* in 2050.

Long-term supply challenges

IEA estimates global technical recoverable natural gas reserves at close to 800 trillion cubic metres (Tcm) and proven reserves at some 200 Tcm, which is comfortably sufficiently to meet our estimated accumulated demand in Renewal, Reform and Rivalry ranging between 125-150 Tcm. Still, the underlying variation in long-term demand across our scenarios point to the gas industry's main priority; ensuring competitiveness. Providing sufficient volume to markets in all geographies requires awareness of building sustainable gas value chains. So, what does it take? Sustainability cannot be limited to relative competition between fossil fuels, but rather, must address environmental concerns linked to production; transportation and end-user gas burn. The gas industry, together with national governments, must strike the balance between rising cost, affordability and sustainable energy supplies to ensure the longer-term role of gas in a more diverse energy mix.

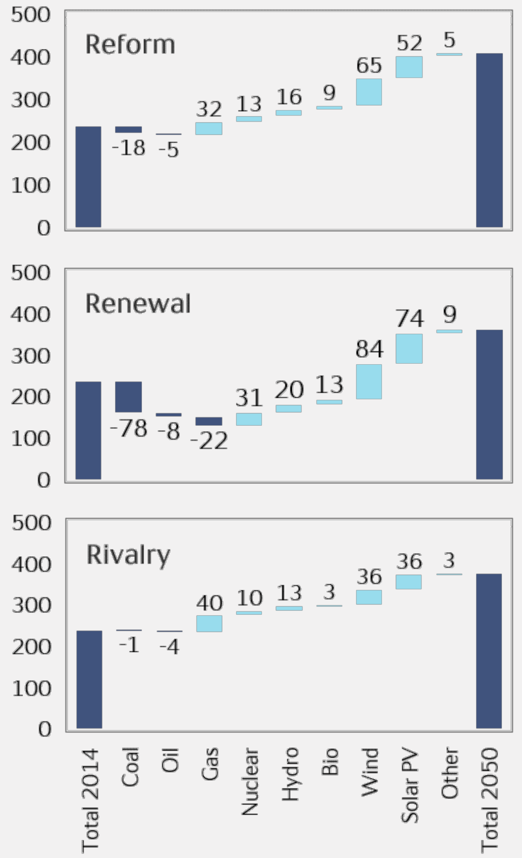
Renewable energy

World renewable electricity generation capacity 2007-2016
GW



Source: IRENA

Changes in global power generation volume and mix 2014-2050
Hundreds of TWh



Source: IEA (history), Statoil (projections)

In 2014, renewable energy made up 14% of global primary energy supply. The share has fluctuated around an almost flat trendline since the 1970s. Renewable energy means however many things, and the composition of this category of energy supply is changing rapidly.

Renewable energy includes traditional biomass like fuelwood and animal waste, modern biomass, bioethanol and biodiesel, and electricity generated from hydro, wind, solar, biomass and geothermal energy. High shares of developing country residents continue to rely on traditional biomass. IEA estimates that more than 85% of African, some 75% of Indian and more than 40% of Chinese households' heating and cooking is based on wood and other organic matter. These shares are not sustainable. Wood is becoming increasingly scarce, and traditional biomass is typically burned in inefficient stoves causing severe pollution problems.

The other components of renewable energy – especially new renewable electricity – are however expected to play key roles in the envisioned energy transition.

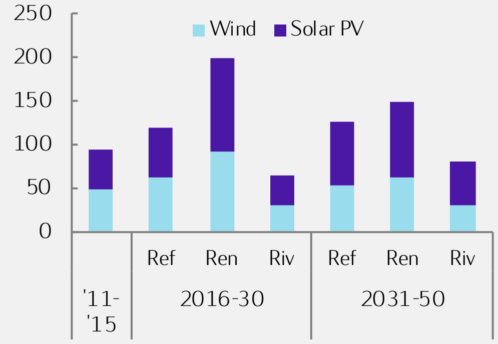
IEA puts the share of renewable electricity generation capacity in total global power generation capacity by 2014, at 30%. Of these 30%, hydro capacity made up 64%. The hydro share is declining – not because hydro capacity has levelled out, but because wind and solar PV power are expanding much more rapidly. The hydro share of total global renewable capacity additions dropped from 48% in 2008 to 21% in 2016.

Asia is home to 42% of the world's hydro electricity generation capacity and the share is growing – of the 319 GW of new hydro capacity that was put online in between 2007 and 2016, 72% was Asian capacity. The other regions with significant hydro power sectors are Europe (17.4% of global capacity by end 2016), North America (15.8%) and South America (13.6%). In the OECD regions, most hydro resources have already been developed. Their combined capacity has recently increased by less than 1% per year, and there are no reasons to expect faster growth in the future. Outside the OECD regions there are however significant untapped opportunities.

Hydro is attractive because it is a major zero carbon resource and because generation can be adapted to fluctuations in demand. Large scale hydro power has however become increasingly controversial because of its impacts on local ecosystems and communities. Scattered small scale hydro power generation can be a benign alternative, but plants with a capacity of up to 10 MW still account for only 12% of total global hydro power capacity, and the scope for growth in this share is unclear. In *Reform* and *Renewal* global hydro power capacity increases between 2014 and 2050 by 465 GW and 618 GW respectively, with India, China and Africa accounting for the biggest increments.

The combined share of wind, solar PV, solar CSP, modern biomass, geothermal and marine electricity in global power generation was not yet 5% in 2015, but has increased rapidly and is expected to continue increasing. On balance, 47 GW of wind power generation capacity and 43 GW of solar PV capacity were added to the global power plant fleet every year between 2011 and 2016. These technologies in 2015 accounted for

Average annual global wind and solar PV capacity additions in Statoil's scenarios
GW



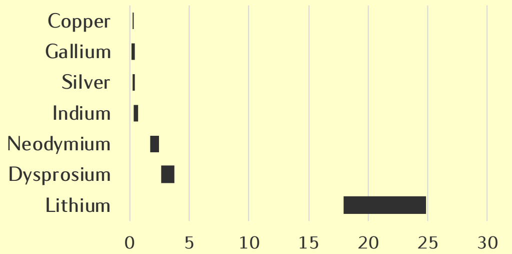
Source: Statoil

The resource challenges of growth in new renewables and electric vehicles

While new renewable energy and electric vehicles are at the very centre of the energy transformation to a low-carbon society, less is said about the large boost in demand for certain metals and minerals caused by it. Copper is a key metal for all renewable energy technologies. Silver, tellurium, indium and gallium are all important for solar PV development. The EV growth projected in both *Reform* and *Renewal* requires lithium and selected rare earth elements (REEs) at several times current production levels, also highlighted in UBS's report called "UBS Evidence Lab Electric Car Teardown – Disruption Ahead?". Demand for REE also stems from wind turbines and other applications.

Affordable access to these metals is critical to enable the deployment of low-cost and efficient energy technologies. The challenges to overcome to be able to increase production derive from grade decline, water scarcity in major production areas, permitting difficulties in established jurisdictions, long lead times for new mines, and the fact that some of the metals are produced solely as by-products to others.

Increase in metals demand in *Reform* and *Renewal*
Multiples compared to current production



Source: Statoil

13.4% of EU generation and 20-25% of several EU member countries' generation.

Onshore wind is the most widely deployed of the new renewable power technologies; IRENA puts global generation capacity by end 2016 at 452.4 GW. Of this total, Asia accounted for 40%, Europe for 32% and North America for 21%. China alone had 147.2 GW of capacity or one third of the global total. The levelised cost of onshore wind power came down sharply during the 2000s and are still falling, although the decline rate has slowed. BNEF's 1st half 2017 benchmark is 67 USD/MWh. Lazard, a financial advisory and asset management firm, estimates that onshore wind costs have declined by around 8% per year since 2011. An expert elicitation carried out in 2016 suggests a scope for further cost reductions of 1.7-3.6% per year up to 2030, and around 1% per year for the 2030-50 period. It is normal that cost declines slow down over time. The rule of thumb is that for each doubling of capacity, learning, economies of scale and technology improvements shave 20% off costs. As the growth base increases it will of course take longer and longer to achieve the next doubling.

Offshore wind is a newcomer in relative terms to the family of new renewable power generation technologies, and has not benefitted from the same economies of scale as onshore wind and solar PV. Global offshore wind capacity was by end 2016 an estimated 14.1 GW, corresponding to 3.6% of total wind power capacity. Only a handful of countries are involved in offshore wind, with Europe accounting for 89% of total capacity. Offshore wind power remains significantly more expensive than onshore wind power – BNEF suggests a benchmark LCOE of USD 124/GWh. Costs have however come down a lot over a short period, with Northwest Europe in the lead. BNEF suggests a 53 USD/MWh LCOE for Danish offshore wind projects, and in April 2017 Dong and EnBW submitted bids for three such projects, claiming zero subsidy requirements.

Solar photovoltaic (PV) power generation has recently been the fastest growing component of new renewable power supply. Global solar PV capacity increased from 8.7 GW in 2007 to 290.8 GW by end 2016, i.e., by an average of 48% per year. Solar PV power remains concentrated to three regions – Asia with 48% of global capacity, Europe with 35% and North America with 12%, and within each of these regions there are typically 2-4 countries accounting for the bulk of regional capacity; thus, China, Japan, Germany and the US in 2016 possessed two thirds of global solar PV capacity. However, several other Asian, Middle Eastern and African countries aim to build sizable solar PV industries. BNEF's benchmark LCOE range for solar PV power is 56-86 USD/MWh, with devices able to track the position of the sun displaying the lowest costs.

New renewable energy supply growth has been policy driven. Progress based on subsidies and other types of public support is notoriously fragile. Bullish long-term new renewable energy supply scenarios have typically reflected the view that policy makers will sustain or preferably increase support levels regardless of costs because energy supply decarbonization is simply unavoidable. This may not be correct. Subsidy levels are being

A bright future for biofuels?

In 2014 biofuels supplied 2.8% of global transport sector fuel use. In IEA's New Policies scenario, the share more than doubles, and in the 450 scenario it increases to almost 16% by 2040. IEA suggests an average annual growth in transport sector biofuels use of 3.9-7.0%. IRENA agrees, seeing a growth of 4.5%/y in its reference scenario and 6.7%/y in its 2° scenario.

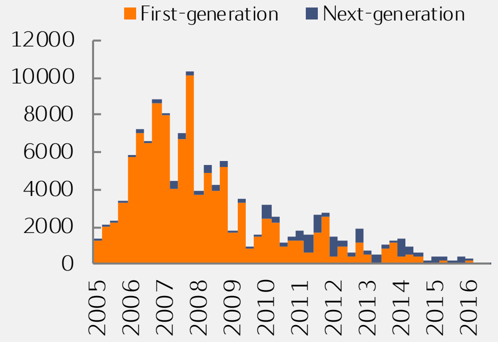
Bioethanol and biodiesel are however struggling to attract the attention many believe these fuels warrant. Investments in biofuels have dropped to a tiny fraction of what they were in the mid-2000s.

Investor confidence has fallen for two main reasons: Oil product prices have declined, eroding the competitiveness of substitutes, and so-called 1st generation biofuels have lost much of the political support they used to enjoy. 1st generation biofuels are produced from food crops like corn, sugar cane, sugar beet, wheat and soybeans, curtailing food supply both directly and indirectly by diverting arable land and water from alternative usages. Advanced or 2nd and 3rd generation biofuels are under development, but 2nd generation biofuels fabricated from the non-food parts of crops, forestry residues or grasses have their own issues, and 3rd generation biofuels based on algae or seaweed remain experimental.

In November 2016, the EU Commission proposed to scrap an existing target to raise the share of renewable fuels in transport fuel use to 10% by 2020, cap the use of 1st generation biofuels to 7% by 2021, declining to 3.8% by 2030, and raise the use of advanced biofuels to 0.5% by 2021, increasing to 3.6% by 2030. Green groups have criticized the Commission for suggesting a too slow phase-out of 1st generation biofuels, and for proposing a hard target for advanced biofuels ahead of time; the jury is still out both on the environmental benefits of key 2nd and 3rd generation options, and on their scalability.

The biofuels share of world transport energy demand is projected to increase to around 3% in both *Reform* and *Rivalry*, and to 5% in *Renewal*. These expectations are below the consensus range. Airlines will need bio jet fuel to decarbonize, and we model increases in the bio shares of world aviation fuel use from zero today to 8% in Reform and 22% in *Renewal*. But we see car owners going electric rather than incentivizing oil companies to blend in more bioethanol and biodiesel in conventional fuels.

Global investment in biofuels
Q1 2005 - Q3 2006 (USD mill)



Source: BNEF

reduced because the new renewables industries have become so big that continuing to support them has become very costly. But continued support may not be crucial for continued growth. Subsidy levels are being reduced also because the new renewables industries are becoming increasingly able to stand on their own feet.

As the bottom chart on page 24 shows, BNEF suggests an LCOE range for coal power of 50-73 USD/MWh with plants in Asia at the bottom of the range and plants in Europe at the top, and a range for combined cycle gas of 52-102 USD/MWh, with North American plants being lowest and Asian plants the highest. Thus, the renewable electricity cost ranges and the fossil fuel based electricity cost ranges overlap, meaning that the former have gained the upper hand in many locations. Besides, whilst the LCOEs of coal and gas power have levelled out, those of wind and solar PV power are set for further decline.

BNEF, which bases its short-term renewable power capacity forecasts on a project-by-project bottom-up approach, believes that global wind capacity additions in 2017-20 will average 62.7 GW per year, of which some 90% will be onshore and 10% offshore. The same source puts growth in global solar PV capacity in 2017-19 at an average of 84 GW per year.

Although bullish long-term wind and solar PV power scenarios now can be based on traditional competitiveness criteria, this does not mean that all projects are or will become viable without subsidisation any time soon. The quality of wind and solar resources varies, and so do connection costs and necessary grid reinforcement investments. As variable renewable electricity grows, the need for, and importance of storage and backup solutions also grow. Hence, the economics of new renewable energy are site specific. This means that long-term new renewable energy supply scenarios continue to have large prescriptive elements.

IEA suggests in the 66% 2° scenario an increase in global wind plus solar power generation capacity from 527 GW in 2014 to 7131 GW by 2050, i.e., an average (CAGR) growth of 7.5% per year. IRENA advocates in the same scenario an increase from 636 GW in 2050 to 11149 GW by 2050, meaning a growth of 8.5% per year. In comparison, *Reform* implies an average growth in new renewables of 7% per year, while *Renewal* delivers 8%.

Projections like these beg the questions whether there are limits to growth in new renewable power, and if so, where those limits go. The most bullish scenarios available not only foresee continued growth, they also expect annual increments to increase over time, i.e., exponential capacity and generation curves, on the argument that this is the kind of growth we have seen in the past. But exponential curves tend to develop into S-curves and it is difficult to believe that new renewable power will be an exception. Wind and solar power will enter territory where their variability becomes problematic. Where this territory starts needs to be assessed country by country and revisited as grid bottlenecks are removed and electricity storage and other ways to handle grid instability problems evolve. Willingness to pay will matter as much as technical opportunities. Most countries have some way to go before the variability of their wind and solar PV power becomes a challenge, but to some, grid stability is already an issue.

Storage to the rescue?

Wind and solar PV electricity generation is variable, meaning that windmills stop when the wind dies down and solar panels cease working when the sun does not shine. In such periods, markets need power rationing mechanisms, i.e., demand side management, or alternative power supply sources. These sources can be dispatchable power plants with spare capacity, or windmills or solar panels in other locations with different wind or sun conditions, or electricity storage facilities. For the moment, ramping fossil fuel based power plants up and down, and demand side management, are the two main ways of preventing power supply-demand imbalances. However, electricity storage is expected to become increasingly important.

Electricity storage capacities are typically tiny compared to electricity generation and consumption. IEA estimated in 2014 global grid connected storage capacity at 140 GW, corresponding to some 2.3% of global generation capacity.

More than 95% of existing storage capacity is pumped hydro storage, which means lifting water from one reservoir to another, more elevated reservoir for release and power generation upon need. Other technologies are compressed air electricity storage, flywheel systems, thermal storage and battery storage. Storage is needed for different purposes calling for all these technologies. Pumped hydro is well suited to meet daily peaks in demand, batteries are interesting for peak load shaving purposes, for handling variations in renewable power generation and for enabling distributed electricity management, and flywheels are optimal for rapid-response frequency regulation.

In recent years batteries have attracted most attention because of their good fit with new renewable power generation. BNEF projects a growth in global electricity storage capacity net of pumped hydro capacity from 1.9 GW in 2015 to 45 GW by 2024. Battery storage is at the centre of this vision. The bulk of the projected 23-fold growth is seen to take place in Japan, India, the US, China and Europe.

Battery costs which have declined very significantly in tandem with the breakthrough for electric vehicles need however to come further down. Lazard estimates a wide range of storage LCOEs for different technologies and purposes, and lithium-ion and zinc batteries are beginning to compare well in many usages, but Lazard still concludes that "none are as yet cost competitive for the transformational scenarios envisioned by certain renewable energy advocates".

Tesla's gigafactory aims to reduce battery costs by 30%

Source: Inside EVs

New renewable power generators will also like other generators be limited by the pace of electricity consumption growth. This constraint is already being felt in developed economies where electricity demand is flat and generation capacity is ample. With low operating costs and zero fuel costs, and typically with priority access to the grid, existing wind and solar power generators have the upper hand under such conditions. Gyrating, occasionally negative, electricity prices have idled much fossil fuel based generation capacity and forced utilities to restructure and search for new business models. But the situation has also led governments to try to reign in growth in new renewable capacity.

In *Reform,* the share of wind in global power generation increases from some 4% in 2015 to 18% by 2050. In *Renewal* and *Rivalry,* the shares go to about 26% and 12%, respectively. Offshore wind capacity, which today makes up only 3.6% of total wind capacity, is seen to increase its share of the total to around one fourth by 2050. Generally stronger winds and less opposition from affected communities to the building of tall, noisy windmills in their backyards are two factors favouring offshore developments – if cost reductions can be realised.

In *Reform,* the share of solar PV in global electricity generation increases from some 1% in 2014 to 13% by 2050. In *Renewal* and *Rivalry,* solar PV captures 2050 market shares of 21% and 10%, respectively. An interesting question is how the split between utility scale solar power generation, industrial and commercial generation and residential rooftop generation will evolve. Growth in distributed power generation relative to total power generation raises supply-demand balancing and tariff issues accentuating the need for more and better electricity storage solutions. Statistics are fragmented, but leave an impression of different experiences in different countries. Apparently utility scale installations dominate, but with rooftop panels accounting for sizable shares of capacity additions.

In addition to wind and solar PV, several other renewable energy technologies are vying for attention. Biogas can be produced from organic material in landfills or wastewater, and be used locally or purified into a pipeline quality substitute for natural gas. Geothermal power plants source heat for their turbines from the earth. This is an important technology in select countries – Iceland, Kenya, the Philippines and parts of the US – where high-temperature hydrothermal resources can be found at reasonably shallow depths. It is less suitable for locations where this condition is not met; however, new technology could widen the scope for geothermal power. Concentrated solar power (CSP) involves the use of lenses or mirrors to concentrate and direct sunlight to a boiler driving a steam turbine. CSP is for the moment disadvantaged on costs – BNEF suggests an LCOE range of USD 255-258 per MWh – but is nevertheless seen as a promising option for very sunny locations, and plays an important role in many 2° scenarios. In IRENA's contribution to this year's joint IEA-IRENA scenario study, global CSP capacity increases from 5 GW in 2015 to 719 GW by 2050. Marine power technologies generate electricity from the kinetic energy of moving water, i.e., waves, currents and tides. Marine power technologies are at an early stage of development and correspondingly costly, with BNEF estimating an LCOE range of USD 440-500 per MWh. However, the theoretical long-term potential is vast, but limited to coastal areas, where wind often is also available.

Other energy carriers

The coal market – status and outlook

Coal covers around ¼ of the world's energy demand, its share is only surpassed by oil. The main use of coal is as steam coal, which accounts for more than 40% of global electricity production, almost twice the share of natural gas. Also, coal is important in steel production and cement manufacturing. Coal is currently the main source of global carbon emissions and contributor to global warming. Compared to coal, natural gas emits only half the amount of CO_2 in a typical power plant, for the same amount of electricity produced.

China is by far the world's largest coal user, accounting for around half of global demand. The United States, India and the European Union are also significant centres of demand. Indonesia, Australia and Russia are the main exporters, trailed by Colombia, South Africa and the United States.

After a long-term growth trend, preliminary estimates indicate that global steam coal use is up only 1% in 2016 compared to 2015, which saw a 6% decline from the year before. In the OECD area, coal has lost market share to natural gas and new renewables in 2016. Demand has grown, however, in China and other parts of the Asia Pacific region.

A price revival in 2016

In 2016, global coal prices bounced back from a five-year downward trend, largely due to an increase in China's imports. Expectations of stagnant electricity demand led Chinese authorities to limit coal supply. However, higher than anticipated industrial and cooling demand boosted coal-fired generation, and import needs surged. Combined with global factors such as several nuclear outages, this resulted in a price increase.

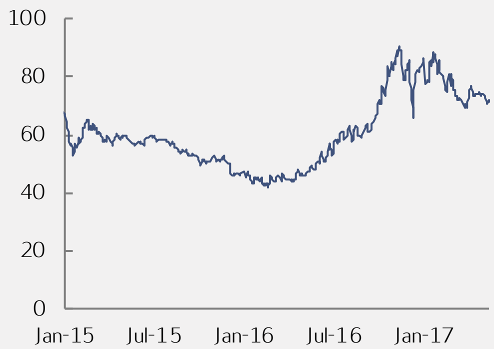
What does the future hold for coal?

Even if modern, highly efficient, coal plants can operate with emission reductions of up to 60%-70% for NOx and SO_2, and with almost no particulate matter emissions compared to the current fleet, CO_2 emissions are not reduced similarly without employing carbon capture technologies. Even with increased use of CCS technology, coal's longer-term global future will largely depend on developments in the electricity sector in Asia, especially in China and India. Demand will be determined by electricity demand and the growth in other forms of generation, especially new renewables and hydro. Driven mostly by environmental concerns, the Chinese government aims to reduce the coal share and thus cracks down on inefficient industries and their excess energy use. They are also launching a nation-wide emissions trading scheme. Consequently, in *Reform*, the Chinese coal demand has peaked, and is slowly decreasing towards the middle of the century. In India, we expect continued strong growth in power generation. However, this is not enough to stem a decline in global coal demand, driven by the OECD area. Due to environmental concerns and competition from natural gas and renewables, demand in 2050 is expected to be around 15% lower than the level in 2014. In the *Renewal* scenario, demand is around 68% lower by 2050 than in 2014, while in *Rivalry*, environmental concerns have less impact, leading to a demand 14% higher than today by 2050.

Coal production has experienced a volatile market in recent year

Source: World Coal Association

Front Month coal price movements 2015 -2017
USD/mt



Source: BNEF

Coal transport is key part of the value chain

Source: World Coal Association

Nuclear fusion

Nuclear fusion is the process by which stars produce energy, requiring the combining of smaller atoms to release energy. This is opposed to nuclear fission, the process of splitting larger atoms to release energy, as used in all current nuclear power plants. It has not yet been possible to build a fusion reactor that can deliver a substantial positive net energy output due to the complexities involved in containing the reaction.

There are many different approaches and research projects, requiring collaboration at the highest level, working to demonstrate nuclear fusion as a viable energy source. The world record for fusion power is currently held by the European reactor JET, set in 1997. JET produced 16 MW of fusion power from a total input power of 24 MW (Giving a fusion energy gain factor of Q=0.67). Currently the world's most advanced fusion project is ITER, designed to produce a ten-fold return (Q=10), producing 500 MW of fusion power from 50 MW of input power. ITER will be the world's largest tokamak, the most promising type of reactor. It is intended to demonstrate the integrated operation of technologies needed for a fusion power plant, sustain a deuterium-tritium plasma through internal heating, and test the tritium breeding required to produce fuel on the scale that would be needed for commercial use. The ITER members are China, the European Union, India, Japan, Korea, Russia and the United States, representing half the world's population and 85% of its GDP. The project expects to have first plasma achieved at the earliest by 2025, and sees 2035 as the start of deuterium-tritium operations. Fusion reactors are not considered in our Energy Perspectives modelling, so any commercial roll out would signify a monumental shift in expectations for the future of global energy. The development of a commercial fusion power plant would represent an energy source that is virtually inexhaustible, safe, environmentally-friendly and universally available.

Small Modular Reactors (SMRs):

SMRs are a type of fission reactor, typically 300 MW capacity or less, small enough to be manufactured in parts and constructed in the region required. This results in less construction requirements, economies of scale in production, increased containment efficiency, and reduced nuclear materials risk. SMRs are well suited to being integrated into regions or countries that have small grid systems and are unable to support larger nuclear power stations. Though there are numerous different reactor designs available, the economics of SMRs are yet to be proven with only one currently in operation. Once a viable economic framework can be determined for them, SMRs could be used to provide electricity to remote and isolated grids, and to replace coal-fired power plants that could not meet tighter emission restrictions. SMRs could therefore play a significant role in the decarbonisation of developed economies, and the electrification of those less developed. Because of this they are part of the nuclear electricity generation development in *Renewal*.

Nuclear energy – status and outlook

Global supplied nuclear electricity in 2015 was approximately 2500 TWh, 11.5% of total electricity generated. 10 new reactors were brought online that year, more than in any other year since 1990. China is the most significant contributor to new nuclear capacity in both the near and longer term outlooks across all three scenarios. Other significant long-term growth regions are Russia, other Eurasia, India and the Middle East. China's nuclear programme has developed significantly over the last ten years and is expected to account for most the growth up to 2050. Towards 2020, further capacity is expected, with eight construction projects starting in 2015. The average construction time for new reactors started in 2015 was 6.2 years, an improvement on 2014's 7.6 years. However, the average build time for the last 46 completed reactors was 10.4 years, implying uncertainty about when future capacity may be brought online. Fourteen countries are currently building nuclear power plants, and as of July 2016, 58 reactors are under construction. The capacity being built is spread amongst Europe (13.9 GW), Asia (47.4 GW), South America (1.4 GW) and North America (6.2 GW).

Of all the reactors under construction, 9 out of the 14 countries have experienced significant interruptions, with 2/3 of projects delayed. These delays are largely due to nuclear companies struggling with falling wholesale electricity prices, contracting markets and consumption in mature economies, high debt loads, increased costs, and competition from renewables entering the sector. Though new nuclear power stations have large capital costs, over the lifetime of a plant they are expected to be cost competitive with most other base load electricity sources. Their use as swing capacity, in conjunction with variable renewals, is limited and unlikely to compete with other power sources and storage. Nuclear safety, waste disposal and decommissioning are also significant hindrances for growth of the sector, with strong and independent regulators being vital for future growth. Given the need to phase out old nuclear capacity, just keeping generation at current levels is a challenge. Nuclear electricity will however continue to play a major role in lowering global GHG emissions, as well as ensuring security of base load supply and stable production costs.

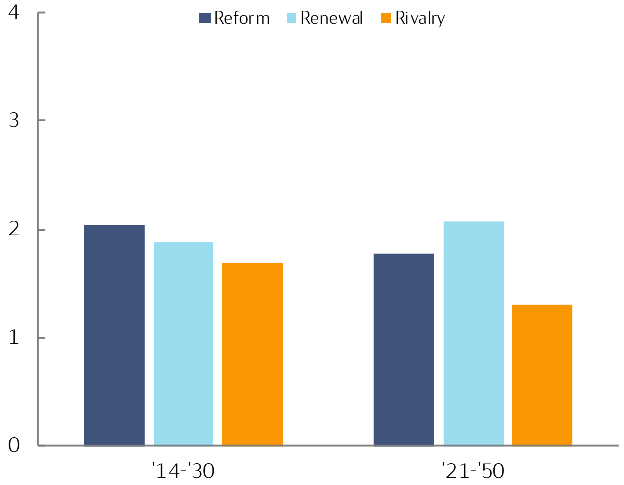
In *Reform,* nuclear electricity increases by 54% from 2014 to 2050, growing on average 1.2% per year. The share of global electricity generation in 2050 is 15% with a generation of 3840 TWh. This is not too dissimilar from the *Rivalry* scenario, with demand increasing 44% over the period. By 2050 total nuclear generation in *Rivalry* is 3640 TWh. This 5% difference is due to the lower economic growth expected in *Rivalry*, as well as a lack of technological exchange and cooperation between regions. Though there is less capital available, the need for supply security due to lack of international trade and protectionism makes nuclear a necessity.

In *Renewal,* nuclear electricity more than doubles, growing by 124%, with a CAGR of 2.3% between 2014 and 2050. Nuclear energy is required to make up a significant portion of global electricity demand, displacing fossil fuels as base load supply to reach the GHG emissions reductions in the scenario. In 2050 nuclear power makes up 16% of the total electricity mix, with total nuclear generation of 5600 TWh. Nuclear is a vital part of a diverse energy mix and is required to secure supply when a significant portion of generation from other base load alternatives has been eliminated.

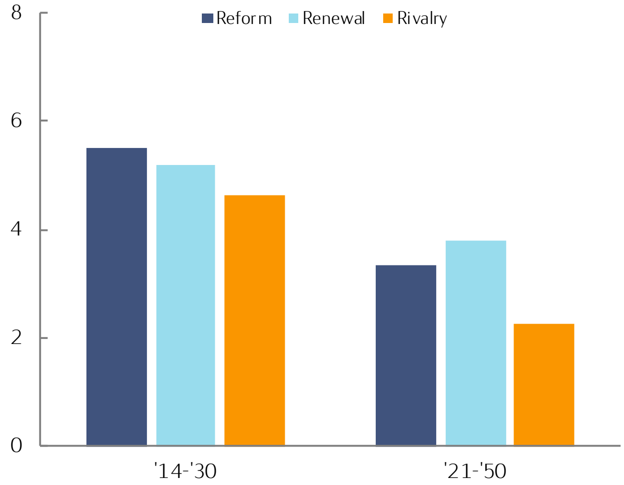
Chart appendix

Economic growth

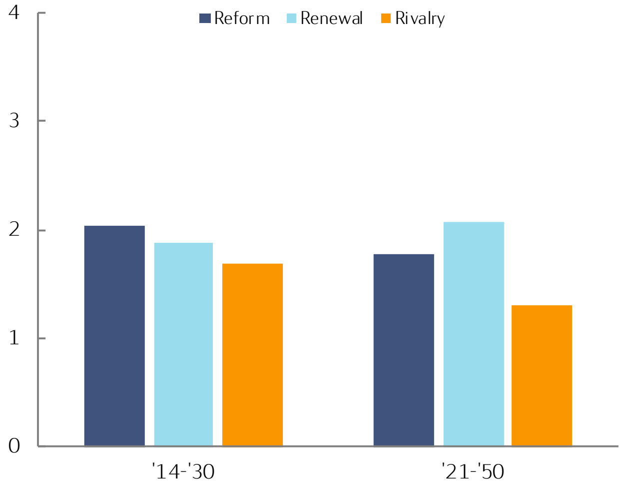
World GDP 2014-2050
Annual growth rate (CAGR), %



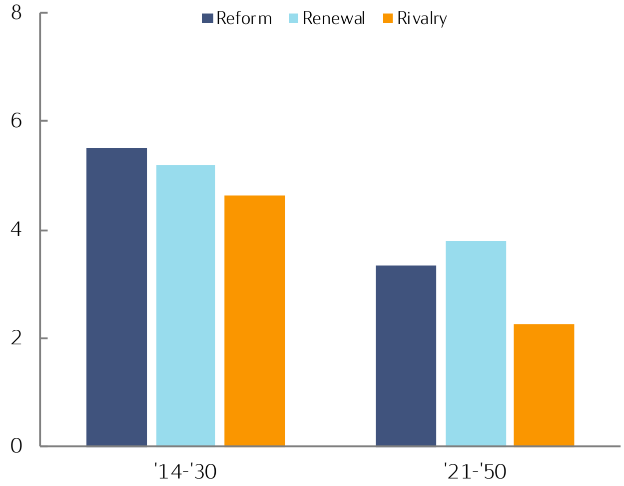
European Union GDP 2014-2050
Annual growth rate (CAGR), %



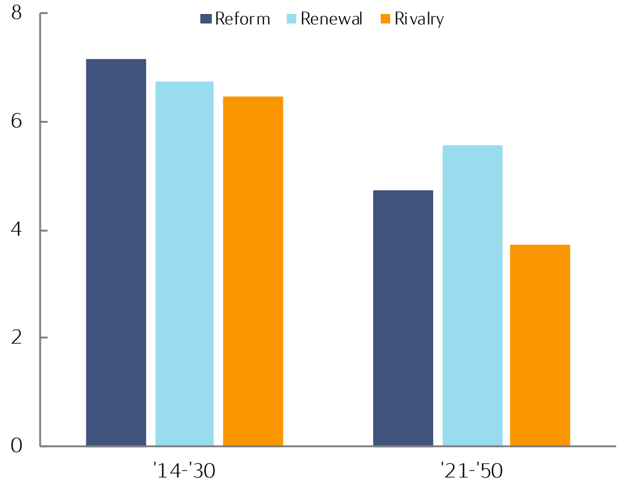
OECD Americas GDP 2014-2050
Annual growth rate (CAGR), %



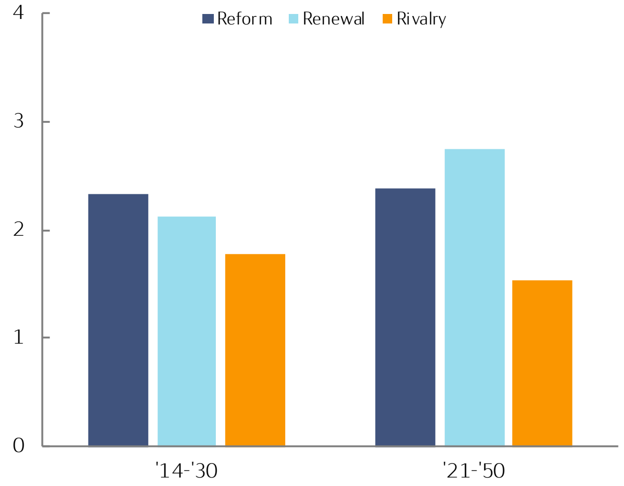
China GDP 2014-2050
Annual growth rate (CAGR), %



India GDP 2014-2050
Annual growth rate (CAGR), %



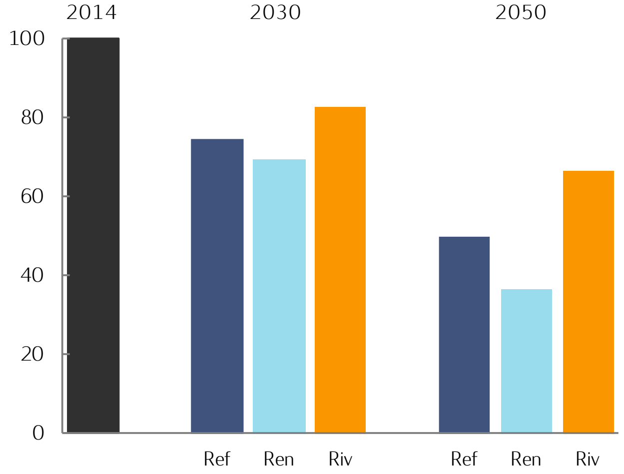
Rest of the World GDP 2014-2050
Annual growth rate (CAGR), %



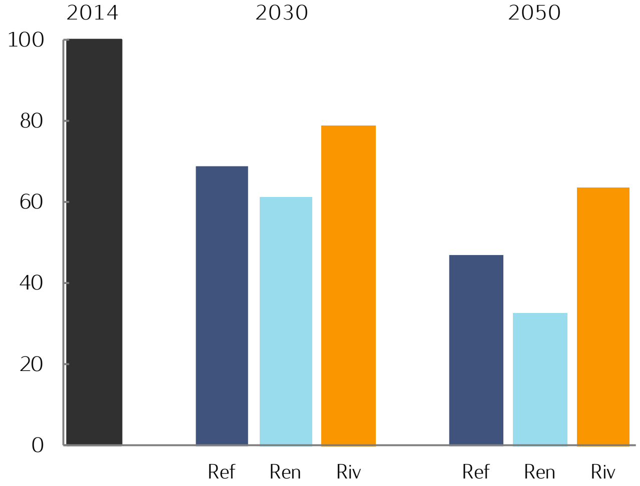
Source: IHS Connect (history), Statoil (projections)

Energy intensity

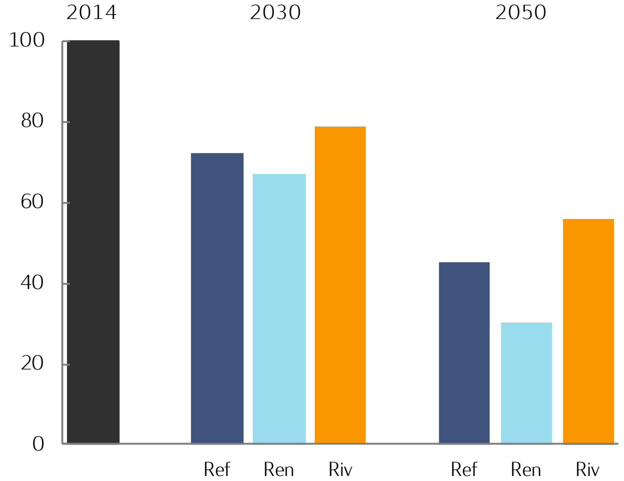
World energy intensity 2014-2050
Index, 2014=100



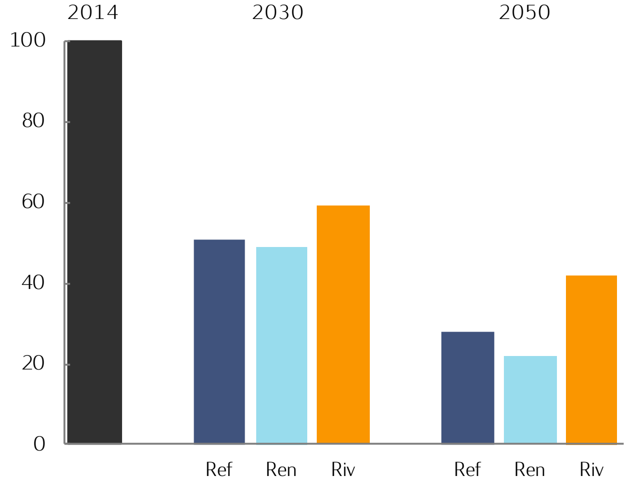
European Union energy intensity 2014-2050
Index, 2014=100



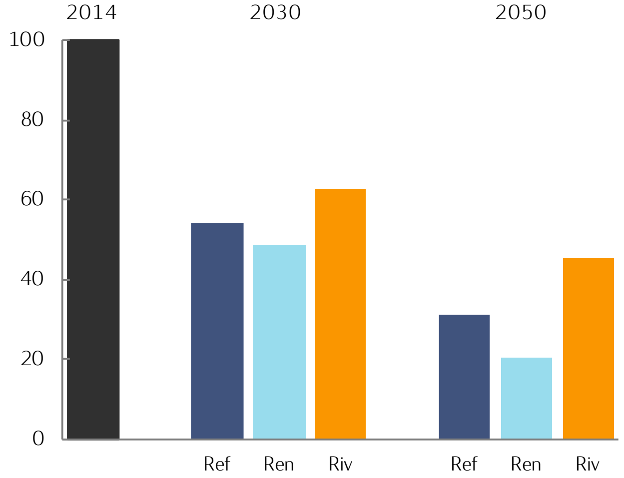
OECD Americas energy intensity 2014-2050
Index, 2014=100



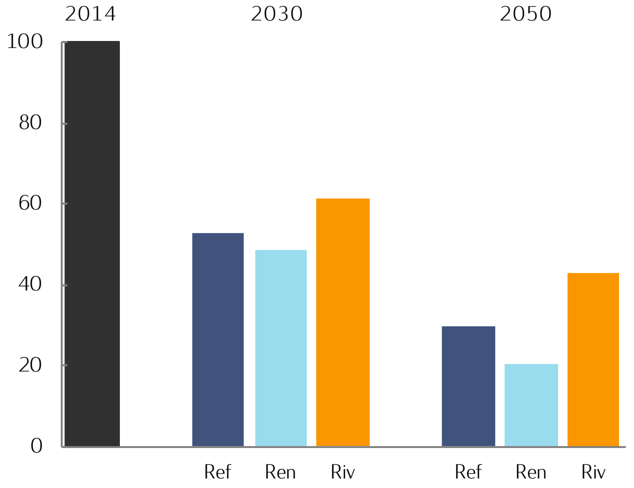
China energy intensity 2014-2050
Index, 2014=100



India energy intensity 2014-2050
Index, 2014=100



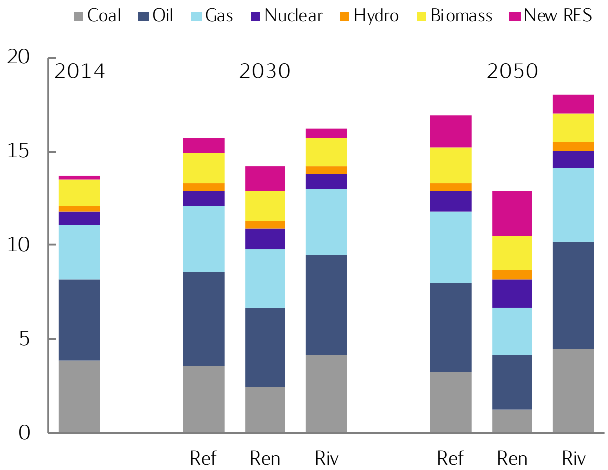
Rest of the World energy intensity 2014-2050
Index, 2014=100



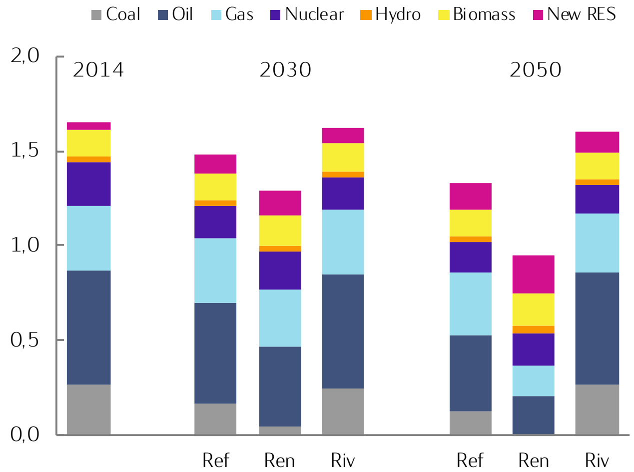
Source: IEA (history), Statoil (projections)

Energy demand

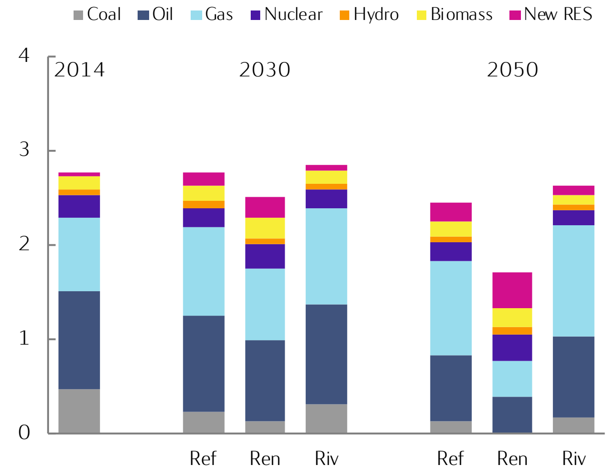
World energy demand 2014-2050
TPED, billion toe



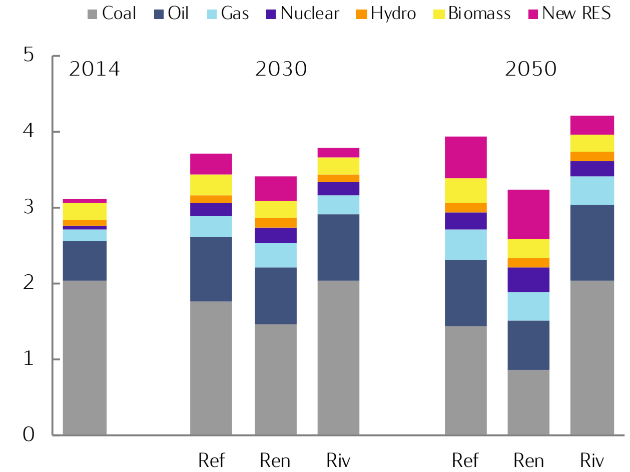
European Union energy demand 2014-2050
TPED, billion toe



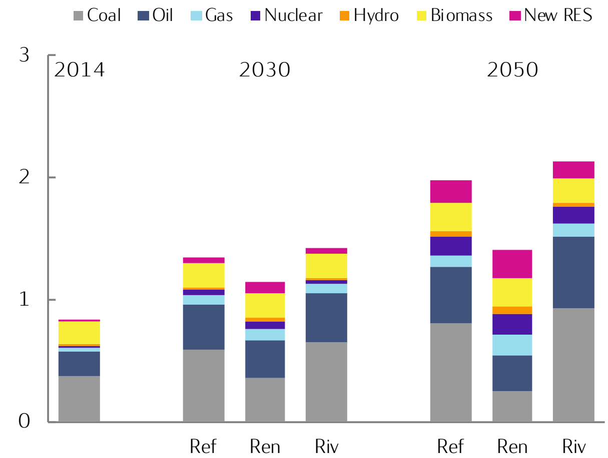
OECD Americas energy demand 2014-2050
TPED, billion toe



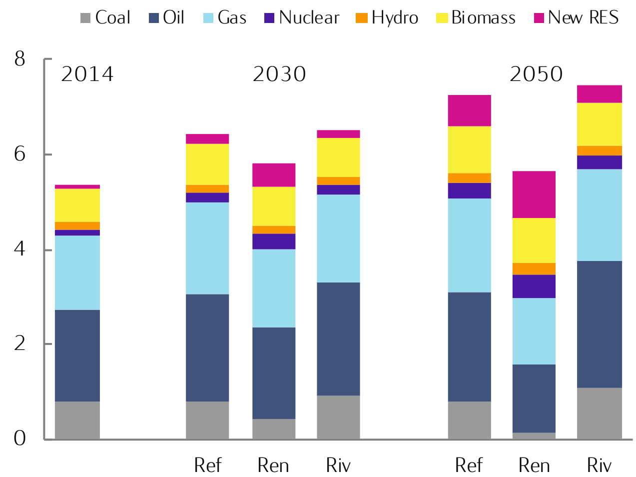
China energy demand 2014-2050
TPED, billion toe



India energy demand 2014-2050
TPED, billion toe



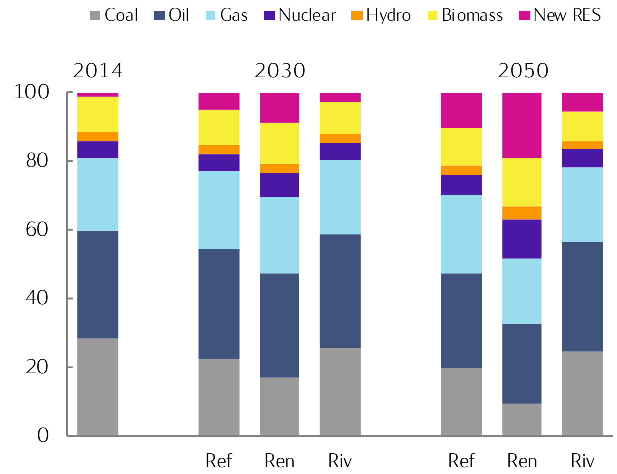
Rest of the World energy demand 2014-2050
TPED, billion toe



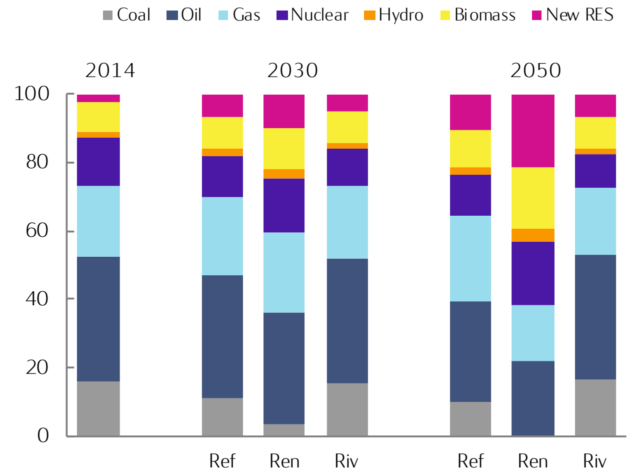
Source: IEA (history), Statoil (projections)

Energy mix

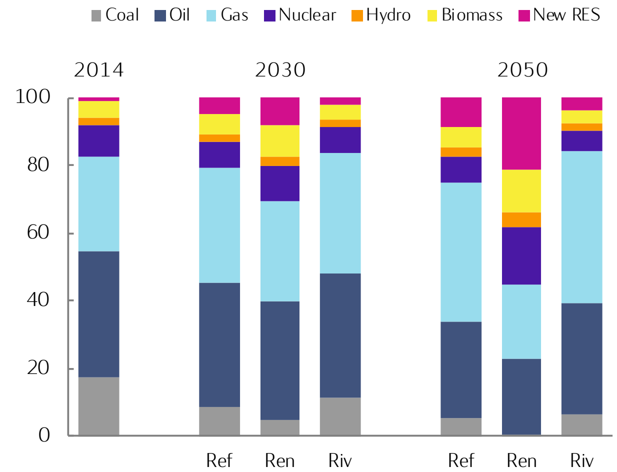
World energy intensity 2014-2050
Index, 2014=100



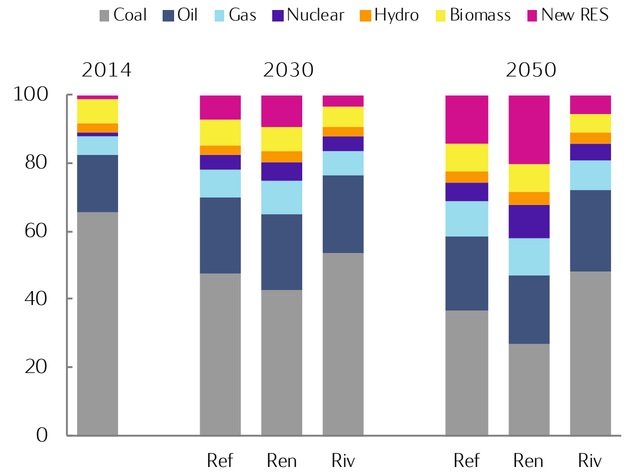
European Union energy intensity 2014-2050
Index, 2014=100



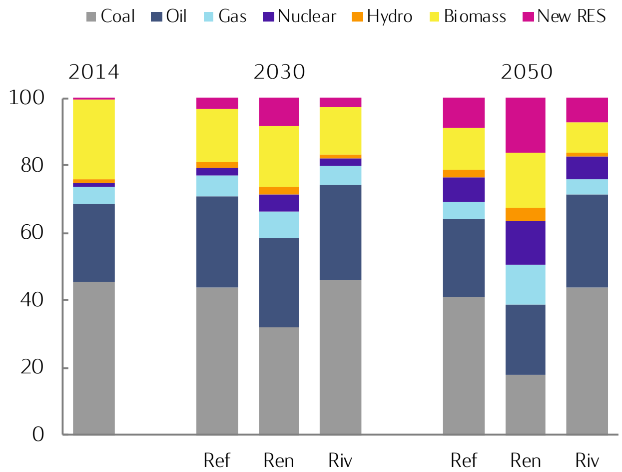
OECD Americas energy intensity 2014-2050
Index, 2014=100



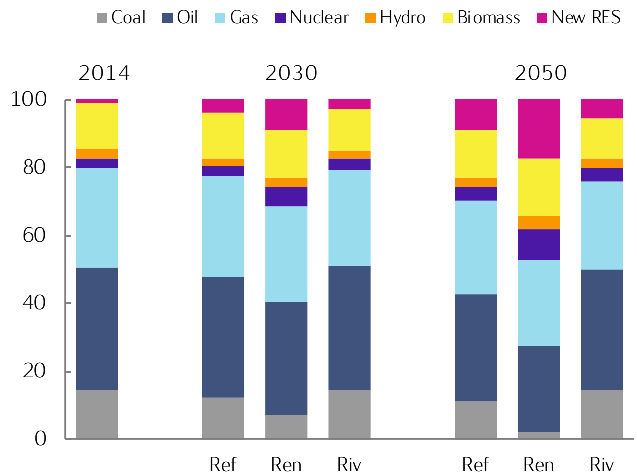
China energy intensity 2014-2050
Index, 2014=100



India energy intensity 2014-2050
Index, 2014=100



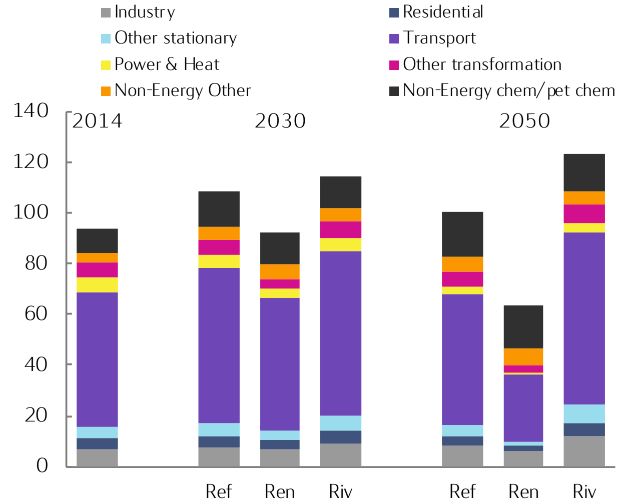
Rest of the World energy intensity 2014-2050
Index, 2014=100



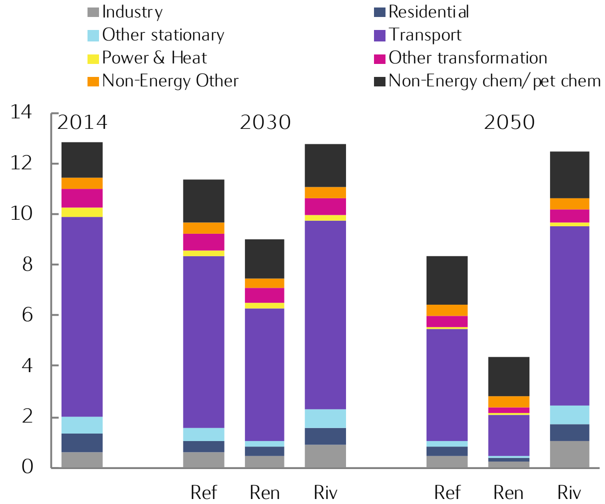
Source: IEA (history), Statoil (projections)

Oil demand

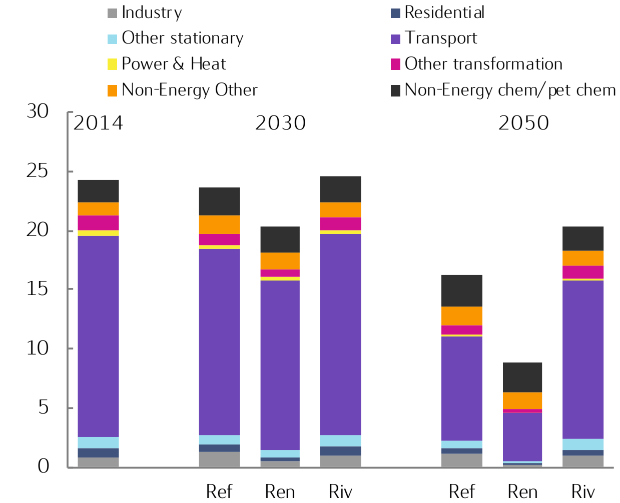
World oil demand 2014-2050
Million barrels per day



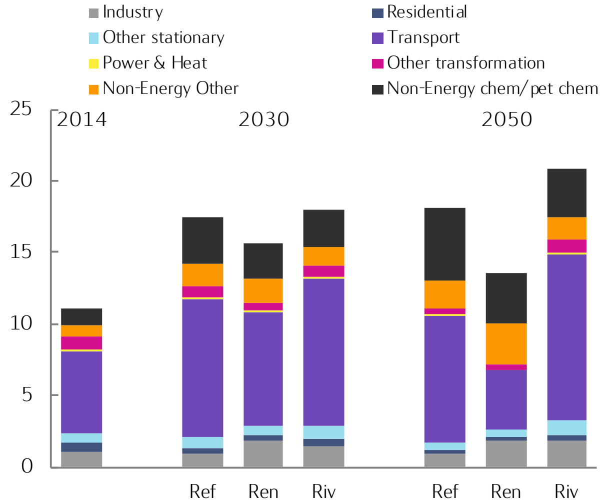
European Union oil demand 2014-2050
Million barrels per day



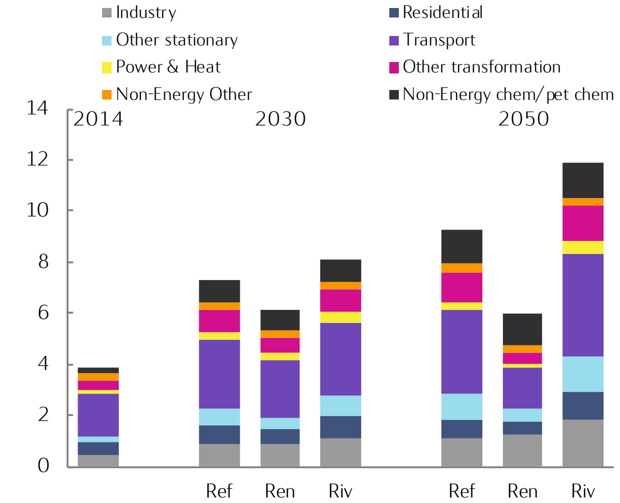
OECD Americas oil demand 2014-2050
Million barrels per day



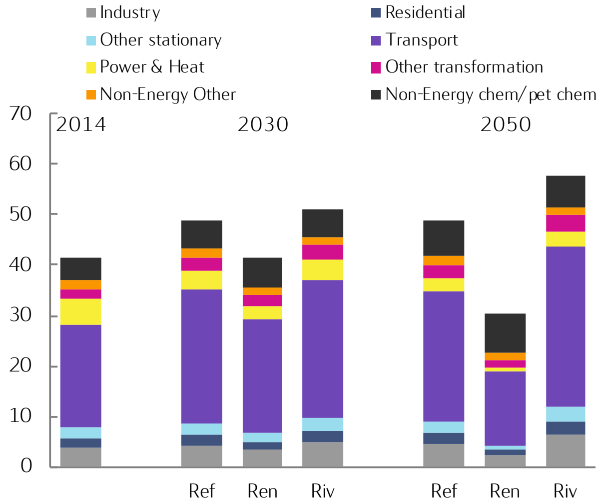
China oil demand 2014-2050
Million barrels per day



India oil demand 2014-2050
Million barrels per day



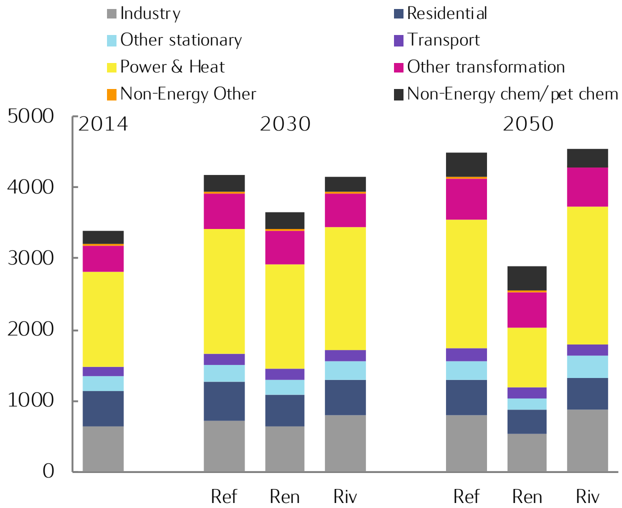
Rest of the World oil demand 2014-2050
Million barrels per day



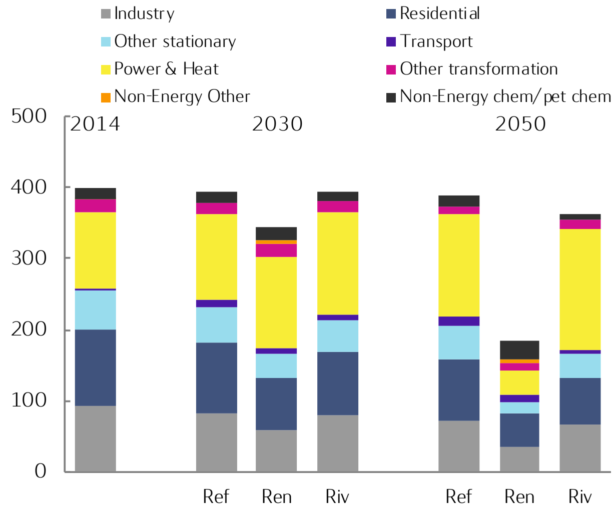
Source: IEA (history), Statoil (projections)

Gas demand

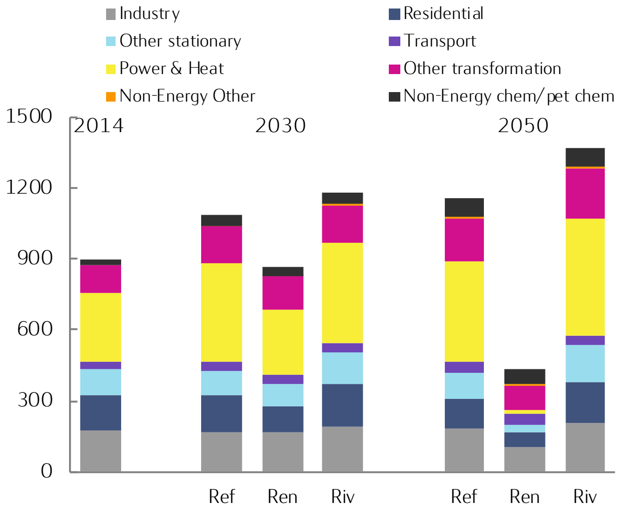
World gas demand 2014-2050
Billion cubic meters



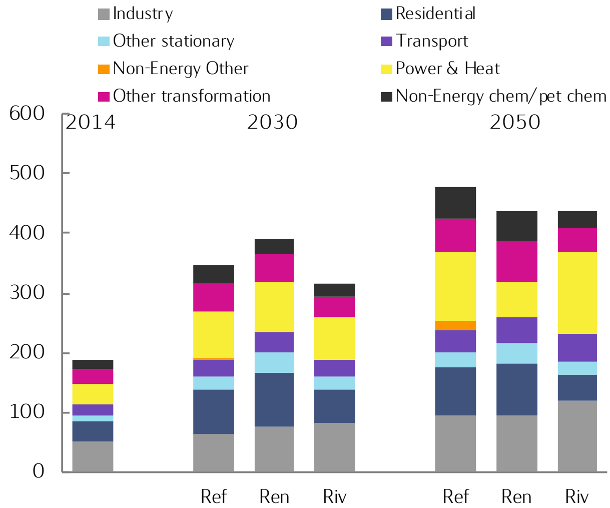
European Union gas demand 2014-2050
Billion cubic meters



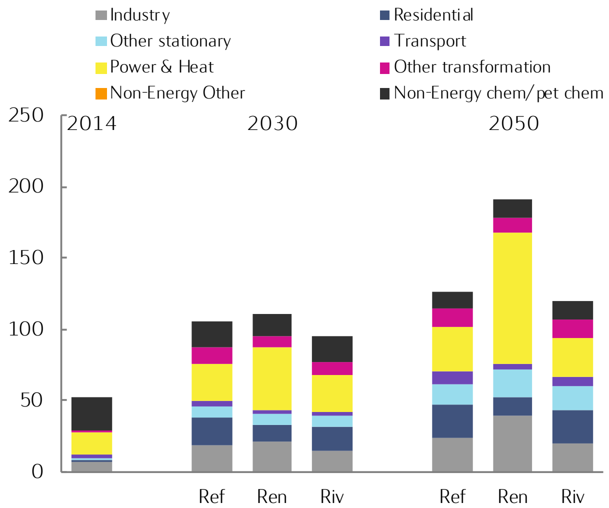
OECD Americas gas demand 2014-2050
Billion cubic meters



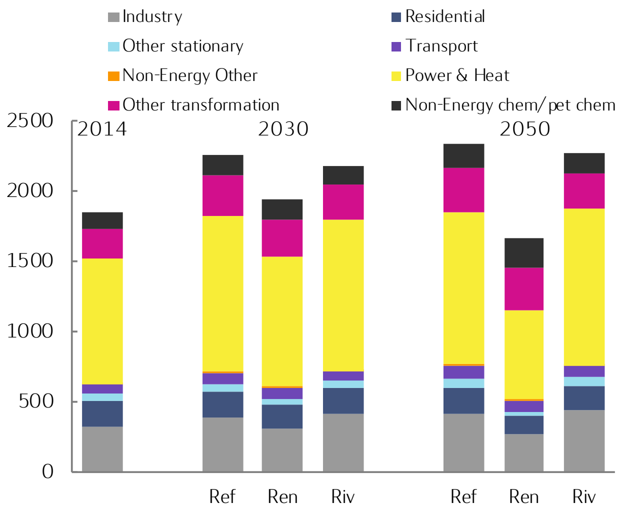
China gas demand 2014-2050
Billion cubic meters



India gas demand 2014-2050
Billion cubic meters



Rest of the World gas demand 2014-2050
Billion cubic meters

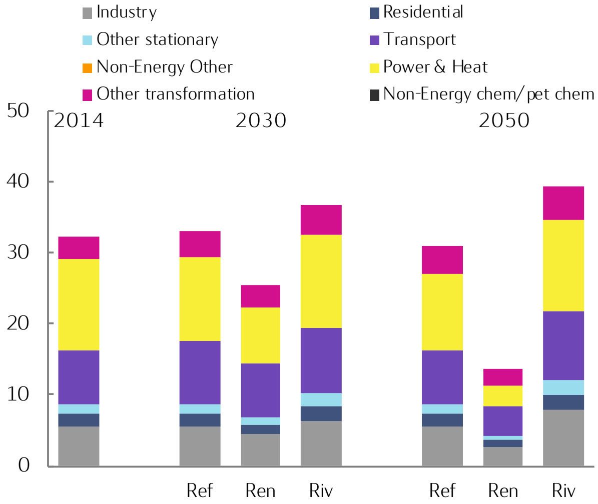


Source: IEA (history), Statoil (projections)

CO_2 emissions

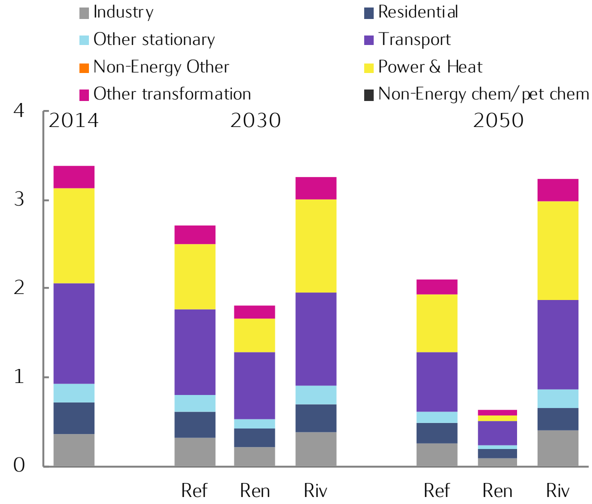
World CO_2 emissions 2014-2050

Billion tons



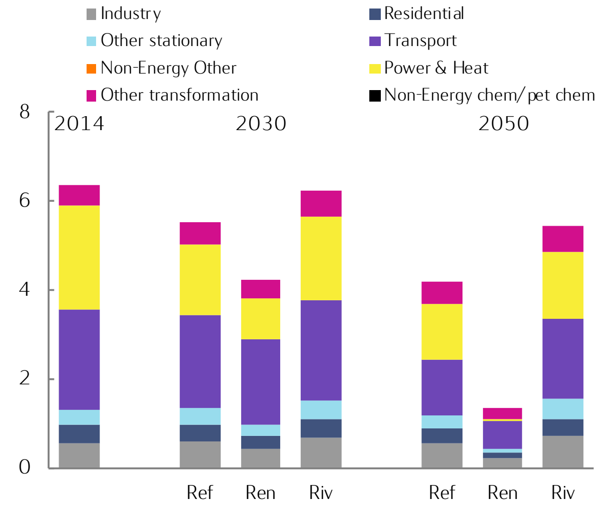
European Union CO_2 emissions 2014-2050

Billion tons



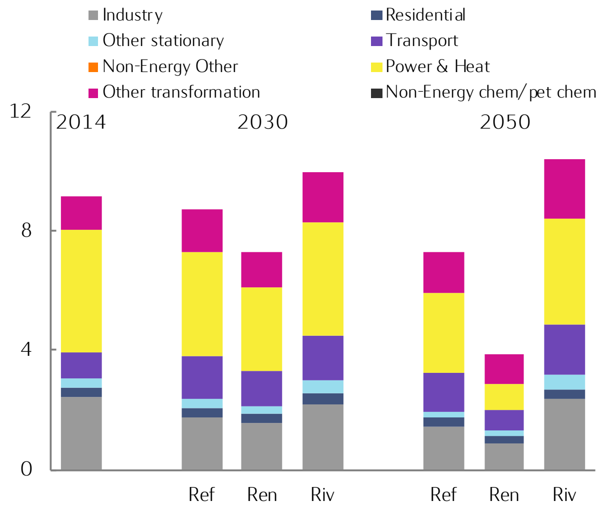
OECD Americas CO_2 emissions 2014-2050

Billion tons



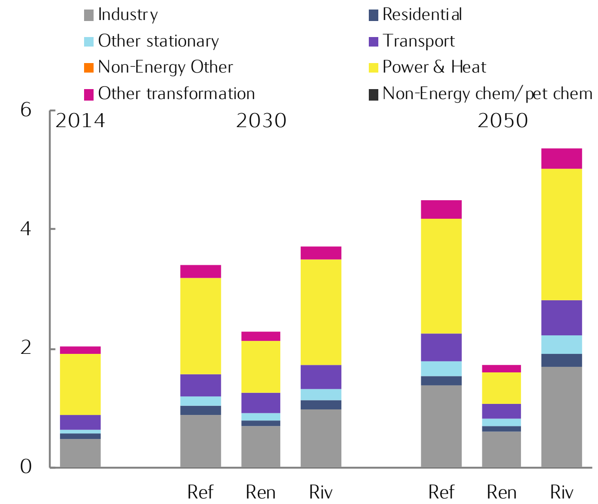
China CO_2 emissions 2014-2050

Billion tons



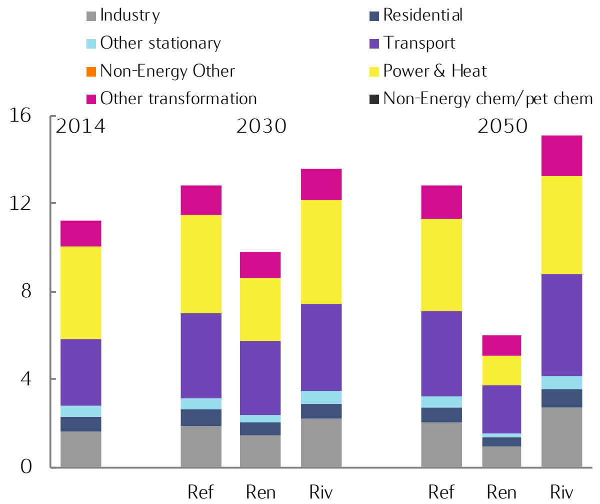
India CO_2 emissions 2014-2050

Billion tons



Rest of the World CO_2 emissions 2014-2050

Billion tons



Source: IEA (history), Statoil (projections)

Data appendix

Global GDP	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Billion 2010-USD		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	73,1	112,7	109,3	104,1	181,5	189,0	144,5	2,6	2,7	1,9

Energy intensity	2014	2030			2050			2014-'50, growth per year (%), CAGR		
2014=100%		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
	100	75	69	83	50	37	67	-1,9	-2,8	-1,1

Global energy demand	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total primary energy demand	**13,7**	**15,7**	**14,2**	**16,2**	**16,9**	**12,9**	**18,0**	**0,6**	**-0,2**	**0,8**
Coal	3,9	3,5	2,4	4,2	3,3	1,3	4,5	-0,5	-3,1	0,4
Oil	4,3	5,0	4,3	5,3	4,7	3,0	5,7	0,3	-1,0	0,8
Gas	2,9	3,6	3,1	3,6	3,8	2,5	3,9	0,8	-0,5	0,8
Nuclear	0,7	0,8	1,0	0,8	1,0	1,5	1,0	1,2	2,3	1,0
Hydro	0,3	0,4	0,4	0,4	0,5	0,5	0,4	1,0	1,1	0,7
Biomass	1,4	1,6	1,7	1,5	1,8	1,8	1,6	0,8	0,7	0,3
New Renewables	0,2	0,8	1,3	0,5	1,7	2,4	1,0	6,6	7,5	4,9
Oil (mbd)	*93,5*	*108,7*	*92,7*	*114,5*	*100,8*	*63,2*	*123,1*			
Gas (bcm)	*3385*	*4188*	*3652*	*4167*	*4487*	*2906*	*4553*			

Global energy mix	2014	2030			2050		
Shares, %		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Coal	28,6	22,4	17,1	25,8	19,6	9,7	24,8
Oil	31,3	32,0	30,2	32,7	27,8	22,9	31,8
Gas	21,2	22,7	22,0	22,0	22,6	19,0	21,6
Nuclear	4,8	5,0	7,2	4,8	6,0	11,5	5,3
Hydro	2,4	2,4	2,9	2,4	2,8	3,9	2,4
Biomass	10,3	10,5	11,8	9,3	10,9	14,2	8,7
New Renewables	1,3	5,0	8,9	2,9	10,3	18,8	5,5

CO_2 emissions	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Billion tons		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**32,2**	**33,2**	**25,4**	**36,8**	**30,9**	**13,6**	**39,5**	**-0,1**	**-2,4**	**0,6**
OECD Americas	6,3	5,5	4,2	6,2	4,2	1,3	5,4	-1,1	-4,2	-0,4
European Union	3,4	2,7	1,8	3,3	2,1	0,6	3,2	-1,3	-4,6	-0,1
China	9,2	8,7	7,3	10,0	7,3	3,8	10,4	-0,6	-2,4	0,4
India	2,0	3,4	2,3	3,7	4,5	1,7	5,4	2,2	-0,5	2,7
Rest of the World	11,3	12,9	9,8	13,6	12,8	6,0	15,1	0,4	-1,7	0,8
World CO_2 stripped by CCS	0,0	0,1	0,5	0,0	0,3	1,5	0,0			

Source: IEA (history), Statoil (projections)

Global LDV sales	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Millions		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total sales	**82,2**	**109,2**	**94,3**	**115,0**	**102,1**	**74,6**	**128,1**	**0,6**	**-0,3**	**1,2**
Gasoline	64,2	68,2	41,1	93,4	29,6	4,8	93,6	-2,1	-7,0	1,1
Diesel	15,1	5,2	1,6	11,8	1,1	0,2	8,3	-7,0	-11,0	-1,6
Plug-in Hybrids	0,1	12,6	15,4	3,7	23,3	10,4	13,0	16,7	14,1	14,8
EV	1,0	21,9	35,7	5,0	47,3	58,8	12,1	11,4	12,0	7,2
Others	1,9	1,4	0,5	1,0	0,8	0,4	1,1	-2,4	-4,3	-1,5

Fuel mix in LDV transport	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**1,1**	**1,2**	**1,1**	**1,3**	**0,8**	**0,4**	**1,4**	**-1,0**	**-2,6**	**0,6**
Oil	1,1	1,1	1,0	1,2	0,5	0,1	1,3	-2,2	-5,8	0,5
Gas	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-2,1	-4,6	-3,4
Biofuels	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-9,5	-15,1	-2,3
Electricity	0,0	0,0	0,1	0,0	0,3	0,3	0,1	22,1	22,6	18,3
Oil (mbd)	23,6	25,0	22,4	27,7	10,5	2,7	27,6			
Electricity (thousand TWh)	0,0	0,5	0,8	0,2	3,0	3,5	1,0			

Fuel mix in other transport	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**1,5**	**2,0**	**1,6**	**1,9**	**2,3**	**1,6**	**2,3**	**1,2**	**0,1**	**1,1**
Oil	1,4	1,7	1,4	1,8	1,9	1,1	1,9	1,0	-0,6	0,9
Gas	0,1	0,1	0,0	0,1	0,1	0,2	0,1	2,2	2,3	2,1
Electricity	0,0	0,1	0,1	0,0	0,1	0,2	0,1	4,9	5,9	4,1
Biofuels	0,1	0,1	0,1	0,1	0,1	0,1	0,1	1,5	1,3	1,5
Oil (mbd)	29,3	36,3	30,0	37,2	41,1	23,4	40,4			

Global power & heat generation	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Thousand TWh		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total generation	**27,6**	**34,8**	**34,0**	**33,9**	**44,5**	**39,1**	**41,3**	**1,3**	**1,0**	**1,1**
Coal	11,3	10,0	6,3	11,4	9,4	2,6	11,5	-0,5	-4,0	0,1
Oil	1,2	1,0	0,8	1,1	0,7	0,3	0,7	-1,6	-4,1	-1,3
Gas	6,8	9,1	7,6	9,1	9,9	4,5	10,6	1,0	-1,2	1,2
Nuclear	2,5	3,0	3,9	3,0	3,9	5,7	3,7	1,2	2,3	1,0
Hydro	3,9	4,4	4,7	4,5	5,5	5,8	5,1	1,0	1,1	0,7
Biomass	0,7	1,3	1,7	1,0	1,7	2,2	1,2	2,3	3,0	1,3
Solar	0,2	1,8	3,2	1,3	5,4	7,6	3,8	9,6	10,7	8,5
Wind	0,7	3,7	4,9	2,3	7,2	9,2	4,3	6,6	7,3	5,1
Geothermal, others	0,2	0,5	0,9	0,3	0,8	1,3	0,4	4,1	5,3	2,3

Fuel mix other uses	2014	2030			2050			2014-'50, growth per year (%), CAGR		
Billion toe		Reform	Renewal	Rivalry	Reform	Renewal	Rivalry	Reform	Renewal	Rivalry
Total	**6,0**	**6,7**	**5,9**	**7,1**	**7,3**	**5,5**	**8,0**	**0,6**	**-0,2**	**0,8**
Coal	1,5	1,5	1,2	1,8	1,5	0,7	2,3	0,0	-1,9	1,2
Oil	1,6	2,0	1,7	2,1	2,1	1,7	2,4	0,8	0,1	1,2
Gas	1,6	1,9	1,7	1,9	2,1	1,6	2,1	0,7	-0,1	0,6
Biomass	1,2	1,2	1,1	1,2	1,3	1,2	1,2	0,3	0,0	0,0
New Renewables	0,0	0,1	0,1	0,1	0,2	0,3	0,1	4,6	6,0	2,0

Source: IEA (history), Statoil (projections)

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