Energy Perspectives 2016

Long-term macro and market outlook





Statoil

Acknowledgements

The analytical basis for this outlook is long-term research on macroeconomics and energy markets undertaken throughout the Statoil organization during the winter of 2015 and the spring of 2016.

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We hereby extend our gratitude to everybody involved.

Editorial process concluded 1 June 2016.

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Energy Perspectives 2016

Global energy markets are in transition. Technological developments are increasing the availability of resources at competitive cost levels. This is reinforced by the priorities of key resource owners and of utilities taking steps to change their business models. Moderate economic growth, economic restructuring and increasing energy efficiency are dampening growth in energy demand. New technologies on the demand side carry the potential for significant shifts in the demand for different fuels. Energy and climate policies are reinforcing these changes and tilting the competitive arena between different energy carriers and resource owners. The agreement reached in Paris at the Conference of Parties (COP21) represents an important milestone for future changes in energy and climate policies, aiming at limiting global greenhouse gas emissions to sustainable levels.

At the same time, geopolitical uncertainty and regional conflicts persist and threaten our common ability to find efficient solutions to common challenges, be it poverty, terrorism, climate change, pollution, or energy inefficiency.

The updated UN sustainable development goals from 2015 include affordable and clean energy for all as a key to ensure sustainable development. With a growing population and billions of people without access to clean cooking facilities or a stable supply of electricity in their homes, reaching these goals represents a formidable challenge for the global energy industry and politicians alike. This is particularly so in a setting where production from existing sources declines, exploration results are disappointing, and the energy industry is cutting costs and reducing its capacity. It is far from given that investments in energy supply will be sufficient to achieve this goal.

How geopolitical uncertainty, sustainable development goals, the climate change challenge and other drivers will interact and affect the global energy picture and economic development over the next decades is impossible to gauge with any degree of certainty. The span of possible development paths in terms of energy demand, energy mix and greenhouse gas emissions is very wide. Like previously, our energy perspectives to 2040 therefore contain three different tales of the future, or scenarios, from now towards 2040. These scenarios rest on different assumptions about regional and global economic growth, conflict levels and implications, technological developments and energy and climate policies.

The central scenario, *Reform*, is influenced by the Nationally Determined Contributions (NDCs) that form the basis for the Paris agreement, supplemented by further tightening of energy and climate policies from 2025 onwards, and builds on other assumptions for energy efficiency improvements and economic restructuring. *Renewal* is a story about one possible pathway to energy-related CO_2 emissions consistent with the target to limit global warming to 2°Celsius (C). It includes rapid improvements in energy efficiency 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 diversified regional development, affected by geopolitical conflict and lack of coordinated policies, and where focus on security of supply and other priorities overshadow global climate targets. While none of these scenarios are intended to describe a probable, exact development in global energy markets, they span a relatively wide outcome space within which the actual development could probably take place.

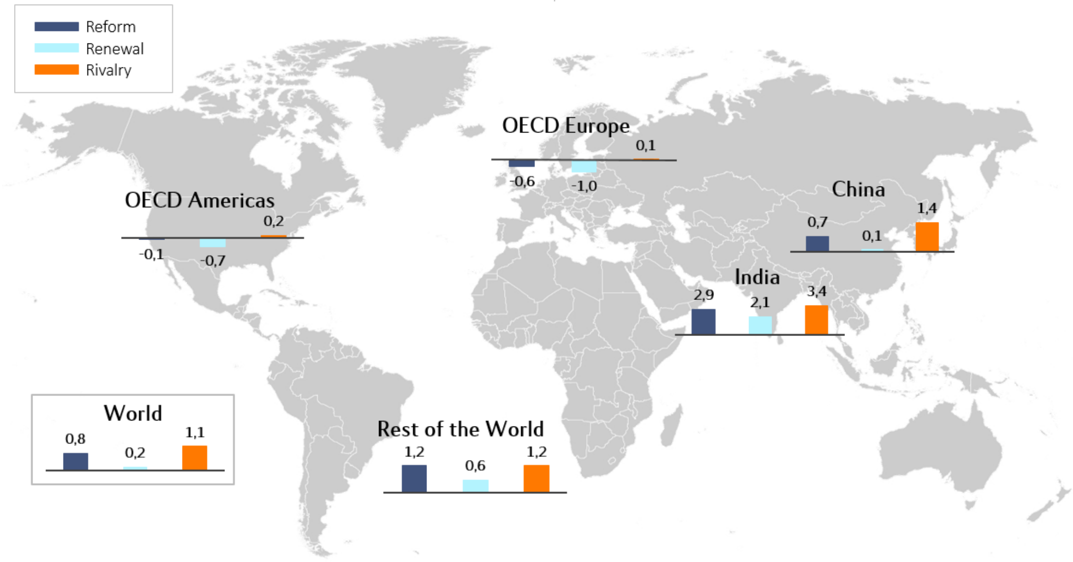
Average global economic growth ranges from 2.6% to 2.9% per year, entailing that global GDP in 2040 will be more than twice that of the level in 2013. Assumptions on energy efficiency vary, but in all scenarios indicate a more rapid improvement going forward than has been observed historically. Total primary energy demand grows between 5% and 35% throughout the period. Note that *Renewal* in particular is a world where global energy demand growth de facto is decoupled from economic growth – a huge challenge. Different assumptions on technological development and energy and climate policies lead to significant differences in the energy mix development going forward. Oil demand in 2040 varies between 78 and 116 million barrels per day (mbd), reflecting annual average growth rates of -0.6% and 0.9%, respectively, and partly reflecting varying, but in all cases ambitious assumptions on technology changes in light-duty road transport. Gas demand in 2040 ends up at between 3,500 and 4,740 billion cubic metres (bcm), compared to 3,507 bcm in 2013, with gas' market share staying unchanged or slightly increasing in all scenarios. There is significant need for new investments in both oil and gas in all scenarios, since production from existing reserves is not even close to keeping up with demand development. New renewable sources of electricity, in particular solar and wind, are expected to grow significantly in importance, delivering between 6 and 17 times more electricity in 2040 than in 2013. Development in coal demand is the most important key to global CO_2 emission developments in our scenarios, with annual growth rates between -3.1% and 0.8%. As a result, global energy-related CO_2 emissions in 2040 vary between 17 and 37 billion tons, compared to 32 billion tons in 2013.

Forecasting development in global energy markets is exciting and necessary, but difficult. Hopefully, Energy Perspectives 2016 contributes to good discussions, sound policies and smart decisions.

Eirik Wærness
Senior vice president and Chief economist

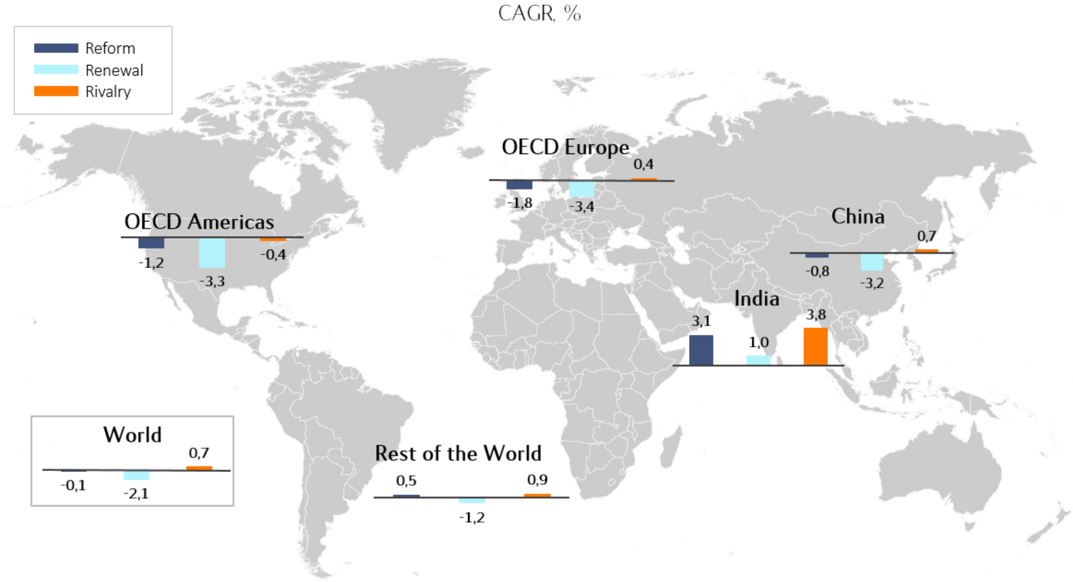
Regional growth in energy demand 2013-2040 in the three scenarios

CAGR, %



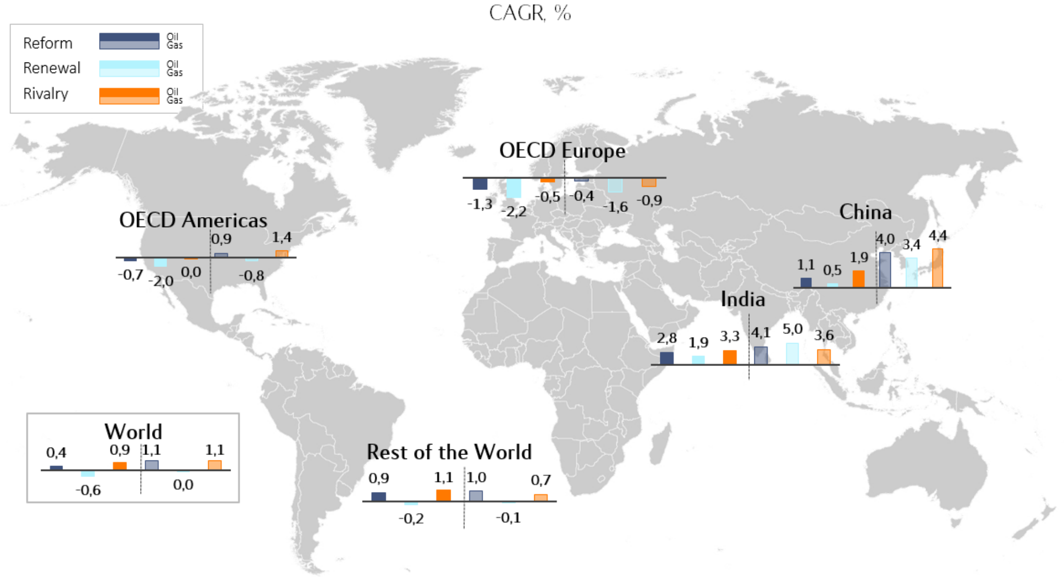
Regional growth in CO_2 emissions 2013-2040 in the three scenarios

CAGR, %



Regional growth in oil and gas demand 2013-2040 in the three scenarios

CAGR, %



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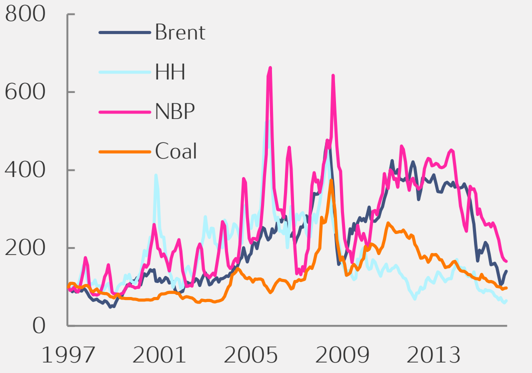
Energy commodity prices

Index, Real April 2016, Feb 1997 = 100

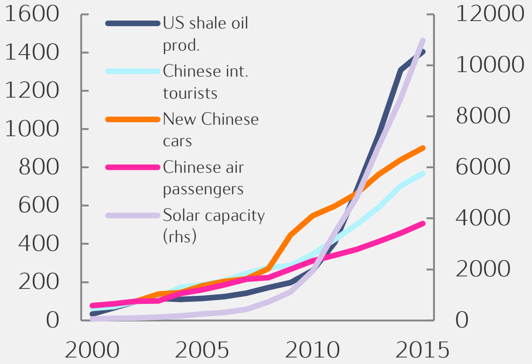


Source: Thomson Reuters Datastream

A long-term industry facing large uncertainties and market volatility

Supply and demand factors

Index, 2002 = 100

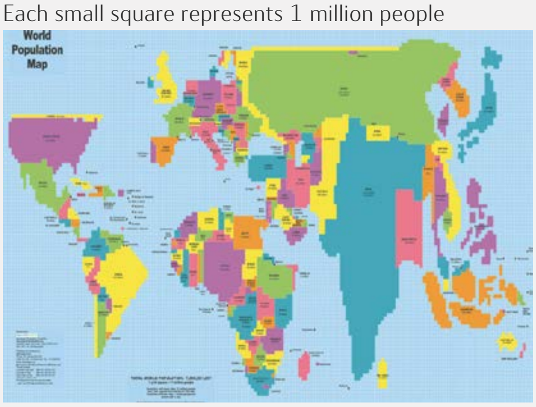


Source: DOE, CEIC, IEA, IRENA

Significant need for new investments across energy carriers

World population map

Each small square represents 1 million people



Source: BigThink

Context and uncertainties

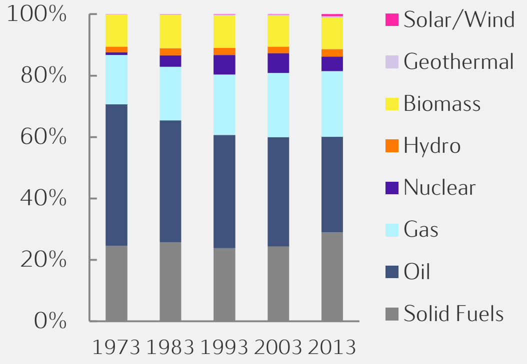
The future of energy is uncertain. Economic development, demand, availability and cost of resources, technology changes, competition between different fuels, development of complementary energy carriers in a complex energy system, energy and climate policies, geopolitics and regional politics in key regions, consumption patterns and consumer choice are examples of factors that will determine and shape the future of energy markets. How these factors will ultimately play out and interact in the global energy business is very uncertain and impossible to predict with any degree of certainty. For some elements of the global energy landscape, history and recent developments give guidance on the likely future development. For others, history gives very little indication of what the future will look like.

The energy business is long-term in nature. Finding new sources of energy takes time, and so does developing resources into a steady stream of energy services to customers in different locations. Capital equipment used to provide and to consume energy has long economic lifetimes and will affect the balance in the energy markets for decades. The energy business is also capital intensive, requiring large scale investments that potentially can yield cash flow to the resource owner for decades, but with uncertain returns. Important sources of energy are geographically concentrated, and not necessarily in the same regions where consumption growth is taking place. Thus, ownership of resources, sharing of economic rent, international trade regulations and level of international and political cooperation are important factors affecting energy flows, energy mix and economic efficiency. A significant part of the energy business is also characterized by falling average costs, indicating large scope for government regulation of the market mechanism in order to ensure economic efficiency. And provision and consumption of energy are often associated with negative external effects, resulting in local pollution, noise and global greenhouse gas emissions. These effects must also be regulated at the correct level of government if economic efficiency and sustainability are to be ensured.

At the same time, the current situation in the energy industry is special and challenging, and may have long-term implications that are difficult to fathom. Cost and activity levels are rapidly adjusting to a period of low prices. Investment levels are low in all traditional sources of energy supply. And even if demand growth is moderate, decline from existing sources of oil and gas virtually guarantees a future gap between demand and supply if investments do not pick up. Transformation of electricity markets implies significant uncertainties for future business models in this part of the energy spectrum, at a time where sustainability requires that electricity generation based on new renewable energy must increase and take a significantly higher share of final energy consumption than today. The forecasts for energy demand presented in this report rest on the assumption that necessary investments in supply and infrastructure will be made in order to balance future supply with demand, and to ensure necessary backup capacities for varying sources of electricity. In order for this assumption to be valid, it seems fair to conclude that the overall economic conditions for energy investments must improve.

Given the large variation in possible outcomes, the low likelihood of any specific and precise forecast and the low ability to predict even the most probable development, this report contains three scenarios, or tales of the future, for global energy market development until 2040.

Total primary energy supply 1973-2013



Source: IEA

Reform
Influenced by COP21 and technology developments

Renewal
A pathway to energy sustainability

Rivalry
Describing a multipolar world

Key parameters for each scenario

2013-2040 average growth per year (%)	Reform	Renewal	Rivalry
GDP	2.8	2.9	2.6
Total primary energy demand	0.8	0.2	1.1
Energy intensity	-1.9	-2.6	-1.5
Coal	-0.6	-3.1	0.8
Oil	0.4	-0.6	0.9
Gas	1.1	0	1.1
Nuclear	1.9	3.2	1.9
Hydro	2.0	2.0	1.8
Biomass	1.0	1.1	0.7
New Renewables	8.1	9.8	6.7

Global energy mix (fuel shares in %)	2013	2040		
		Reform	Renewal	Rivalry
Coal	29.7	20.3	12.3	27.1
Oil	29.2	26.5	23.8	27.5
Gas	22.0	24.0	20.9	21.8
Nuclear	4.9	6.5	10.9	6.0
Hydro	2.5	3.4	4.0	3.0
Biomass	10.4	11.2	13.3	9.3
New Renewables	1.2	8.1	14.6	5.2

CO_2 emission growth 2013-40 (%)	Reform	Renewal	Rivalry
Total	-6	-45	18
CAGR	-0.2	-2.2	0.6

Source: Statoil

These three scenarios – *Reform*, *Renewal* and *Rivalry* – are described in more detail in the next chapter. Interestingly, history and recent events may support any of the three scenarios, depending on which development is considered. For example, the co-existence of conventional and new technologies points towards *Reform*, COP21 in itself could lead towards *Renewal*, while the continued regional conflicts indicate *Rivalry*.

A key uncertainty going forward is long-term economic growth, driven by population development, characteristics and availability of labour and capital resources, as well as improvements in productivity. Varying assumptions on long-term economic development lead to different conclusions on future energy demand and greenhouse gas emission levels. In terms of assumptions on average global economic growth over the forecast period, the three scenarios are not very different, although the timing of growth and the regional composition of growth do differ across the scenarios.

The differences across scenarios when it comes to energy demand, energy mix and emission levels are primarily caused by a set of significantly diverse assumptions across the following set of driving factors:

- **Geopolitics and regional conflict**
  Will the world until 2040 be characterized by a more multipolar world, where different regions develop in different directions and prioritize differently? Or will cooperation and coordination ensure that efficient global solutions to common challenges are implemented cost efficiently? Will the recent policy changes in Opec and between Iran and the West have implications for the future supply mix and cost levels of oil and gas?

- **Energy and climate policies**
  Will the COP21 agreement be followed up by a consistent set of measures driving the development in energy efficiency and CO_2 emissions in a direction that is consistent with the agreed targets? Or will other regionally differentiated priorities result in less improvement in energy efficiency and slower changes in the global energy mix?

- **Technological development**
  Will the recent development in resource estimates for oil and gas, and cost reductions in extraction, prevail and affect the competitiveness of different fuels? Will the recent cost developments and innovation in renewable electricity generation, battery technologies and car technologies pave the way for a revolution in the energy mix in the power sector and parts of the transport sector? Will changes in consumer preferences and behaviour, combined with new technologies, deliver much lower energy demand?

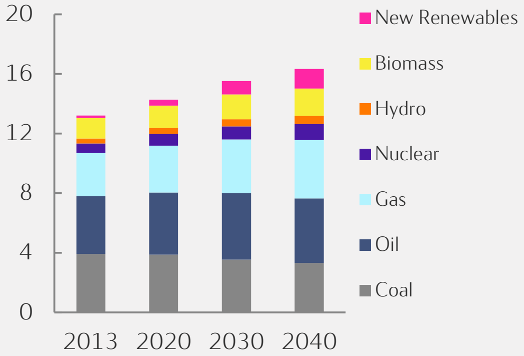
The answers to these questions will drive the development of the global energy business in different directions over the next decades. In addition, a number of unforeseen changes and surprises will come our way and affect global markets. In terms of energy market forecasting, getting it right is not an option. Avoiding being exactly wrong is the best we can hope for.

Reform foresees energy policies driven by the Nationally Determined Contributions from COP21 and the co-existence of conventional and new technologies through the 2020s, with a substantial technology acceleration and substitution taking place beyond 2030

Wind turbines surrounding a coal-fired power plant near Garzweiler, Germany

Source: National Geographic

Primary energy demand by fuel: *Reform* scenario
Billion tons oil equivalent (Btoe)



Source: IEA (history), Statoil (projections)

The three scenarios

This chapter briefly outlines the three scenarios that form the basis of Energy Perspectives 2016. Each scenario is constructed from an internally consistent set of assumptions regarding the possible future development of the world economy and global energy markets, and subsequent chapters will provide richer descriptions of the economic and energy-market specific implications of each scenario. No probabilities are attached to the likelihood of any of these scenarios matching future reality. Instead, the scenarios presented here are intended to span a relatively wide outcome space within which the actual development is likely to take place.

Reform: COP21 and technology developments

Last year's *Reform* scenario assumed gradual, but significant, change in governments' energy and climate policies, in particular with respect to energy market regulation. In that scenario, increasing global population and continued growth in global GDP outweighed the effects of a strong decline in energy intensity, so that forecasted energy demand continued to grow, and fuel switching was assumed to be too slow to stabilize and reduce energy-related CO_2 emissions significantly during the forecast period. Therefore, *Reform* was not a sustainable scenario in the long run, neither for societies nor companies, in terms of global warming and the consequences of climate change.

Inspired by the momentum achieved at COP21 in Paris, this year's *Reform* scenario takes further steps in the direction of sustainability and builds on the Nationally Determined Contributions (NDCs) issued by a majority of nations in the run-up to the conference. The quality, usefulness, conditionality and ambition level of the NDCs vary from nation to nation, and analysts that have reviewed the NDCs in detail have demonstrated that they are far from sufficient to achieve the necessary emission reduction to reach the 2°C target. However, the NDCs do represent an important joint effort in the right direction and offer useful reference points for long-term energy market analysis.

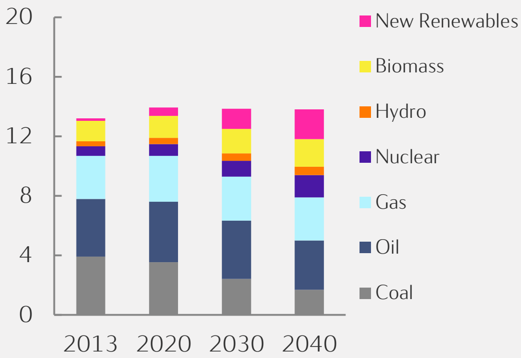
In *Reform*, it is assumed that the current NDCs leave a strong mark on nations' energy policies, energy intensity decline rates and energy mix into the 2020s. As emission targets and policies are revisited every fifth year from 2020 in line with the COP21 agreement, marginal tightening is expected in 2025, followed by more significant tightening in 2030. This climate policy change is facilitated by a geopolitical backdrop that is not very different from the generally benign global investment climate currently experienced, albeit one where local and regional conflicts, migration and terrorism divert some decision makers' attention from economic and energy policy priorities. In terms of economic growth, the global trend is negatively impacted in the 2020s by reduced capital efficiency as a result of policy-induced investments especially in the new renewables sector. This negative impact is then balanced by a long-term benefit post-2030 due to increased energy efficiency.

Commodity prices provide a boost to economic growth in net importing regions: oil and gas prices are depressed early in the forecast period and moderate demand growth caps their subsequent increase. Coal prices are also low, reflecting slow growth and persistent oversupply. Carbon pricing and taxation is implemented in all OECD regions and in some non-OECD regions during the 2020s, which leads to fuel switching away from coal, and has minor positive impact on investments in low-carbon.

Source: iStock

Renewal is a backcasting scenario to illustrate how the necessary reductions in energy-related CO_2 emissions may be achieved in order to reach the 2°C target

Primary energy demand by fuel: ***Renewal*** **scenario**
Btoe



Source: IEA (history), Statoil (projections)

Source: AP Photo

In terms of technology, *Reform* calls for accelerated development and deployment of energy efficient buildings, transportation and industrial equipment compared to their current states. In particular, the scenario assumes a rapidly changing transport sector, mainly through changing the fuel efficiency and altering the fuel composition of the growing global car fleet significantly and at a much faster rate than recent statistical trends indicate. New renewable sources of electricity are projected to significantly increase their share in the energy mix, becoming possible through continued stimulus via subsidies, further declines in the costs of wind, solar and other new renewable power generation, and the continued improvement in battery performance and costs. In summary, *Reform* foresees the co-existence of conventional and new technologies through the 2020s, with substantial technology acceleration and substitution taking place beyond 2030.

Renewal: a pathway to energy sustainability

The *Renewal* scenario was first introduced in *Energy Perspectives 2015*, in response to the need to understand how the future energy landscape could develop if the world moves along a sustainable climate path. *Renewal* was constructed as a backcasting scenario. It started from the assumption that the world would be able to achieve the necessary reductions in energy-related CO_2 emissions in order to reach the 2°C target, as indicated by the Intergovernmental Panel on Climate Change's (IPCC) "Representative Concentration Pathway" scenario and also by the International Energy Agency's (IEA) "450 ppm" scenario. This assumption was based on the broad consensus among scientists, governments, the energy industry and other institutions on what needs to happen to prevent the most dramatic effects of climate change.

The adoption of climate pledges agreed at COP21 constitutes a crucial step in the process of tackling climate change. However, since climate targets put forward by countries in COP21 and adopted into the *Reform* scenario are insufficient to achieve the 2°C target, and the ambition of the Paris agreement is even more far reaching – limiting global warming to well below 2°C – CO_2 emissions from the energy sector in this year's *Renewal* scenario are positioned somewhat below the established benchmark used last year.

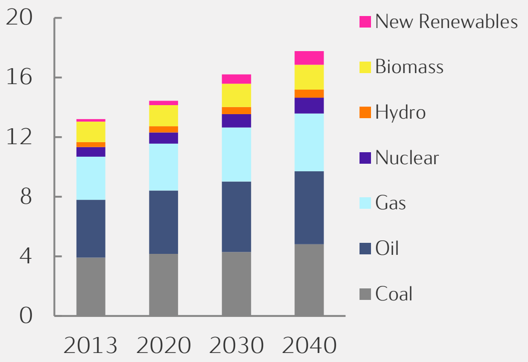
Renewal describes a transition to a low-carbon economy resulting from the successful and prompt implementation of a combination of measures. These include aggressive improvements in energy efficiency, growth in renewable and low-carbon sources of energy to decarbonize the power sector and other parts of the energy sector, an even more rapid electrification in transport than in *Reform*, and gains in vehicle fuel efficiency. Overall, *Renewal* contains energy and climate policies substantially tighter than those assumed in *Reform*. These actions have to be carried out sufficiently quickly to result in global carbon emissions peaking as soon as possible, followed by a rapid decline thereafter.

Renewal assumes a geopolitical framework that compares favourably to *Reform*. There is a high level of global cooperation originating mainly in a high degree of willingness from world leaders, policy makers and business to move beyond ideological debates and address the climate challenge as the largest common threat. Global economic growth up to the mid-2020s is slightly lower in *Renewal* than in *Reform*, as the transition from

Source: theexpatcoachassociation.com

Rivalry is driven by a series of political crises, protectionism and fragmentation, resulting in weaker technology development and less impact of global climate policy, hence a less sustainable energy mix

Primary energy demand by fuel: *Rivalry* scenario
Btoe



Source: IEA (history), Statoil (projections)

Source: *The Economist*, 17th October 2015

unsustainable growth to green growth is bound to entail some dislocation. In the longer term, the deployment of green technology creates jobs, boosts incomes and reduces the costs of adapting to climate change, thereby elevating economic growth above the level assumed for *Reform*.

Wholesale fossil fuel prices in the *Renewal* scenario are lower than in *Reform* as a consequence of supply and demand alignment, but retail prices are high to ensure market support for energy efficiency gains and investment in renewables. Carbon pricing and taxation are implemented in all major economies, and at levels substantially higher than in *Reform*, to provide incentives to speed up the transition towards a low-carbon economy. Carbon Capture and Storage (CCS) is gradually rolled out during the 2020s and covers bigger shares of remaining fossil fuel use than in *Reform*. In spite of this, captured CO_2 volumes by 2040 are limited due to the decarbonization of electricity generation.

Rivalry: a multipolar world

The *Rivalry* scenario comes about as a result of the definite end of the post-cold war era and the weakening of the West's global economic and political power amidst the "rise of the rest" that was accelerated in the aftermath of the 2008 financial crisis. The scenario is driven by a series of political crises, growing protectionism and a general fragmentation of the state system, resulting in a multipolar world developing in different directions. It becomes increasingly clear that emerging economies never really were on a straight path towards free-market economy and liberal democracy. Instead, authoritarian politics gain ground in most of the world, including parts of Europe.

In *Rivalry*, the US, relatively sheltered by its geography, develops a bipartisan isolationism and takes a step back from global affairs, and emerging world powers such as China and India do not fill the governance gap. Traditional international institutions such as the UN, NATO and the WTO fail to mitigate the world's problems and lose relevance due to a lack of support and funding from the main powers. Institutions backed by emerging powers such as China fail to become truly global. A marginalized EU breaks up into smaller regional alliances with an element of free trade. The authoritarian political system in Russia proves durable and capable of projecting its influence around Eurasia.

In this multipolar world, there is growing disagreement about the rules of the game and a decreasing ability to manage crises in the political, economic and environmental arenas. Protectionism and the weakening of global economic institutions like the IMF and the World Bank lead to a shift from global to regional trade. The economic fortunes of the world's regions drift apart, and megacities on all continents become increasingly important as economic and political hubs.

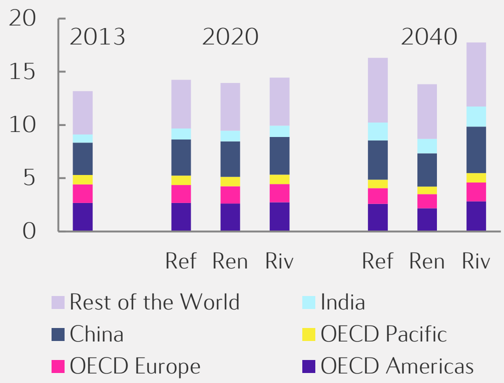
Technology, demographic and environmental pressures, transnational ideologies and religions create a faster-moving and less predictable world. Technology and increased connectivity mean that a large number of actors can build geopolitical impact, creating a far more complex and volatile context. Corporations, organized crime networks and terrorist groups all see their relative capabilities and influence rise, often undermining the reach of traditional states.

Source: iStock

These dynamics do not have uniform effects on states across the globe, and the trajectories of different regions of the world therefore diverge. In most of the Middle East and North Africa, the state system seems in terminal decline, with perpetual regional strife. A string of failed states lead to a growing territory no longer governed by any government or international body. Though the impact is less dramatic in Europe, the security spill-over exacerbates political fragility and regional disunity in the countries of the former EU. By contrast, countries in South and East Asia that face less of an immediate challenge continue to leverage economic growth and are able to pursue their state-building projects. Sub-Saharan Africa also sees volatility in the security and political field, but economic growth continues, particularly around increasingly important cities.

In *Rivalry*, regulatory attention paid to climate change is fluctuating and in some regions the capabilities to implement efficient climate policies are consistently low. Therefore *Rivalry* has a detrimental long-term effect on the environment, economy and welfare. This development, a more modest technology development and deployment, and the general desire to take advantage of domestically available energy sources, result in less energy efficiency improvements, higher energy demand and a significantly less sustainable fuel mix than in *Reform* and *Renewal*.

Global primary energy demand by region
Btoe



Source: IEA (history), Statoil (projections)

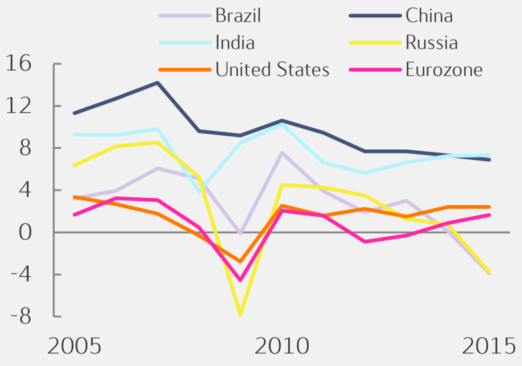
Recent events and developments that illustrate that any of the scenarios may unfold

Reform	Renewal	Rivalry
China closing 1,000 coal mines and US coal production dipping to record low levels in contrast with 500 coal-fired power stations under construction in Asia	Global carbon emissions levelling out in 2014 and 2015	Influx of migrants and refugees in Europe
Slow change in the share of fossils in primary energy demand, 85% in 1973 versus 81% in 2013	The COP21 climate deal	Terrorist attacks in the Middle East and Europe
Rising wind and solar generation handled successfully by electricity grids, but fossils still account for most generation	Continued cost decline for new renewables	Hydro-climate disasters
160 NDC-s submitted prior to COP21	Record investments in new renewables in 2015	Brexit, Grexit, Eurosceptics
	EV sales up by 60% in 2015	US elections
		Protectionist trade restrictions
		Security of supply concerns

Source: various recent news headlines

GDP growth 2005-2015 by region

Real annual % change at market exchange rates



Source: The International Monetary Fund

The Productivity Puzzle

Total Factor Productivity (TFP), primarily driven by labour productivity, has for several Western countries fallen since the IT boom of 1994-2004. This is unfortunate as its stimulus to economic activity has been slow and productivity gains are a necessity for a robust wage development. It seems legitimate to ask why this weakening has come about. Some of the recent new information products, such as social media, are innovative and improve people's living standards, but do not seem to increase efficiency in the same way that the advent of PCs or the growth of the Internet did. Since the end of the financial crisis, companies have had easy access to labour and hence expanded the labour force instead of investing in technology to boost output. Furthermore, job creation has to a large extent been within low-skilled jobs in the service industry, where productivity improvement is typically low. It is also possible that companies have become more reluctant to invest in labour productivity due to stricter and more complex government regulations introduced in recent years. These regulatory efforts boost growth over the longer term, but slow the current momentum within industry and trade. Finally one might question if productivity gains are fully measured and captured in the "new economy" of e-commerce and so-called "sharing", and in the service industry in general.

The world might have to get used to somewhat lower future productivity growth compared to recent decades, with a consequent slightly negative impact on the economic outlook. However, there will be supportive factors for productivity that could push it upwards. Reaping the full effects of the IT boom might come with a delay, as was the case with many earlier inventions, which were so comprehensive that it took years for their full impact to emerge. This - combined with the more recent drop in the cost of 3D printers and sensors, big data management, ongoing automation, and more - has the potential to transform the economy and increase productivity. Today, the world is increasingly connected and progress can spread rapidly. As labour markets in the Western world continue to tighten, putting pressure on wages, companies will have a stronger incentive to invest in training and technology, which will add support to productivity growth. Governments' policy support, reform, and increased ability to invest in infrastructure will also be decisive for productivity in the decades to come.

The global economy

Current situation

These days global economic development is fragile, with only moderate growth in the OECD economies. The US economy is experiencing slow expansion due to muted business activity and weak external trade, and expectations of the Federal Reserve's willingness and ability to swiftly raise interest rates have come down. In the Eurozone, the slow recovery continues, while Japan is hampered by weak external demand. Development in key emerging economies has been weak, driven by commodity exporters Russia and Brazil being hit by low commodity prices and country specific challenges such as sanctions (Russia) and a corruption scandal and associated political upheaval (Brazil). As a consequence of industrial restructuring and rebalancing, China is currently not able to provide the stimulus the world has become accustomed to, although this is partly balanced by India's dynamic growth.

To raise the pace of economic expansion, structural economic policies that encourage innovation, promote investment in productive capital, and counteract the negative impetus from an aging population will be important. The growth forecasts over the medium- to long-term time horizon for the three scenarios are discussed below.

Forecasting economic development, our approach

Economic activity in the medium term is shaped by total demand for final goods and services, namely private consumption, business investment, government spending and net exports. It is natural that the economy fluctuates 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 thus the production potential or trend progress of economies. Our framework is based on modelling changes in input factors such as labour and capital and a residual that reflects production efficiency, Total Factor Productivity (TFP). Convergence between economies is a key assumption, as developing countries will grow at faster rates than advanced countries.

Medium-term outlook (2016-20)

Reform: gradual normalization lifted by emerging economies

The global economy during 2016-20 grows by an average of 2.8% per year. Emerging markets lead the acceleration, but under the conditions of a growth slowdown in China, increasing commodity prices and most central banks providing monetary stimulus.

The US economy is as usual carried by solid consumer spending, partly helped by accommodative monetary policy from the Federal Reserve. Business investment picks up speed on replacement needs and increased activity in the energy sector. Continued weak labour productivity development and a prolonged drag from net exports lead to an average GDP growth forecast of 2.2% per year for the next five years, slightly below the historical rate. In the Eurozone, domestic support for economic activity, expansive monetary policies and low commodity prices are providing stimuli, but disinflation is a worry. The refugee crisis requires supportive government spending into the medium term. An average GDP growth of 1.7% per year is achieved over the period. In Japan, the recovery in consumer spending remains feeble as a result of sluggish wage development. In the absence of significant structural reforms, investment remains weak due to deflation, slow corporate profit advance,

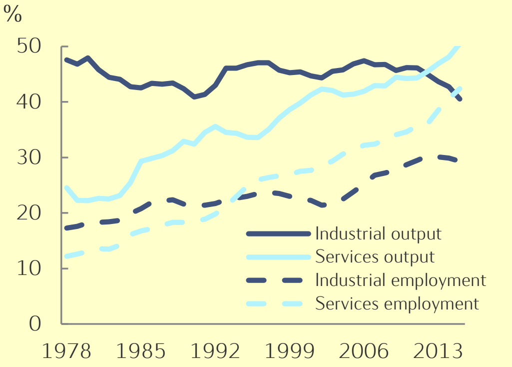
China rebalance: a thorny path ahead

The prolonged slowdown beginning in 2012 was triggered by a property market correction. Huge property gluts were created and had knock-on effects on industrial and mining activities which suffer from severe overcapacity, deflation and debt. This caused setbacks in global commodity demand and prices.

The economy's transition to a lower growth path reflects a juxtaposition of structural and cyclical constraints that need to change towards a sustainable growth model. The fall in working population and an inefficient capital market that favours SOE-led heavy industry, have hampered demand, private investment and productivity. The property and industrial overcapacity due to the stimulus in 2008 reduced investment and export competitiveness while anti-corruption dampened spending.

Rebalancing from manufacturing to services, investment to consumption, rural to urban, and public to private growth is taking place at varied speed. Service sector value creation is robust due to the e-commerce boom which partly offsets heavy manufacturing decline. The share of the service sector in GDP is expected to increase steadily. Industry upgrading and relocation are growing while overcapacity creates headwinds for backward facilities. The one-child policy has been dropped, while tax cuts boost the share of consumption. Easing of restrictions for obtaining urban residency in lower tier cities is promoting urbanization. The SOE reform has been slow and will be hastened by higher profits of private sector relative to SOEs.

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



Source: CEIC

The success of the economic transformation rests on financial reforms to lower debt levels and market liberalization to remove price distortions. Private initiatives in the allocation of resources would benefit job creation and income growth. A wider social security buffer and more income redistribution could spur more consumption. However, uncertainty remains with the speed of reform as intertwined policy interests make China's rebalancing difficult. Stimulus to stabilize the economic slowdown would inevitably prolong, if not derail, rebalancing in the absence of capital discipline. A thorny path to a new economic model with uneven success in reforms impacting the global commodity market is expected. However, the government's Five-Year Plan, which focuses on innovation and sustainable development, could see poverty, urbanization and public services improved.

slack demand and a stronger yen. Growth averages around 0.7% per year as the effects of the consumption tax hike and fiscal consolidation begin to be felt.

China's debt and overcapacity challenges remain despite recent growth stability as a result of monetary easing, infrastructure investments and property sales. Structural reforms of State-Owned Enterprises (SOEs) and financial markets pose daunting challenges, with growth averaging around 5.6% per year in 2016-2020. India's industrial recovery remains gradual, while easing inflation provides grounds for interest rate cuts to boost lending. Growth averages 7.4% per year due to privatization, and increased utilization of resources as a result of foreign direct investment and increased public spending. Brazil and Russia underperform significantly in the years up to 2020 due to the commodity cycle and political issues.

Renewal: initial investment costs create a drag on growth

Strict climate targets and the application of strong policy regulations create a basis for investments in new low-carbon energy production and infrastructure. Green investments and climate reducing initiatives are scaled up immediately. Reallocation of investments towards the green economy are initially driven predominantly by the need to reduce global CO_2 emissions and fulfil agreed targets, and not by expectation of the highest short-term economic return. China experiences lower growth due to faster overcapacity reduction of polluting manufacturing. The world has to lower the amount of energy used, which leads to less economic progress. In sum, the global GDP progress is reduced somewhat, compared with the *Reform* scenario.

Rivalry: geopolitics trump economics

The medium-term economic development in the *Rivalry* scenario is weaker than in *Reform*, but somewhat stronger than in *Renewal*. The lower growth path is a reflection of constraints on international trade and technology exchange, and the result of a channelling of political and economic resources to less productive purposes. There are regional differences in economic activity, where primarily North America gains compared to *Reform*, and where progress is weaker first and foremost in the Middle East and North Africa (MENA), but also to some extent in Europe. This is based on the assumption of a continuation of the tumultuous geopolitical situation seen today in MENA and Eastern Europe, while other regions are more sheltered. Global expansion is nevertheless adequate, as investments in environmentally friendly energy systems are undertaken to a lesser extent than in the *Reform* and *Renewal* scenarios.

Long-term outlook (2021-40)

Reform: solutions needed to keep growth on track

In the US, a growing population secures a sound basis for a growing labour force, but on the other hand the old-age dependency ratio rises. Capital investments contribute to growth, partly helped by the energy sector. Climate investments however reduce capital efficiency over the 2020s, but boost efficiency in the 2030s. Being a mature economy, the TFP growth component in the US is moderate. The economy grows at an average of 2.1% per year. In the Eurozone, dividends from labour market reforms and investments in research and development (R&D) and more productive capital materialize during the 2020s. However, long-term challenges such as an aging population, generous retirement benefits and slowing capital investments disturb growth in the 2030s, although immigration helps the situation somewhat. The Eurozone economic performance reaches 1.5% per year on average. Poor demographics in Japan continue to slow consumer spending and housing demand, while higher welfare costs and fiscal consolidation limits government spending. Increased female participation in the labour force partially mitigates the decline in labour productivity. Despite a strong education system, R&D, and corporate tax cuts, long-term investment growth slows down. The economy grows at an average 0.6% per year, compared with 0.9% since 1990.

China's growth prospects depend on overcapacity and debt reduction in addition to other market reforms. A successful rebalancing towards a more consumption-oriented economy requires an overhaul of the financial system that is currently biased towards SOEs and is at risk of a credit crunch. The Chinese economy grows on average by 5.1% per year in the 2020s as financial and industry reforms improve capital efficiency, before moderating to 3.8% per year in the 2030s when the positive impact of the two children policy partially offsets a rapidly aging population. Although India reaps the benefits of strong demographics and undeveloped resources, its long-term growth prospect depends on the success of diverse structural reforms. Besides reducing bureaucracy and tackling difficult fiscal, financial and land reforms, India has to liberalize its rigid labour market, reduce subsidies, and diversify from IT-enabled services into value-added manufacturing. The economy grows at an average of 5.9% per year, supported by a larger middle class. As economic bottlenecks are removed, Brazil capitalizes on its huge resource base and favourable demographics, resulting in an average expansion of 2.8% per year. Demanding demographics, slowing investments, and the need for innovation and diversification curb Russia's growth forecast to an average of 2% per year.

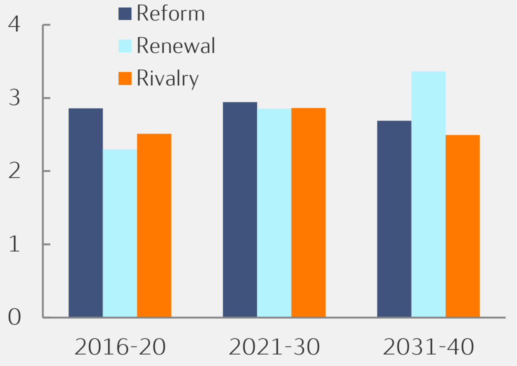
OECD economies expand at an annual average of 1.9% over the 2021-40 period. Progress in non-OECD economies decelerates, but averages a solid 4.1%. Consequently, global growth over the next 25 years is close to the average of the previous 25 years.

Renewal: harvesting of investments starts during the mid-2020s

Green technology, efficiency improvements, and a gradual removal of fossil fuel subsidies contribute positively to global growth. Green investments gradually yield the highest return and are more attractive than traditional energy investments. The phasing out of subsidies, and a significantly higher global carbon cost, help the funding of new energy systems.

The developed world leads the technological revolution required in this scenario with cost-efficient new solutions. The developing world adapts and replicates the technology developments, helped by global arrangements that foster international relationships in areas important for green growth. For China, larger green investments start to pay off after 2020 as technology upgrades boost productivity, overcapacity of heavy industry is scaled back, and industry is retrofitted with cleaner equipment. India's progress is accelerated as well, with smart cities and industrial corridors benefitting from cleaner infrastructure.

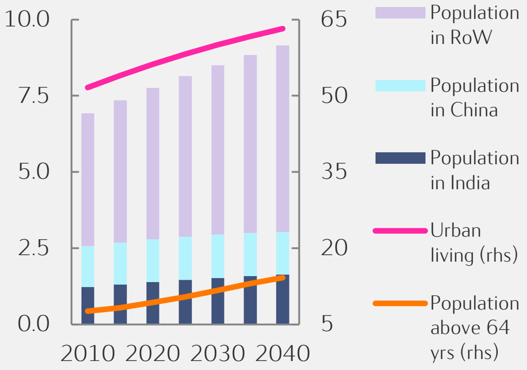
Global GDP growth
% change (CAGR), real



Note: CAGR = Compound Annual Growth Rate
Source: Statoil

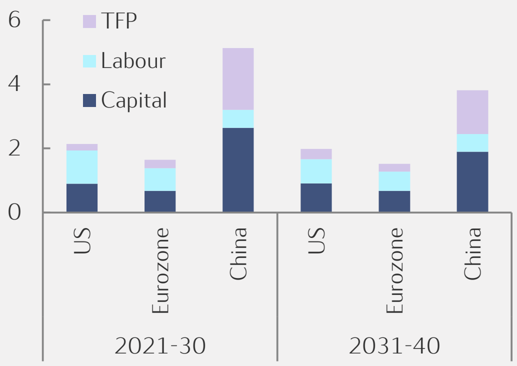
Climate investments reduce capital efficiency over the 2020s, but boost efficiency in the 2030s

Global population
Billion people (lhs), % of total population (rhs)



Source: United Nations

Long-term GDP growth by source
%

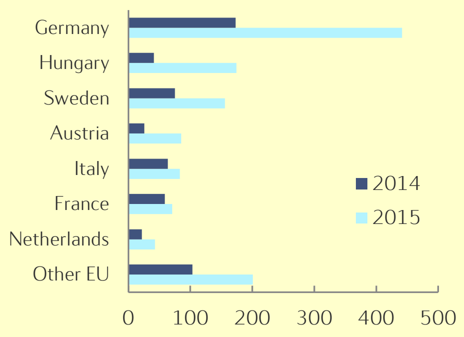


Source: Statoil

Migration and its economic impact on Europe

According to the UN, more than 15 million people are uprooted refugees who have fled their home countries, and Europe is a strong draw for many seeking a better life. Whatever its source, migration has important impacts on society, and the economic impact is no exception. For Europe, the wave of refugees comes at a time when many economies struggle with the aftermath of the financial crisis.

First time asylum applicants to the EU, thousands



Source: Eurostat

Migration has a demographic impact, not only by increasing the size of the population, but also by changing the age pyramid of receiving countries. Migrants tend to be more concentrated in the younger and economically active age groups and therefore contribute to reduced dependency ratios. Over the long term, Europe faces a demographic crisis, and over the next two generations the old-age dependency ratio will almost double. Immigrants are a key contributor to solving the demographic crisis. The presence of immigrants provides fiscal benefits to an economy in the form of taxes and social contributions. However, countries with high unemployment rates face short-term challenges with integrating immigrants into the labour market.

The source of migration can be decisive for the impact on a nation's fiscal position. In countries where recent labour migrants make up a large part of the immigrant population, the fiscal position is more favourable than in countries where humanitarian migrants account for a significant part of the immigrant population. For instance, Syrian refugees are humanitarian refugees and to host so many arrivals will entail an immense cost for the receiving country. Some, like Germany, can probably afford this, but most other EU countries have a budget deficit and high debt-to-GDP ratios. Then again, these cost are regarded as short term, as many refugees will turn into workers (or return to their home countries).

A study on the fiscal impact of migration on OECD Europe (Liebig and Mo, 2013) suggests that the cumulative impact of the waves of migration over the past 50 years is on average close to zero (+/- 0.5% of GDP). However, it is hard to conclude since the current refugee crisis is unprecedented in European terms. Increased governmental spending initially boosts the economy, but may negatively influence the country's financial solidity. Countries where the migrants come from will also suffer a labour loss and brain drain with a potential hampering of their economies over the long term. But as immigrants move to more advanced economies the net effect might be slightly positive - also for energy demand.

Output increases also in the service sector based on improvements in the wider economy. Investments in the green economy have a positive impact on employment, as green investments are more employment intensive. Further, improved air quality results in an increased life expectancy in some areas. The economic growth rate in *Renewal* outpaces that of *Reform* during the mid-2020s, and economic progress is significantly stronger during the 2030s in *Renewal* compared to *Reform*. This is when the transformation really starts to take effect, enabling the world to harvest on investments made during 2016-2025. Starting from the end of the analysis horizon, a significant and increasing difference between the scenarios materializes, with negative climate change related economic consequences in *Reform* or *Rivalry* compared to those in *Renewal*.

Rivalry: on divergent paths

The geopolitical environment during the 2020s calms down to a certain extent and the world order turns more stable than in the 2016-2020 period. The economic expansion is slightly lower than in the *Reform* scenario, but with regional differences. However, conflicts seethe under the surface before the world turns more unstable again during the 2030s, reducing the global growth rate somewhat. There is downside risk to the GDP outlook towards the end of the forecast period as negative environmental consequences gradually filter through and escalate.

Throughout the period, the Americas enjoy thriving inter-regional trade counteracting increased protectionism for the region and enabling relative prosperity. In South America exports remain dominated by commodities, though with an increasing share of manufactured goods. Europe is unable to compete effectively on the global scene and drifts into stagnation and protectionism. Russia does about as well as in *Reform* with less emphasis on reforming the economy, but a continued focus on capitalising on its big resource base. The Chinese economy also manages well with a combination of a large domestic market and strong regional trade links. India emerges as a global manufacturing hub and maintains impressive growth.

The economic performance in MENA is less favourable than in the *Reform* scenario. Economic activity is driven by oil and gas exports, but the instability across the region restricts trade within and between states and also impacts economic expansion directly. Oil and gas production expansion is hampered due to growing security threats. Governments in the region are unable to fund large-scale energy subsidies.

Global climate policy and greenhouse gas emissions

World's nations sign climate change agreement
Conference of Parties 21, Paris, December 2015

Source: IISD Reporting Services

The NDCs are not legally binding and the extent to which countries will fulfil and strengthen their climate plans will depend on the global and national political and economic conditions

The Paris agreement and the NDCs

The Paris agreement is a bridge between today's policies and climate neutrality in the second half of this century. Governments agreed on the need for global emissions to peak as soon as possible, recognising that this will take longer for developing countries, and to undertake rapid reductions thereafter in accordance with the best available science.

The agreement is based on the NDCs, which cover 97.8% of global emissions (2010) and 97% of global population, with remaining emissions come from aviation, maritime transport, and non-UNFCCC affiliated countries. The NDCs are to be prepared and updated every five years, beginning in 2020.

The content of the NDCs is not legally binding. However, progress reporting is mandatory, and governments have committed to come together every 5 years to set more ambitious targets as required by science, report to each other and the public on how well they are doing to implement their targets, and track progress towards the long-term goal through a robust transparency and accountability system.

The Paris agreement facilitates for cross-border transfers of emission reductions and use of carbon pricing to meet and enhance the NDCs. This implies that countries can achieve parts of their national climate targets by investing in more cost-efficient emission reduction in projects or sectors in other countries. The agreement does not include specific guidance on the measures (CCS, CO_2 taxation, technology subsidies, etc.) to achieve the targets.

Norway, aligned with the EU NDC, commits to reduce emissions by 40% from 1990 to 2030. The United States commits to a 26-28% reduction from 2005 to 2025. China intends to peak its emissions before 2030. India has no emission reduction target, and makes its NDC conditional on external financing. Developing countries will get a minimum of 100 billion USD per year by 2020 for mitigation and adaptation to climate change.

Climate policy

On December 12, 2015 at COP21 in Paris, 195 countries adopted a new universally applicable climate agreement, effective from 2020. The aim is to mobilize actions and investments towards a low-carbon, climate resilient and sustainable future. The ambition is to keep the average global temperature rise by the end of this century compared to pre-industrial time well below 2°C and pursue efforts to limit it to 1.5°C by peaking global emissions as soon as possible and achieve global zero net emissions in the second part of this century. The agreement is based on the NDCs, with each country delivering on its national climate plan for reduced emissions.

The Paris agreement will influence the energy markets in various ways:

- Country regulations are evolving – larger regulatory burden for fossil fuels, in particular coal, and incentives geared towards renewables, also affecting public R&D spend;
- Increased stakeholder pressure towards limiting access to acreage for oil and gas – new licensing rounds and exploration activity are placed under greater scrutiny;
- Higher investments in renewable energy sources and energy efficiency – more financial resources available for investments in renewable energy leading to greater competition for bankable projects, and good opportunities for new wholesale agreements on renewable energy;
- Technology development – CCS is clearly needed, but incentives and access to capital may be restricted without conducive government engagement to support oil and gas.

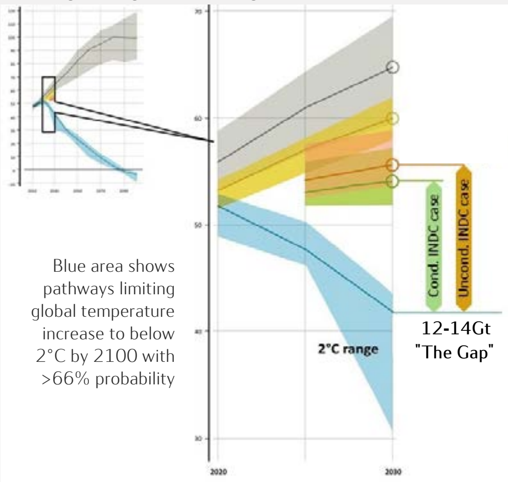
Main uncertainties

The NDCs are not legally binding, and the extent to which countries will fulfil and strengthen their climate plans will depend on the political and economic conditions globally as well as nationally. For example, a shift of government in the US could prevent planned regulations for the power sector, which in turn will influence on the US' ability to reach their 2025 climate target. Lower economic growth in China could influence the country's ability to reach their renewable target. Some European countries currently show little appetite for strengthening the EU's 2030 greenhouse gas target. India has ambitious plans for renewables which would require huge investments, while Brazil is in the middle of a political and economic crisis that could influence their ability to achieve the country's climate plans.

Scenario impact

In the *Reform* scenario the current NDCs are to a large extent implemented, and somewhat tightened from 2025-2030. Climate finance ambitions of 100 billion USD per year are only partially fulfilled, therefore some of the financially conditional NDCs are not fully reached. Carbon pricing schemes to stimulate cost-efficient reductions in countries and across national borders gradually develop.

NDC contributions and the emissions gap
Annual global greenhouse gas emissions, $GtCO_2e$



Source: "The Emissions Gap Report 2015", UNEP

From a 2°C to a 1.5°C target?

The *Renewal* scenario assumes climate policies, and policy implementation success rates, in line with the 2°C target on global warming. This has been advocated for more than a decade with a view to stave off the worst impacts of climate change on weather patterns, living conditions in exposed places, food and water availability, and so on.

In the run-up to COP21 it became increasingly clear that not everybody was content with the 2°C target. Island states at risk of disappearing in the event of a significant rise in the sea level called for a replacement of this target with a 1.5°C target, and received much sympathy for their particular challenges. Eventually the conference decided to pursue a 1.5°C target on a 'best effort' basis.

The implications of a 1.5°C target – in particular what changes in energy supply and demand it calls for – are not as well researched as those of the 2°C target. Research[1] suggests however that a 1.5°C cap on global warming points towards significantly earlier and more forceful action than a 2°C cap, and an elimination of net carbon emissions by around 2050, which is 10-20 years earlier than required by the 2°C target. The costs in terms of lost GDP up to 2030 are put at 2-3 times the costs of steering towards a 2°C target. Another preliminary finding is that the scope for additional supply side changes to deliver the difference between 2°C and 1.5°C could be limited, since the potential for fuel switching may need to be so heavily exploited to merely hold the 2°C line that there may be little remaining. Consequently, demand side changes and (from 2050) measures to remove CO_2 from the atmosphere such as CCS in combination with biomass use could be essential. Scenarios consistent with the 1.5°C target tend to show more CO_2 being removed from the atmosphere between 2050 and 2100 than injected into the atmosphere between 2010 and 2050. Generally a 1.5°C target is seen to offer countries less flexibility in their choice of measures. All levers will need to be pulled to the maximum, and not only in the energy industry.

The *Renewal* scenario takes note of the signs of a more restrictive global warming cap gaining support, but is not tailored to a vision of a 1.5°C world. Instead CO_2 emissions from the energy sector are positioned slightly below the established benchmark from the IEA used last year.

[1] See for example J. Rogelj et.al.: "Energy System transformations for limiting end-of-century warming to below 1.5°C", Nature Climate Change, May 2015

In the *Renewal* scenario the current NDCs are fully implemented and significantly tightened starting from 2020. Climate finance ambitions are met and further increased, and global carbon pricing is implemented by 2025.

In the *Rivalry* scenario the climate issue has low priority on the regulatory agenda. While local pollution issues are attended to, large-scale international climate agreements are not the chosen way forward. As a consequence, the current NDCs are only partly implemented. Climate finance ambitions are not met, and carbon pricing to stimulate cost-efficient reductions in countries and across national borders are limited. Therefore *Rivalry* has a detrimental long-term effect on the environment and the economy.

Global carbon emissions

Global energy-related CO_2 emissions were almost flat in 2015 in spite of a 3% growth in the world economy. They did not change notably in 2014 either. Stable CO_2 emissions in spite of positive economic growth have not been seen before and underpin hopes that it could be possible to de-link emissions from GDP on a world-wide, sustained basis.

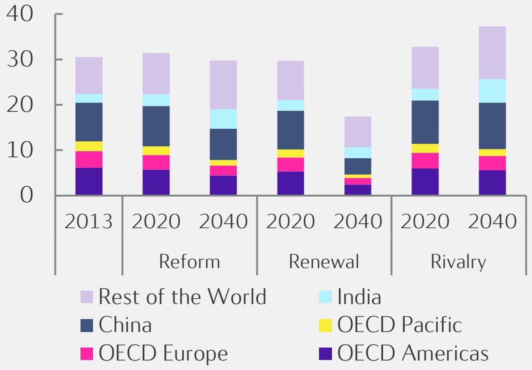
Global energy-related CO_2 emissions increase between 2013 and 2040 in only one of this year's scenarios. In *Rivalry*, where geopolitical conflict management clouds opportunities to achieve climate target attainment and where the pace of green technology development and deployment slows, emissions grow by an average of 0.6% per year or by a total of 18% over the period, and are still on a rising trend by 2040. In *Reform,* emissions increase until sometime between 2020 and 2025, but decline by an average of 0.2% per year thereafter and are by 2040 6% lower than they were in 2013. In *Renewal* – which is tailored to achieve the 2°C target – they decline by an average of 2.2% per year or by a total of 45% between 2013 and 2040.

In relative terms the OECD regions accomplish the biggest emission declines in both *Reform* and *Renewal*, but in absolute terms China contributes a comparable decline in *Reform* and a much bigger decline in *Renewal*. Indian and African emissions grow in all scenarios. All other regions see declines in *Renewal*.

This year's *Reform* scenario is considerably greener than last year's *Reform* scenario where energy-related CO_2 emissions were 12% higher in 2040 than in 2013. These revisions reflect the NDCs and various COP21 independent developments such as the signs of an earlier peak in Chinese emissions, as well as changes to other assumptions.

Taking the NDCs into account is not straightforward, given the many different commitment formulations and the high share of commitments that are not meaningfully quantified. Recent energy and CO_2 emission scenarios that try to do so, and that extend the NDCs beyond 2030, show more or less flat emission curves going forward. All scenarios based on the IPCC's much stricter sustainability criteria show emission curves resembling *Renewal*. Some scenarios delay the assumed transition from a *Reform* type world to a *Renewal* type world to the 2020s. That may be a realistic assumption given the time it will take to mature green solutions and prepare the global population for radical action. However, such sce-

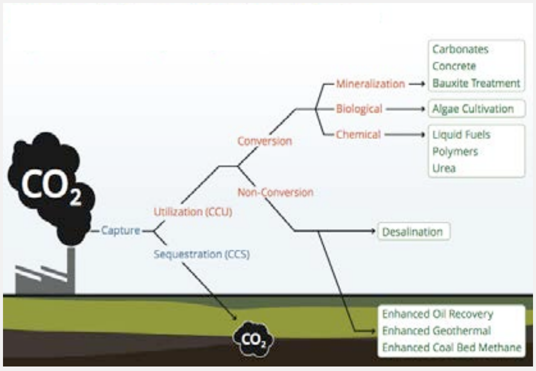
Regional energy-related CO_2 emissions
Billion tons



Source: IEA (history), Statoil (projections)

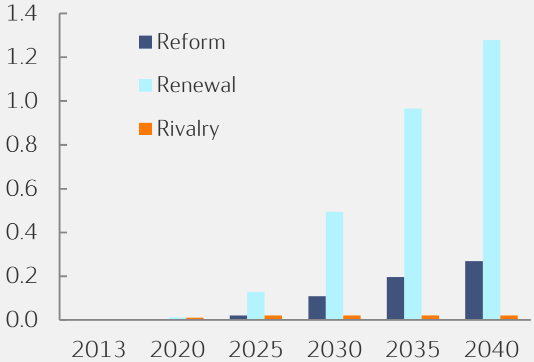
Lingering doubts in political circles about the merits of supporting CCS keep the outlook for this option very uncertain

CCS and CCU at a glance
Selected current CCS and CCU pathways



Source: breakingenergy.com

CO_2 from power plants and industry captured and stored
Billion tons



Source: Statoil

narios need to assume even steeper declines in fossil fuel use in the remaining years to 2040 or 2050, highlighting other feasibility issues.

Intentionally sustainable scenarios may combine different policies (carbon pricing and taxation, green technology subsidization, mandates and standards) and assumptions on technology (nuclear, renewables, CCS, etc.) targeting different results (higher energy efficiency improvement rates, faster uptake of zero-carbon technologies and fuels) in different ways. No one can be certain at this stage of the winning combinations.

The role of carbon capture and storage

Carbon capture and storage (CCS) edged forward in 2015, sustaining hopes that removing CO_2 from exhaust gases and storing it underground may one day become an important global warming risk mitigation tool. However, lingering doubts in political circles about the merits of supporting CCS relative to those of backing other mitigation tools keep clouding the outlook for this option.

At the moment 15 large-scale CCS projects are up and running, and 7 more are due to become operational. Global CCS capacity could by the end of next year total around 40 million tons of CO_2 per year. Most of the projects in operation are linked to oil and gas operations. Only one captures and stores CO_2 from a coal power plant, although this is the usage of CCS required to play the biggest role in stabilizing the climate.

Whereas the costs of new renewable energy are falling, CCS appears to be standing still in this respect. Financing and deployment problems have slowed the accumulation of experience and learning which is necessary to make new technologies commercial. Also, the clustering of projects and common use of infrastructure envisaged to cut costs have not been possible and seem some time off. Other clouds on the near-term horizon for CCS are that companies emitting CO_2 face carbon market prices so low that it costs less to buy emission allowances than to invest in capture and storage, and that unless they can link up with nearby oil producers in need of CO_2 for enhanced oil recovery, CCS only adds costs, not compensating revenues, to projects. Research on carbon capture and utilization (CCU) is ongoing.

Statoil continues to believe that CCS has a role to play in managing CO_2 emissions. In the medium term we will likely see more industrial pilot projects than large-scale power sector projects going ahead. Industry does not have the wealth of options to reduce its CO_2 emissions that the power sector has. In the long term, however, the application of CCS on remaining thermal power generation could take off. As renewables and energy efficiency approach their limits, incremental carbon reductions will likely be more costly without CCS than with CCS. In *Reform*, CCS remains a marginal contributor to global warming containment, but in *Renewal* it handles some 7% of global energy-related CO_2 emissions and much bigger shares – up to 30% – of certain regions' power and heat sector emissions by 2040. In *Rivalry*, costly climate stabilization options get low priority and CCS remains limited to the handful of projects currently in or near operation.

Outlook for the EU ETS

The EU greenhouse gas (GHG) emission objectives are recorded in the EU NDC, and are to be implemented using the EU Emissions Trading System (ETS), which enables companies to choose the most cost-effective options to address their emissions, either through carbon reduction investment, shift of energy source or purchase of allowances. The most important binding EU targets are 40% less GHG emissions by 2030 compared with 1990, and a minimum 27% share of renewable energy in total final energy consumption by 2030.

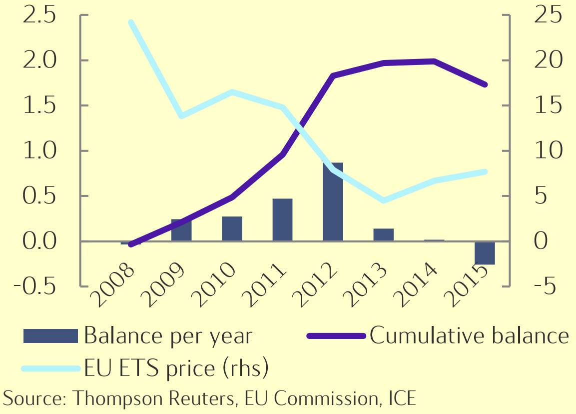
The underlying idea of the EU ETS is to establish a cost on carbon emissions, giving a value to emissions saved to incentivize emission reduction, and allowing companies to choose the most cost-effective options to address their emissions – either through carbon reduction investment, shift of energy source or purchase of allowances.

The EU ETS framework has evolved in phases in line with EU's ambitions. In the current phase 3 (2013-20) and the upcoming phase 4 (2021-2030), companies receive or trade emission allowances within an EU wide cap. Each member state auctions a share of the overall volume of greenhouse gases that can be emitted yearly. In phase 3, the cap on emissions is reduced by 1.74% every year. This results in 21% lower emissions in 2020 than in 2005. For phase 4, the cap will be reduced by 2.2% of the 2010 emissions every year to achieve a reduction of 43% by 2030 versus 2005 from the sectors covered by the ETS.

In 2014, the European Council made changes to the ETS system to remedy the mismatch which had developed between allowance supply and demand and cure the resulting low price of allowances. Most importantly, a Market Stability Reserve with the intention to reduce price volatility was established. In effect from 2019, the reserve will absorb past surplus allowances and release or absorb future allowances in circulation if the number exceeds or falls below certain limits.

EU ETS price and "stationary" allowance balance

Balances in billion tons of CO_2, price in EUR per ton of CO_2



Source: Thompson Reuters, EU Commission, ICE

There are significant uncertainties around the future EU ETS development, and how different initiatives will impact the system. One question is whether the currently agreed reform measures will result in carbon prices that are high enough to incentivize meaningful levels of fuel switching or significant investment in carbon reduction initiatives. The current price is far from this level, and the system needs continued reform measures to achieve a higher price.

Other uncertainties can be seen in evolving national carbon legislation, when countries view the ETS reform attempts as too cumbersome and the system inadequate to drive necessary change. For instance, both the UK and France have established separate CO_2 tax regimes. Lastly, world leaders launched a global carbon pricing initiative during COP21, sponsored by the World Bank and IMF, which will impact the EU ETS if such a global scheme is established.

The US Clean Power Plan

The Clean Power Plan (CPP) was issued by the US Environmental Protection Agency (EPA) in August 2015 to regulate greenhouse gas (GHG) emissions in the power sector. It is the centrepiece of the Obama administration's effort to reduce CO_2 emissions in the US and was an important US contribution to COP21. The CPP requires states to reduce CO_2 emissions to meet state-specific goals. If the goals are met, CO_2 emissions from the power sector will be 32% lower in 2030 than in 2005.

The CPP does not specify how the targets will be met. Each state is allowed to meet the target by any means of their choice. Only when states file compliance plans will it be possible to see how the CPP will work. When states submit compliance plans they will have great flexibility in meeting the goals. States can combine to meet the goals jointly and can create a carbon market if they choose. The CPP neither creates a carbon tax, nor a carbon market, since federal legislation would be needed for such a change, and such a federal law is unlikely in the near future.

The outlook for the CPP is cloudy. Twenty seven states, including coal-producing regions, have opposed the CPP in the courts. They argue that the EPA does not have the authority to enact the CPP. In February 2016, the US Supreme Court granted a stay to these opponents, meaning the EPA cannot take action to implement or enforce the plan until legal challenges are resolved. The stay means that this component of the Obama administration carbon policy will be delayed until the legal questions are resolved, a process that could take years and result in a Supreme Court ruling. Because of the delay, implementation of the CPP or any other carbon policy will be the responsibility of the next president of the US.

Methane emissions

Within the energy sector, CO_2 resulting from fuel combustion dominates total GHG emissions with a share of 90%. The second largest anthropogenic GHG behind CO_2 is methane, the key constituent of natural gas, accounting for about 9% of GHG emissions. Although methane has a shorter lifetime in the atmosphere than CO_2, it traps heat far more effectively. Methane is emitted into the atmosphere from oil production and the production, processing, transmission and storage of natural gas, as well as from agriculture, waste dumps, etc. Sources in the energy sector include venting, inefficient flaring and leakages from processing equipment, which makes identification, measurement and compilation of data on methane leakages complicated.

Methane emissions are starting to receive more attention in the global warming mitigation strategy discussion. Several COP21 NDCs refer to total GHG emissions (including both CO_2 and methane), signalling acknowledgement that accomplishing these ambitions might entail efforts to abate both types of emissions. In countries where energy-related methane emissions are substantial, addressing these might be one of the most impactful, short-term measures that can be implemented to slow the rate of global warming. Such is the case in the US, where interest in this issue escalated in the wake of the shale gas revolution. Going forward, regulating methane emissions from the gas sector is a pre-requisite for ensuring that gas is seen as a credible part of the future, lower-carbon energy mix. This poses a greater challenge for the US, where projected growth in gas production will come from development of unconventional gas from shale deposits. Methane emissions are currently less of an issue in Europe, where shale gas production is not significant and where reported methane leakage rates are low.

In January 2015, the Obama administration announced an ambition to reduce methane emissions from the oil and gas sector by 40 to 45 percent from 2012 levels by 2025. Since then, the EPA has been working on building a regulatory approach to achieve this ambition. In May 2016 the EPA finalized the first-ever standards to cut methane emissions from both new and existing sources in the oil and gas sector, a step that puts the US on the path to achieving their methane emissions reduction goal.

The global energy market

Energy demand outlook

World primary energy demand continues to increase, although growth is dampened by economic, technological and political factors. IEA and BP estimate average annual growth between 2000 and 2013 at 2.3% and 2.4%, respectively. BP suggests 0.9% for 2014. Inter-country variations are significant. Indian energy consumption jumped by 7.6% in 2014. At the other end of the scale, Greek and Ukrainian demand fell by 6.6% and 14.1%, respectively.

World economic growth between 2000 and 2013 averaged 2.6% per year. This means that the energy intensity of the global economy – that is, world energy consumption divided by world GDP – declined by around 0.4% per year over this period.

Energy consumption per unit of GDP produced has trended down since the early 1970s when the first oil price shock triggered concerns about oil and gas shortages and kick-started public interest in energy efficiency. There have been years when energy demand has increased faster than GDP. Such rebounds have typically occurred in direct response to energy price troughs, or in periods of normalization after price spikes, but they have as a rule been short-lived.

What will drive energy demand growth during the 2020s, the 2030s and the 2040s? Economic growth continues to matter, but various factors have broken the link between economic growth and energy demand growth in the OECD countries, and weakened it in the rest of the world. This begs the question whether and when the link can be eliminated on a global and permanent basis.

Leading energy forecasters believe that the developed world is already there. In IEA's baseline scenario the OECD economies' energy demand declines by 2.9% between 2013 and 2040 in spite of a 66% growth in their combined GDP. The main debates these days are not whether the OECD economies' energy requirements will bounce back – the consensus opinion being that they will not – but how much they can be depressed and how soon the rest of the world's energy demand can be stabilized.

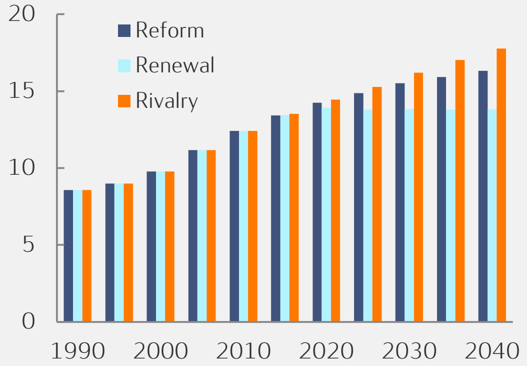
Energy intensities change for several reasons, as outlined below.

Structural changes in economies

As countries develop, capital and labour typically migrate first from the primary sectors to the secondary sectors and then onwards to the tertiary sectors. Providing services requires less energy per unit of value added than, for example, turning iron ore into steel or producing cement. Thus economic development leads in itself first to increasing and then to declining energy intensities.

This mechanism is at the core of China's ambitions to rein in its energy needs, coal use, CO_2 emissions and local pollution. Heavy industry and construction are shrinking, with the idled capital and people finding opportunities in high tech manufacturing and in the consumer service sectors. Forecasters should keep in mind however that one country's downsizing may be reflected in another country's upsizing of its heavy industry. Some of China's steel mills and cement factories will be idled on a

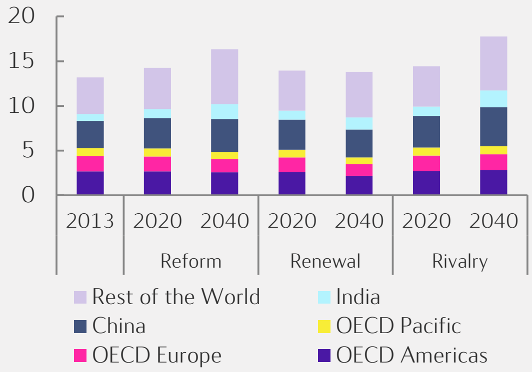
Global primary energy demand
Btoe



Source: IEA (history), Statoil (projections)

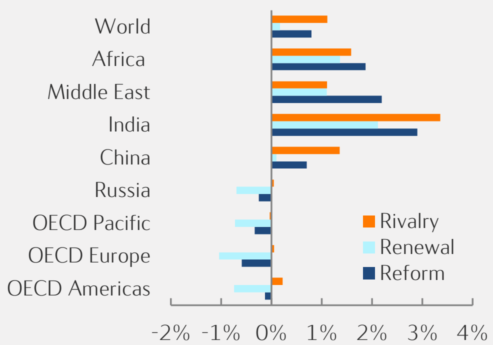
Global energy demand growth is dampened by economic, technological and political factors

Regional primary energy demand
Btoe



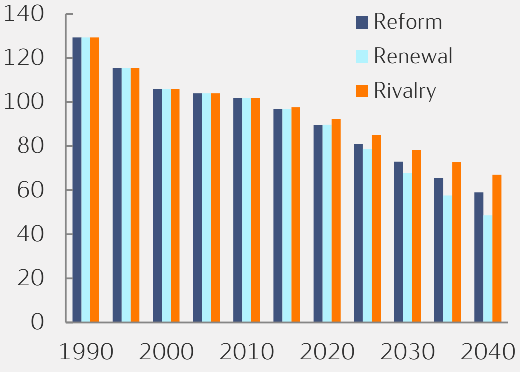
Source: IEA (history), Statoil (projections)

Average annual growth in primary energy demand
2013-2040



Source: Statoil

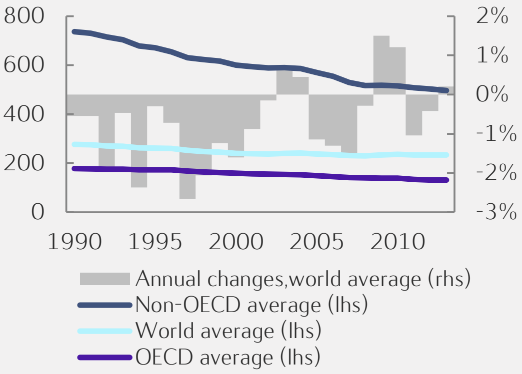
Global energy intensity
Index, 2013 = 100



Source: IEA (history), Statoil (projections)

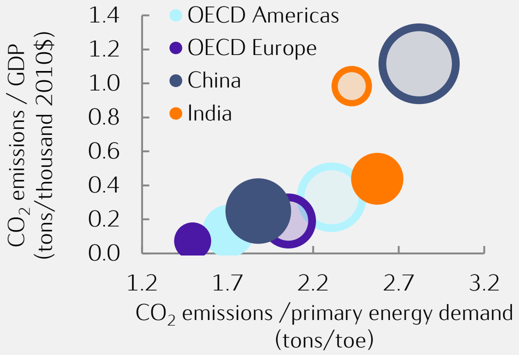
A lot is expected from energy efficiency improvements

Primary energy consumption per unit of GDP
Toe per thousand USD (2005 values)



Note: GDP measured at market exchange rates
Source: IEA

Change in carbon intensities 2013 - 2040, *Reform* scenario
2013 = lightly shaded circle, 2040 = filled circle



Note: size of circle indicates total CO_2 emissions
Source: IEA (2013), Statoil (2040)

permanent basis, but others may find new homes in China's Asian neighbours.

Energy efficiency improvements

New equipment typically delivers more output for the same amount of energy (and labour) input, or the same amount of output for less input, than old equipment. The pace of improvement can be accelerated by economic incentives or by requesting manufacturers to make extra effort.

A lot is expected from energy efficiency improvements. The 0.4% per year decline in the energy intensity of the world economy realized between 2000 and 2013 is not seen as indicative of the scope for future reductions. IEA assumes a decline of 2.4% per year in its New Policies scenario. Globally, many drivers including structural changes will be involved, but in developed countries with relatively settled economies energy efficiency improvements will need to do the heavy lifting.

The debate on the scope for energy efficiency improvements has reignited old controversies on the risk of energy demand rebounds. If energy demand goes down, energy products will – everything else equal – become cheaper, incentivizing consumers to want more of them. Thus if energy markets work normally, an initial demand reduction may erode over time. There is no disagreement on the existence of this effect, but a lot of uncertainty about its importance.

Fuel switching

Replacing one technology designed for one fuel with another can lead to significant fuel savings and energy intensity declines. An example is the replacement of coal power plants with combined cycle gas power plants. So-called subcritical coal power plants have an average thermal efficiency (the ratio of mechanical work output to heat input) of 32-33%. So-called ultra-supercritical coal power plants can have efficiencies of up to, or even above, 40%. Combined cycle gas power plants can reach efficiencies of almost 60%. Switching from coal to gas power generation consequently reduces the amount of fuel required to generate the same amount of electricity.

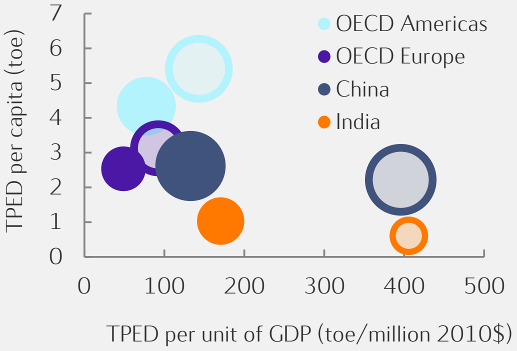
Development of "smart cities"

Reshaping cities to reduce commuting needs, dampening building sector energy requirements, and preventing the kind of mismatches between electricity supply and demand that tend to be met by investments in overcapacity, has elements of both structural change and energy efficiency improvements.

Changes in consumer behaviour

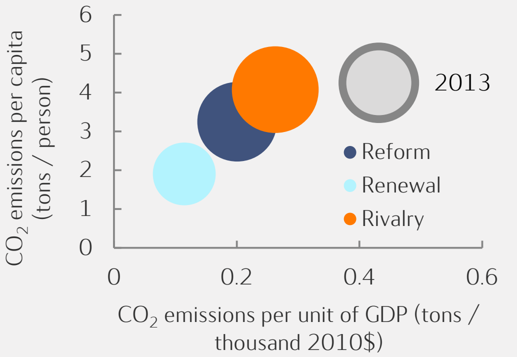
People may change their energy consumption habits independently of market signals or policy. Dissatisfied with dominant lifestyles, they may decide to get used to lower heating levels, to less travel, and to getting around by foot or bike rather than by car. The emergence of green political parties in many countries testifies to mood swings along these lines. Similar changes in the past were relatively short-lived. But then, there may never before have been an incentive as capable of sustaining interest in lean lifestyles as the threat of global warming.

Change in primary energy demand per unit GDP and per capita, *Reform* scenario
2013 = lightly shaded circle, 2040 = filled circle



Note: size of circle indicates total primary energy demand
Source: IEA (2013), Statoil (2040)

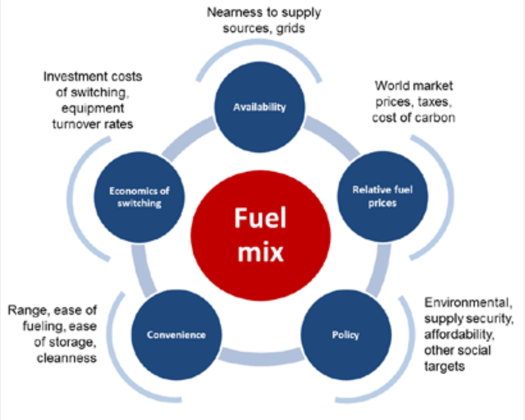
Global carbon intensity in 2040
Size of circle represents total CO_2 emissions



Source: IEA (2013), Statoil (2040)

For many decades world primary energy supply and demand has been dominated by coal, oil and gas

Key fuel mix drivers



Source: Statoil

Different assumptions across the three scenarios

In *Reform*, world primary energy demand growth averages 0.8% per year between 2013 and 2040. The energy intensity of the world economy drops by an average of 1.9% per year. *Reform* is not a sustainable scenario – it does not deliver the conditions for a containment of global warming at 2°C – but it is characterized by countries striving to fulfil their COP21 commitments. Decline rates differ significantly across regions, with China achieving 4% per year against the OECD regions' 1.5-2.3% per year. China benefits from the ongoing rebalancing of its economy, with heavy industry stagnating or going into decline and less energy-intensive sectors picking up the slack. India also sees an above average decline in its energy intensity.

In the *Renewal* scenario world leaders decide to give global warming their full attention and go to the limits of the 2°C line. The energy intensity of the world economy drops by an average of 2.6% per year. China and India deliver declines of well above 4% per year. North America's energy consumption per unit of GDP falls by 3% per year and OECD Europe is not far behind, in spite of these regions' economic maturity with fewer and smaller pockets of inefficiency left to eradicate. The technologies to lower energy demand as envisioned are available. The economics could be challenging – energy inefficient capital may need to be prematurely retired – but in *Renewal* this is considered a price worth paying.

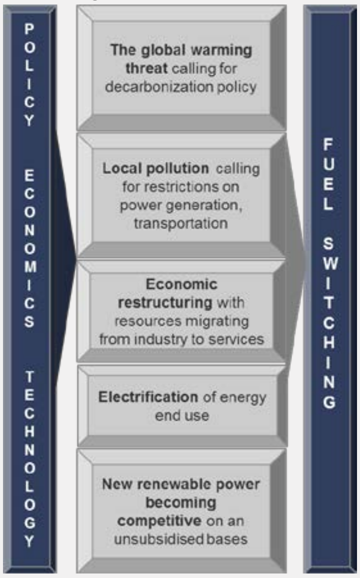
In the *Rivalry* scenario world energy demand grows by 1.1% per year, reflecting a 1.5% per year decline in the global energy intensity between 2013 and 2040. World leaders remain interested in energy efficiency as a means to reduce energy import requirements in addition to protecting the local environment. Some regions – those least affected by the tensions and conflicts defining *Rivalry* – make about the same efforts and deliver roughly the same energy intensity decline rates in *Rivalry* as in *Reform*. But the regions most affected have neither funds, expertise, nor political will to pursue energy issues beyond securing energy supply from day to day.

Fuel mix outlook

For many decades world primary energy supply and demand has been dominated by coal, oil and gas. By the mid-1960s the combined share of these fuels in demand was almost 95%. Within the fossil fuel category coal was in decline and oil on a rising trend. The 1970s' oil price shocks triggered a desire to reduce dependence on oil in general and OPEC oil in particular. Coal rebounded for a while, gas continued to grow and nuclear took off. The fossil fuel share of total primary energy demand (TPED) dropped to marginally below 87% in the late 1990s.

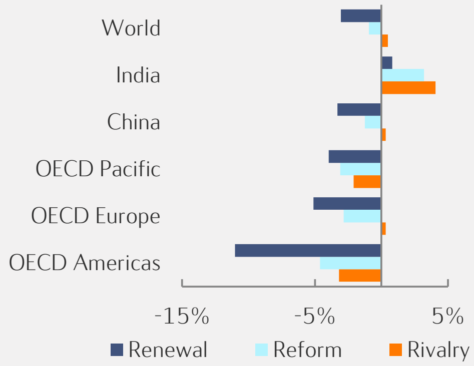
Since then, however, this share has been fairly stable, with the main changes in the global fuel mix taking place inside the fossil and non-fossil components of energy demand. On the fossil fuel side the coal share of TPED increased from 24% in 2000 to 30% in 2013. Oil has fallen from 35% to 29%. On the non-fossil fuel side nuclear has dropped from more than 6% to around 5% with wind and solar power increasing from 0.5% to almost 2.5%. While the fuel mix changes that have taken place are significant, they also highlight the challenges of reconfiguring energy systems. The coal share of world primary energy demand was exactly the same in 2013 as in 1970, in spite of decades of debate on the climate

Key fuel switching drivers in 2016



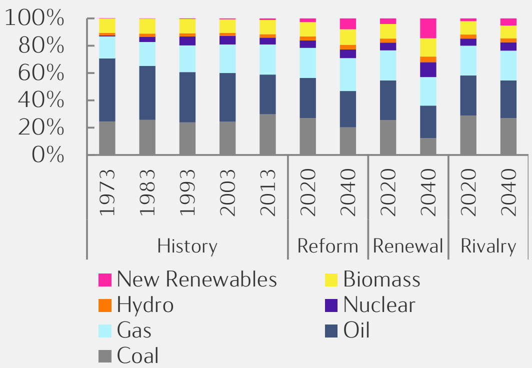
Source: Statoil

Average annual changes in coal consumption
2013-40



Source: Statoil

Global fuel mix
1973-2040



Source: IEA (history), Statoil (projections)

and a growing awareness of the role of coal in driving CO_2 emissions and global warming, and with total coal demand growing by more than two and a half times.

Scenarios that foresee rapid changes in the global fuel mix going forward, in spite of the relatively sluggish changes in the past, proceed from the following opinions:

- The global warming threat which is behind today's fuel mix concerns is incomparable in scale and scope to the geopolitical risks and (largely misplaced) fossil fuel shortage concerns that drove fuel diversification efforts in the past. Interest in clean energy, which has ebbed and flowed, may therefore be expected to be sustained in the future;

- Wind and solar power are becoming competitive on an unsubsidized basis with fossil fuel based power. Switching to these power generation technologies will therefore likely become a self-sustaining process rather than one dependent on constant political attention and economic support;

- Local pollution reaching critical levels in the world's megacities will call for the same shifts in fuel consumption as global warming;

- Key countries – in particular China – are refocusing on consumption, the domestic market and service provision at the expense of investments, and export led growth. These macroeconomic adjustments will, independently of fuel policies, dampen energy demand growth in general and coal demand growth in particular.

The fuel composition is expected to change in all sectors, although the relatively long lifetimes of industrial and residential buildings and heating equipment narrow the scope for rapid fuel switching.

In *Reform*, the coal share of OECD area industrial energy consumption declines from 12% to 8% between 2013 and 2040. The share drops significantly in many non-OECD regions too, but increases marginally in India and some other Asian countries. The oil share of global industrial energy demand increases marginally from 12 to 13% in *Reform*. The gas share declines from today's approximately 20% to between 17% and 18%. Residential oil use (which does not include private driving) declines in both absolute and relative terms, especially in the developed world. Residential gas use increases in absolute terms but gas only manages to hold on to its current 20% household market share in relative terms. This apparent stability hides large variations from region to region. The transport sector sees major fuel mix change, with the oil share dropping from 91% to 75%, the gas share increasing from 4.5% to 8.5% and the electricity share going from 1.2% to 14%.

In *Renewal* the coal shares of industrial and residential energy consumption are further reduced, with electricity, biomass, new renewables and in some places gas picking up the slack. However, the scope for changes in the fuel mixes of these end-use sectors to contribute to the desired CO_2 emission reductions appears limited. More importantly, the oil share of global transport energy consumption drops by 10 percentage points, with the electricity share increasing to 24%.

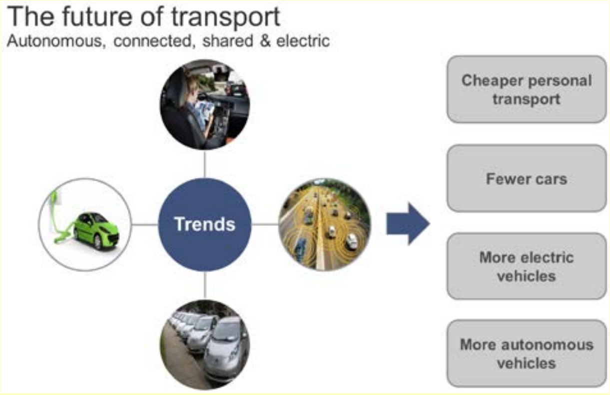
Technology and digitalization

During the past 15 years, the internet has redefined business-to-consumer industries such as media, retail and financial services. Currently the integration of complex physical machinery with interconnected sensors and software (known as the Internet of Things or IoT) is dramatically altering manufacturing, energy, agriculture, transport and other industrial sectors of the economy which together account for nearly two-thirds of global GDP. All industries are expected to face digital disruptions of some form in the 2020s, and will need to transition to new digital models to optimize their business. The transport sector represents a clear example of how digitalization is enabling disruption also in the energy business, as mobility is becoming increasingly electric, autonomous, shared and connected, thus changing a key demand sector for transportation fuels.

Digitalization in an industrial context

Digitalization can improve efficiency and reduce costs, as illustrated by the progress made in the airline industry since the end of the 1990s. Sensors on planes have helped airlines realize fuel efficiency targets, maintenance and route optimization, while digitalization of sales and reservations has reduced errors and led to the "pricing and overbooking business" – where companies use big data to optimize plane occupancy. New ideas are developed as airlines understand their own data better, leading to a continuous learning journey of adapting and testing the operating model.

Companies particularly at risk are those that rely on large physical investments to provide services or act as intermediaries in value chains where the end consumer is gaining more power. The clearest examples so far include: Uber, the world's largest taxi company, which owns no vehicles; Facebook, the world's most popular media owner, which creates no content; Alibaba, the most valuable retailer, which has no inventory; and Airbnb, the world's largest accommodation provider, which owns no real estate. All these businesses are agile, scalable, and connected.



Digitalization in the context of the energy industry

Digitalization is also accelerating the emergence of cheaper renewable technologies which combined with new smart and connected devices are enabling consumers to take new roles as both buyers and sellers of energy.

The potential supply side implications of devices such as the Nest thermostat (acquired by Google for 3.2 billion USD in 2014) are that they could reduce utilities' need for flexible gas plants and enable the creation of smart electrical grids where distributed energy production can be optimized – although utilities are also paying customers to switch off electricity in peak times.

Consumers' values and preferences continue to evolve – with digital applications empowering improved demand management – leading to changes in consumption that can happen far quicker than supply side changes. These include:

- Expansion of distributed energy systems: Peer-to-peer platforms could convert the energy sector to smart grids supplied by millions of small, distributed solar and wind powered plants. When added to the emergence of storage, electric vehicles and renewables, a variety of technology advances are emerging and combining to create new ways for consumers to obtain, store and sell energy.
- New transport patterns: Smart commuting and ride-sharing have the potential to reduce the demand for oil products, but also to increase demand for road transport services.
- On-Demand services: New business models have emerged that enable consumers to get services "on demand." In home entertainment, the traditional approach of offering a standard cable package and optional bundles has been overtaken by new forms of media consumption (e.g., YouTube, Apple TV, Netflix) where consumers choose what, when and how they watch. "On-demand" energy consumption, where consumers choose when and how they buy electricity from the grid, combined with the emergence of the collaborative economy, are beginning to impact how consumers interact and consume energy.

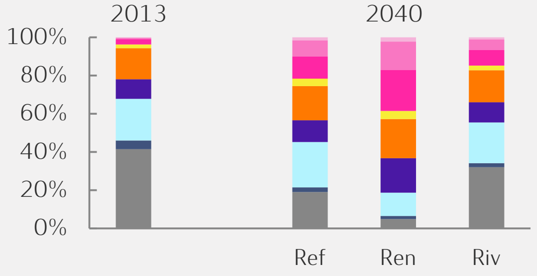
Digitalization is changing the way energy is produced and consumed, with energy efficiency becoming an increasingly important energy source in itself.

Transport and mobility

The transport sector is a low hanging fruit for disruption. The way in which IT, energy and transport are merging is the key to the potential emergence of a new reality in the sector.

The recent emergence and continued development of autonomous vehicles (Google, Apple, Tesla), IT platforms which enable efficient sharing in transport (Uber, BlaBla Car) and the learning curve effects on the costs of solar power generation and battery technology, are bringing big data, renewables and transport together.

Global power generation by fuel



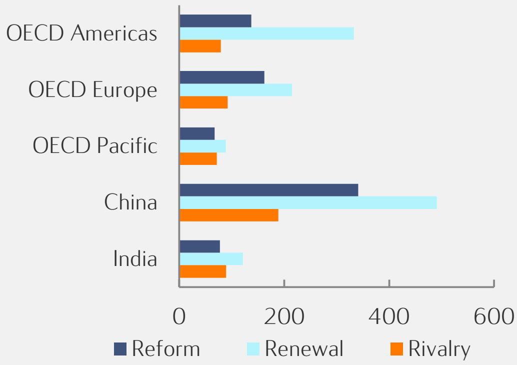
Source: IEA (history), Statoil (projections)

Inter-fuel competition in the electricity sector
Aghios Dimitrios lignite power station in Greece

Source: AFP Photo

Coal is under pressure from gas, wind and solar in all scenarios

Absolute growth in new renewable energy supply
2013-40, mtoe



Source: Statoil

Green scenarios typically assume rapid growth in the electricity share of final energy consumption since it will be easier to decarbonize a limited number of power plants than to incentivize hundreds of millions of consumers owning buildings and vehicles to replace equipment and change consumption habits. *Renewal* also assumes more emphasis on bringing electricity to the 1.3 billion people that have no access to this type of energy today. Thus the electricity share of global final energy consumption increases from 19% to 27% in *Renewal* against an increase from 19% to 24% in *Reform*.

In *Rivalry*, the coal share of global industrial fuel use increases from 29% to 32%, rather than declining as in *Reform*. The oil share is stable, but the gas share declines more than in *Reform*, since those regions that worry about the security of imported gas supply outweigh those opting for gas as an indigenous resource. The fuel mix of the residential sector changes in a similar manner, with coal falling, albeit less than in *Reform*. The electrification of final energy demand proceeds, but more slowly than in the other scenarios.

Energy demand in power generation

The power sector is a key arena for fuel mix changes. The coal share of global power generation has increased from 37% in 1990 to around 41% in 2013, but coal power is under pressure and the future is unlikely to replicate the past. In OECD Europe the coal share was down from 38% in 1990 to 24% in 2010 before staging a small comeback in 2011-13, partly driven by low prices and inefficient climate policies. In North America it dropped from 47% in 2000 to 35% in 2013. In China and India the coal shares of power generation are much higher – 75% and 73% in 2013, respectively – but in China it is coming down due to the ongoing economic transformation and intensifying pressure to do something about the country's urban pollution problems.

The main beneficiaries of the assumed gradual marginalization of coal will be gas, wind and solar. Gas is attractive on costs and on the rise in North America, but has recently lost ground in Continental Europe, to coal for competitiveness reasons and to new renewables for policy reasons. Gas to power is increasing in China, but is behind targets due to persistent competitiveness problems. India is in a similar situation, but Indian leaders frequently restate their interest in capitalizing on the current international gas price slump to boost LNG and possibly pipeline gas imports, which would consequently boost the gas share of energy supply. Wind- and solar-based power generation is increasing rapidly nearly everywhere. Nuclear is on the rise in China and is counted on by many other emerging economies, but is not for the moment a favoured option in Europe and North America.

Many countries are still building coal power plants. The Global Coal Plant Tracker, an NGO publication, estimates that 352 GW of coal power generation capacity is under construction (47% in China) and 1,075 GW at various stages of planning (57% in China). Some new plants will replace existing plants, but many will represent incremental capacity. It is an open question though how much of the planned capacity will actually be built – utilization rates in China are already severely down. In *Reform*, the coal share of global power generation is cut in half, from more than 40% to barely 20% in 2040. In the OECD area the share falls from 32.5% to a mere 8.5%. In China it declines by two thirds, from 75% to

Water scarcity driving geopolitical tension

One likely threat to future economic growth, and a likely source of future political tensions and conflict, is the growing scarcity of freshwater.

Recent research suggests that 4 billion people – some 60% of the global population – live under conditions of severe water scarcity for at least one month per year, that 2.5 billion people have to endure severe water scarcity for at least half the year, and that half a billion people face severe water scarcity year round. Water scarcity is defined as the ratio between freshwater used up and freshwater supplied to a given area. Severe water scarcity means that this ratio is above 2.

High water scarcity levels are typically found in areas with high population density and/or much irrigated agriculture and/or limited natural water availability. Other drivers are energy intensive economic growth and some of the results of this growth.

The energy industries strive to reduce water consumption, but coal mining, oil production from oil sands and gas production from shale are still water intensive activities. The worst fuels from this perspective are however biofuels. Ethanol processing is credited with a higher water consumption factor than oil sands production, and that consumption comes on top of water spent on irrigating the fields used for biofuels cultivation.

Global warming will affect different water stressed countries in different ways, since annual rainfall will increase in some places and decline in others. The expected disappearance of glaciers in a number of countries could initially boost, but eventually eliminate an important source of water supply.

Water scarcity is not only a matter of nature striking back; it is also a question of management. Water losses during transportation, agriculture in places unfit for agriculture, ineffective irrigation and a hesitance to price water properly are just four sources of scarcity that can in principle be mitigated through proper policy and regulation.

However, the risk of mitigation falling short of requirements and water problems worsening is high. The Middle East, North Africa and Central Asia are particularly exposed, but China, India, Australia and parts of southern Europe and the US are also in the danger zone. Water scarcity could interfere with food supply, drive up food prices, induce migration and thereby affect economic growth and divert political attention worldwide.

The risk of conflicts or even wars over water resources breaking out is also high. Water problems alone may not be sufficient to turn downstream countries against upstream countries or drive domestic upheavals. But they may aggravate existing disillusionment with poor leadership, poverty and environmental degradation. Drought and water shortages in Syria likely contributed to the unrest that stoked the country's 2011 civil war.

25%, and in India by close to 30%. The gas share of global power generation increases marginally, from 22% to 24%. The nuclear, hydro and biomass shares also increase marginally, by 1-2 percent points each. Wind and solar are the winners – their combined share goes from 3.3% in 2013 to 20% by 2040.

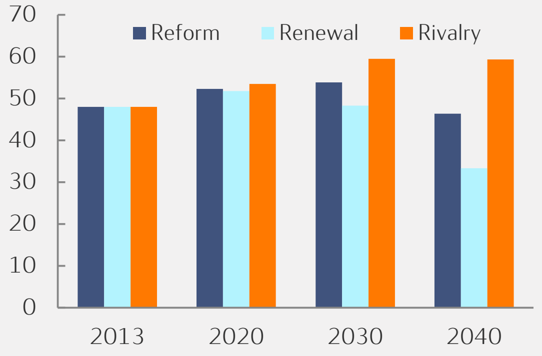
In *Renewal* power sector coal use is nearly eradicated – globally coal contributes barely 5% to power generation, and even in India and the other Asian developing countries apart from China, the last bastions of coal, the shares in 2040 are down to 17% and 14%, respectively. The gas share of global power generation declines in *Renewal* from 22% to 12% – in a sustainable outlook all fossil fuel use must be reduced, barring massive deployment of CCS – whereas the nuclear share goes from 11% to 17%, the wind share from 3% to 23% and the solar share from 1% to 16%.

Rivalry's emphasis on energy supply security implies a reluctance to leave indigenous energy resources in the ground even if they should be more carbon-intensive and polluting than the alternatives. Thus where coal is easily available, coal is retained in the fuel mix in spite of its problematic aspects, some of which can be mitigated in other ways than by cutting consumption. And, where gas is in ample indigenous supply, gas is used. However, regions that need to import gas from troubled areas launch particular efforts to reduce the market shares of this fuel.

The coal share of world primary energy demand does not decline nearly as rapidly in *Rivalry* as in the other scenarios; it drops from 30% in 2013 to 27% in 2040. The share is more sharply down in China but increases in other parts of Asia. The oil share is slightly higher by 2040 in *Rivalry* than in *Reform*, and the gas share is slightly lower. Gas is affected differently in different regions, as previously noted. In North America the gas share increases, whilst in Europe it declines.

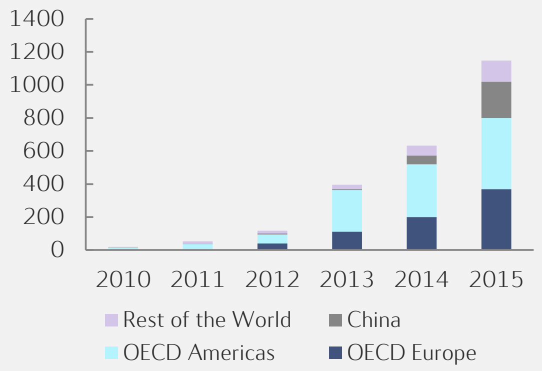
Wind and solar are indigenous resources too, and interest in these options remains strong in *Rivalry*. But international trade in technology suffers, and funds for new renewable energy R&D are many places in short supply, dampening the pace of deployment. Thus different regions proceed in different directions. While some become about as green as in *Reform*, others have for long periods of time neither capital nor political energy to spend on global environmental challenges. The share of new renewable energy in global primary energy demand increases to 5.2% by 2040, which is significant, but pales in comparison to 8.1% in *Reform* and 14.6% in *Renewal*.

Oil demand in the transport sector
Mbd



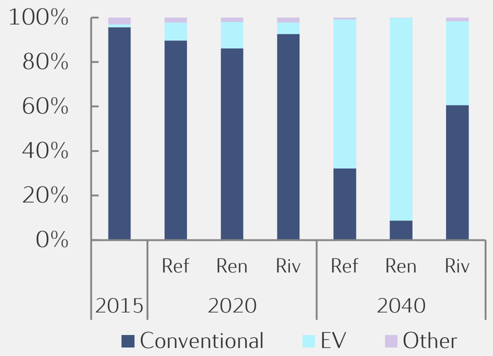
Source: IEA (history), Statoil (projections)

Global electric vehicle fleet
Thousands of vehicles



Note: electric vehicles plus plug-in hybrids
Source: IEA

Global light-duty vehicle sales



Note on vehicle classifications:
EV = fully electric and plug-in hybrids;
Conventional = gasoline, diesel and hybrid gasoline;
Other = LPG, CNG and LNG
Source: Statoil

Energy demand in transport

With transport contributing over 50% of the world's oil demand, developments in this sector are instrumental to the future oil balances. Since 1990 oil demand from transport has grown by 60%, reaching 49 mbd in 2014. Of this, 90% comes from road transport such as cars, buses, trucks and two-wheelers. Historical development has been characterized by a growth in the number of vehicles, directly translating into higher gasoline and diesel demand. Today the transport sector is at a turning point, with a number of new trends and developments capable of changing the way humans transport themselves in the future. This makes the demand for energy in transport more complex to predict, but even more important.

Growing demand for mobility requires new solutions

Fuelled by growth in population and GDP the demand for mobility is rapidly increasing. Regions such as OECD Europe and OECD Americas have reached saturation levels for passenger vehicles, but continued growth in non-OECD countries is expected, although the likelihood of these countries ever reaching the same degree of car ownership is small. Major cities such as Beijing and Delhi are already facing severe congestion and local pollution challenges, and governments are forced to take measures to limit the number of cars on the road. For future transport needs to be met in a sustainable manner a new way of thinking of and organising mobility will be required.

Urbanization encourages flexibility and new business models

The rapidly growing urban population leaves a pressing need for more efficient ways to organize transport. In addition to expanding public transport services such as buses, trains and subways, the widespread use of smartphones has allowed development of new business models such as car-pooling and cab services like Uber. The popularity of such services is growing, either as an alternative or an addition to owning a private vehicle. The new generation in the OECD is less interested in owning a car; the key is to get from A to B in the most flexible, convenient and affordable way. In 2014 only 24.5% of 16-year-olds in the US had a driver's license, a decrease from 46% in 1983, caused at least in part by changing priorities.

Autonomous vehicles could impact car ownership

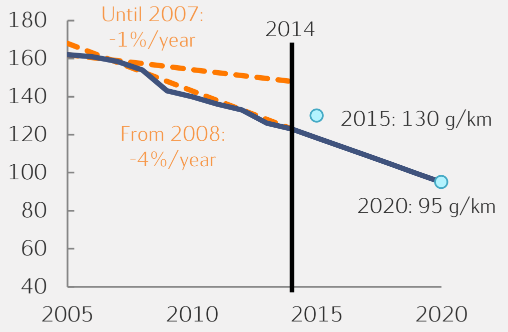
Car manufacturers and technology companies such as Google and Apple now have a major focus on autonomous driving. Autonomous vehicles could be utilized more efficiently by a larger number of people, but could also increase car use by people not in a position to drive themselves. Removing the driver will make car-pooling and public services considerably more cost competitive compared to owning a private car. This could enhance the trend of consumers increasingly viewing mobility as a service rather than in terms of a vehicle. Autonomous technology is still some years away and implementation is likely to raise a number of legal and ethical issues related to safety and liability. Significant impacts on the car fleet are therefore not expected until the late 2020s.

Tightening fuel emission standards push technology forward

Transport contributes almost a quarter of global energy-related greenhouse gas emissions, and is growing faster than any other end-use sector. Recent years have seen global momentum towards lowering emissions in

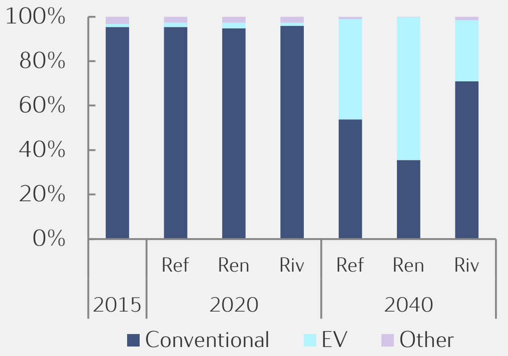
CO_2 emissions of new cars in the EU vs. targets

CO_2 g/km



Source: The International Council on Clean Transportation

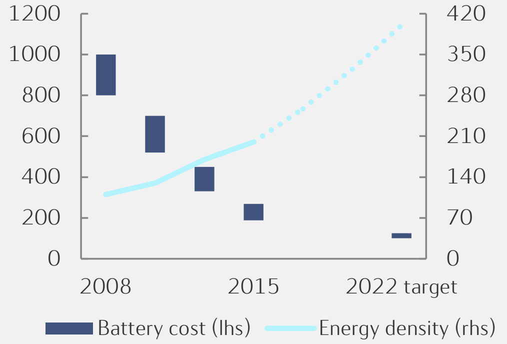
Global light-duty vehicle fleet



Note on vehicle classifications:
EV = fully electric and plug-in hybrids;
Conventional = gasoline, diesel and hybrid gasoline;
Other = LPG, CNG and LNG
Source: Statoil

Battery costs and energy density

USD/kWh (lhs), Wh/L (rhs)



Source: US Department of Energy

the passenger vehicle fleet, and the Paris agreement will likely translate into increasingly strict regulations for passenger cars.

In the EU each member state is required to track and report manufacturers' emissions. On paper the 2015 targets were reached ahead of time, largely due to increased fuel efficiencies of internal combustion engine vehicles (ICEVs). However, actual achievements are being questioned with major automakers such as Volkswagen and Mitsubishi now admitting manipulation of emissions data. This indicates that there are significant challenges for ICEVs to live up to today's standards. The EU's target levels are tightening from 2020, to 95 g/km of CO_2 for new vehicles. This additional reduction of 27% from the 2015 target, combined with new tests aimed at reporting more realistic emission figures, is likely to make electrification key. The EU has historically been a front-runner in such regulations, however in recent years most large economies, such as the US, Canada and Japan, have specified CO_2 targets for new vehicles.

Penetration of Electric vehicles still dependent on subsidies

Despite the low oil price environment, demand for battery electric vehicles (EVs) continues to grow. In 2015 the number of EVs reached a milestone of over one million globally, nearly a doubling from the year before. Battery technology, the key for overcoming EVs' main hurdles of short driving range and high cost, has in the last years seen rapid improvements. A new series of EVs with a 350 kilometre range – nearly double the current levels – is coming to the market in 2017. This could be the turning point for consumers' acceptance of EVs.

Despite consumer preferences changing and technology improving, EV market shares are still highly dependent on subsidies and incentives from local governments. The effect of subsidies can be seen in countries such as Norway and the Netherlands, current global leaders in terms of EV market shares. The rest of the world is just beginning to see the impacts of increased subsidies and green focus. EV penetration is expected to be reliant on subsidies until at least the mid-2020s, when costs are assumed to break even with ICE vehicles.

Country targets and industry commitments point in the same direction

The global momentum towards a green shift in transport has led to a large number of countries now setting specific targets for the number of EVs on the roads. China alone aims at 5 million EVs on the road by 2020. Germany is discussing a 1.4 billion USD joint spending with automakers to boost EV sales. The Electric Vehicles Initiative (EVI), a multi-government forum of 16 countries, calls for 20 million EVs in the global fleet by 2020 (the so-called "20-by-20 target"). A number of countries are discussing a ban on fossil fuel cars from the mid-2020s. Although not likely to materialize, it does indicate the extent to which electrification in transport has been recognized as instrumental for achieving emission reductions.

The need to comply with increasingly strict frameworks has led most major car manufacturers to formulate clear strategies for expansion of alternative fuel vehicles in their fleet. The focus on various technologies differ, but in the coming years a significant number of new car models will be released with hybrid, plug-in hybrid or pure electrical technology. This is also likely to spark increasing interest among consumers, who until now have had very limited choice.

Battery technology

Lithium-ion cells and the battery packs that hold them are the most costly part of modern electric cars. Despite significant recent improvements, further developments in energy density and cost are needed to overcome the main hurdle to EV adoption, namely the need for longer driving ranges at a lower cost.

Figures from the US Department of Energy (DOE) show that battery cost dropped by 73% from 1000 USD/kWh in 2008 to 268 USD/kWh in 2015. Policies and support directly into R&D have helped this development. Ambitious targets for further improvements to cost, size and weight of batteries is set. By 2022 DOE expects battery cost to reach 125 USD/kWh.

The level of 100 USD/kWh is generally viewed as the point at which electric cars become cost-competitive with ICEVs. With a continuation of recent years' development it is expected that battery driven vehicles will be able to break even with ICEVs from mid-2020s.

As EVs become more widespread, economies of scale will also help the economics. This is part of the thinking behind Tesla's factory in Nevada, which at full production capacity of 35 GWh by 2020 will produce more lithium batteries than the number in use today, at an estimated 30% reduction in cost.

Are resources sufficient for such a ramp-up?

Lithium resources are not endless and some question whether there will be sufficient amounts to accommodate the significant growth in batteries an EV revolution will require. Global economic reserves are estimated at 13.5 million tons, with resources at 40 million tons. Reserves are sufficient for over 300 years of current production, but with the expected EV growth the resources will be depleted at a much faster rate.

Should the price of lithium increase it is likely that additional resources could be unlocked. Increasing costs and potential scarcity could also incentivize alternatives. Substitution for lithium compounds in batteries is possible. DOE mentions battery chemistries "beyond Li-ion" such as lithium-sulphur, magnesium-ion, zinc-air and lithium-air among the possibilities, with energy levels significantly greater than those for current lithium-ion batteries and potential for further cost reduction. Further research however is required for this to happen.

Meanwhile, optimizing the geometry and chemistry of the battery cells is also a possibility. By doing so, Tesla aims for less cells in their coming Model 3 compared to the existing Model S. Combining increased battery sizes, which bring more power to each cell, with more efficient chemistry results in a higher energy density in each pack, requiring fewer cells for the same capacity.

Due to increasing demand, recycling of lithium from batteries has become more common and is expected to accelerate.

Should the momentum and the numerous initiatives that are observed today continue, the future is wide open for battery technology. By the time EVs are really expected to take off it is assumed that batteries will no longer be a bottleneck to EV adoption – on the contrary, a driving force, making EVs the preferred choice for consumers. However, if resource constraints on key components turn out to be relevant, the development could slow down.

Oil demand growth until 2030 despite high levels of electrification

The three scenarios suggest different pathways and drivers for development of the car fleet. In the *Reform* scenario the current momentum to reduce emissions continues. Tightening regulations and increased investments are the main drivers to improve EVs' competitive advantage compared to ICEVs. In *Renewal,* technological breakthroughs occur sooner, and are the main driver behind the electrification of the fleet. EVs become competitive at an earlier stage, rapidly becoming the preferred choice for consumers, regardless of government targets and subsidies. In *Rivalry*, due to increasing geopolitical unrest the global momentum on environmental efforts eases and capital is prioritized elsewhere. This leads to a slower growth in technology development and EV sales and a parallel development of technologies such as EVs and plug-in hybrids.

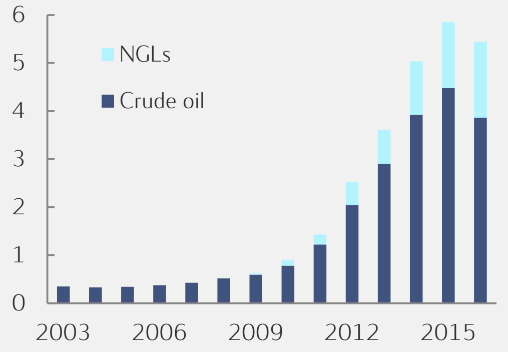
In *Reform* the EVI "20-by-20 target" is reached with a combination of fully electric and plug-in hybrid vehicles, amounting to a market share of around 2% of the global fleet. This is not enough to impact oil demand in any significant way. Following *Reform* assumptions on tightening emission targets from 2025 onwards, fossil fuel driven vehicles become increasingly less attractive. By 2025 a turning point is reached where EVs start capturing significant market shares. By 2030 the share of EVs in the global fleet reaches nearly 17%. By 2040 it is 45%. The sale of diesel cars, currently high in Europe, is nearly eliminated due to the adverse effects on local pollution. Gasoline cars remain an important part of the mix throughout the period. After 2030 there is a decline in demand for oil, as several markets become saturated in terms of personal vehicles, and the impact from changes in transport patterns such as car sharing and autonomous driving become visible. Also in the freight segment better utilization and more alternative fuels start having impacts.

Common for all scenarios is the continued growth in oil demand until mid-2020s, but after this period the pathways for *Renewal* and *Rivalry* become more distinct. *Renewal* has significantly higher growth in electrification of the LDV segment compared to *Reform*, with EV sales reaching close to 60% by 2030 and 90% by 2040. The impacts of urbanization and digitalization, and an increase in the use of public transport and services such as car sharing and autonomous driving, result in a slower growth in car sales. In *Rivalry,* due to lack of consensus and globalized efforts pulling in the same direction, there is a more fractured development of the car fleet. While some regions are able to prioritize greener technologies and the combatting of local pollution, others are not. It therefore takes longer before a high degree of electrification penetrates the fleet. Technologies such as hybrids, EVs and gasoline hybrids co-exist for a prolonged period of time.

Oil demand from freight transport remains robust

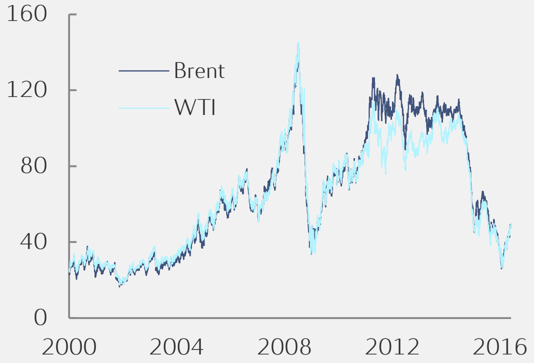
Despite a high share of electrification in the global light duty vehicle (LDV) fleet, total oil demand from transport remains robust for a sustained period, driven by continued growth in the passenger car fleets of non-OECD countries in the medium term as well as growth in the freight transport segment, where there is less potential for electrification, particularly in heavy trucking. Non-LDV share of total energy demand from transport was 58% in 2013 and the segment is expected to retain its importance. Oil demand for freight is unchanged in *Renewal*, but increases by 28% and 48% by 2040 in *Reform* and *Rivalry*, respectively.

US shale oil production
Mbd



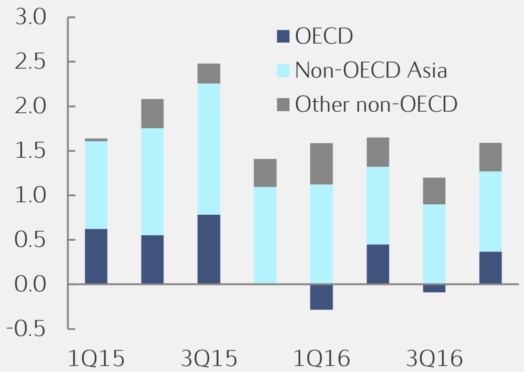
Note: NGLs figure is an estimate
Source: US EIA, March 2015, Statoil (projections)

Crude oil prices
USD/bbl



Source: Platts

Global oil demand
Quarterly y/y change, mbd



Source: IEA (history), Statoil (projections)

The global oil market

The aftermath of the US shale revolution

Build-up to a perfect storm (2011-2014)

The Arab Spring and the nuclear-related economic sanctions towards Iran in 2011-2012 generated supply disruptions of more than 3.0 mbd, and pushed oil prices above 110 USD per barrel (USD/bbl). This highly stimulating price environment encouraged the emerging US shale oil industry to undertake large expansions in shale production. From 2011 and up to mid-2014 the oil market was walking a tightrope between the supply disruptions and the shale oil revolution – clearly an unstable equilibrium. The further acceleration in US shale output in 2014, combined with the outlook for recovery of Iranian exports and Iraqi output gains, effectively forced Saudi Arabia to give up its traditional strategy of price defence – which has pushed the market into a process of fundamental rebalancing.

Oversupply, record high oil stocks, price collapse and recovery

After weak growth in global oil demand in 2014, oil demand growth recovered strongly in 2015. However, resilient US shale production, a continued rise in non-Opec supplies outside the US, and expansions in Iraqi and Saudi oil output pushed total oil supplies 2.75 mbd higher, and have up to 2Q16 kept the market consistently oversupplied. Although some of the surplus oil filled up new refineries and pipelines, and significant volumes flowed into strategic storage, the important price-setting OECD commercial oil stocks continued to rise up to 1Q16, which encouraged the market to push prices steadily lower. Brent prices reached a bottom below 30 USD/bbl in January, but prices started to recover in March on speculation that talks between Russia, Saudi Arabia and other Opec producers could potentially reduce the surplus. Despite unsuccessful freeze talks and strong gains in Iranian oil exports, reports of rising supply disruptions in Nigeria, Canada and Venezuela in April-May, as well as indications that the commercial oil stocks were levelling out, encouraged financial players to push oil prices higher and into the mid-40 USD/bbl range. The market view is that the point of rebalancing between oil demand and oil supply has come closer.

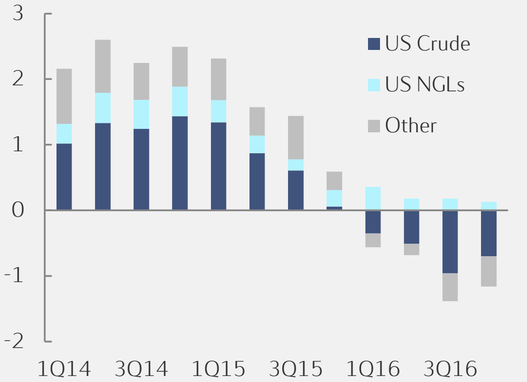
Low retail prices – and India – support oil demand

Despite unimpressive economic growth, lower retail product prices and colder than normal weather in 1Q15 pulled global oil demand up by 1.85 mbd in 2015, which was the third highest demand growth since the 1980s. China, India and the US, where retail prices fell significantly, contributed two thirds of the total demand growth, while oil demand in Russia and Brazil contracted moderately. The 2016 outlook is influenced by diverging factors. Milder than normal weather slowed 1Q16 OECD oil demand, but low oil prices are expected to continue to exert stimulus. The US economy has been up for a slow start, large parts of Latin America are struggling and the Middle East is hampered by low oil revenues. However, as Indian oil demand now appears to be growing at a rate 0.4-0.5 mbd, and faster than Chinese demand, non-OECD Asia oil demand as a whole is bound for an increase of 1 mbd in 2016. Net contribution from all other regions should take the global oil demand growth to 1.3 mbd in 2016.

Industry response – lower spending and large efficiency gains

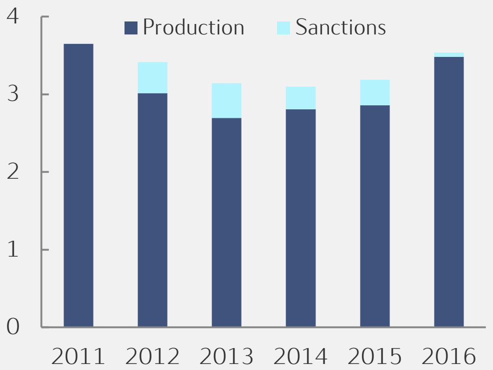
During 2015-2016, the oil industry has responded increasingly strongly to the slide in oil prices. In nominal terms global exploration and production capital spending fell by more than 30% in 2015 and is projected to fall by another 15-20% this year. The lower demand for all

Non-Opec production
Quarterly y/y change, mbd



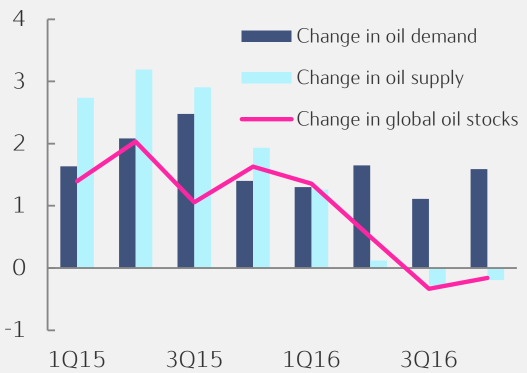
Source: IEA (history), Statoil (projections)

Iranian oil production capacity
Mbd



Source: IEA (history), Statoil (projections)

Global oil balance
Quarterly y/y change, mbd



Source: IEA (history), Statoil (projections)

types of supplier services in 2015 pushed the overall market supplier price index down by more than 20%.

Further spending cuts in 2016 suggest that the supplier market price index is likely to fall further, and, much neglected by the market, this means that the decline in upstream capital spending has been less dramatic in real terms than the headline/nominal numbers suggest. Moreover, most companies have also initiated comprehensive efficiency improvement programs. Anecdotal information suggests that the productivity gains have been large. Together with project optimizations, this has significantly lowered break-even prices of most unsanctioned projects.

Supply resilience up to end of 2015 – but prices are now biting

Despite sharply lower crude prices, US shale oil production showed resilience in 2015. Shale production peaked in April 2015, but production hardly fell until the very end of last year. Thus, average shale production in 2015 was 0.6 mbd higher than in 2014 – an impressive result given that the number of oil rigs fell by two-thirds up to the end of 2015. The implied large gains in the overall productivity of shale production were driven by reallocation of rigs to the most productive formations, and large improvements in well and rig productivity. However, the monthly decline rates appear to have accelerated in 1Q16, and the widespread view is that production should fall by 0.7-0.9 mbd this year. Outside the US, non-Opec production was even more resilient as several new fields came on stream, which more than compensated for the depletion of existing fields. It appears that most companies have given priority to sustain production in existing fields. In aggregate, production increased by 0.5 mbd in 2015, only marginally lower than the year before. However, as the wave of new fields is subsiding, depletion should tip total production in most regions into moderate decline.

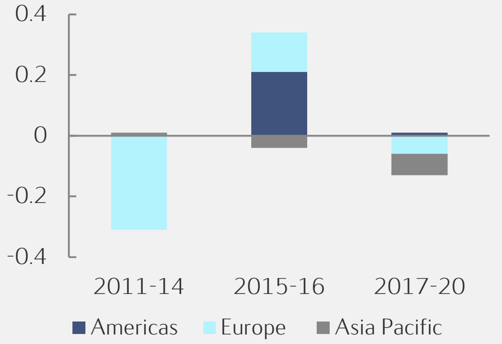
How much can Iran deliver in 2016?

Together with the US shale revolution, geopolitics-induced changes in Iranian oil production appear to become among the key drivers behind the oil market development in this decade. In the years prior to the economic sanctions (2012-2015) Iranian crude capacity and production were on a declining trend with an assessed crude capacity in 2012 of 3.6-3.7 mbd. In the sanction period crude production was relatively stable around 2.85 mbd. During 2015, Iran's oil minister Bijan Zanganeh reiterated that once sanctions were lifted, production would increase almost immediately by 0.5 mbd and by another 0.5 mbd at the end of 2016. Most experts were more cautious and reckoned that production should reach a maximum 3.5-3.6 mbd at year end. Following the lifting of the sanctions in January, production has increased steadily and reached around 3.5 mbd in April-May.

Towards alignment of supply and demand in late 2016

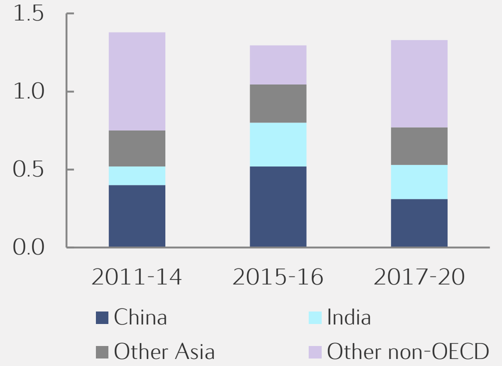
Despite further gains in Iranian and Iraqi oil production, the combined outlook for healthy growth in oil demand and a 0.7-0.9 mbd decline in non-Opec production means that after two years with large surplus, the global oil balance is approaching a turning point of alignment between demand and supply. Dependent on the level of supply disruptions, this could occur in 2H16. However, more than 300 million barrels of excess oil kept in storage in the OECD alone has to be removed before the market is fully back to normal – a process that will be volatile and take time.

OECD oil demand
Annual average change, mbd



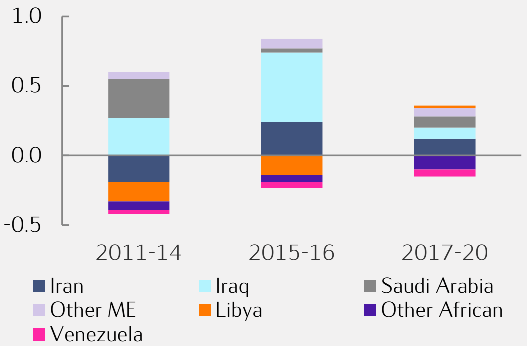
Source: IEA (history), Statoil (projections)

Non-OECD oil demand
Annual average change, mbd



Source: IEA (history), Statoil (projections)

Opec crude capacity
Annual average change, mbd



Source: IEA (history), Statoil (projections)

The medium term – towards a new, but different, cycle

Drivers that influence the shape of the next cycle

Commodity markets, including the oil market, certainly move in cycles. History shows that the shape of oil market cycles is particularly influenced by the market behaviour of Saudi Arabia, the size of oil stocks, the spare capacity buffer and the leads and lags in supply and demand. On top of that comes the influence from the wild cards of geopolitics and the inherently cyclical world economy. However, the emergence of the US shale industry, where the time lags between investment decisions and start-up of production are short, creates new dynamics and a new shape of market cycles compared with the past.

Trend growth in oil demand – if most emerging economies recover

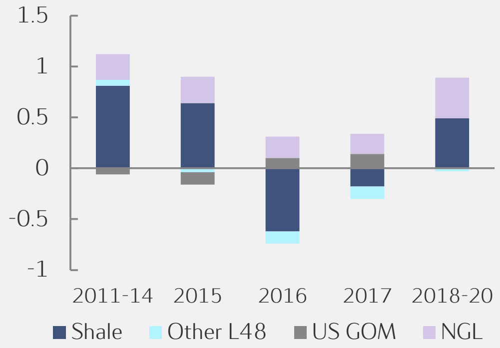
Up to 2020 OECD oil demand is expected to revert to the demand trends of moderate decline seen prior to the 2014-2015 price fall. After two years of tailwinds from low retail prices, headwinds in the coming years from higher retail prices and acceleration of fuel efficiencies should lead to stagnant US oil demand and declining demand in Europe and OECD Asia. The restructuring of the Chinese economy towards services has so far shifted the demand structure from diesel and other investment-led fuels to gasoline, jet fuel and LPG, without significantly reducing the growth rate of total products demand. However, as retail prices recover and the government continues to push for efficiency improvements and electric vehicles, overall demand growth may slow. The acceleration in Indian oil demand in 2014-2016 to an annual growth of 0.25-0.30 mbd could last for another year, but infrastructure bottlenecks and regulations to curb local air pollution suggest a lower demand growth over the subsequent years. In Russia, the Middle East, Brazil, and other Latin-American countries, where the economies are struggling, oil demand is vulnerable and uncertain. However, if the macroeconomic conditions normalize, global oil demand should rise annually by 1.1-1.2 mbd over the medium term.

Only moderate capacity growth in the Middle East

Given the huge resources of low cost oil, Iran and Iraq have the potential to undertake large crude capacity expansions. However, the challenging business environment in both countries means that the range of possible outcomes of capacity and production is wide. In a politically divided Iran, the pace of capacity development is critically dependent on the power base of the reform-friendly government of President Rouhani. Even if sufficient domestic support for the engagement of international oil companies (IOCs) can be mobilized and the IOCs are offered attractive economic terms, the negotiations with most IOCs are likely to drag on. Thus, after crude production has recovered towards full capacity in 2016, production will most likely grow only modestly over the next few years, but with scope for larger capacity additions in 2019-2020.

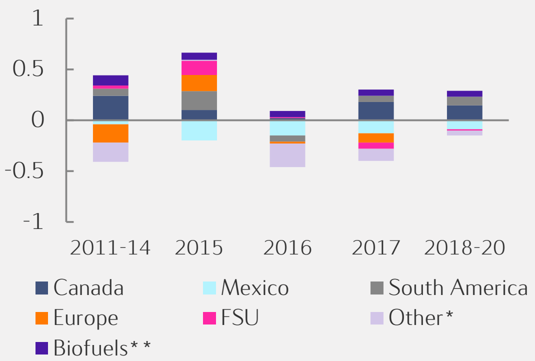
In Iraq, ethnically and socially divided, and periodically threatened by terrorists, the government's challenges of developing the oil sector are even more complex. Provided that the forces of fragmentation can be controlled, further expansion of Iraq's crude oil capacity is critically dependent on the level of oil prices and the government's ability to reimburse the IOCs' upstream investments. As before, development of new infrastructure and overall oil sector coordination are also needed. Moderately rising oil prices over the next few years suggest that moderate capacity expansions are within reach, but the uncertainties are numerous and large. Elsewhere in the region, Kuwait and UAE have plans for

US oil production
Mbd



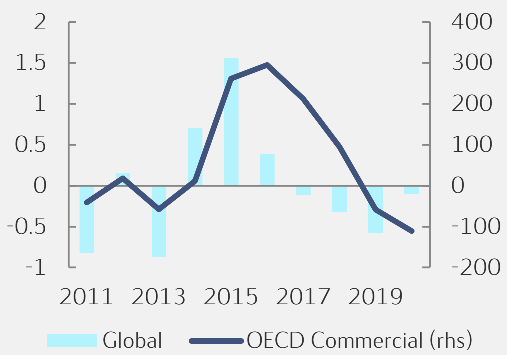
Note: US GOM includes Alaska
Source: EIA (history), Statoil, various sources (projections)

Non-Opec production outside the US
Annual average change, mbd



Notes: * Other includes Asia, Middle East and Africa;
** Biofuels includes processing gains
Source: IEA (history), Statoil (projections)

Change in oil stocks
Mbd (lhs), kbd (rhs)



Note: OECD Commercial shows deviations from the normal level of the period 2011-2014
Source: IEA (history), Statoil (projections)

further capacity growth, while the capacity outlook for Venezuela and the African members of Opec are negatively affected by the lower oil price level, which has not only led to reduced investments and delayed new projects, but also sparked social unrest and threatened the stability of several regimes. Amid mixed signals, it appears that Saudi Arabia does not plan for any significant increase in its net crude capacity over the next five years. In aggregate this means that Opec's crude oil production may rise annually by about 0.3 mbd over the medium term.

A second – but more moderate – wave of US shale production

After the first wave of strong, debt-financed expansion (2010-2014) and years of retreat and consolidation (2015-2017), the US shale industry is bound for a second wave of production growth. As prices recover and move through the 50 to 60 USD/bbl level, more of the non-core shale formations will reach break-even, which will encourage new drilling activity. However, the industry's retreat in 2016 has revealed a large share of heavily indebted companies, which means that cash flow and financing may become restraining factors. Moreover, it would probably take some time to mobilize new drilling rigs and personnel, which suggests that the production growth in 2018-2020 will be relatively moderate. After five years of expansion, US Gulf of Mexico production is expected to level out, while shale gas-based NGL production will continue to grow by about 0.2 mbd per annum.

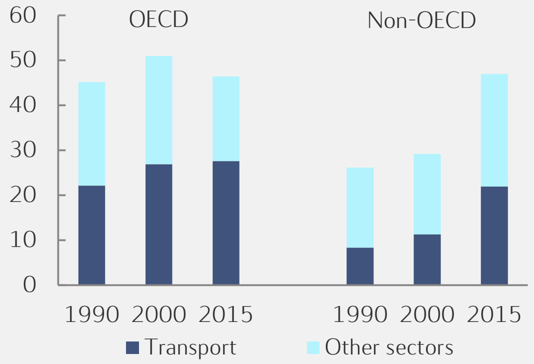
Non-Opec supply outside the US remains stagnant

Outside the US shale industry, a three to five year time lag between final investment decision and production start is the typical picture. This means that several larger fields decided in 2014-2015 will come on stream in 2017-2020, for example the much delayed Kashagan field, several Brazilian deep-water projects and the Johan Sverdrup field in Norway. Furthermore, after two years of moderately depressed level of real investments, capex is expected to recover in 2017-2020. Still, the industry's investment cuts will be felt and delays and underinvestment in 2015-2017 will lead to a period of stagnation in non-Opec production outside the US. The regional picture is however diverse with outlook for moderate output gains in Canada and in Brazil and moderate declines in Russia/FSU, China and most other Asian countries.

Towards a marked tightening

By adding up non-Opec oil, Opec crude, and Opec NGL/condensate supplies, where the latter is expected to increase annually by 0.1-0.2 mbd, total oil supplies should increase by about 1.0 mbd per annum in 2018-2021. As total oil demand is projected to grow by 1.3-1.4 mbd, including crude demand from new infrastructure and strategic storages, the oil market looks bound for a marked tightening from 2017 and onwards. Commercial oil stocks should shift from a position well above normal levels in 2015-2017 towards a moderate deficit in 2020-2021, and Saudi Arabia's spare capacity will remain on the low side.

Composition of oil demand
Mbd

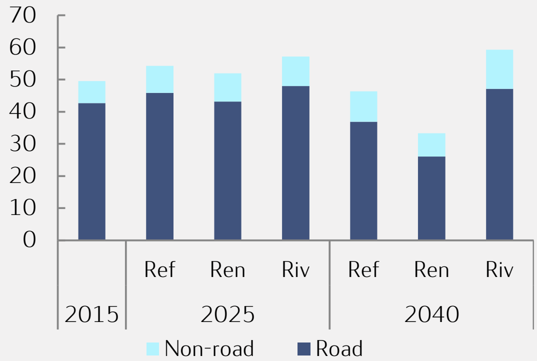


Source: IEA, Statoil

Changes in the transport sector will shape trends in the oil market

Source: pembrokeshireclassiccampers.co.uk, pinterest.com, carzz.co, Tesla,

Oil demand in the transport sector
Mbd



Source: IEA (history), Statoil (projections)

The long term – speed of EV penetration is key

Reform, *Renewal* and *Rivalry* define a wide range of outcomes

Mega-drivers like geopolitical cooperation, technological developments, demographic trends, dimensions of national and regional energy policy and the power and influence of Opec have for decades shaped the main trends of the oil market. In the same way, the various attributes of the three scenarios are foreseen to shape and potentially transform the structure of oil demand and the oil industry, with far-reaching implications for supply costs and the level of supply. Since more than 50% of global oil demand is consumed in the transport sector and oil products up to now have kept a monopoly position, this sector remains the backbone of oil demand. However, several forces on the horizon have the potential to undermine the market position of oil. The main features of the three scenarios are:

- *Reform*
  Electric vehicles (EVs) become competitive in the mid-2020s, which together with strong efficiency gains lead to stagnation in global oil demand around 2030. Steady expansions in Middle East and US shale oil supplies reduce the demand for higher-cost non-Opec supplies.

- *Renewal*
  Very rapid penetration of EVs, driven by sharper reductions in battery costs, and broad-based governmental incentives, pull the peak in oil demand forward to 2025, and thereafter push the level of oil demand steadily lower. Together with ongoing capacity expansions in Middle East and in most US shale oil plays, this lowers the need for oil supplies from other regions.

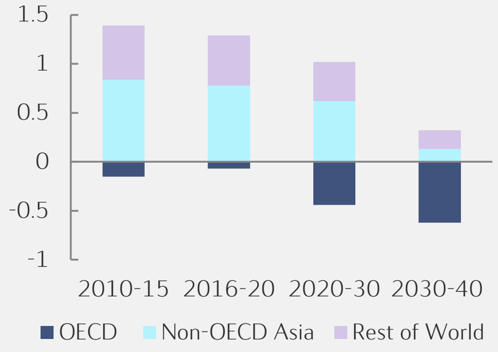
- *Rivalry*
  The combination of steady oil demand growth, driven by slow improvements in energy efficiency and moderate market share losses for oil, and large Middle East supply disruptions and low capacity growth, require large contributions from higher-cost non-Opec supplies to balance the market.

Demand from other sectors support oil demand growth

As described in the chapter on transport, the momentum behind electrification is strong and new engine technologies have the potential to make strong inroads into the market position of oil in transport – particularly in the LDV segment. However, for other sub-segments within transport the pace of technological development, and hence the impact on oil demand, is likely to be slower. Heavy trucking is expected to grow in line with increased economic activity and trade. Fully electric heavy duty trucks are quite some way off, due to the sheer size and weight of these vehicles, demanding significantly stronger battery capabilities than LDVs. Technology is continuously being developed to optimize driving patterns and increase fuel efficiency; however oil is still expected to be the dominant fuel throughout the forecast period. Despite increasing shares of LNG and electricity, oil demand still constitutes 80% by 2040.

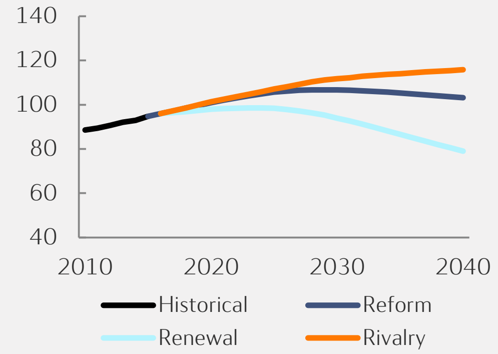
Similar to trucking, demand for non-road transport such as marine, aviation and rail is expected to rise as global population grows and economic activity increases. In all three sub-sectors combined energy demand is expected to grow by nearly 60% from 2015 to 2040. Despite an increased use of LNG in shipping and electrification in rail, demand for oil

Global oil demand: ***Reform*** **scenario**
Annual average change, mbd



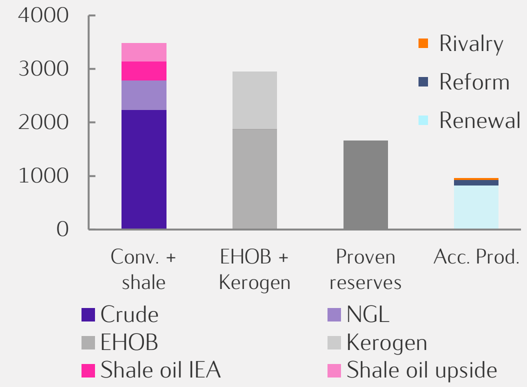
Source: IEA (history), Statoil (projections)

Global oil demand
Mbd



Note: includes biofuels
Source: IEA (history), Statoil (projections)

Recoverable oil resources
Billion barrels



Notes: EHOB denotes Extra Heavy Oil and Bitumen;
Acc. Prod denotes accumulated production across scenarios
Source: IEA, WEO 2015, OGJ, Statoil

is expected to grow by 65%, still retaining a significant share of 70% of total non-road energy by 2040. The rest of the transport sector will therefore be supporting a continued robust growth until 2030, when the impact from electrification of the LDV segment, combined with higher shares of alternative fuels and energy efficiencies in non-road and trucking will be significant enough to decrease demand for oil in transport.

Oil demand – towards 80 mbd, 100 mbd or 115 mbd by 2040?

Oil demand in other sectors than transport continues to be driven by economic growth, energy efficiency and inter-fuel competition. The momentum of these forces differ considerably between the scenarios and are discussed above. Given the outlook of decelerating oil demand growth in the transport sector, the non-energy sector, where petrochemicals represent the lion's share, becomes the most rapid growing sector for oil. Demand growth for petrochemical products is expected to remain high and the potential for energy efficiency is relatively limited. Therefore demand for petrochemical feedstock rises steadily, from 15 mbd in 2015 to about 24-27 mbd by 2040, dependent on the scenario. The energy and oil demand simulations of *Reform*, *Renewal* and *Rivalry* depict a wide range of outcomes. From an oil demand level around 100 mbd by 2020, demand growth in *Renewal* slows dramatically in the first part of the 2020s, before it goes into steady decline in the subsequent years. In *Reform,* where the losses of market share are less dramatic, global oil demand peaks at 106 mbd around 2030 and falls moderately through the 2030s. In *Rivalry,* where efficiency improvements and the losses of market shares in all sectors are moderate, oil demand continues to grow through the 2030s, but levels out at 115 mbd in 2040.

Potential effects on the oil industry and the supply side

Uncertainties about the demand outlook raise crucial questions about the resource picture, oil producers' strategies and the global oil supply:

- **Economically recoverable resources**
  Historical experience clearly suggests that the size of remaining recoverable oil resources is not given, but highly dependent on oil prices. But still, will the economically recoverable oil resources in a lower price environment be large enough to support a high level of oil demand up to 2040 and beyond?

- **Depletion strategies of key Middle East producers**
  Will perceptions about an early peak in oil demand in the large resource rich and low cost producers of the Middle East lead to a change in their depletion and economic development strategies? And can the region overcome the above-ground challenges?

- **Strategies of international oil companies**
  How will the international oil companies respond to the new uncertainties and challenges? How much should be invested, and where, and which technology strategy should be chosen? Should long-term exploration activities be stepped up or down?

Clearly the strategic choices of key countries and the international oil industry – in a fast changing and particularly challenging business environment in the Middle East – will be crucial determinants of supply costs, supply volumes and oil price formation up to 2040 and beyond.

Saudi Arabia's Vision 2030

The high oil prices in 2011-2014 camouflaged the fact that Saudi Arabia has been on an unsustainable economic pathway since the mid-2000s. Although the kingdom has run a comfortable, but declining, current account surplus in the years up to 2014, other macroeconomic indicators have been less balanced.

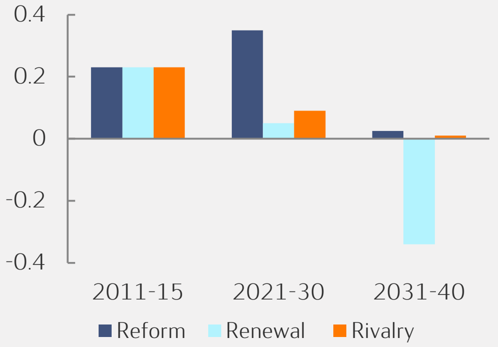
Unemployment, especially among the younger generations, has been steadily rising and has reached alarming levels. Furthermore, driven by higher welfare spending, energy subsidies and other inefficiencies, the central government's budget shifted from the normal surplus position to deficit in 2014. On top of that, both total exports and the government's total revenues have been almost entirely (85-90%) dependent on oil revenues. The oil price collapse in 2014-2016 has fully revealed and aggravated these structural weaknesses. For 2016, the current account and fiscal budget look to reach a deficit close to 10% and 15%, respectively.

The aspirations of Vision 2030 are to address the structural weaknesses and to diversify the economy, to be less "addicted to oil" and to revitalize the non-oil economy. The main instruments of the vision include:

- Limited (up to 5%) privatization of Saudi Aramco.
- Establishment of a Public Investment Fund (PIF) with a role like traditional sovereign wealth funds; of investing both in the domestic economy and abroad. The PIF is seen as one of the key vehicles of revitalizing the non-oil sector.
- Tax increases, spending cuts, efficiency drives and general initiatives that allow for a larger role for the private sector.

A *National Transformation Plan* will be announced in June. The plan is expected to reveal more concrete steps and details about the implementation of the vision.

Opec production capacity
Annual average change, mbd



Source: IEA (history), Statoil (projections)

Technically recoverable resources are sufficient

The US Geological Survey's assessments are the key source for most institutions' estimates of the remaining technically recoverable oil resources. On this basis, IEA estimated in 2015 the total remaining recoverable conventional crude resources at 2,200 billion barrels (bb) and NGL at 560 bb, an upward revision of 72 bb since 2014. The estimate of total recoverable crude resources consists of known oil of 900 bb, reserve growth and yet-to-find resources of approximately 650 bb each. For the recoverable resources of unconventional oil of 3,300 bb, including shale oil, extra heavy oil and kerogen oil, IEA's 2015 estimates are unchanged, but they are on the conservative side compared with other institutions. The estimates of the future reserve growth and yet-to-find resources have always been a subject of discussion. However, even if a cautious estimate (P95) is applied for reserve growth and yet-to-find, the remaining technically recoverable resources are – globally – sufficient to cover accumulated oil supply of 0.8-1.0 bb in the three scenarios. The size of the economically recoverable resources depends on technological improvements, oil quality issues, other cost drivers and tax regimes and ultimately the level of oil prices. If access to the large known resources of the Middle East is constrained, prices may – if necessary – move higher to incentivize shale oil developments in all regions, as well as enhanced recovery of conventional oil and/or more exploration.

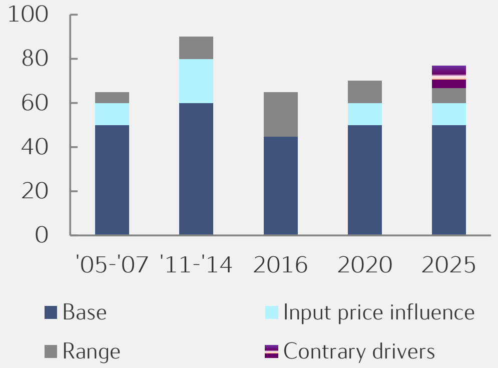
Saudi Arabia – diversification is a long-lasting process

In April 2016 the Saudi leadership, with Deputy Crown Prince Mohammed bin Salman in the lead, put forward goals for a far reaching transformation and diversification of the Saudi economy in its "Vision 2030". Although this is not the first time Saudi leaders have revealed aspirations to become "less addicted to oil" and create new pillars for the economy, the circumstances are different this time. The overall Saudi economy is on an unsustainable trend and the oil market is more uncertain than ever. Furthermore, it appears that Mohammed bin Salman has the courage to start the challenging process of change. Although the vision is limited to economic reforms, implementation could probably meet resistance from several vested interests, which will clearly slow down progress. The privatization of Saudi Aramco will provide extra funds, but Saudi Arabia will remain dependent on oil and a high level of export revenues for several years to come. Most likely the speed of the diversification drive and upstream investments will also be a function of the crude price level and oil market outlook. In *Rivalry,* where oil prices are relatively high, crude production capacity could be lifted above the current capacity of about 12 mbd, while *Renewal* incorporates a lower level of upstream investments.

The Middle East production – restrained by instability and market

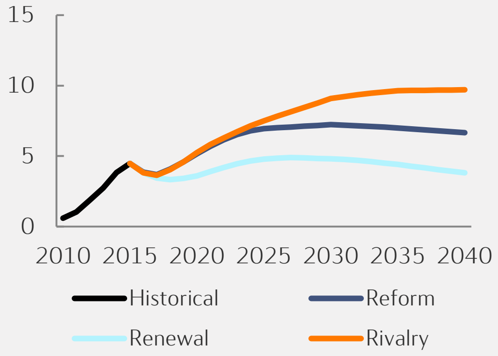
For several decades oil producing countries like Iraq, Libya and Syria were governed by autocratic regimes that kept the underlying sectarian and political conflicts suppressed. However, the toppling of Saddam Hussein's regime in 2003 and the Arab Spring have not only led to the destabilizing of several countries, but also to a shake-up of the power balance in the region between the two opposing powers, Saudi Arabia and Iran, which has bolstered the long-lasting mistrust between Sunnis and Shias. Most observers only see a continuation of the historical trends of sectarian conflicts, further fragmentation of nation states and outlook for more semi-autonomous areas, where the business environment remains unstable and the risk of supply disruptions is high.

Supply costs outside the Middle East
USD/bbl



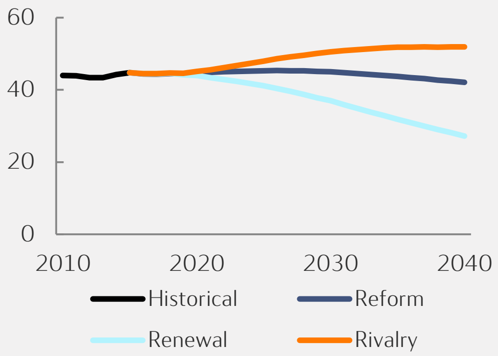
Note: 'Contrary drivers' refers to the net effect of efficiency gains, smaller or more remote fields, and fiscal regimes
Source: Statoil

US shale oil supplies
Mbd



Source: IEA (historical), Statoil (projections)

Non-Opec supplies
Mbd



Source: IEA (historical), Statoil (projections)

In Iran and Saudi Arabia where a higher level of stability is assumed, oil policy and the overall business climate remain the critical determinant of oil capacity development. However, in *Reform,* and even more protractedly in *Renewal*, with outlook for slowing oil demand growth in the 2020s, the capacity additions in Iran and Iraq have to be weighed against negative market and revenue effects. In *Rivalry*, where a high level of instability is assumed, which restrains Iraqi oil production, Saudi Arabia may choose to expand its crude oil capacity beyond 12 mbd.

Supply costs outside the Middle East

The projected level of oil demand and oil production from the Middle East and North Africa, where full-cycle costs (FCC) of new capacity are relatively low, define the call for oil production from the rest of the world. Prior to the price shock, the FCC of higher-cost non-Opec supplies, like Canadian oil sands, ultra-deep water and Arctic supplies were widely assumed to be in the 80-90 USD/bbl range. The sharp fall in most supplier market prices and the industry's simplification and efficiency efforts over the last two years, have substantially reduced the supply costs in all regions. Oil company officials now indicate that the FCC of the current generation of typical new projects could be as low as 40-60 USD/bbl. However, a large share of cost reductions come from the cyclical gains of the supplier markets. After the recovery of upstream spending and normalization of the supplier markets in 2017-2020, the development of FCC will mainly be driven by the race between technology and efficiency improvements and the underlying trend of smaller and more remote fields forming part of the supply portfolio, which lifts supply costs. History clearly suggests that the level of oil prices and intensity of industry competition are key drivers behind the rate of efficiency improvements. Thus, the lower level of crude prices in *Renewal* will exert a strong downward pressure on supply cost, while large volumes of higher-cost oil are needed in *Rivalry*.

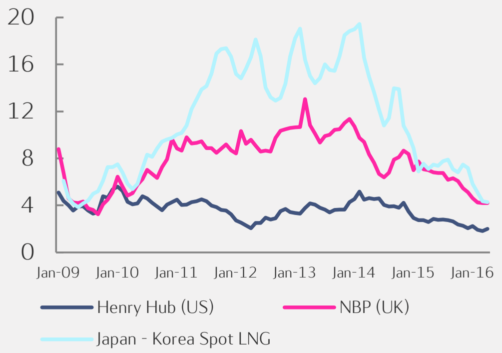
If needed, US shale oil remains a key source well into the 2030s

Since the take-off of US shale oil production at the start of this decade, the estimates of the remaining recoverable shale oil resources have been revised up every year, and despite the current activity setback, several industry sources and companies have revised the resource base further up this year. The FCC of most formations appear to be in the range between 50 and 80 USD/bbl, which mean that future production levels depend on the price level assumed in the three scenarios. In *Reform* and *Rivalry* US shale production of crude and condensate will grow from 4.5 mbd in 2015 to 7.2 mbd and 9.5 mbd, respectively, while the expansion will be more moderate in *Renewal*. On top of these volumes comes 0.5-3.0 mbd of additional NGL production, dependent on the scenario.

Other non-Opec provides the residual volumes

With the exception of small volumes of high-cost production in some Opec countries, total non-Opec supplies are mainly determined by the residual between oil demand and Opec supplies. In *Reform* and *Rivalry* most of the US shale oil resources are believed to be economic, which means that non-Opec production outside the US has to provide the residual volumes. Production is stable at around 45 mbd in 2015-2020 and rises towards 52 mbd in *Rivalry* to replace capacity shortfalls in the Middle East, but falls moderately in *Reform*. In *Renewal* both US shale oil, oil sands and conventional oil production outside the US have to take a big hit, as oil demand falls sharply during the 2030s.

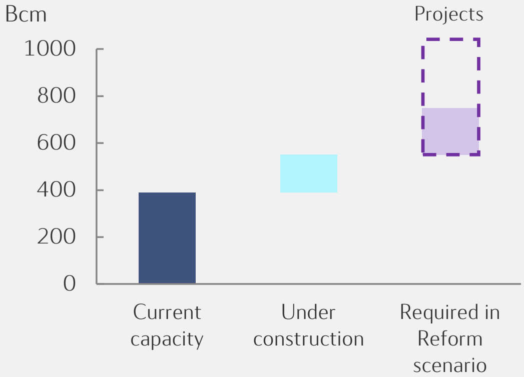
Regional gas price markers
January 2009 - April 2016, USD/MMBtu



Source: Platts, ICIS Heren, NYMEX

Regional gas prices are more correlated than they have been for many years

LNG liquefaction capacity by 2040: surplus or deficit?



Source: Statoil

Commitment to climate change has implications for natural gas demand

The global gas market

Setting the scene – what are the issues?

The fall in oil and natural gas prices

The global gas market is awakening to a new reality of low gas and energy prices. The new price environment could have profound impacts on the industry, market fundamentals, trade patterns and pricing. Lower prices should as such spur gas demand, but so far there are few signs of incremental price-sensitive demand outside North America and some countries in Asia. In China, LPG has replaced gas in certain sectors due to a misguided price reform. Low oil prices are slowing down the penetration of gas in the transport sector. In Europe, generators lack incentives to switch from coal to natural gas as coal and carbon prices have plummeted as well.

Gas value chains are typically capital intensive and have long lead times, and the industry and host nations are reassessing projects. Focus is often on the large projects, such as LNG liquefaction schemes, but the industry is also cutting exploration activity, which will eventually result in lower production levels. It is expected that over the medium term the industry gradually will regain confidence in the market and resume investments. Costs are down from recent highs, in some countries also helped by tax breaks and depreciation of the local currency.

The global LNG market is primed for change

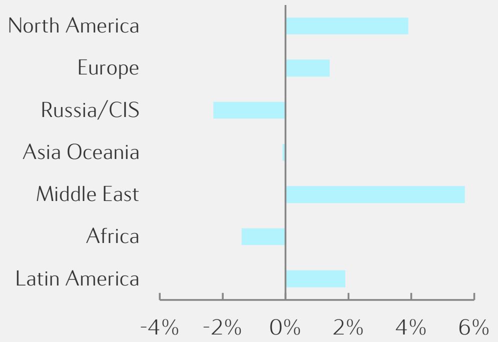
A critical question is whether new gas supplies will be developed in time to meet future forecasted demand, or if the current gas surplus will turn into a deficit and a tight market? The global LNG market is exposed to boom-and-bust cycles. World liquefaction capacity is expected to increase by 50% between 2014 and 2020. The underlying growth in world LNG demand is itself not sufficient to absorb the scheduled growth in supply, but markets need to balance. Europe will need to play an important role in balancing the global LNG market due to its underutilized regasification capacity, liquid gas markets and flexible pipeline supply and storage.

LNG projects still have to conclude bilateral long-term contracts in order to secure finance. However, buyers are looking for more flexible terms. Although low oil prices have made it less urgent for buyers in Asia to diversify away from oil-indexation, the dominant view is that indices to a larger extent should reflect gas market fundamentals. Due to sluggish demand, many gas buyers in Asia have contracted more LNG than needed and are now offering cargoes into the spot market. This highlights the need for contracts with destination and volume offtake flexibility. The start-up of Cheniere Energy's export plant at Sabine Pass in Louisiana, liberalization of gas and power markets in Japan, and the LNG "glut" resulting from new capacity in Australia and elsewhere should accelerate the transition of global LNG into a more regular commodity market.

Climate policies and natural gas

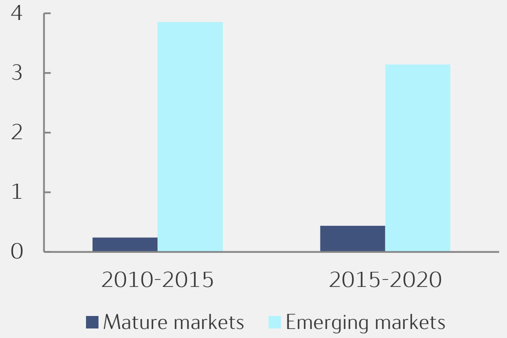
COP21 and the NDCs were not specific on the role of gas going forward, but many country targets promise a significant role for gas. World gas demand is rising in the *Reform* and *Rivalry* scenarios, but not in *Renewal*,

Changes in gas consumption by region in 2015
% change in apparent consumption from 2014



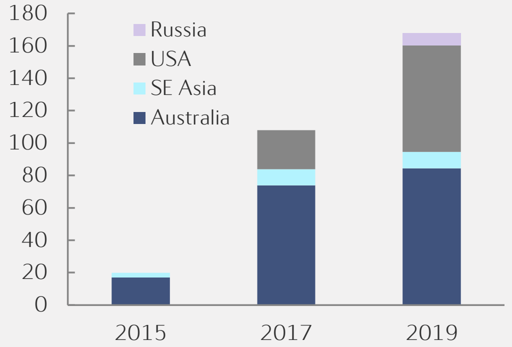
Note: Apparent gas consumption = Marketed production + Imports - Exports
Source: Cedigaz

Gas demand growth by market segment
Annual growth rates in % (CAGR)



Note: Mature markets = OECD, Russia & FSU
Source: IEA (history), Statoil (projections)

Indicative LNG capacity additions by 2019
Bcm, cumulative addition at year end vs. end of 2014



Note: Excluding re-starts & smaller projects
Source: Statoil

suggesting that the long-term target of transition to a fully sustainable low-carbon energy system constitutes a downside risk to gas demand. Overall, lower energy demand and faster penetration of wind and solar weigh on gas demand.

Outlook to 2020

Emerging markets drive gas demand growth rates

CEDIGAZ – the international association for natural gas – estimates global gas consumption growth at 1.6% in 2015. This represents an uptick in growth after stagnation in 2014. One reason was a weather-driven recovery in gas consumption in Europe. North America and the Middle East had growth rates above the trend. Apparent gas consumption was stable in Asia Oceania, and contracted in Japan and Korea, whereas growth slowed down to 3% in China.

World gas demand increases by 1.4% per year in *Reform* and *Rivalry*, and at a somewhat slower pace in *Renewal*, between 2015 and 2020. OECD Americas is a mature market with potential, but medium-term demand growth is concentrated in China, India, the Middle East and Africa. Europe, Russia, OECD Pacific and Latin America are only delivering modest or negligible growth.

The global LNG market is depressed by mounting supply

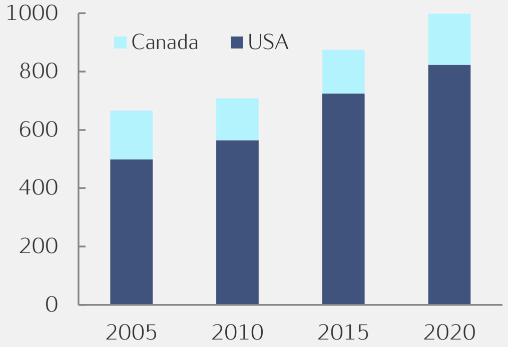
Large investments in LNG export plants over the past six years are showing up in rapidly growing supply. This is already weighing on LNG prices. Global liquefaction capacity is expected to grow by around 180 bcm or 50% between 2014 and 2020. Over the last two years, six large LNG projects have commenced operation in Papua New Guinea, Australia and in the US Gulf of Mexico. Additional projects are under construction in Australia and the US, and also in Russia and Southeast Asia. Some existing LNG producers are facing political unrest or feed-gas issues. Egypt, an LNG exporter until 2014, imported significant volumes in 2015. Indonesia added a smaller liquefaction unit in 2015, but is diverting cargoes from exports to domestic use.

Mixed outlook for Asian gas demand

Gas demand in Japan and South Korea contracted by 10 bcm in 2015 and may remain on a downward trend for the rest of the decade. Higher nuclear availability, not only in Japan, and commissioning of new coal-fired generation in South Korea, will squeeze gas out of power generation. Renewables (solar power gains momentum in Japan) and lower than expected demand for electricity further aggravate the outlook for gas demand in the power sector.

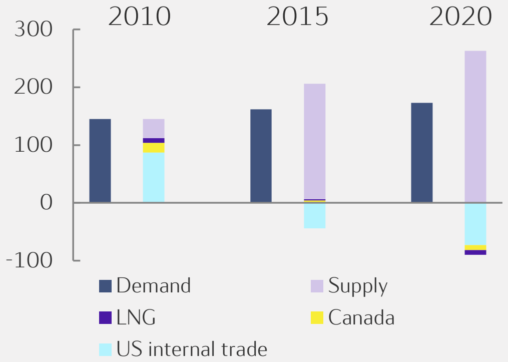
After years of double-digit growth, gas consumption in China grew by only 3% in 2015. Soft demand was a result of sluggish economic activity and a price reform leaving gas uncompetitive in the industrial sector. Weaker than expected demand has turned China from a supply-constrained to an over-supplied market. Indian gas demand is price-sensitive and low prices should allow gas to replace naphtha in the petro-chemical sector, fuel oil in industry and LPG in cities. However, growth is conditional on new regasification terminals and that connecting pipelines are in place. The diverse group of countries in South and Southeast Asia plus Taiwan use roughly as much gas as China and India combined. Despite economic growth and constrained energy supplies, gas will need

US and Canada gas production
Bcm



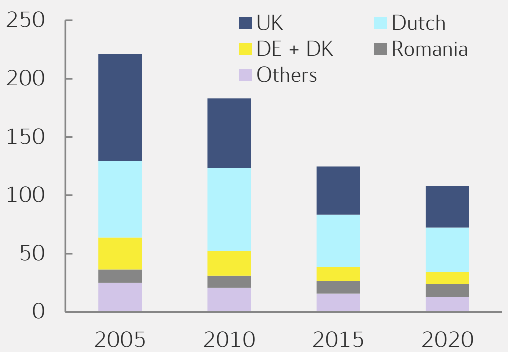
Source: IEA (history), Statoil (projections)

US Northeast gas balance
Difference between trade and LNG export/import, Bcm



Source: EIA (history), Statoil (projections)

European indigenous gas production (excluding Norway)
Bcm



Source: Statoil, compiled from various sources

to defend existing and capture new markets from coal, LPG and fuel oils – and defend against growing competition from new renewables. Some countries are struggling to maintain domestic output. Thailand intends to curtail domestic production due to limited resources and instead step up LNG imports. Nonetheless, a growing import share may make governments less inclined to pursue ambitious gas penetration schemes.

Structural demand growth in North America

A multi-year wave of gas supply growth in the US came to a temporary end in 2015. Producers responded to low prices by withdrawing rigs. Medium-term gas production will have to resume catering for both higher domestic demand and for exports. Dry gas production is seen by the US Energy Information Administration (EIA) to grow from 750 bcm in 2015 to around 820 bcm in 2020. The industry will develop the most economic plays, often in the Marcellus/Utica formations. Rising production in the Northeast far exceeds local demand growth and will require infrastructure expansions in order to ensure outlets to markets to the west and south.

The next five years will see a number of structural changes that will translate into higher demand for US gas. LNG export plants now under construction could absorb 80 bcm of gas by 2020, and will be supplemented by significant pipeline exports to Mexico. The migration of gas-intensive industries to the US and permanent closures of coal-fired generation will result in higher domestic gas demand. Tougher greenhouse gas policies and competitive prices are incentivizing generators to turn to gas. For the first time, natural gas exceeded coal use in the power sector during most of 2015.

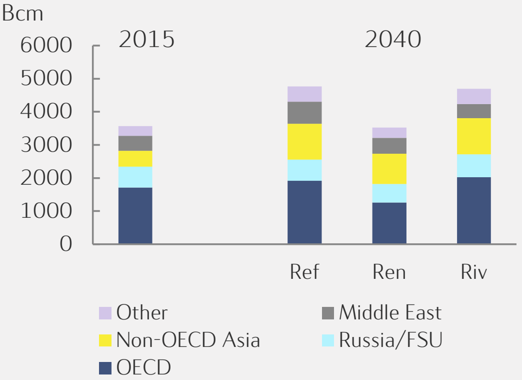
Mexico's gas demand also shows robust growth across scenarios. The government is promoting the use of gas in power generation, low-efficiency oil-fired power plants are converted to gas, and new plants are built. A reform of the energy sector facilitates inter alia investments in new pipeline infrastructure. Domestic production is facing headwinds; thus a doubling of pipeline imports from the US is a cost-efficient way to meet the requirements. Gas demand in Canada is muted. A struggling oil sand industry consumes less gas than previously expected.

Europe needs some new gas volumes

Gas consumption in Europe regained ground in 2015, but much of the increase was attributable to weather patterns. Demand is expected to remain subdued except for some growth potential in power due to closures of coal-fired generation capacity. Gas prices have not entered the coal-switching range; only in the UK have gas plants regained competitiveness towards coal thanks to an additional carbon tax. Continued growth in renewable generation and muted demand for electricity are dampening the use of thermal power plants in many parts of Europe.

The recent sharp fall in EU gas production is levelling off. Near-term developments will depend on Dutch policy on Groningen production levels. UK gas supply could for some time remain at current levels as new fields come on stream. Norwegian gas production is expected to stay above 100 bcm per year for the rest of the decade. Algeria struggles to raise output and curb growth in domestic demand. The start-up of the second stage of the Shah Deniz field in the Caspian Sea should lift imports from Azerbaijan towards 2020. Russian pipeline gas along with LNG will meet

Gas demand in 2040 by region

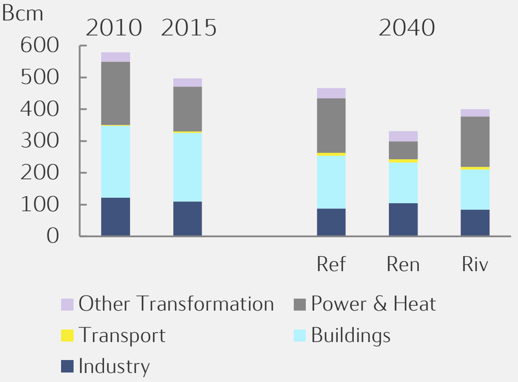


Note: OECD includes non-OECD Europe

Source: Statoil

Continued growth in world gas demand is at risk in the *Renewal* scenario

European gas demand by sector



Source: IEA (history), Statoil (projections)

Both *Reform* and *Rivalry* show steady gas demand growth in the forecast period

the remaining requirements for gas in Europe. Gazprom has a large surplus of production capacity and apparently has an ambition to maintain a market share of 30% of European gas supply. LNG imports to Europe in 2015 were roughly halved since 2011, but are now growing thanks to ample supplies.

The long-term outlook

Large variation in global gas demand across scenarios

Gas demand and supply developments towards 2040 differ strongly across the scenarios. Two of them, *Reform* and *Rivalry*, see continued healthy growth in demand. The third, *Renewal*, is characterized by stagnant demand. Global gas consumption increases from its current level close to 3,600 bcm to more than 4,700 bcm by 2040 in *Reform*, i.e. by 1.1% per year, and to a slightly lower level in *Rivalry* which portrays a more volatile world discouraging gas use in import-dependent regions. However, the share of gas in world primary energy demand increases from 22% in 2015 to around 24% in both of these scenarios.

Gas demand remains almost stable over the forecast period in the *Renewal* scenario. Although natural gas has a lower carbon footprint than oil and coal, it is only India, and for a period China – two emerging economies heavily reliant on coal – that use more gas in *Renewal* than in *Reform*. In all other regions, decarbonization of generally more energy-efficient economies results in lower gas demand. By 2040, one out of three cubic meter consumed in the OECD region, most sensitive to the climate challenge, is lost in the *Renewal* compared to the *Reform* scenario. Demand growth in emerging gas markets worldwide is just sufficient to compensate for losses in the mature markets of OECD and Russia/FSU.

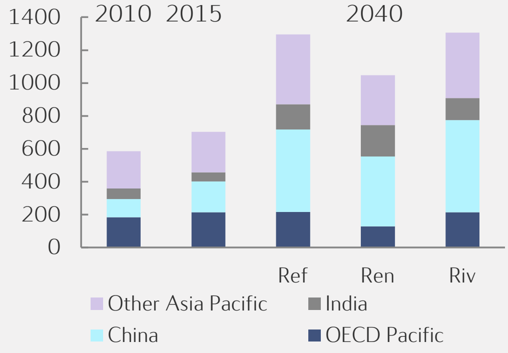
Security of supply, which is a concern for gas importing countries, moves up on the agenda in the *Rivalry* scenario. Leaving aside attempts to diversify the supply mix and not become too dependent on a single supplier, the fall in European gas demand is deeper in the *Rivalry* scenario than in *Reform*. Conversely, OECD Americas and Russia, two regions with significant indigenous resources, use more gas at home. The Middle East – the region hardest hit in the *Rivalry* scenario – also relies less on gas. In a constrained environment non-associated gas projects are not developed, and it is challenging to realize inter-regional trade solutions or even LNG import terminals.

Supply often responds to demand

Lack of demand rather than lack of resources will shape the global gas market in the decades ahead. Gas production will mirror – and also shape – gas demand. The *Reform* scenario assumes growing supplies in all world regions except Europe. Russia's pivot to China gains momentum in the *Rivalry* scenario as Europe imports less gas and China more. China and other gas importers also incentivize local production and thereby replace imports from countries perceived to be politically less stable. Gas trade falls, and some new export schemes such as a pipeline from Iran to South Asia do not materialize.

The *Renewal* scenario needs a significantly smaller gas supply industry. OECD Americas gas production contracts as the rise in LNG exports does not compensate for a fall in local gas demand of 200 bcm between 2015 and 2040. Russian gas production decreases by more than 100 bcm over

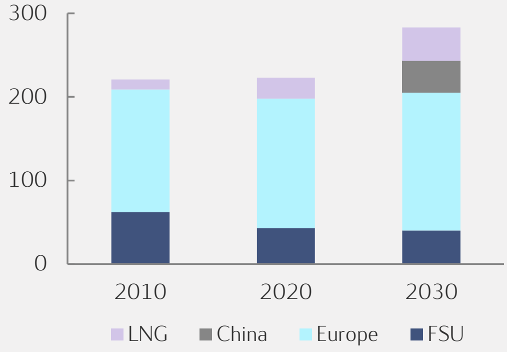
Asia Pacific gas demand
Bcm



Source: IEA (history), Statoil (projections)

Robust gas demand growth in non-OECD Asia in all three scenarios

Potential Russian pipeline gas and LNG exports
Indicative "consensus" view, Bcm



Source: Statoil compiled from OIES, Cedigaz, and others

The growth impulses for Russian gas production will come from China and LNG

the period due to lower local demand and less exports to Europe, with the EU succeeding with its decarbonization agenda. Producers serving traditional pipeline markets face stiffer declines than LNG exporters. The reason is that gas markets in Asia Pacific grow by close to 300 bcm in the *Renewal* scenario even allowing for contracting gas demand in Japan and South Korea. LNG imports to Asia rise beyond the surge caused by LNG liquefaction projects now under construction and that come on stream by 2020. Potential LNG developers nonetheless face tougher times. The *Renewal* scenario requires fewer projects to meet demand, and expensive LNG value chains are most exposed to being deferred or cancelled.

Asian gas demand drives global gas markets

Asia consumed around 700 bcm of natural gas in 2015, a fifth of the world total. OECD Asia Pacific has at best limited long-term growth prospects, whereas the region's non-OECD markets – China, India and South and Southeast Asia – are forecast to show the strongest growth rates. These vary between 2.9% per year over the 2020 and 2040 period in the *Reform* scenario and 1.4% in the *Renewal* scenario. By 2040 Asia Pacific gas demand reaches 1,300 bcm, equal to 27% of the world total in the *Reform* scenario, and 1,050 bcm, as much as 30% of the world total in the *Renewal* scenario.

In most local markets in non-OECD Asia, natural gas will play a more prominent role as time evolves, but there are hurdles that can impede a trend towards gas. Gas penetration is supported by a diversified supply mix. China is one example enjoying domestic gas, pipeline imports from Central Asia and Russia, and LNG. A number of countries are less fortunate and face declining indigenous production. A higher share of imports typically raises the weighted average cost of gas in a country. Industry uses more gas by 2040 in the *Renewal* scenario, power generators less, except in India. More renewables (and nuclear in China) is the answer to the climate challenge, not natural gas.

Mixed interest for Russian and Caspian gas

Russia possesses the resources to cover domestic demand, step up gas exports to Europe and establish itself as a key supplier to China and the global LNG market. Growth can however not be taken for granted. Russian domestic gas demand declines in *Reform* and *Renewal* due to a huge energy savings potential and slow economic growth, but recovers in *Rivalry* to a level close to the current level. In any event, new fields have to be developed on the Yamal Peninsula and in Western Siberia in order to replace falling output from the legacy fields in Nadym-Pur-Taz. Europe remains the key destination market for Russian gas exports, even though EU gas demand declines due to economic, climate policy and security of supply issues.

Beyond Yamal LNG, few Russian LNG projects move ahead in the scenarios. Reasons include a well-supplied LNG market and Western sanctions. The pivot to Asia materializes but on a lesser scale than previously expected, the main reason being slower demand growth in China. The Power of Siberia pipeline starts delivering gas around 2021, ramping up to annual exports of 38 bcm during the decade. Moscow is eager to supply China with Western Siberian gas, but Beijing targets smaller volumes of Sakhalin gas for the North-eastern provinces of China. Projects targeting China are more likely to go ahead in the *Rivalry*

EU heating and cooling strategy

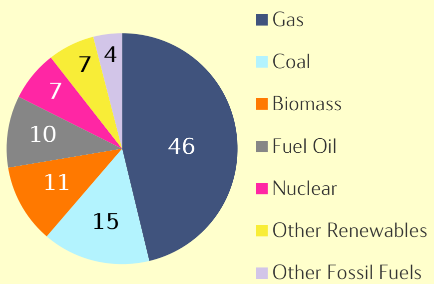
The EU heating and cooling strategy was released in February 2016 as the first EU initiative addressing the use of energy for heating and cooling in buildings and industry. Energy for heating and cooling in buildings and industry accounts for 50% of the EU's annual energy consumption, and 75% of the energy comes from fossil fuels. The EU's climate goals call for a full decarbonization of the sector by 2050 and that the overall energy consumption in the sector is cut by half.

There is certainly a large potential for reducing energy consumption from heating and cooling. Buildings in EU are in general old; almost half have boilers installed before 1992 with an efficiency rate of below 60%. Natural replacement of old boilers will make the use of natural gas more efficient, and coal and oil boilers will continue to be phased out. Building refurbishments will reduce the overall requirement for energy for heating and cooling and new buildings will be much more efficient than existing ones. There is also a substantial waste of heat energy from industry.

The main challenge for EU is that the transformation is going too slowly, with annual refurbishment rates below 1%. The EU strategy aims to make such renovations easier, develop energy efficiency guidelines and improve energy performance certificates. Further, the strategy includes plans for better integrating electricity systems with district heating and cooling systems as well as connecting waste heat from industry to district heating systems. There will also be measures to increase the level of renewable energy used for heating and cooling.

It is yet to be seen how effective the EU will be in achieving its objectives. What is clear is that the current progress towards energy efficiency and decarbonization of the sector is not sufficient and a step change is necessary. Development within heating and cooling will be one of the main factors determining the outlook for natural gas demand in Europe as heating and cooling currently accounts for almost 60% of the EU's direct use of gas.

Primary energy mix for EU heating and cooling sector
%, as at February 2016



Source: The European Commission

scenario, where closer political ties between the two countries are envisaged.

Central Asian gas is becoming "stranded" as long distances put it at a competitive disadvantage to LNG. There is no additional export infrastructure beyond the fourth pipeline to China. At the same time Central Asian gas, once an integral part of the Soviet gas system, is becoming decoupled from Russia. Turkey has signalled an interest to increase offtake of gas from the Caspian region and Iraqi Kurdistan, but tension with Russia over Syria may ease in the future. The lifting of sanctions on Iran could facilitate new exports, either as LNG or pipeline gas. Iran exporting pipeline gas to Pakistan and India makes most sense in the *Renewal* scenario as gas is perceived to be a part of the climate solution in India.

European gas remains politicized

The European Commission is pursuing a number of competition, climate and energy security objectives that may have huge impact on European gas markets and demand over the long term. The role of gas in a decarbonized fuel mix will inter alia depend on the targets adopted in legislation and on their actual implementation. The EU launched a strategy for heating and cooling in February 2016 which has the potential to be particularly detrimental to the use of natural gas, since gas has a high market share in buildings.

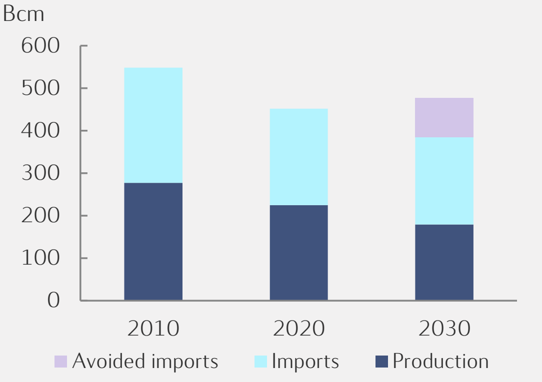
Europe's decarbonization agenda also serves a political agenda to lower gas imports. The EU is becoming increasingly reliant on gas imports as indigenous gas production (including Norway) is on long-term decline and demand is rising. This has long been a security of supply concern in the EU, but actions taken will depend on how the political situation unfolds. More tension and suspicion between the EU and its suppliers (as in the *Rivalry* scenario) suggest directionally lower gas demand. Existing infrastructure, sales contracts and business relations provide a high degree of inertia in EU's supply mix, but successful steps to curb gas demand will hit all suppliers.

In *Reform*, the use of natural gas for power generation rises until 2030 and declines thereafter. The scenario captures an observed growing political willingness to restrict the use of hard coal and lignite for power generation in countries such as the UK, Germany and the Netherlands due to tightening climate ambitions and policies. Decommissioning of some nuclear plants further underpins gas demand in the sector. However, a continued rise in renewable power generation and the advent of coal generation with CCS towards the end of the forecast period limits the growth in gas in the 2030s. In the *Renewal* scenario gas is used to support intermittent wind and solar in the power sector and for heat purposes.

North American potential for further growth

North American gas demand is on a continued, long-term growth trajectory in the *Reform* scenario and increases even in the *Rivalry* scenario. A comparatively healthy US economy, competitive gas supplies and more stringent environmental legislation on thermal power generation all support more use of natural gas. Electricity generation from natural gas dwarfs that from coal. However, the rise in gas-fired generation does not allow the region to sufficiently lower GHG emissions to meet the 2°C target. Wind and solar, and not natural gas, capture the

Indicative EU gas import requirements



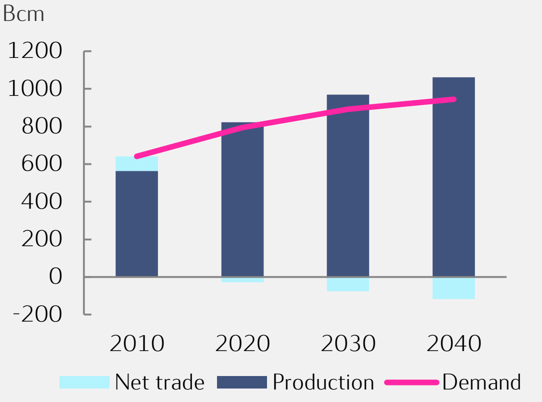
Production: EU & Norway
Source: EC, IHS, IEA, Statoil

The European Commission aims to lower the Union's import dependency for gas

Source: Shale Gas International

Carbon control regulation will be decisive for the development of US gas demand

US gas balance – *Reform* scenario



Source: EIA (history), Statoil (projections)

growth in generation in the *Renewal* scenario, resulting in a modest fall in total gas demand in OECD Americas.

The shale gas revolution has not run its course, and resource updates show that more gas can be supplied at moderate prices. Thus gas is available for domestic consumption, exports to Mexico and feed-gas for LNG liquefaction plants beyond those currently under construction. Some existing US liquefaction projects can add additional trains, and such brownfield projects are perceived to be cost competitive. It will be far more challenging to go ahead with the large greenfield projects in British Columbia, Canada. Highly dependent on how demand unfolds, North American LNG export capacity could expand by a third in the 2020-2040 period.

Potential for shale gas outside of North America

Some 80% of global shale gas and other unconventional gas resources are located outside of North America. Although the prospects for a rapid growth in shale production are deteriorating in Europe and in some other areas, shale gas could nevertheless make a sizeable contribution to the longer-term supply of gas in countries such as China and Argentina. The pace of China's development of shale gas and other unconventional gas is a major uncertainty facing global gas markets. China's shale gas resources are contained in the Sichuan Basin and six further basins. There are questions on the quality of the reserves, and the supply industry has limited shale gas experience. The outlook however depends on regulatory aspects concerning access to resources and transportation to the market, the amount of subsidies given, and the pricing of this source of gas in the domestic market. In Argentina, there are large expectations to the Vaca Muerta formation. The quality of the shale resources in Argentina is promising, but uncertainty exists as to whether or not the regulatory framework, including pricing, will attract sufficient investments.

Development of shale resources in Europe is complicated by a relatively high population density and a widespread environmental opposition to fracking. Australia is ramping up production of coal-bed methane primarily to feed three of its new LNG export plants, all located in Queensland.

The industry needs to take FID on new LNG projects

The global LNG industry will enter the 2020s with more than 550 bcm of annual liquefaction capacity, but eventually new projects will be needed to meet a forecast growth in LNG demand and dwindling supplies for some existing plants. There is no shortage of projects: over 60 LNG projects with 500 bcm capacity are targeting final investment decision (FID). However, the industry will only take FID on new liquefaction capacity if expected sales revenues are sufficient to secure necessary project returns. Thus projects with relatively low costs (such as expansion projects) are more likely to go ahead than expensive greenfield projects.

The traditional approach to bridging supply and demand is to stack existing LNG supply, volumes from projects under construction and a chunk of proposed projects, and compare this to one or more LNG demand forecasts. Such an approach, which typically shows a surplus of capacity building up and extending into the future, assumes that the energy industry is capable of taking FID on a large number of projects, almost regardless of circumstances.

The role of gas in a low-carbon power market

The competition between coal and gas has developed very differently in Europe compared to the US. In the US cheap natural gas is outcompeting coal in the power sector while in Europe the situation has largely been the opposite. Power generation from natural gas has dropped from almost 900 TWh in 2008 to less than 600 TWh in 2015. The utilization rate of European gas power plants has during the same time period dropped from over 50% to around 30%. If gas power capacity was utilized at the same level as in 2008, the use of coal for power generation in Europe could almost be cut in half.

In China, coal accounts for around 75% of power generation, while gas accounts for only a fraction of the total. China has stated targets to increase natural gas share in the energy mix and replacing some coal power generation with gas power generation, which have been seen as important measures to improve local pollution. Despite this, the growth in use of gas for power generation has slowed down due to lower electricity demand growth and a spur in other power generation capacity such as solar, wind, hydro and nuclear.

India also relies heavily on coal for its power generation, with a share of over 70%. Utilization of India's gas power generation capacity is only around 25%, indicating that there is an immediate potential for coal to gas switching.

The problem is that even though there is an environmental case for switching from coal to gas, there is not an economic case apart from in the US. As long as it remains cheaper to generate electricity from coal compared to gas, this is not likely to change. Stricter environmental regulation or a higher price for carbon could have an immediate effect in regions where there is surplus gas power generation capacity and could also steer the longer term investments away from coal.

Another role for gas in a low-carbon power market is that of backup source for intermittent renewables. Intermittent power sources such as solar and wind are likely to gain a substantial share in a low-carbon power mix. As this happens, the composition of power generators in the system will need to change. Traditionally base load demand (the minimum load during the year) is covered by "base load power plants". These plants are typically coal and nuclear plants that are characterized by high capital costs and low variable costs and are therefore dependent on a high utilization rate to cover investment costs. Increasing power generation from solar and wind cuts into the base load demand and creates a larger need for flexible power generation as well as other measures to balance supply and demand such as smart-grid technologies, demand response and energy storage. Gas, in particular open cycle gas turbines with low capital cost, can be well suited to cover the growing need for flexible power generation. Gas will still run into competition in the market for flexible generation from dispatchable renewables such as hydro and biomass, while diesel generators and even coal can in some cases be used for flexible generation (currently the situation in Germany).

The fall in oil and LNG prices, reinforced by an impasse in many contractual negotiations over sales terms, has the potential to offer an alternative scenario to the (until recently) conventional view of an 'ever-lasting' supply surplus. First, softer prices underpin demand in price-responsive markets or segments. But more importantly, energy companies may fail to take their LNG projects to FID due to elevated price uncertainty, tougher capital constraints and project specific issues. In such a scenario, the global LNG market may flip once more and this time from a surplus to a deficit. The boom-and-bust characteristics of a capital-intensive and non-scalable industry may continue to frame the LNG industry.

Stricter cost disciple and falling costs due to generally lower supply industry activity will ensure that liquefaction projects go ahead, with the number depending on perspectives for demand. Most non-US LNG projects that have not yet passed FID face challenges beyond current low oil prices. Russia's LNG ambitions are choked by Western sanctions. Canadian front-runners are deferring FID due to high (transport) costs and First Nations issues. Australia awaits the verdict of the market for projects currently under construction before embarking on expansion projects. East Africa is a new greenfield LNG supply region in all aspects, but will enable Asian buyers to diversify supply. Other potential LNG suppliers have their distinct issues, but in the current market, smaller projects including some floating LNG projects may progress first. In Papua New Guinea, a third train could be built at the existing plant, but the country also has prospects to become host for new LNG projects. Iran has a number of pre-sanction LNG projects at varying degree of construction level, but it is uncertain how many, if any, will be completed. Existing projects in Algeria, Oman and the Emirates face feed-gas issues and domestic demand is strong.

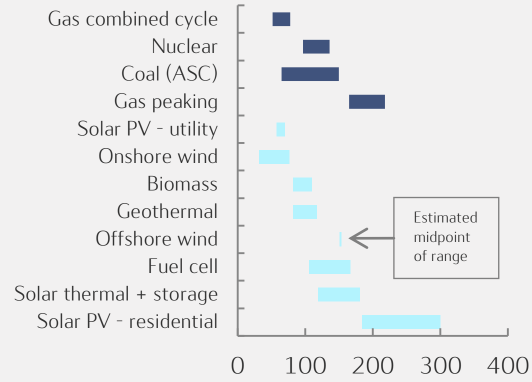
LNG projects in the US are differentiated from their competitors as they take feed-gas from the national transmission grid, rather than from a dedicated upstream field developed as an integrated part of the LNG project. This significantly shortens the time to production. The price risk typically rests with the buyers – midstream portfolio players or end-user market wholesalers who believe that their sales price will be attractive to Henry Hub plus the costs to liquefy and transport the gas to the destination of choice. Developers of most US liquefaction projects are adding liquefaction to existing import terminals for LNG and otherwise capitalize on a skilled labour force and local supply industry.

Technically and economically recoverable resources are not the same

Estimates for global proven gas reserves by the end of 2014 vary between 187 and 200 trillion cubic meters (tcm) from Cedigaz and BP. Keeping track of proven, probable and possible reserves and undiscovered resources has become more challenging with the advent of unconventional gas. The world's proven gas reserves by the end of 2014 corresponded to 52-54 years of consumption at 2014 level. The current global oil and gas reserves to production ratios are thus fairly similar. These ratios are changing from year to year and should not be over-interpreted. The size of the economically recoverable resources will depend on geopolitics, technological improvements, cost drivers, tax regimes and ultimately on achievable gas prices that all need to be there to secure investments going forward.

Renewable energy

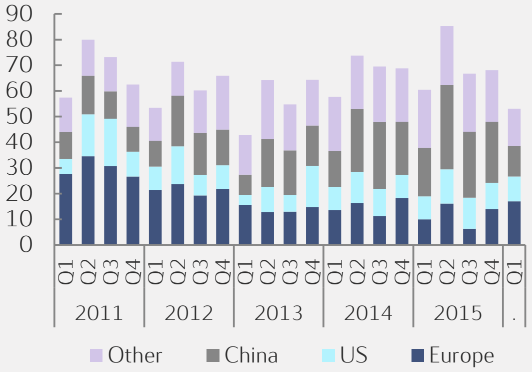
Levelized cost of electricity
USD/MWh



Source: Lazard (2015)

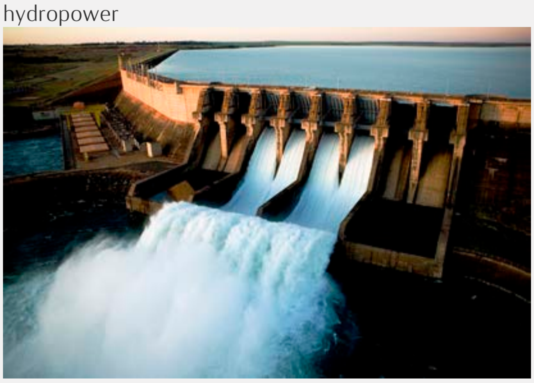
New renewable energy includes wind, solar, geothermal and marine power plus small scale hydro, biofuels and biomass used for power generation

New investment in renewable energy
Billion USD



Source: Bloomberg New Energy Finance

The Itaipu hydropower plant, Brazil
Over 80% of electricity in Brazil is generated from hydropower



Source: www.amaze.com

Renewable energy – mainly electricity generated from renewable sources, including hydro, biomass and new renewables – keeps growing, in absolute and relative terms. IRENA, the International Renewable Energy Agency, reports a 7.5% per year growth in *total* renewable power generation capacity, and a 21% annual growth in *new* renewable power capacity, between 2006 and 2015. New renewable energy includes wind, solar, geothermal and marine power, plus small scale hydro, biofuels and biomass used for power generation.

Global investments in renewable energy (including modern biomass and biofuels) dropped in 2012 and 2013 by 7% and 8% respectively, but jumped 16% in 2014 and increased by another 4% in 2015. Bloomberg puts investments last year at 329 billion. USD 2016 could on present indications see another set-back – 1st quarter investments were down 22% on 4Q2015 investments and 12% on 1Q2015 investments. The downturn was due mainly to a sharp fall in investments in China, reflecting in turn the expiry of certain favourable electricity tariffs at the beginning of 2016. Investments in North America are steady and those in Europe seem to have picked up after a couple of relatively weak years. Such fluctuations should in any event not be interpreted as indicative of changes in the overall trend towards bigger market shares for new renewable energy.

Limited growth potential for hydro energy

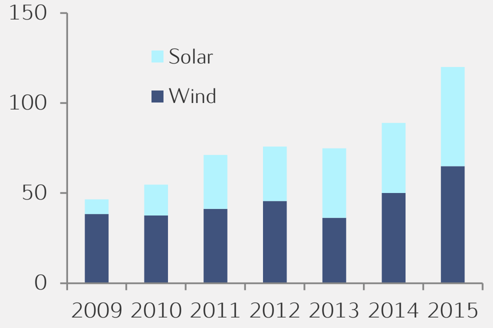
Large scale hydro power generation capacity increased by 3.4% per year between 2006 and 2015. Every year 30-45 GW of new capacity was put on line. In 2006 incremental hydro capacity was 1.3 times bigger than incremental wind, solar and other new renewable capacity combined. This ratio has fallen dramatically. In 2015 new hydro capacity was 0.3 times new wind, solar and other new renewable capacity. Hydro power remains bigger globally than new renewable power. But the hydro share of the total was down from 86% in 2006 to 61% in 2015 and will likely soon dip below 50%.

In principle hydro power generation could be increased faster than the 2005-15 growth performance suggests. The International Hydropower Association suggests a worldwide capacity potential of around 3,450 GW, three times the capacity developed by 2015. In the OECD countries most opportunities have been exploited, but in East Asia, Africa and Latin America many rivers and waterfalls remain untouched. However, large scale hydro projects have become increasingly controversial as negative stories about local interests set aside, farmland under water, people being displaced and ecosystems being destroyed have surfaced. Hydro power availability can also vary strongly from year to year, depending on rainfall, presenting major risks to countries prone to droughts. Small scale hydro is less problematic, but the potential is limited. For these reasons, global hydro power growth rates are assumed to remain in a narrow 1.8-2.0% range across the scenarios, with generation in the OECD regions hardly growing at all.

Controversial future for biomass

Biomass is being used in traditional ways in poor countries and in modern ways in rich countries. African, Asian and Latin American households' burning of fuel wood in stoves needs to come down as it leads to deforestation, forces family members to spend most of their time collecting burnable material and is polluting. Modern biomass includes biofuels

Global solar and wind capacity additions
GW

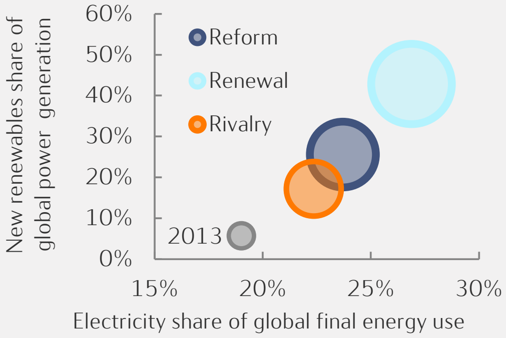


Source: Clean Energy Pipeline, BP Statistical Review 2015

Offshore wind is coming, but remains small compared to onshore wind

Source: California Energy Commission

Renewable power generation in 2040
Size of circle represents total generation



Source: IEA (history), Statoil (projections)

blended with gasoline and diesel, and wood pellets used for power and heat generation. Opinions on the merits of modern biomass are mixed and the scope for growth is unclear, as it typically takes land and water that could be used for other purposes, or conserved, to grow the input. In the scenarios global biomass use increases by 0.7-1.1% per year. The share of biomass in world primary energy demand is more or less stable at 9-13% in *Reform*, increases to 13% in *Renewal* and drops marginally in *Rivalry*.

Solar and wind account for the lion's share of growth in new renewables

Growth in new renewable power generation capacity declined from a peak of 25.5% in 2009 to 17.6% in 2015. In absolute terms, however, 116 GW of new renewable capacity was put on line in 2015 against 53 GW in 2009. Several countries now supply 15-25% of their total electricity consumption from new renewable sources. According to Enerdata, Portugal's wind and solar power output was in relative terms the highest in the world in 2014 at 24.5% of its electricity consumption. In Spain and Italy the shares were 23.9% and 16.7% respectively. The average for the EU was 11.0%. Data for 2015 are still patchy, but reportedly one third of electricity generated in Germany, and one fourth of electricity generated in the UK, came from renewable sources, and Energinet DK puts the wind share of electricity generated in Denmark last year at 42%.

The US and China lag behind with wind and solar shares of 5.4% and 3% in their power supply, respectively. Asia in general and China in particular are still rising stars on the new renewable energy scene. China in 2015 accounted for 43% of total additions to global new renewable capacity. Europe, including all the central and eastern European countries plus Ukraine and Belarus, accounted for 16%. North America contributed with 13%.

Within the new renewable energy category wind power is still in the lead, in spite of spectacular growth in solar power generation capacity. Wind power increased its share of total new renewable capacity from 51% in 2006 to 56% in 2015. Solar leaped forward from a share of 4.5% in 2006 to 29% in 2015. The losers in relative terms have been biomass-based capacity and geothermal capacity. Offshore wind is coming – average annual growth in capacity between 2006 and 2015 was 34%, and growth in 2015 was 40%. Offshore wind remains however a very small sibling of onshore wind, with a share of total wind power capacity of barely 3%.

New renewables are small, but growing rapidly

In generation rather than capacity terms, new renewable power remains small. The IEA, whose worldwide numbers go only to 2013, reports an increase in new renewable power from 1.9% of total power in 2003 to 5.7% in 2013. The share continued to increase in 2014 and 2015, and is (as already indicated) much above this global average in some countries and regions, but it will take some time before new renewable power reaches the levels suggested in most scenarios based on sustainability considerations.

New renewable power has progressed for two reasons: government support in the form of R&D, feed-in-tariffs, green certificates, tax breaks, and renewable portfolio standards; and in addition cost declines. Until now support has been imperative, but that phase is gradually coming to

Increasing reliance on variable sources of electricity - some issues

As already noted, rapid growth in the share of electricity generated from intermittent and seasonally variable sources is expected going forward. Such a development, while welcome and necessary, raises a number of market and regulatory issues where global answers do not yet exist. The ability to model developments in light of these challenges is limited. In developing alternative scenarios it is assumed that cost efficient and technically feasible solutions will be found. One issue is the grid requirements in electricity systems that depend heavily on variable sources. Grids must be expanded to ensure efficient deployment of electricity when the sun shines or the wind blows far from the centres of electricity demand. Grid investments, characterized by large economies of scale, are also necessary to ensure delivery of back-up electricity. How they will be financed and built is not clear. As an example, an analysis at NTNU of the implications of a 90% decarbonization of the European electricity sector by 2050 through investments in solar and wind indicates that total grid capacity in the least costly alternative must increase 7-8 fold.

Another issue is the investments in and availability of storage and backup capacity that can deliver electricity over long periods during long, cold and dark winters. Cost issues, resource availability, investment incentives and pricing mechanisms for backup with low utilization, negative externalities associated with producing and disposing of batteries etc., are issues that call for solutions. Furthermore, the future pricing mechanisms for generation capacity and electricity in a system characterized by significant amounts of variable, zero marginal cost sources of power are uncertain. Today's electricity markets are designed to reflect the cost structures and optimize the dispatching of conventional technologies and are not suited for the integration of new technologies at large scale. Recent years have witnessed declining - occasionally zero or even negative - wholesale electricity prices in spite of rising system costs, eroding the financial position of the traditional utilities which in Europe have also had to cope with sluggish electricity demand growth and competition from distributed energy.

The future pricing of electricity will determine the viability of generating and selling renewable electricity and companies' preparedness to invest in wind and solar when support arrangements are wound down. Pricing mechanisms will also determine the incentives for investing in backup capacities, be it batteries, gas or other sources. It is vitally important that renewable capacity, grids and backup capacity are developed in an integrated manner. The utilization of backup capacity could be low, but its availability in times of shortage will still be critical. Normal rates of return on investment in backup, and incentives for scaling up and down electricity generation in line with demand, could require new regulatory mechanisms - especially if "prosumers" are incentivized to go "off-grid" and not contribute to covering the "public goods" elements in future electricity systems. In the scenarios, it is assumed that these and other challenges are solved efficiently. Efficiently does however not mean "free of charge". This will cost money and require resources.

[1]Skar, C., R. Egging, and A. Tomasgard. 2016. "The role of transmission and energy storage for integrating large shares of renewables in Europe." IAEE Energy Forum 1st Quarter.

an end. Some technologies - for example offshore wind and marine power - will likely need support for many more years, but judging by recent so-called levelized cost of electricity (LCOE) estimates, onshore wind power is already competitive with other power on an unsubsidized basis in big parts of the world, and solar PV power is fast becoming a viable option in sunnier locations. LCOEs have been on the decline due to globalization of supply chains enjoying economies of scale and increasing efficiency of generation equipment as a result of technology developments.

New renewables becoming cost competitive

Lazard - a financial advisory and asset management firm - suggests a cost range of 32-77 USD/MWh for wind power, and a range of 50-70 USD/MWh for utility scale solar PV power. In comparison, the ranges for gas combined cycle power and coal power are put at 52-78 USD/MWh and 65-150 USD/MWh respectively. Recent auctions confirm the realism of these estimates. Deals have been done in Peru for wind power at 38 USD/MWh and for solar power at 48 USD/MWh, in PV power at only 36 USD/MWh. The latter bid is suspiciously low and could reflect special circumstances (or be overly ambitious), but the signs that wind and solar power will capture market share from fossil fuel based power regardless of future levels of subsidization and renewable portfolio mandates, are undeniable.

The LCOE of new renewable power will continue declining. Barring unforeseen technological breakthroughs, onshore wind and solar PV cost curves will flatten, but since no one expects fossil fuel based power generation to become much cheaper than it already is, relative costs are still expected to continue evolving to the advantage of the new renewables.

LCOE estimates tell only part of the story of individual power generation technologies' competitiveness. They do not typically include system costs - the back-up solutions, extra infrastructure and demand side flexibility required by wind and solar power - and they do not account for the fact that intermittent electricity may not fetch the same prices as dispatchable electricity.

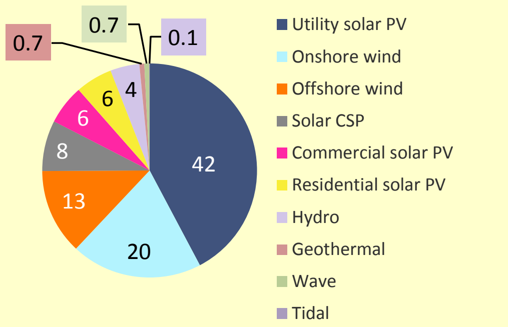
How much new renewables can be accommodated in the generation mix?

Analytical results and opinion differ on how much intermittent renewable power that electricity systems can accommodate at non-prohibitive costs. There is agreement that the share of intermittent power can increase to 10-15% without putting any stress on the system. Beyond that range, investment requirements become noticeable but up to perhaps 40% they remain manageable. At shares above 40% significant investments in additional flexibility and daily storage will be called for. Shares above 50-60% have never been experienced anywhere on a national scale and represent many unknowns, but investments in seasonal storage could be a pre-condition, in which case one would need technology that is not yet commercial. What seems clear however is that most countries can continue shifting their power supply from fossil fuels and nuclear to wind and solar for a long time before running into severe intermittency related constraints.

Is a world energy supply based 100% on renewables thinkable?

Researchers at the US Stanford and Berkeley universities believe it is. Assuming that absolutely all energy end use – even air transportation – can be electrified, and examining the preconditions, country by country, for replacing fossil fuel based and nuclear power with different types of renewable power, they arrive at the following fuel mix for a sample of 139 countries.

Global fuel mix in an all renewable energy supply scenario for 2050
%



Source: Mark Z. Jacobson et. al: "100% Clean and Renewable Wind, Water and Sunlight (WWS) All-Sector Energy Roadmaps for 139 countries of the World", December 2015

The authors have answers to all the questions a 100% renewable vision raises – on the availability of space, materials and resources for the windmills, solar panels and batteries that will be required, on the replacement of all energy end use technologies relying on fossil fuels by technologies running on electricity, and on the grid stability requirements considered a key constraint on the amounts of intermittent wind and solar power that can be fed into systems.

Many of their proposals rest on challenging assumptions, and their timeline to 2050 seems illustrative rather than fit for a believable scenario as it requires immediate action on issues and in countries where there is little visible preparedness – and/or limited money – for such action. As an antidote to the business as usual thinking and trend extrapolation that remain key forecasting approaches, this and similar efforts to think outside the box are however to be welcomed.

Varying level of penetration in the three scenarios

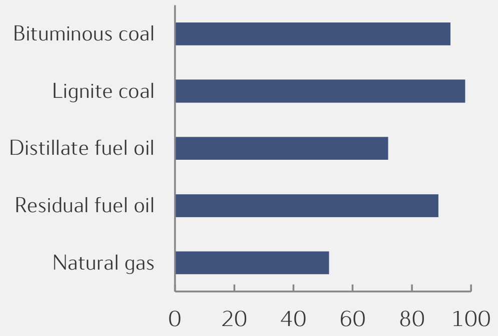
New renewable power supply is assumed to grow rapidly in all three scenarios. This is because renewable power meets not only the CO_2 emission concerns in focus in *Renewal*, but also the energy supply security concerns prioritized in *Rivalry* and the cost and efficiency concerns prevailing in all scenarios including *Reform*.

In *Reform*, power generation based on new renewables increases globally by an annual average of 8.5%. The OECD regions see annual growth rates of 5-9%, and China and India accomplish 10% and 12%, respectively. In OECD Europe the new renewable share of total power generation is nearly 40% by 2040. In absolute terms China realizes the biggest leap with an almost 1,875 TWh increase in generation. This is 0.7 times the increase in the OECD regions' generation combined.

In *Renewal,* national power industries decarbonize as rapidly as possible. Global renewable generation increases by an average of 11% per year. Since efficiency improvements depress energy and electricity demand growth rates in this scenario, modest differences between new renewable generation growth in *Renewal* and in *Reform* translate into much bigger differences in the new renewables' shares of total power generation by 2040. OECD Europe in this scenario gets over 50% of its electricity from new renewable sources, and OECD Americas is not far behind. In China new renewable energy sources account for some 45% of total power generation. Most other regions are in the 20-40% range.

In *Rivalry* power generation based on new renewable sources increases by an average of 7.1%. The regions that have pursued renewable power for several years and have significant wind and solar industries already, like OECD Europe and OECD Americas, turn in growth performances of only 4-5%. In China growth is very close to the world average. Only the relative newcomers to renewable power that also are relatively lightly affected by the tensions characterizing *Rivalry*, like India, manage growth rates above 10%.

CO_2 emission factors
CO_2 kg/million Btu



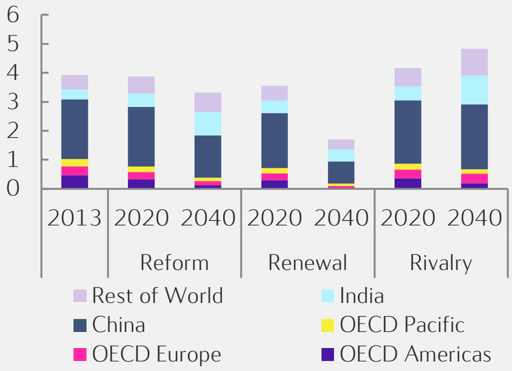
Source: EIA

Coal provides around 30% of global primary energy demand and generates around 40% of the world's electricity

Air quality in some Chinese cities is a major issue

Source: Reuters Media

Global coal demand by region
Btoe



Source: IEA (history), Statoil (projections)

Other energy carriers

The coal market – status and outlook

Despite recent declines in global coal demand, and a worsening reputation as a primary fuel, coal still provides around 30% of global primary energy needs and generates around 40% of the world's electricity, almost double the share of gas, the next largest source. It is also used in the production of 70% of the world's steel.

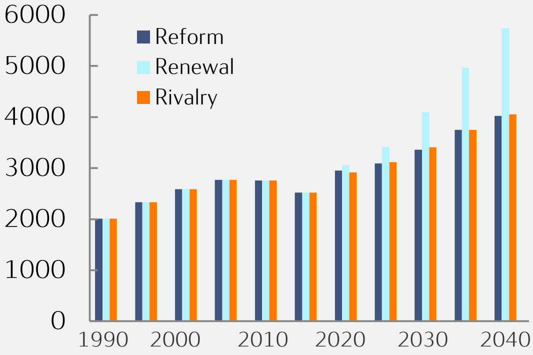
For the first time since the 1990s, global coal demand growth halted in 2014, and preliminary data for 2015 suggests that the downward trend is continuing. This trend is the result of a combination of structural and temporal factors. China, where half of global coal is used, witnessed the most noteworthy demand reduction by around 3.5% in 2015, due to weaker power demand and lower activity in the industrial sector. The environmental measures taken by the Chinese government during the last year or two, to lower local air pollution and try to stem the growth in CO_2 emissions, will have further effects on coal demand. Other Asian countries experience growing demand, to a large extent due to growing electricity demand, a sector where coal has a dominant role. Among the industrialized nations, coal demand is stagnant, with mounting pressure to reduce emissions and pressure to minimize capital cost. Political and legislative initiatives to limit the role of coal are numerous, with different measures from the US EPA and the different European countries, for instance the UK's plan to phase out coal.

What will the future bring for coal?

Going forward, stagnant global demand is expected towards 2020, and then a slow decline of somewhat less than 1% per year on average towards 2040 in *Reform*. The decline is most pronounced in the industrialized world, with a more stringent environmental legislation and a continued gradual trend towards closures of aging coal plants. China, the dominant global coal user, still sees a slight increase towards 2020 based on a continued build-up of coal-fired power plants and increasing electricity demand. The current policies aiming for a less manufacturing intensive economy with higher environmental focus and reduced emissions per unit of electricity produced, will eventually lead to a gradual decline in coal use from the early 2020s onwards. Further coal demand growth, however, is expected in other fast-growing Asian economies, most notably India, where significant growth in electricity demand will most likely continue through the forecast period. Despite massive planned investments in renewable energy, coal will still play a dominant role in power generation, with expected yearly demand increase of around 3% on average towards 2040. Expanding economies like Vietnam, Malaysia and Thailand are also expected to experience a coal demand growth on the back of increasing electricity demand.

However, it is acknowledged that the future of coal in the global energy system is highly uncertain, mainly due to the increased focus on carbon emissions, but also challenges linked to local pollution. Policy measures and legislative initiatives will continue to exert downward pressure on coal demand, despite continued favourable economics and development of more efficient coal plants with reduced pollution. In the *Renewal* scenario, coal demand is around 50% lower than in the *Reform* scenario by the end of the forecast period, and around 55% lower than today's level. By contrast, *Rivalry* assumes 2040 coal demand 45% above that of *Reform* and 25% higher than current consumption.

Global nuclear power generation
TWh



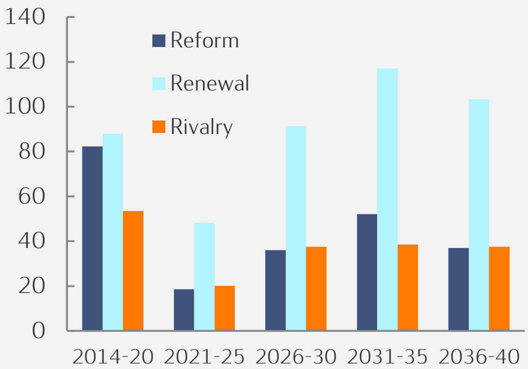
Source: IEA (history), Statoil (projections)

China remains the engine of the global nuclear industry, with a target of 58 GW capacity running in 2020

Nuclear power is struggling in Europe
The Olkiluoto 3 nuclear power plant in Finland

Source: world-nuclear-news.org

Incremental nuclear capacity required
GW, assuming 85% utilization



Source: Statoil

Nuclear energy – status and outlook

Global nuclear power generation was 10% lower in 2014 than in 2007. The decline was due mainly to the shut-down of all Japanese reactors. As a share of world total power generation, nuclear peaked in the early-mid 1990s at around 17.5%. By 2014 the share was 11%.

For the moment a total of 49 countries either have nuclear power plants or are in the process of acquiring them. Of these, 31 share a total of 440 operative reactors, however this total includes 43 Japanese reactors that are offline and face an uncertain future. 16 countries have a total of 62 new reactors under construction. 8 countries without any previous experience with nuclear power are planning to build reactors. However, many nuclear programs have been sitting on shelves for years without generating much action. Governments await clearer signals on where electricity markets and power generation technologies are heading.

After the Chernobyl disaster manufacturers started work on so-called Generation III designs with much improved safety features. However, 30 years after Chernobyl, no Generation III reactors have entered service. Design issues, component quality issues, skilled labour shortages and financial problems have repeatedly thrown spanners in the works. The two Generation III plants under construction in Europe, one in France and one in Finland, are seriously behind schedule and over budget. A third, planned project in the UK is on hold in spite of UK and French government support and a "contract for difference" considered by many to be overly generous.

China remains the engine of the global nuclear industry. The government is again permitting new projects after a long period of analysing the Fukushima disaster. The 13th Five Year Plan covering the 2016-20 period confirms the targets of having 58 GW of capacity up and running and another 30 GW under construction by 2020.

Forecasting nuclear power generation is challenging. In the west the competitiveness of nuclear has eroded, and the safety image of nuclear has never recovered from Chernobyl and Fukushima. Perhaps as important, the climate case for welcoming a renaissance for nuclear has become debatable. A decade ago energy decarbonization visions seemed to require a large nuclear component. Today such visions are considered by many to require only more renewable energy. This view needs however to deal with the fact that unlike fickle wind and solar power plants, nuclear plants are dependable workhorses that can be run 80-90% of the year. It might be considered reckless to try to marginalize the two options that in many countries have accounted for the bulk of base load electricity supply – coal and nuclear – simultaneously.

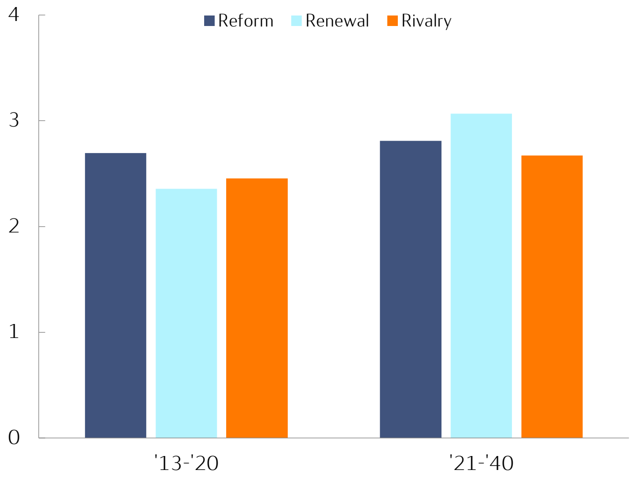
In the *Reform* scenario global nuclear power generation increases by an average of 1.9% per year or by a total of 65% between 2013 and 2040. The nuclear share of total generation remains at about 11%. Global nuclear generation net of Chinese generation increases by only 0.8% per year. In *Renewal* nuclear bounces back, alongside new renewables, increasing by 3.2% per year or by a total of 133%. The nuclear share of total generation increases to 17-18%. In *Rivalry* nuclear power generation increases by 1.9% per year. As many countries may be interested in nuclear in *Rivalry* as in *Reform* but those affected by the tensions and conflicts defining *Rivalry* cannot afford the capital costs. Also, proliferation concerns block the transfer of nuclear technology to countries suspected of unreliability.

Chart appendix

Economic growth

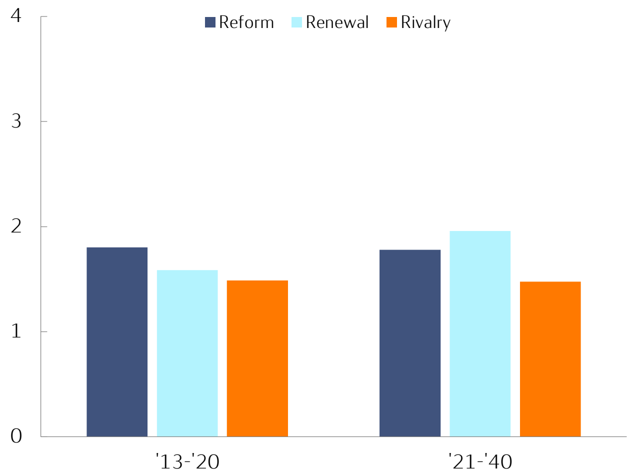
World GDP 2013-2040

Annual growth rate (CAGR), %



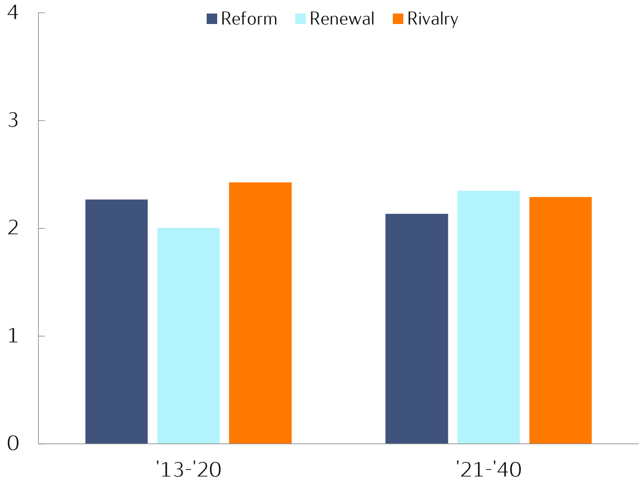
OECD Europe GDP 2013-2040

Annual growth rate (CAGR), %



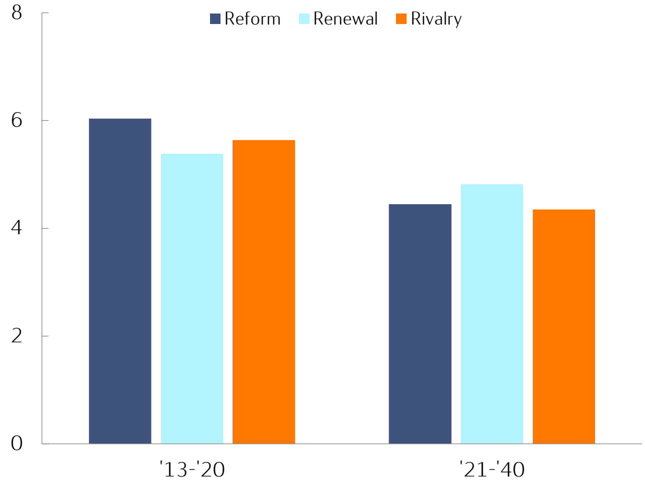
OECD Americas GDP 2013-2040

Annual growth rate (CAGR), %



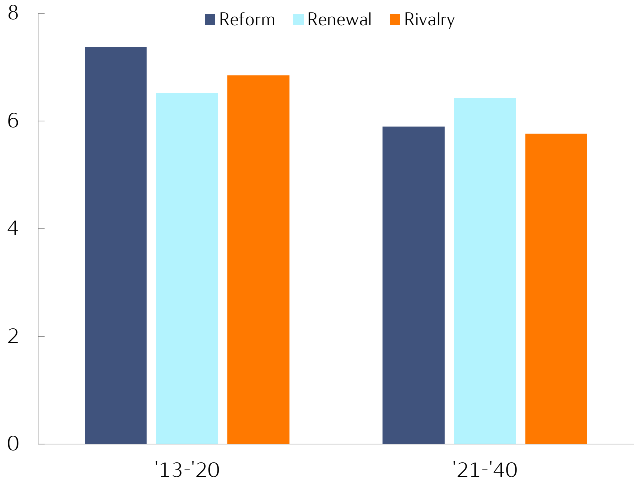
China GDP 2013-2040

Annual growth rate (CAGR), %



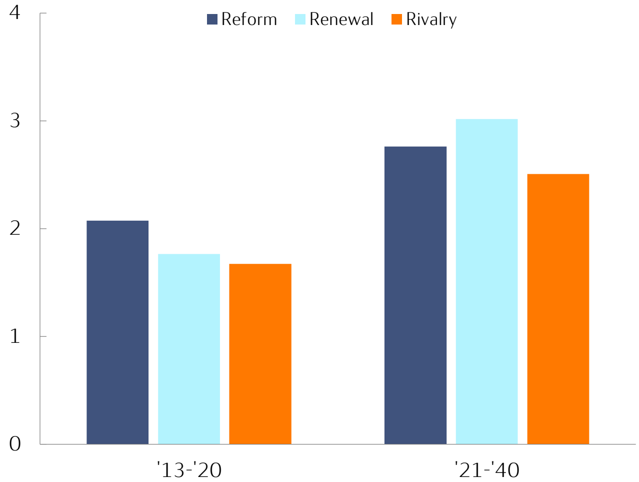
India GDP 2013-2040

Annual growth rate (CAGR), %



Rest of the World GDP 2013-2040

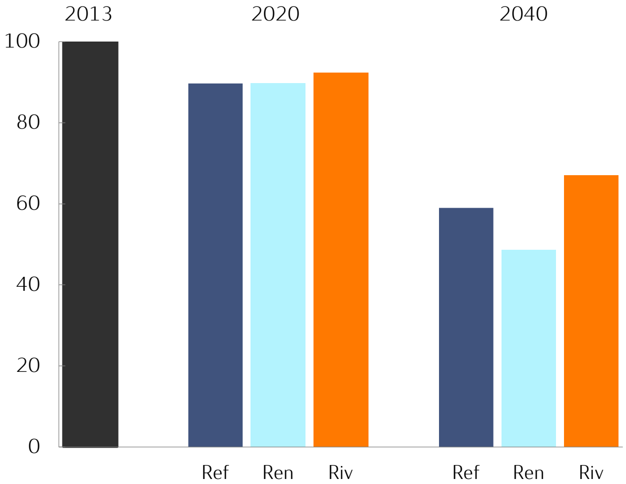
Annual growth rate (CAGR), %



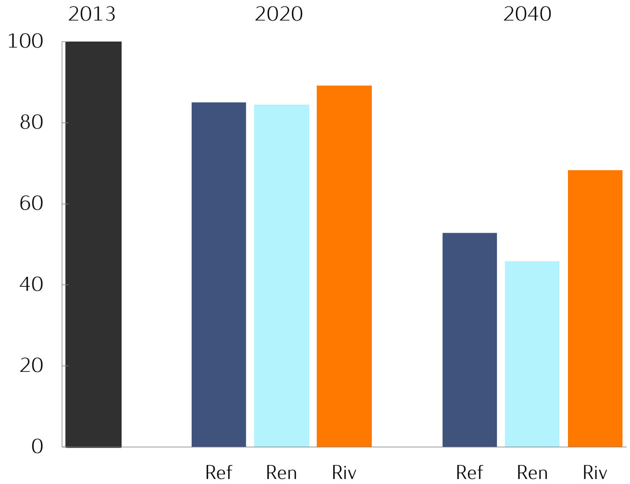
Source: IHS Connect (history), Statoil (projections)

Energy intensity

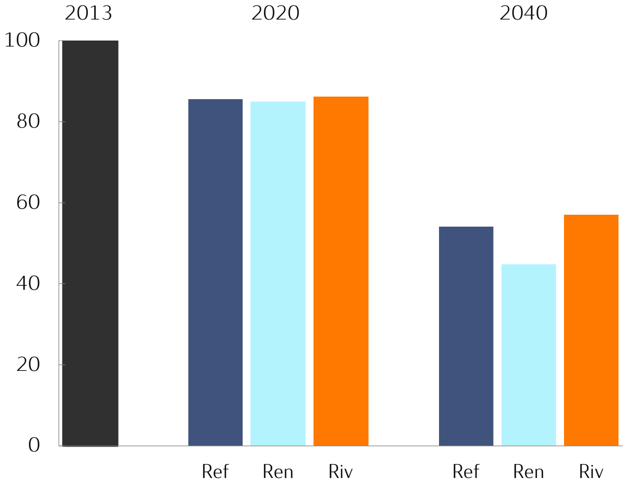
World energy intensity 2013-2040
Index, 2013=100



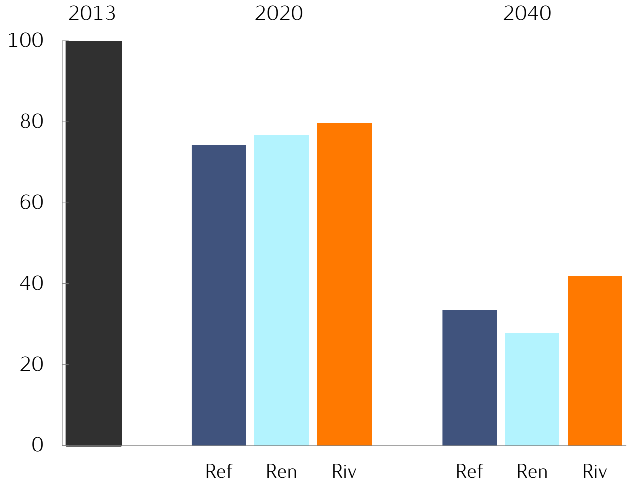
OECD Europe energy intensity 2013-2040
Index, 2013=100



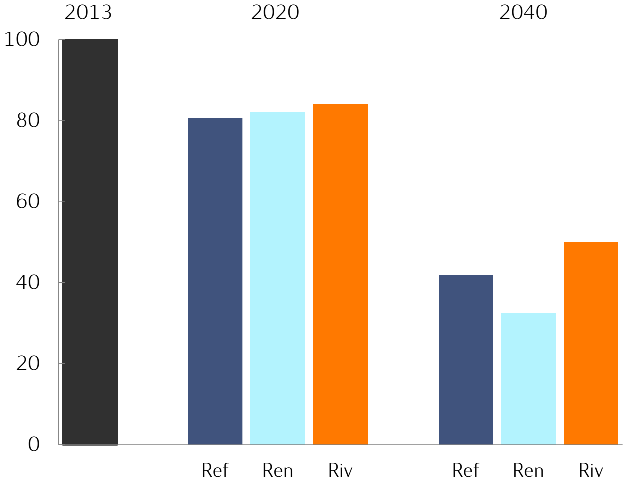
OECD Americas energy intensity 2013-2040
Index, 2013=100



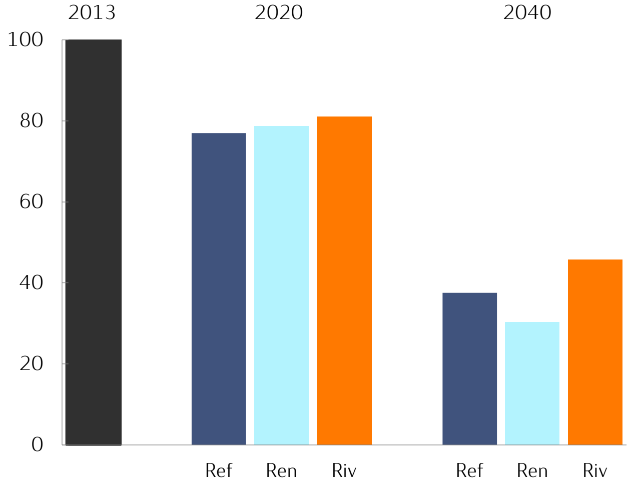
China energy intensity 2013-2040
Index, 2013=100



India energy intensity 2013-2040
Index, 2013=100



Rest of the World energy intensity 2013-2040
Index, 2013=100

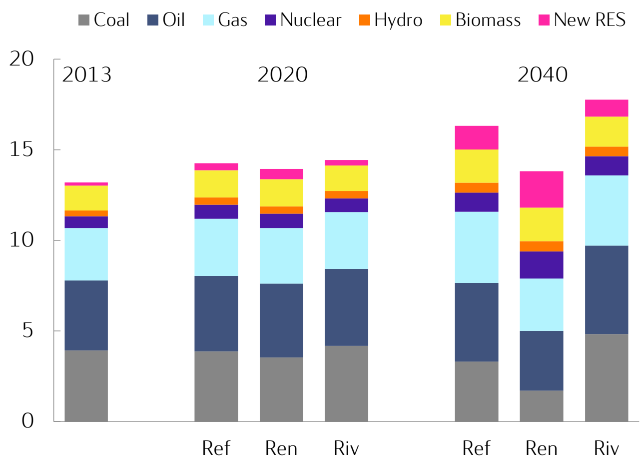


Source: IEA (history), Statoil (projections)

Energy demand

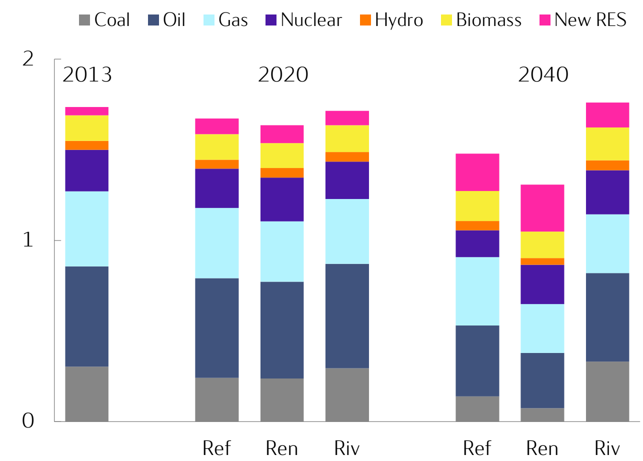
World energy demand 2013-2040

TPED, billion toe



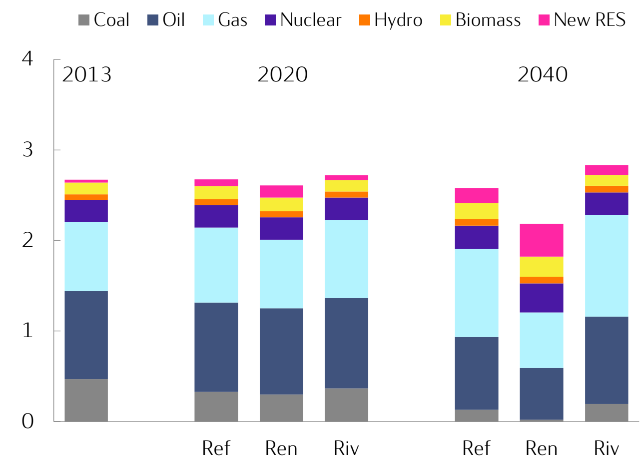
OECD Europe energy demand 2013-2040

TPED, billion toe



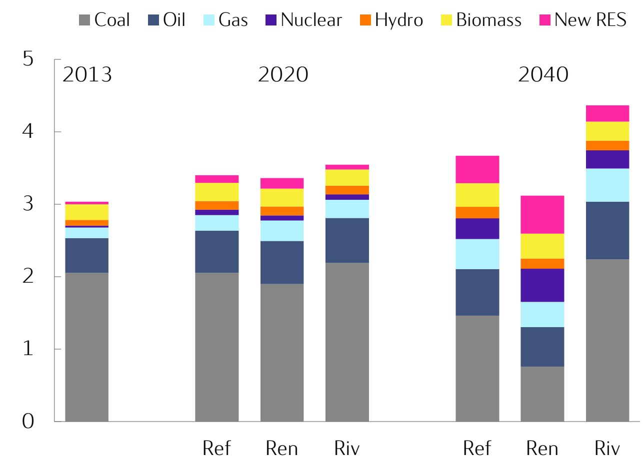
OECD Americas energy demand 2013-2040

TPED, billion toe



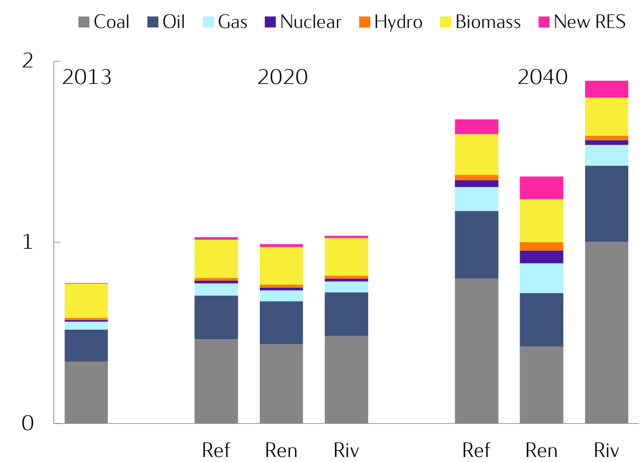
China energy demand 2013-2040

TPED, billion toe



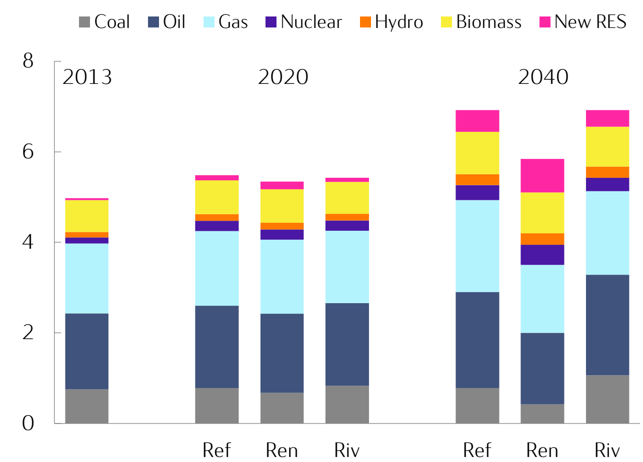
India energy demand 2013-2040

TPED, billion toe



Rest of the World energy demand 2013-2040

TPED, billion toe

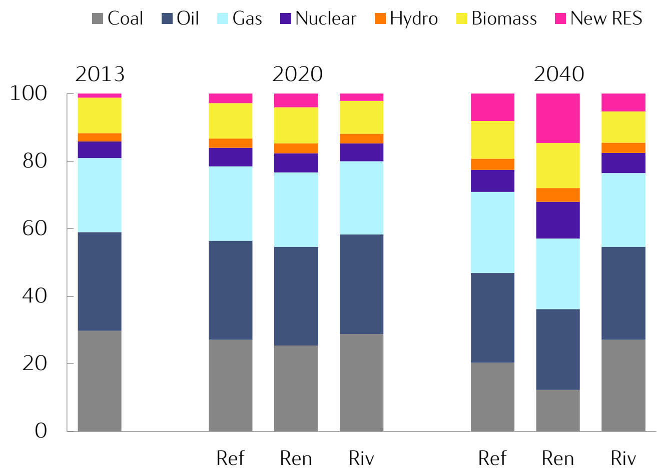


Source: IEA (history), Statoil (projections)

Energy mix

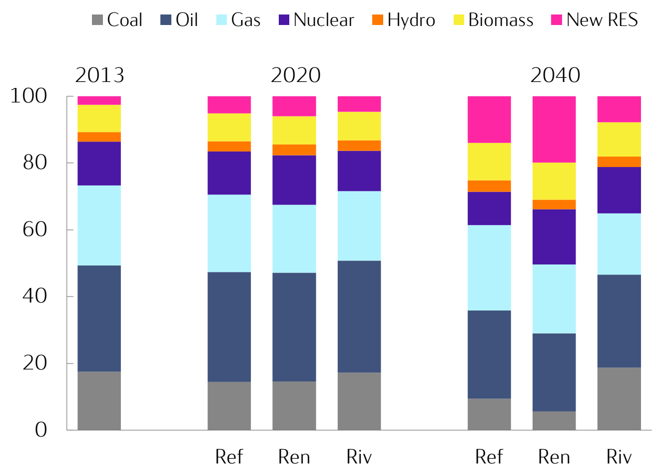
World energy mix 2013-2040

TPED, %



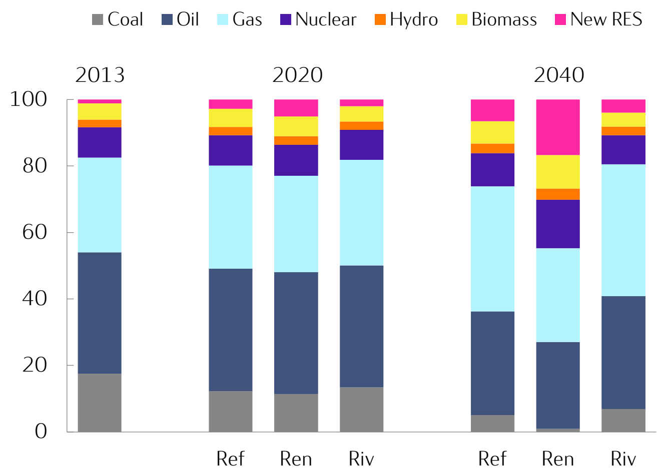
OECD Europe energy mix 2013-2040

TPED, %



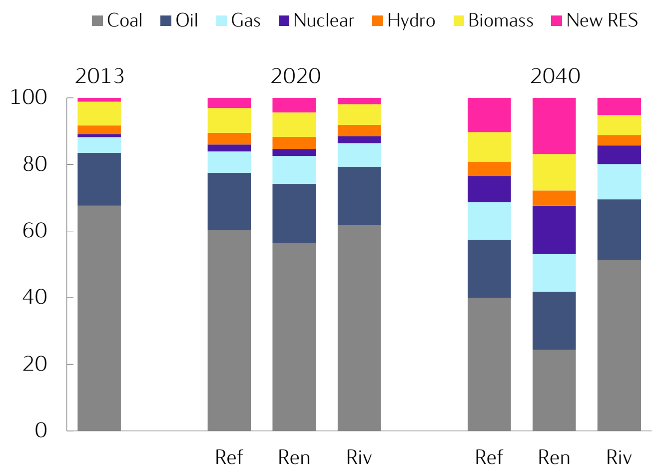
OECD Americas energy mix 2013-2040

TPED, %



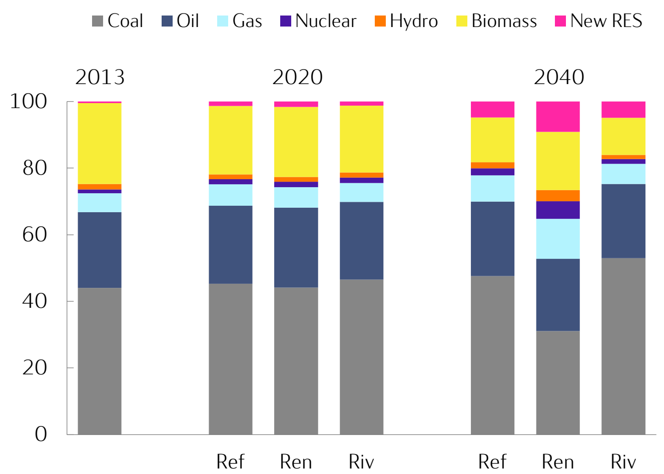
China energy mix 2013-2040

TPED, %



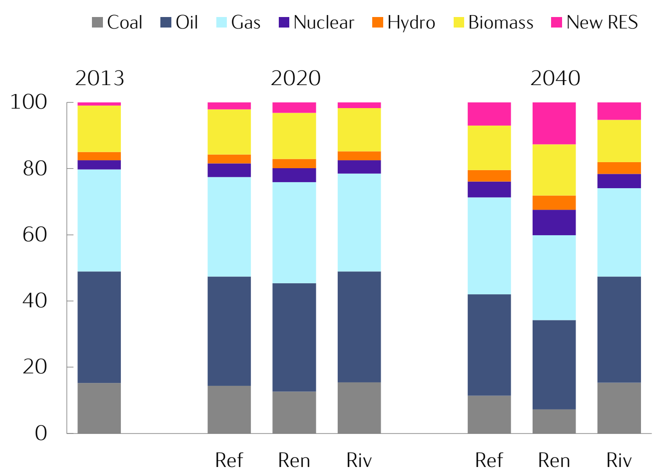
India energy mix 2013-2040

TPED, %



Rest of the World energy mix 2013-2040

TPED, %

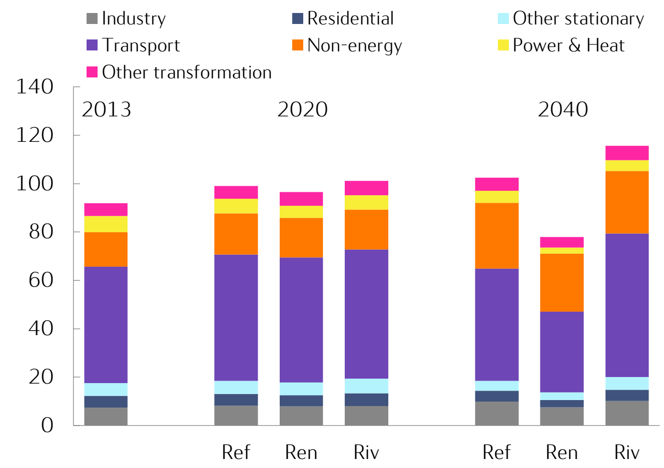


Source: IEA (history), Statoil (projections)

Oil demand

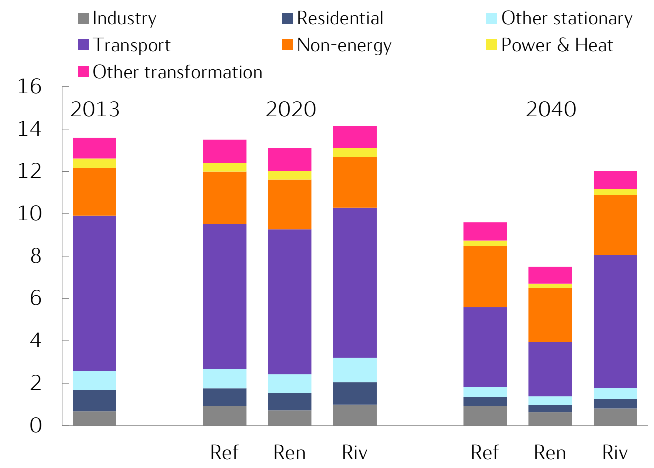
World oil demand 2013-2040

Million barrels per day



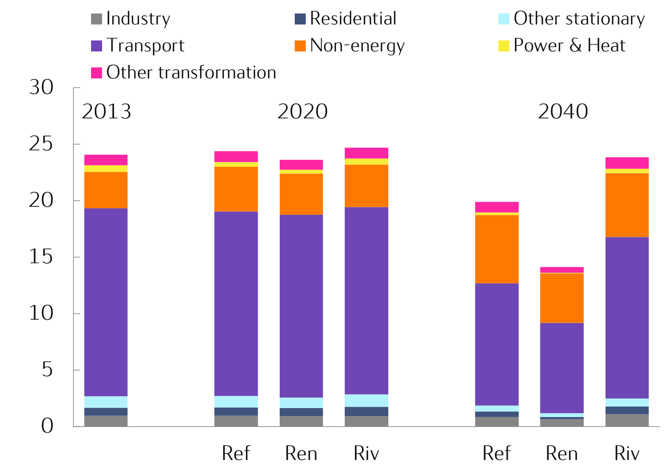
OECD Europe oil demand 2013-2040

Million barrels per day



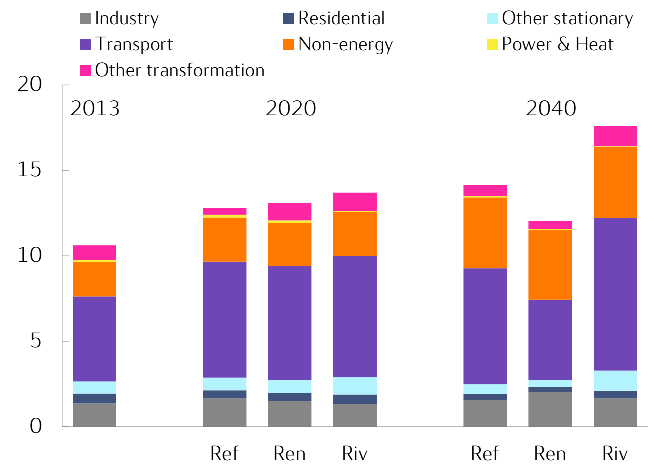
OECD Americas oil demand 2013-2040

Million barrels per day



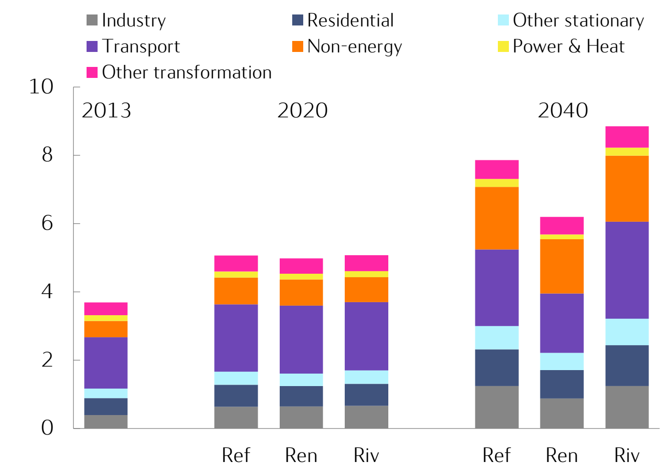
China oil demand 2013-2040

Million barrels per day



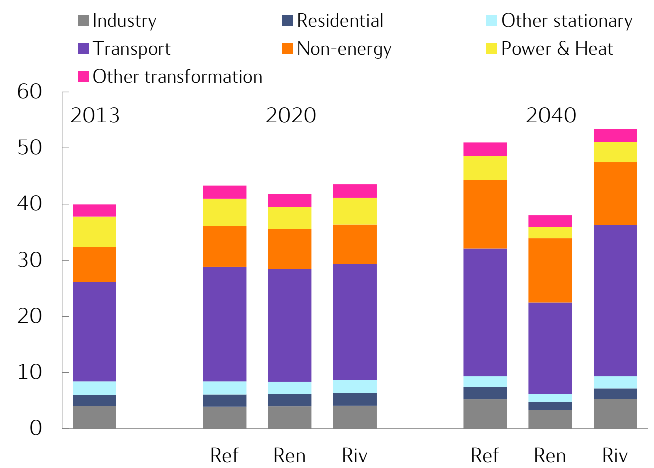
India oil demand 2013-2040

Million barrels per day



Rest of the World oil demand 2013-2040

Million barrels per day

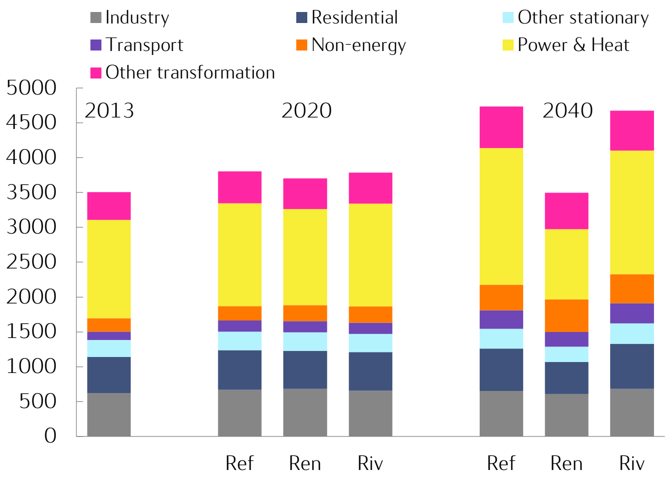


Source: IEA (history), Statoil (projections)

Gas demand

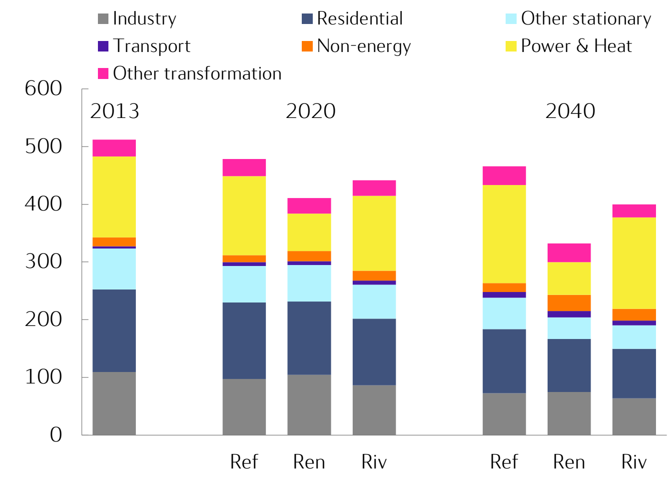
World gas demand 2013-2040

Billion cubic meters



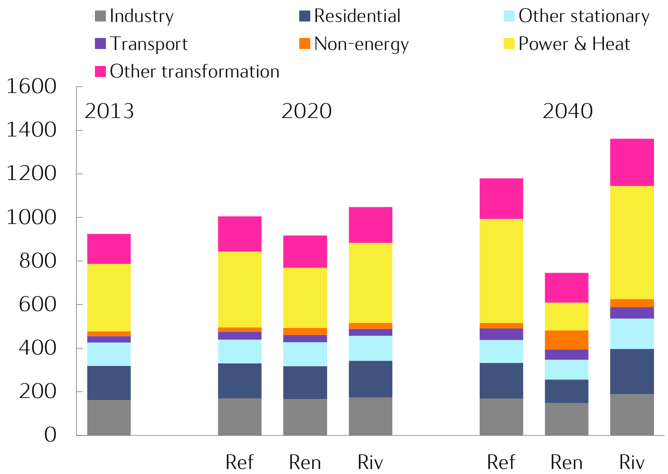
OECD Europe gas demand 2013-2040

Billion cubic meters



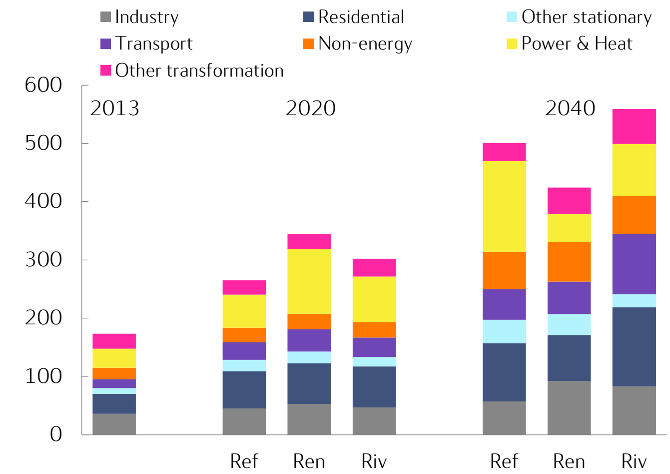
OECD Americas gas demand 2013-2040

Billion cubic meters



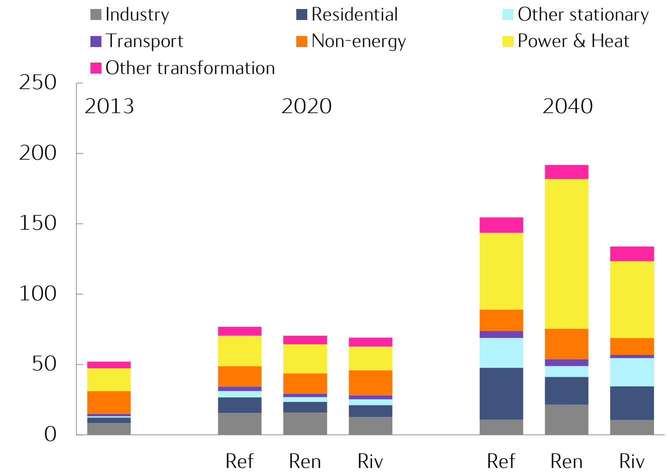
China gas demand 2013-2040

Billion cubic meters



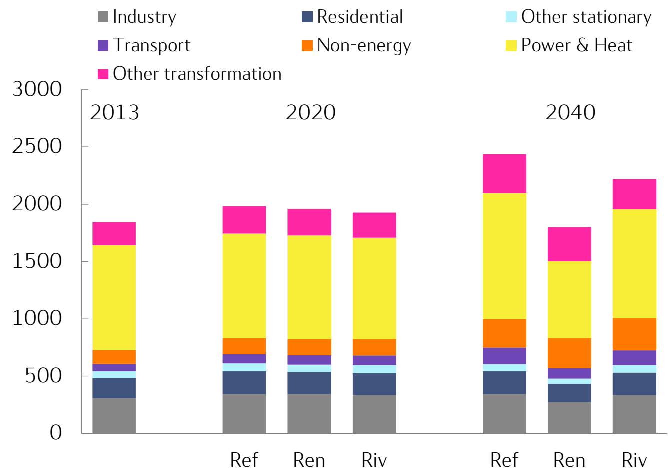
India gas demand 2013-2040

Billion cubic meters



Rest of the World gas demand 2013-2040

Billion cubic meters

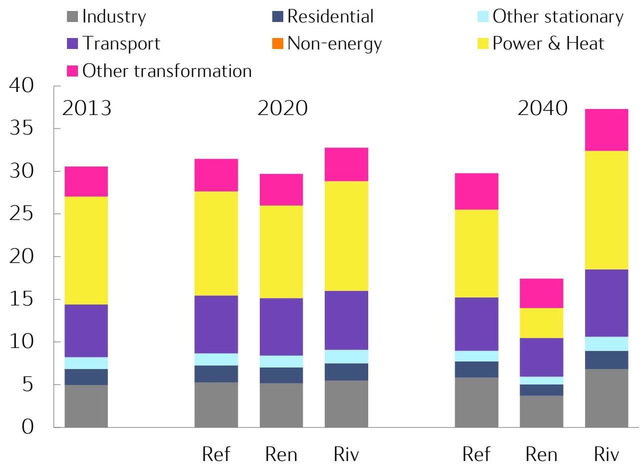


Source: IEA (history), Statoil (projections)

CO_2 emissions

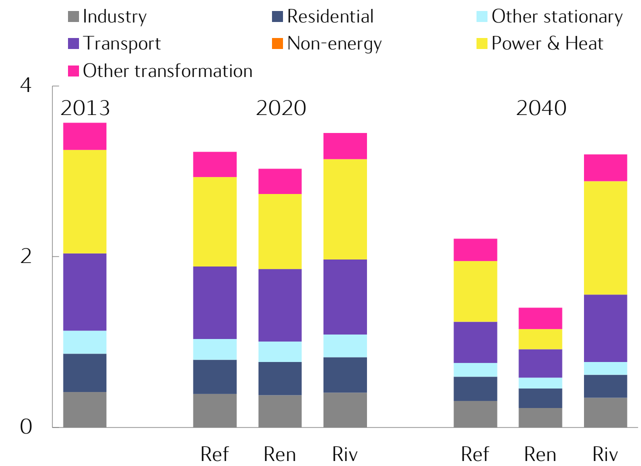
World CO_2 emissions 2013-2040

Billion tonnes



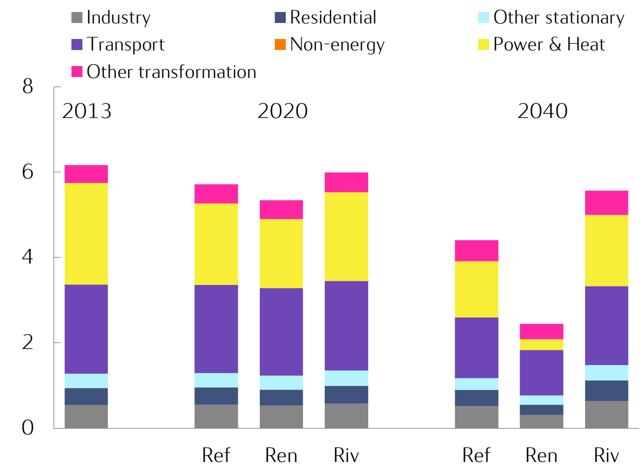
OECD Europe CO_2 emissions 2013-2040

Billion tonnes



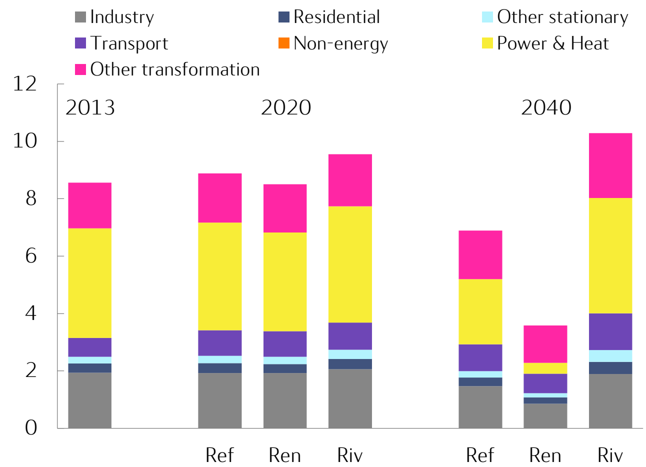
OECD Americas CO_2 emissions 2013-2040

Billion tonnes



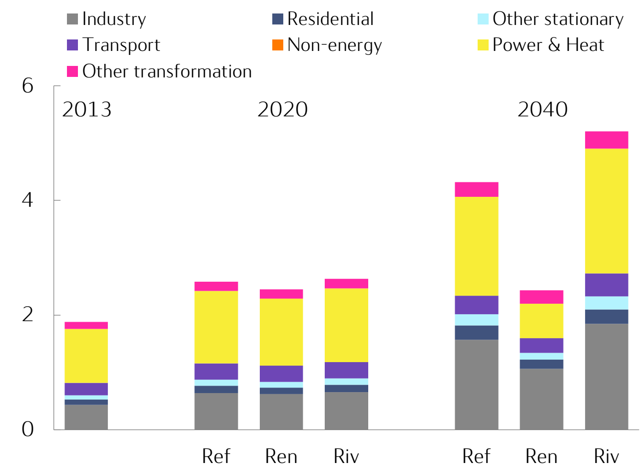
China CO_2 emissions 2013-2040

Billion tonnes



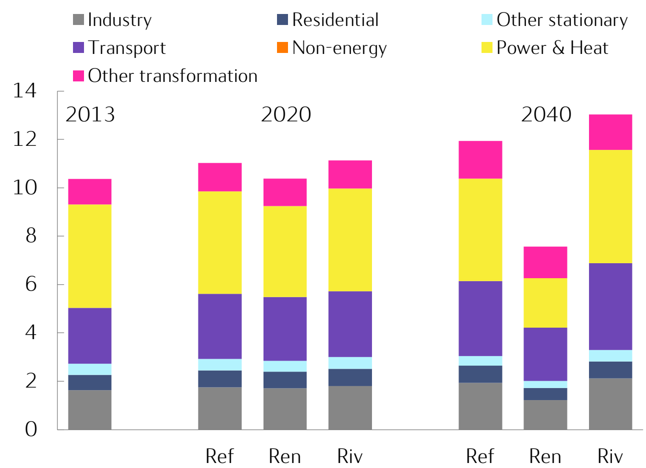
India CO_2 emissions 2013-2040

Billion tonnes



Rest of the World CO_2 emissions 2013-2040

Billion tonnes



Source: IEA (history), Statoil (projections)

Energy Perspectives 2016

Statoil ASA
NO-4035 Stavanger
Norway
Telephone +47 51 99 00 00
www.statoil.com