

BP Energy | 2018
Outlook | edition

BP energy economics
bp.com/energyoutlook
#BPstats





BP Energy Outlook

2018 edition

The Energy Outlook explores the forces shaping the global energy transition out to 2040 and the key uncertainties surrounding that transition.

The Outlook considers a number of different scenarios. These scenarios are not predictions of what is likely to happen or what BP would like to happen. Rather, they explore the possible implications of different judgements and assumptions by considering a series of “what if” experiments. The scenarios consider only a tiny sub-set of the uncertainty surrounding energy markets out to 2040; they do not provide a comprehensive description of all possible future outcomes.

For ease of explanation, much of the Outlook is described with reference to the ‘Evolving Transition’ scenario. But that does not imply that the probability of this scenario is higher than the others. Indeed, the multitude of uncertainties means the probability of any one of these scenarios materializing exactly as described is negligible.

The Energy Outlook is produced to aid BP’s analysis and decision-making, and is published as a contribution to the wider debate. But the Outlook is only one source among many when considering the future of global energy markets. BP considers the scenarios in the Outlook, together with a range of other analysis and information, when forming its long-term strategy.

Welcome to the 2018 edition of BP's Energy Outlook



The publication of BP's Energy Outlook provides an opportunity to step back from the here and now, and consider some of the lessons and insights the Outlook contains about where energy is heading over the next few decades.

Reading this year's Outlook, a core theme is the speed of the transition underway. Change is ever present in our industry: the energy industry today is very different to the one I joined almost 40 years ago. Likewise, government policies, new technologies and social preferences will alter the way in which energy is produced and consumed in the future in ways which are impossible to predict today. The Energy Outlook aids our understanding of that uncertainty by considering a number of different scenarios. BP needs a strategy that is resilient to all these possibilities and many more, ensuring that we are fit and ready to meet the energy needs of tomorrow's world, whatever form they take.

Another insight from this year's Outlook is that competitive pressures within global energy markets are intensifying. Demand will continue to grow, with global energy consumption set to increase by around a third or so by 2040. But technological advances mean our ability to produce energy is growing ever faster – be that in unconventional oil and gas, or in renewables like wind and solar energy. Indeed, the continuing rapid growth of renewables is leading to the most diversified fuel mix ever seen. Abundant and diversified energy supplies will make for a challenging marketplace. Don't be fooled by the recent firming in oil prices: the focus on efficiency, reliability and capital discipline is here to stay.



The third, and most important, takeaway for me from this year's Outlook is the need for more downward pressure on carbon emissions. The Outlook's Evolving Transition scenario suggests that a continuation of the recent progress and momentum in policies and technologies is likely to cause the growth in carbon emissions to slow markedly relative to the past. But this slowing falls well short of the sharp drop in carbon emissions thought necessary to achieve the Paris climate goals. We need a far more decisive break from the past.

There is no silver bullet that will achieve this break: as the Outlook shows, policies focussed on specific fuels or technologies are unlikely to be sufficient on their own. We need a comprehensive approach encouraging both improvements in how efficiently we use energy as well as the continuing shift to a lower carbon fuel mix. In BP, we continue to believe that carbon pricing must be a key element of any such approach as it provides incentives for everyone – producers and consumers alike – to play their part.

I feel very privileged to work in the energy industry. It is an industry which literally fuels the world economy, enabling billions of people over the next 25 years to be lifted out of low incomes. We work at the epicentre of new technologies and the shifting global landscape, providing energy solutions for a changing world. At the same time, we need to adapt and change to play our part in achieving the transition to a low carbon energy system. This raises important challenges – but also opportunities and choices. I hope you find this year's edition of BP's Energy Outlook a useful contribution to your own discussions and thinking.

Bob Dudley
Group chief executive

Executive summary

- The Energy Outlook considers the energy transition from three different viewpoints (sectors, regions and fuels) and by exploring a number of different scenarios.
- In the Evolving Transition scenario, world GDP more than doubles by 2040, driven by increasing prosperity in fast-growing emerging economies, as more than 2.5 billion people are lifted from low incomes.
- This rising prosperity drives an increase in global energy demand, although the extent of this growth is offset by accelerating gains in energy efficiency: energy demand increases by only around one third over the next 25 years.
- Industrial demand for energy accounts for around half of the increase in energy consumption; growth in transport demand slows sharply relative to the past.
- The world continues to electrify, with almost 70% of the increase in primary energy going to the power sector.
- The share of vehicle kilometres powered by electricity increases, as the number of electric cars grows and they are used more intensively. The interaction of fully autonomous cars with shared mobility substantially boosts the intensity with which electric cars are driven.



Executive summary (continued)

- All of the growth in energy consumption is in fast-growing developing economies: China and India account for half of the growth in global energy demand.
- Renewable energy is the fastest-growing energy source, accounting for 40% of the increase in primary energy. The energy mix by 2040 is the most diversified the world has ever seen.
- Demand for oil and other liquid fuels grows over much of the Outlook, but gradually slows and plateaus in the later years of the Outlook.
- The increase in liquids production is initially dominated by US tight oil, but is later driven by OPEC, as members adopt a strategy of increasing their market share.
- Natural gas grows strongly, supported by broad-based demand and the continuing expansion of liquefied natural gas (LNG) increasing the availability of gas globally.
- Global coal consumption flatlines, with Chinese coal demand declining.
- In the ET scenario, carbon emissions continue to rise, signalling the need for a comprehensive set of actions to achieve a decisive break from the past.

Contents

Introduction and Overview	11
Economic backdrop	17
<ul style="list-style-type: none"> • GDP • Energy intensity 	18 20
Sector demand	23
<ul style="list-style-type: none"> • Industry • Non-combusted • Buildings • Transport <ul style="list-style-type: none"> Alternative scenario: Impact of ICE ban on liquids demand • Power 	24 28 30 32 42 46
Region demand	51
<ul style="list-style-type: none"> • China's energy needs are changing • India becoming the largest growth market • Africa's increasing role • US's global role in oil and gas production • EU leading the transition to a lower carbon economy 	56 58 60 62 64



Contents (continued)

Demand and supply of fuels	67
• Oil Alternative scenario: Growth in US tight oil	70 76
• Natural Gas Alternative scenario: Less coal-to-gas switching	80 84
• Coal	92
• Renewables Alternative scenario: More support for renewables	94 98
• Nuclear and Hydro	100
Carbon emissions	103
Alternative scenarios: Faster Transition and Even Faster Transition	106
Comparisons	109
• Comparisons to last year's outlook	110
• Extending the outlook to 2040	112
• Comparisons to external outlooks	114
Annex	119
• Key figures, definitions and sources	120



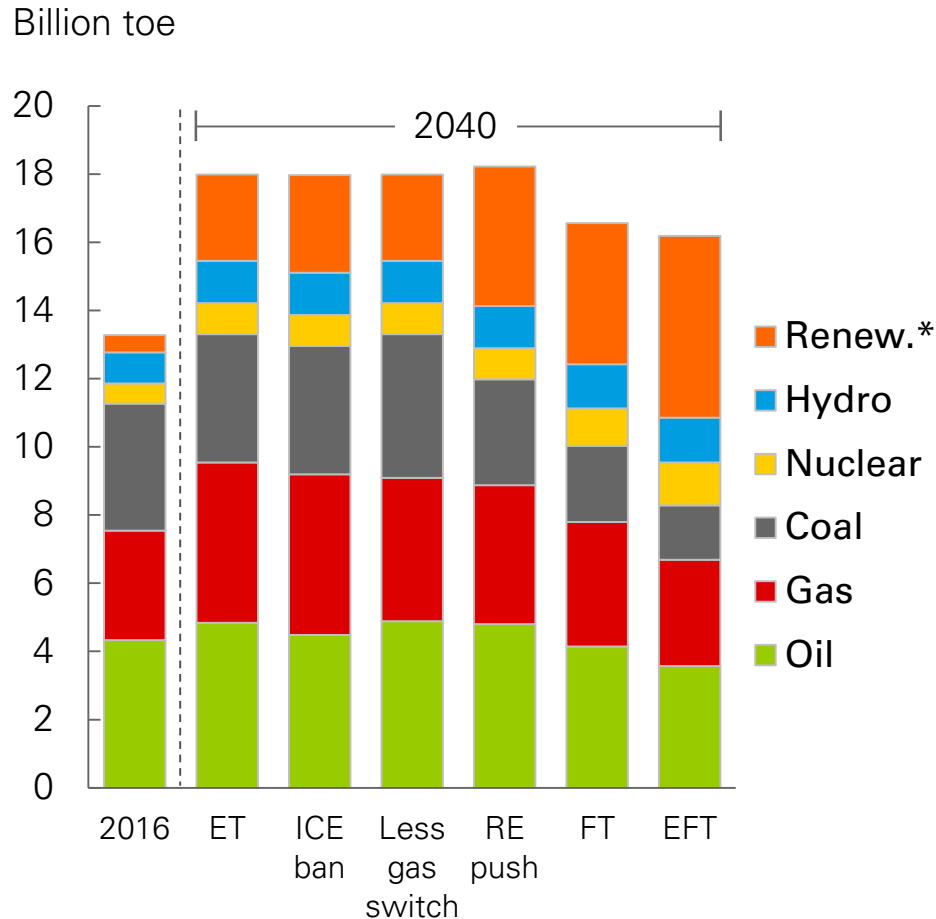


Overview

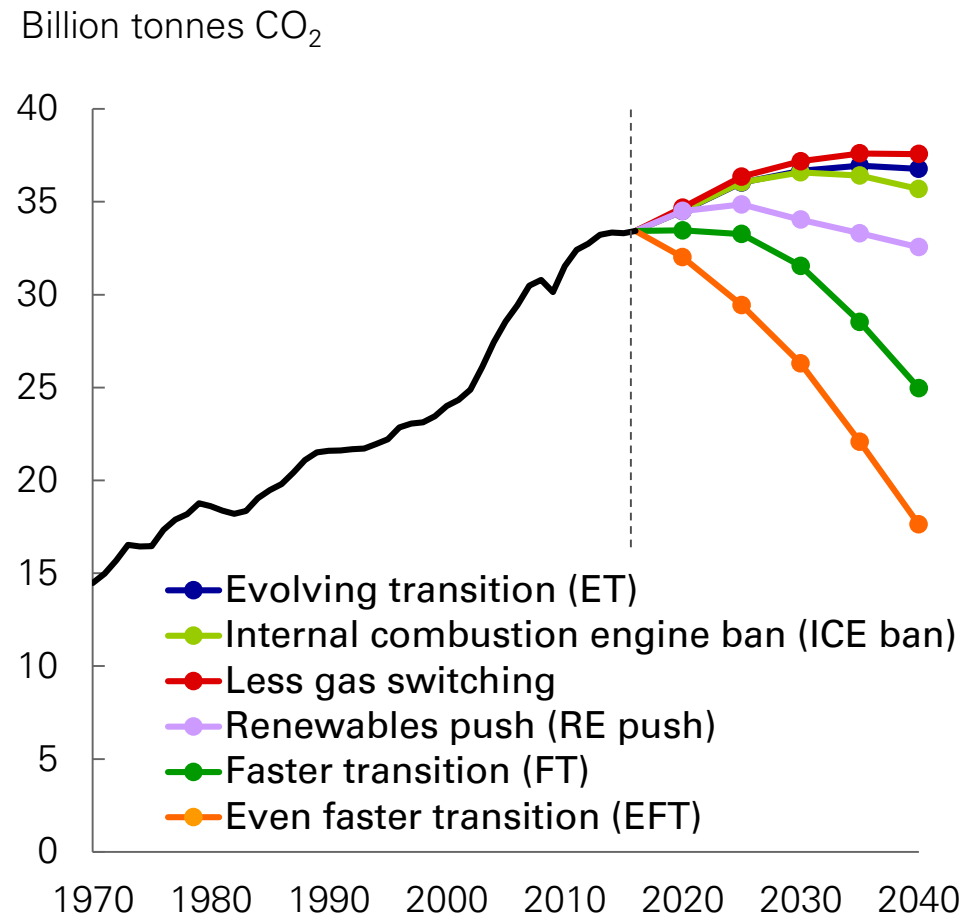


The Energy Outlook considers a range of scenarios...

Primary energy consumption by fuel



Carbon emissions



*Renewables includes wind, solar, geothermal, biomass, and biofuels
For full list of data definitions see p122



...to explore different aspects of the energy transition

- The Energy Outlook considers a range of alternative scenarios to explore different aspects of the energy transition. The scenarios have some common features, such as a significant increase in energy demand and a shift towards a lower carbon fuel mix, but differ in terms of particular policy or technology assumptions.
- In what follows, the beginning of each text page (unless stated otherwise) highlights features of the energy transition which are common across all the different scenarios considered. For ease of exposition, much of the subsequent description is based on the Evolving Transition (ET) scenario, which assumes that government policies, technology and social preferences continue to evolve in a manner and speed seen over the recent past. But carbon emissions in this scenario are not consistent with achieving the Paris climate goals, highlighting the need for a more decisive break from the past.
- Some scenarios focus on particular policies that affect specific fuels or technologies, e.g. a ban on sales of internal combustion engine (ICE) cars (pp 42-45), a greater policy push to renewable energy (pp 98-99), or weaker policy support for a switch from coal to gas (pp 84-87). Some general alternative transition paths are also considered, e.g. faster and even faster transitions (pp 106-07).



The Outlook examines the energy transition...

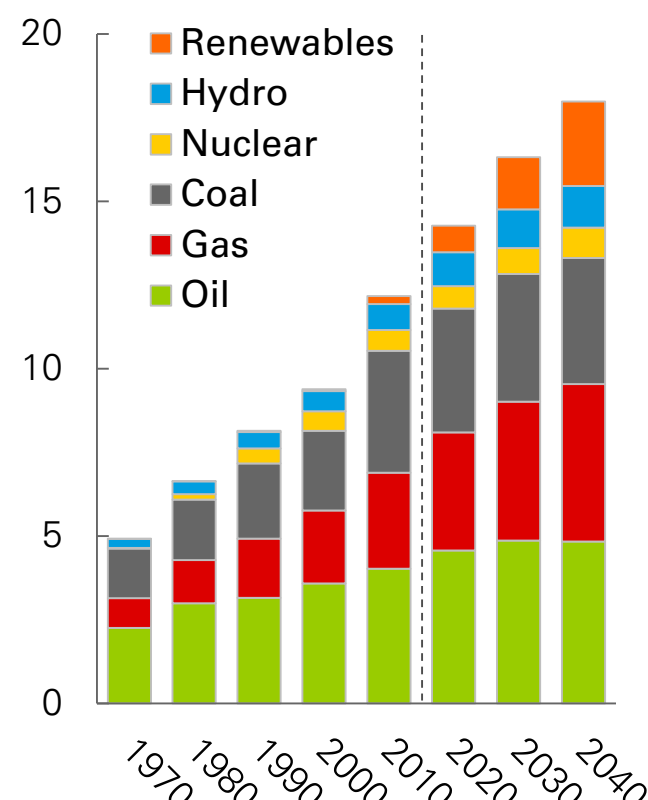
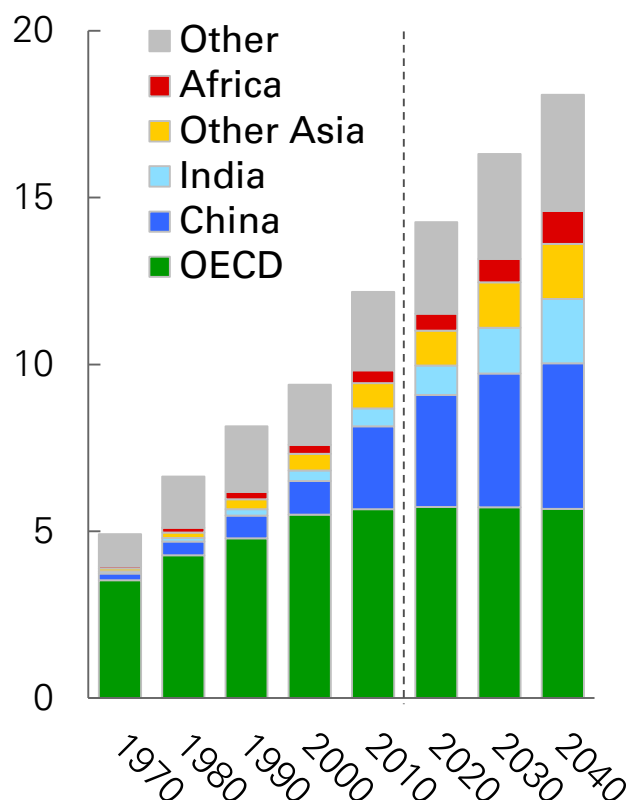
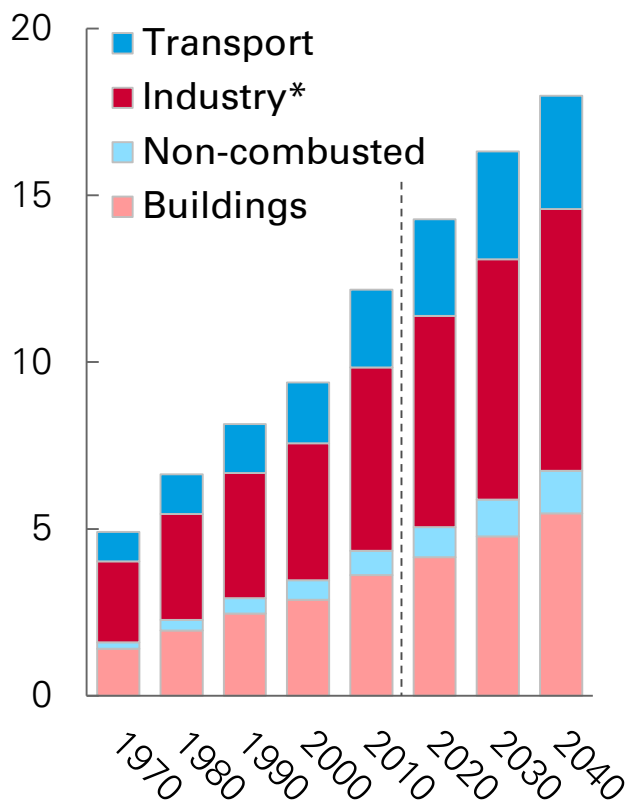
Primary energy demand

End-use sector

Region

Fuel

Billion toe



*Industry excludes non-combusted use of fuels



...through three different lenses: sector, region and fuels

- The Outlook considers the energy transition through three different lenses – sectors, regions and fuels – each of which illuminates different aspects of the transition.
- In the ET scenario, global energy demand grows by around a third by 2040 – a significantly slower rate of growth than in the previous 25 years.
- Demand growth is broadly based across all the main sectors, with the industrial sector accounting for around half of the overall increase. Growth in transport demand is much slower than in the past, reflecting faster gains in vehicle efficiency (Sectors pp 32-41).
- By region, all of the growth in energy demand comes from fast-growing developing economies, driven by increasing prosperity. China, India and other emerging Asia account for around two-thirds of the growth in energy consumption (Regions pp 52-65).
- Renewable energy is the fastest growing energy source, accounting for 40% of the increase in energy. Natural gas grows much faster than either oil or coal. The energy mix by 2040 is the most diversified ever seen (Fuels pp 68-01).



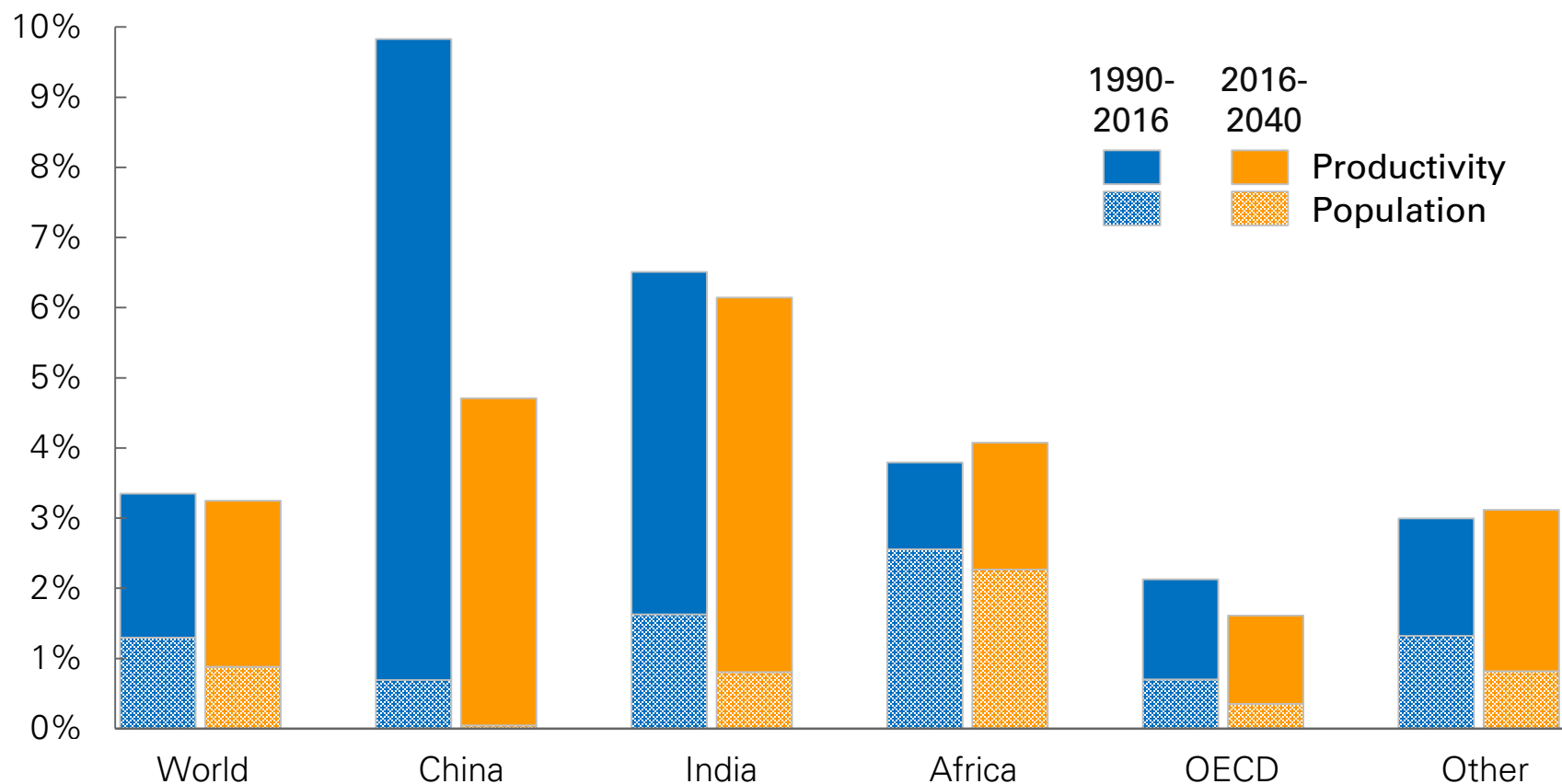
Economic backdrop



GDP is projected to grow at a similar rate to past 25 years...

GDP growth by region and factor

% per annum





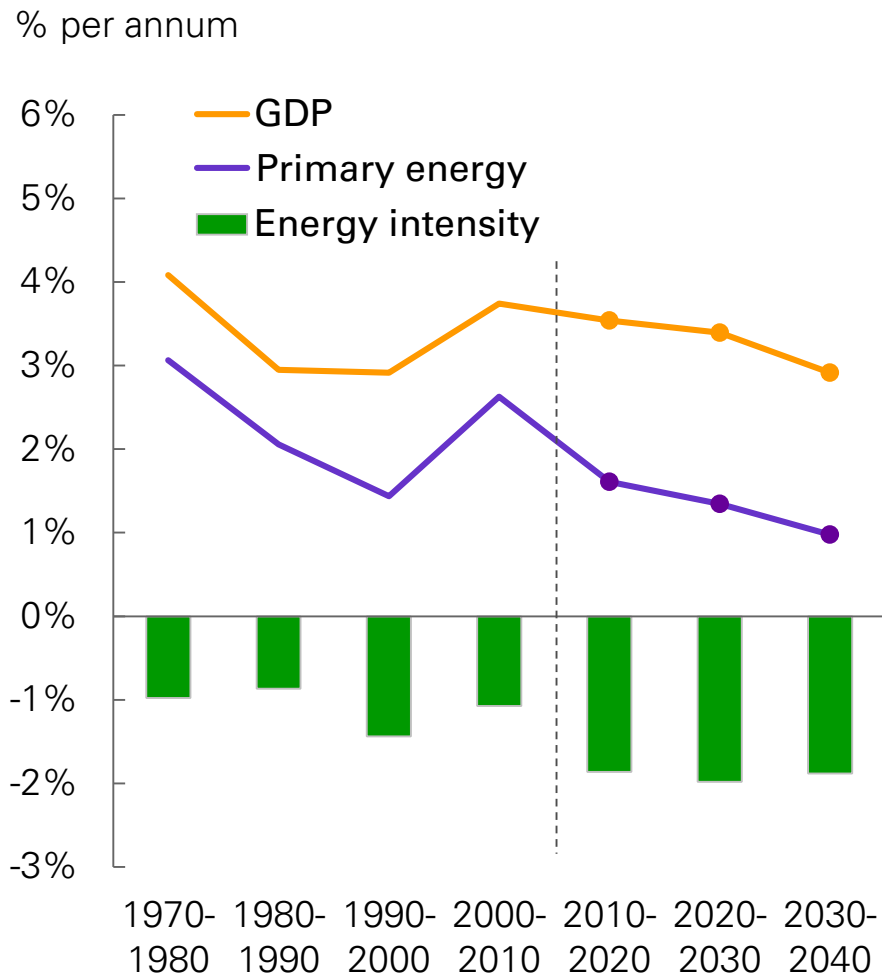
...driven by increasing prosperity in the developing world

- The world economy continues to grow, driven by increasing prosperity in the developing world.
- In the ET scenario, global GDP growth is projected to average around 3 ¼% p.a. (at Purchasing Power Parity exchange rates), broadly in line with growth seen over the past 25 years.
- Global output is partly supported by population growth, with the world population increasing by around 1.7 billion to reach nearly 9.2 billion people in 2040.
- But the main driver of economic growth is increasing productivity (i.e. GDP per person), which accounts for three-quarters of global expansion and lifts more than 2.5 billion people from low incomes. The increasing prosperity of the developing world is a key force shaping economic and energy trends over the next 25 years.
- Over 80% of the expansion in world output is driven by emerging economies, with China and India accounting for over half of that expansion.
- Africa continues to be weighed down by weak productivity, accounting for nearly half of the increase in global population but less than 10% of world GDP growth.

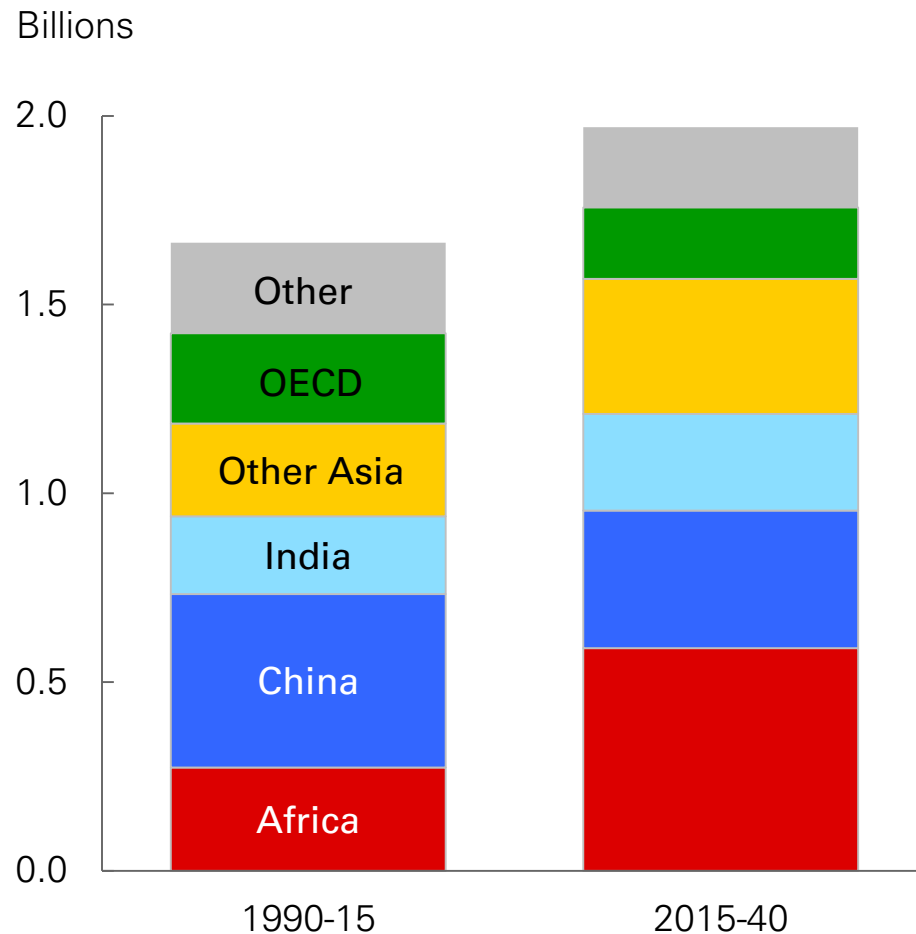


Increasing global prosperity drives growth in energy demand...

Growth in GDP and primary energy



Growth in urban population by region





...partly offset by more rapid falls in energy intensity

- The expansion in global output and prosperity drives the growth in energy demand, with growth in energy consumption led by fast-growing developing economies.
- Global energy demand in the ET scenario grows at around 1.3% p.a. over the Outlook, down from over 2% in the previous 20 years.
- This slowing in demand growth is largely due to energy intensity (energy used per unit of GDP) falling more quickly than in the past: global GDP more than doubles over the Outlook, but energy consumption increases by only 35%.
- The global trend towards increasing urbanization is projected to continue, with almost 2 billion additional people likely to live in urban centres by 2040, a slightly faster rate of urbanization than in the past.
- Much of this urbanization occurs in Africa where the urban population is projected to grow by nearly 600 million – about one-third of the global increase. The impact on Africa's energy consumption and intensity depends on the extent to which this urbanization facilitates increased levels of industrialization and prosperity (pp 60-61).



Sector demand

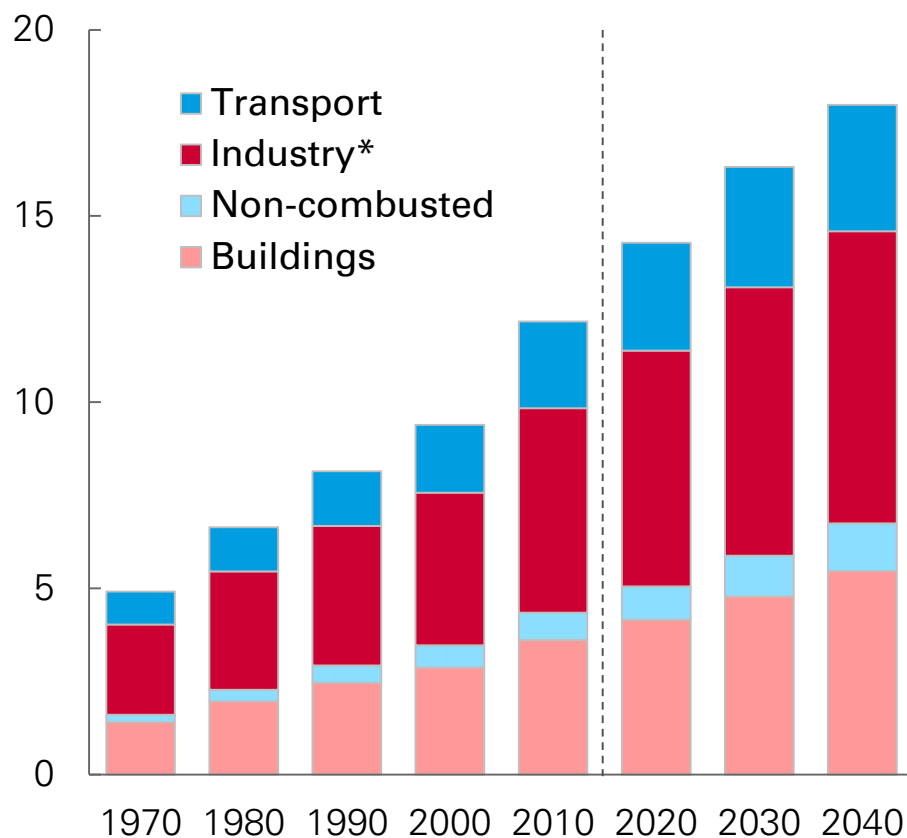
- Overview
- Industry
- Non-combusted
- Buildings
- Transport
- Power



Growth of energy demand in industry and transport slows...

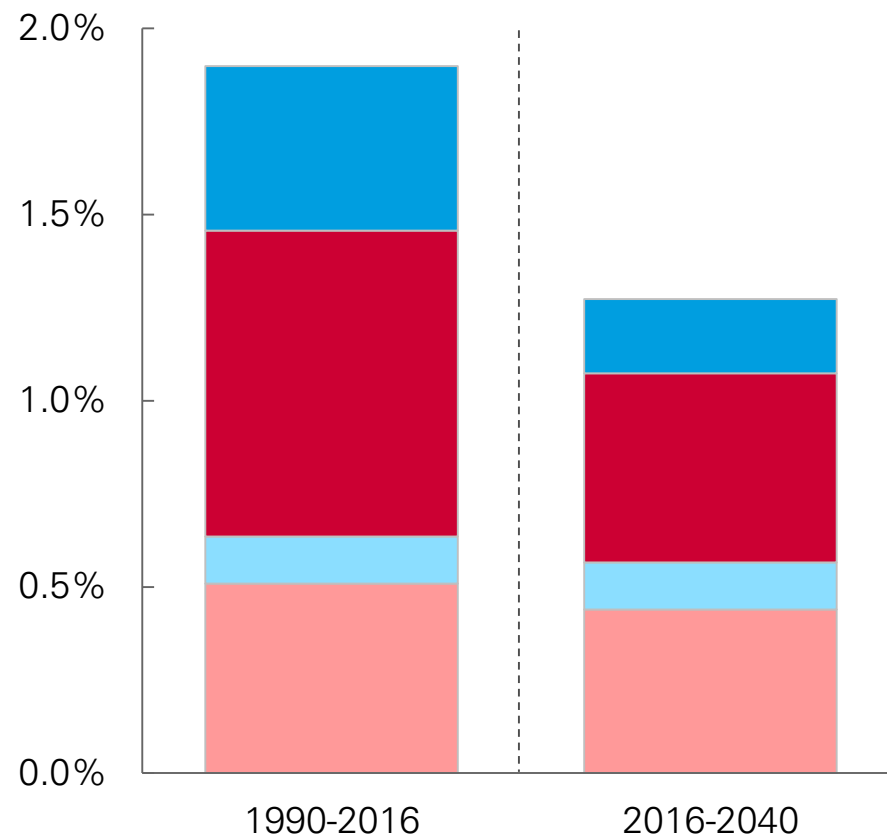
Primary energy consumption by end use sector †

Billion toe



Annual demand growth and sector contributions

% per annum



† Primary energy use in power is allocated according to final sector electricity consumption

* Industry excludes non-combusted use of fuels



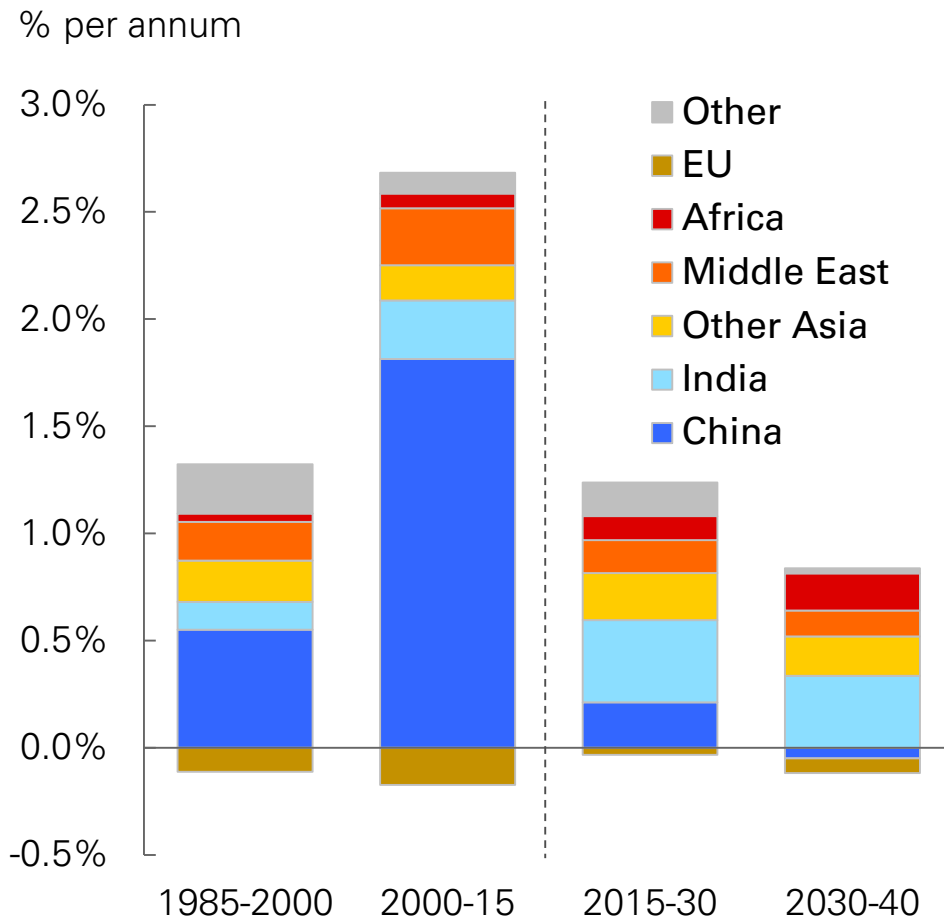
...while buildings and non-combusted use grow in importance

- Growth in global energy demand is broad-based across all the main sectors. Differing trends in the way energy is used and consumed in these sectors has an important bearing on the energy transition.
- The industrial sector (including the non-combusted use of fuels) currently consumes around half of all global energy and feedstock fuels, with residential and commercial buildings (29%) and transport (20%) accounting for the remainder.
- In the ET scenario, the industrial sector accounts for around half of the increase in energy consumption, although improving energy efficiency causes growth of industrial use outside of the non-combusted sector to slow (pp 26-27).
- In contrast, the non-combusted use of fuels, particularly as a feedstock in petrochemicals, is projected to be the fastest growing source of demand (pp 28-29).
- Energy growth in the buildings sector also grows robustly, driven by an increase in demand for space cooling, lighting and electrical appliances (pp 30-31).
- The slowing in demand growth is most marked in the transport sector as improvements in vehicle efficiency accelerate (pp 32-33).

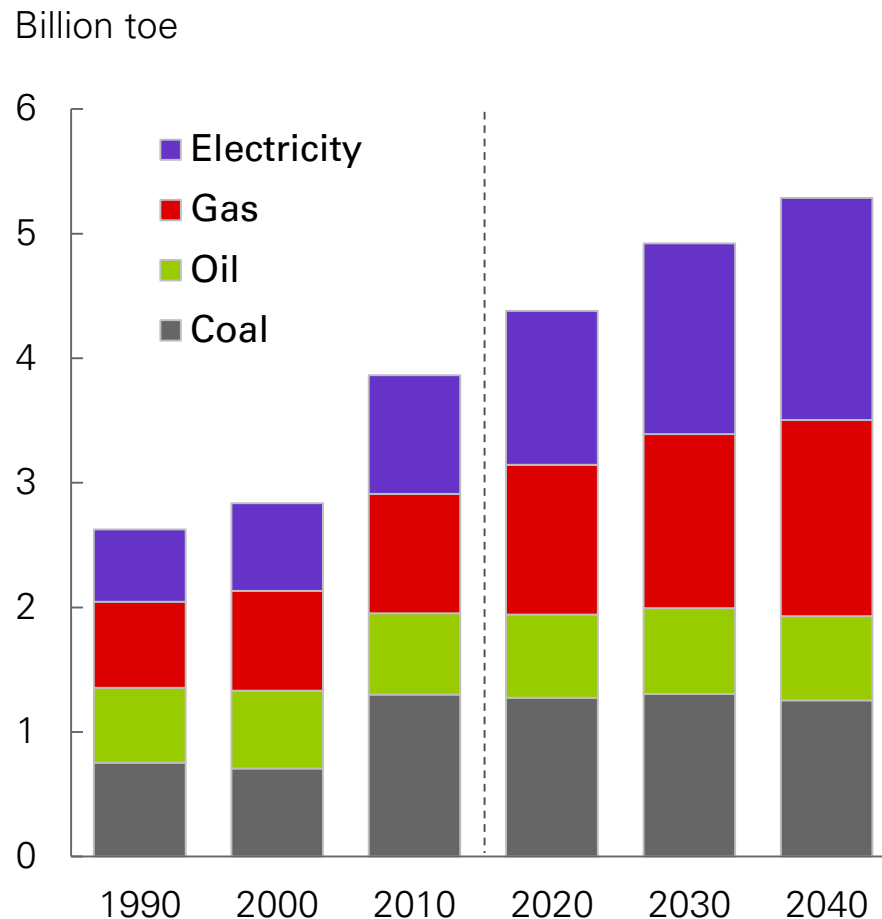


Growth in industrial energy consumption slows...

Growth in final energy consumption in industry* by region



Final energy consumption in industry* by fuel



*Industry excludes non-combusted use of fuels



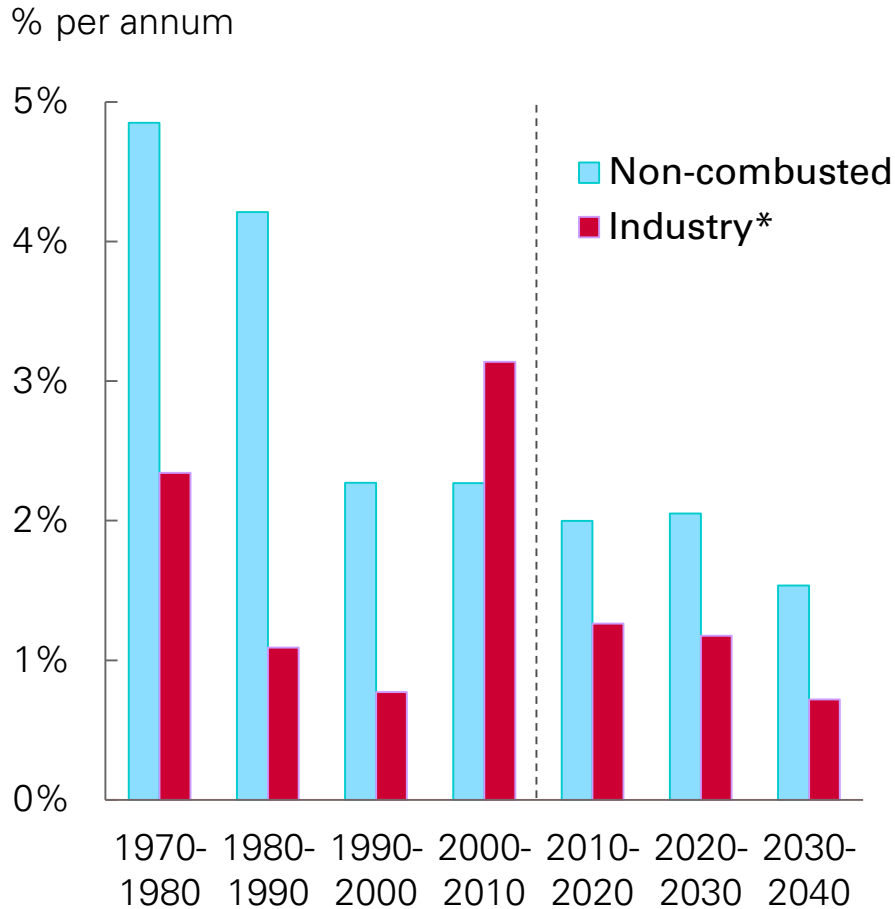
...as China's rapid industrialization comes to an end

- The slower growth of energy consumption within the industrial sector (excluding the non-combusted use of fuels) masks sharply differing trends across regions as the global composition of industrial production shifts.
- After tripling over the past 15 years, growth in Chinese industrial energy demand in the ET scenario slows to a virtual standstill, as the Chinese economy transitions away from energy-intensive industrial sectors, such as steel and cement, towards less energy-intensive service and consumer-facing sectors.
- Some of this growth in industrial production is displaced to lower-income economies, with India, other emerging Asia and Africa together accounting for around 70% of the growth in industrial energy consumption.
- This shift in industrial composition is accompanied by coal-to-gas switching, particularly in China, with the share of industrial energy provided by coal declining from almost a third today to less than a quarter in 2040.
- Natural gas and electricity supply all of the incremental industrial energy demand, providing around two-thirds of total industrial energy by 2040.

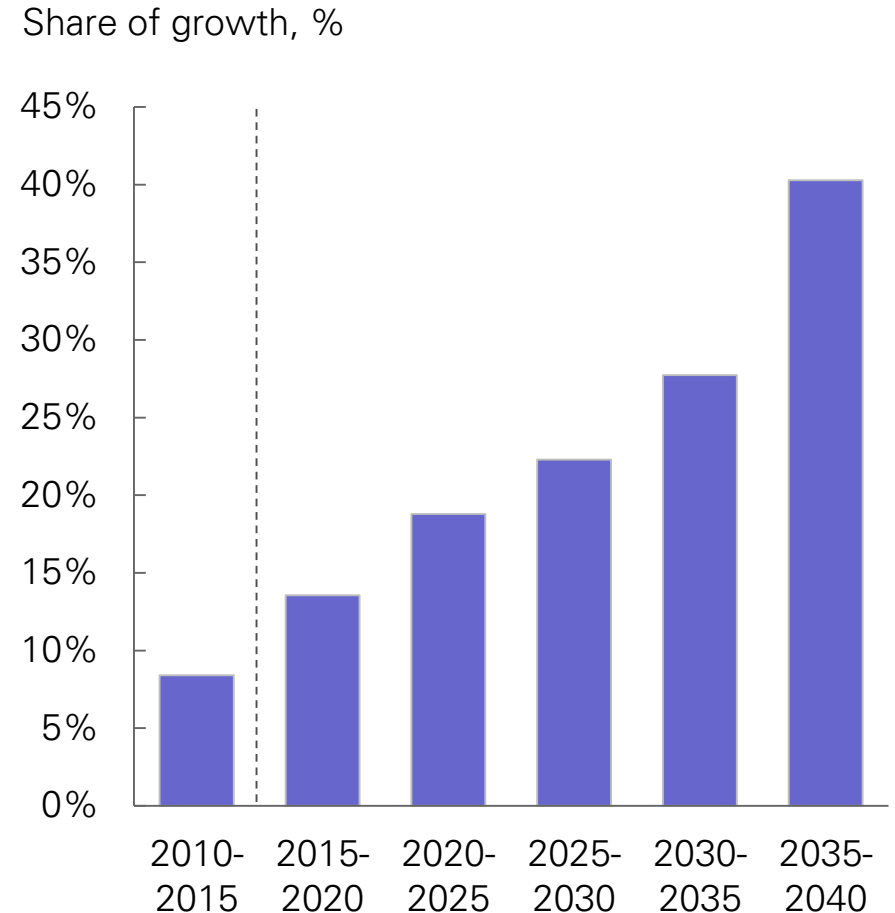


Non-combusted use of fuels grows in importance...

Final energy consumption growth: non-combusted versus industry



Non-combusted share of total oil & gas consumption growth



*Industry excludes non-combusted use of fuels



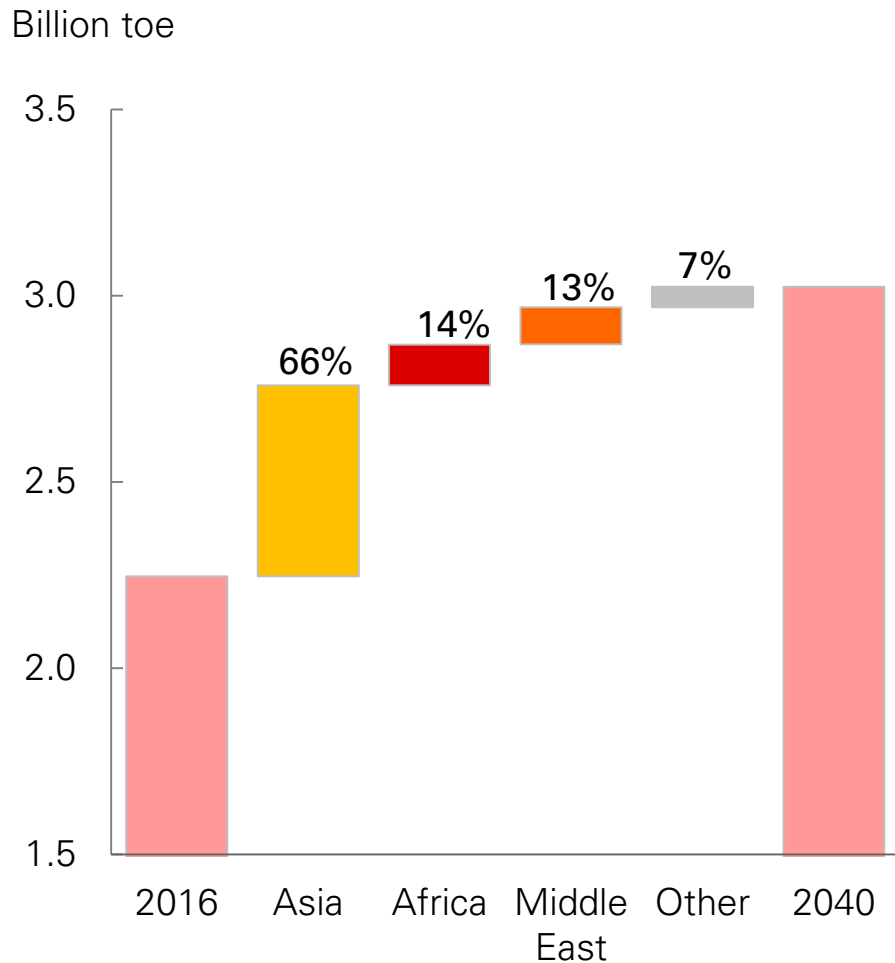
...becoming the main source of demand growth for oil and gas

- The non-combusted use of fuels, e.g. as feedstocks for petrochemicals, lubricants and bitumen, becomes an increasingly important component of overall industrial demand over the Outlook.
- In the ET scenario, non-combusted use of fuels grows at almost twice the rate of other industrial uses (1.9% p.a. versus 1.0% p.a.), with its share of overall industrial demand increasing to nearly 20% by 2040.
- This stronger growth reflects the more limited scope for efficiency gains when oil, gas and coal are used as a feedstock rather than as a source of energy. Although increasing environmental pressures on the use of some products, particularly single-use plastics and packaging, dampens growth quite materially relative to past trends.
- Oil accounts for nearly two-thirds of the growth in the non-combusted use of energy, with natural gas providing much of the remainder.
- Despite accounting for only a small fraction of current oil and gas demand (10%), the non-combusted use of oil and gas is the largest contributor of their combined growth in the latter part of the Outlook.

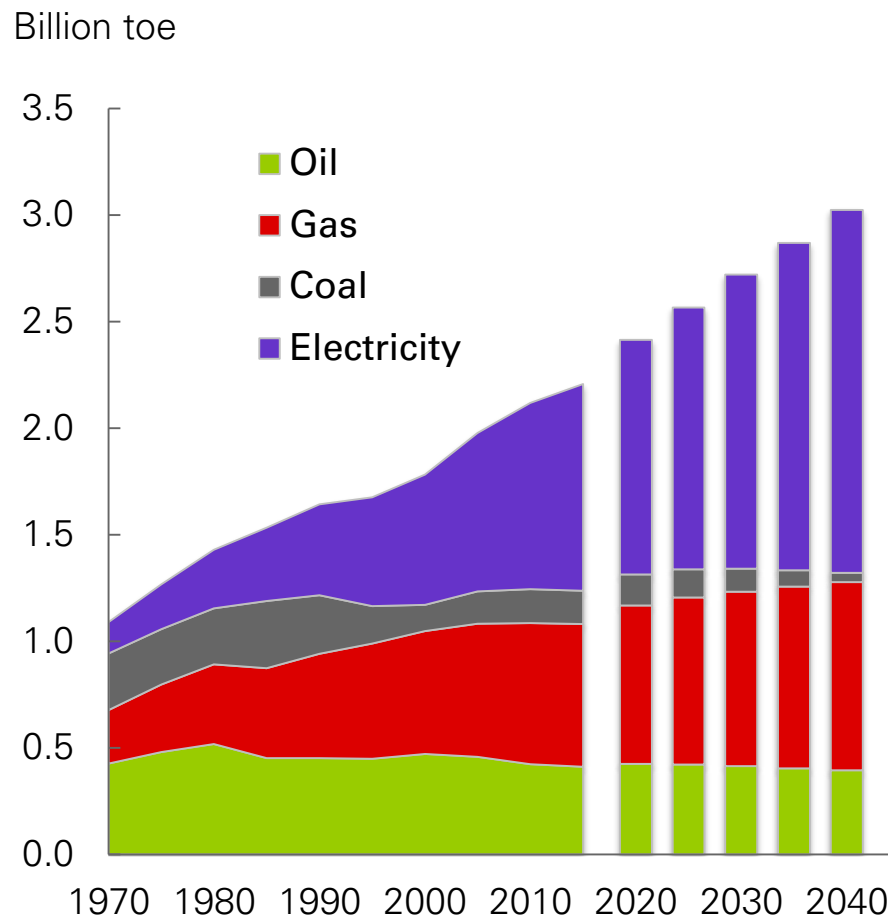


Buildings account for a third of global energy growth...

Growth in final energy consumption in buildings by region 2016-2040



Final energy consumption in buildings by fuel type





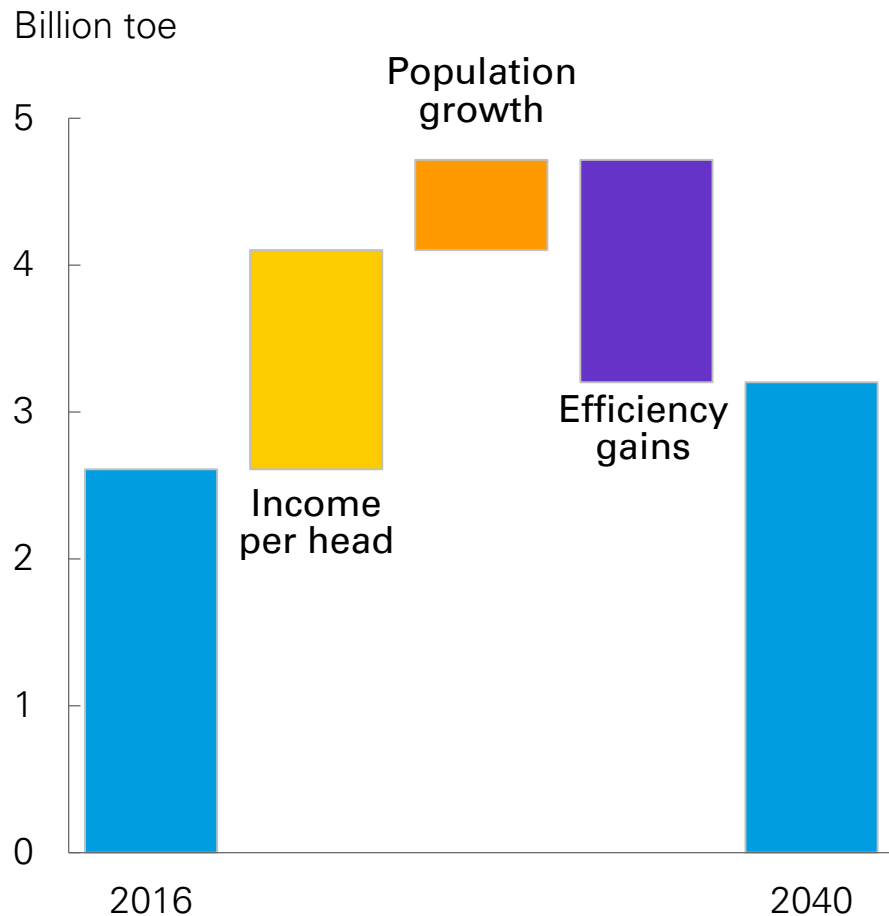
...almost entirely driven by increased electricity consumption

- The increase in energy use in buildings is driven by a combination of growing population and increasing prosperity, allowing people to live and work in greater comfort.
- In the ET scenario, both of these trends – growing population and increasing prosperity – are particularly concentrated in Asia, Africa and the Middle East, which together account for over 90% of the growth in building energy use.
- The relatively warm climate covering much of these regions means that the increase in demand for space heating is small. Instead, the majority of demand is driven by the need for space cooling (air conditioning), together with growing prosperity increasing demand for lighting and electrical appliances.
- As a result, almost all of the increase in energy consumption in buildings over the Outlook is provided by electricity, which is the most efficient source of energy for meeting these demands.
- There is also a small increase in gas consumption, which gains share from both coal and oil in space heating.

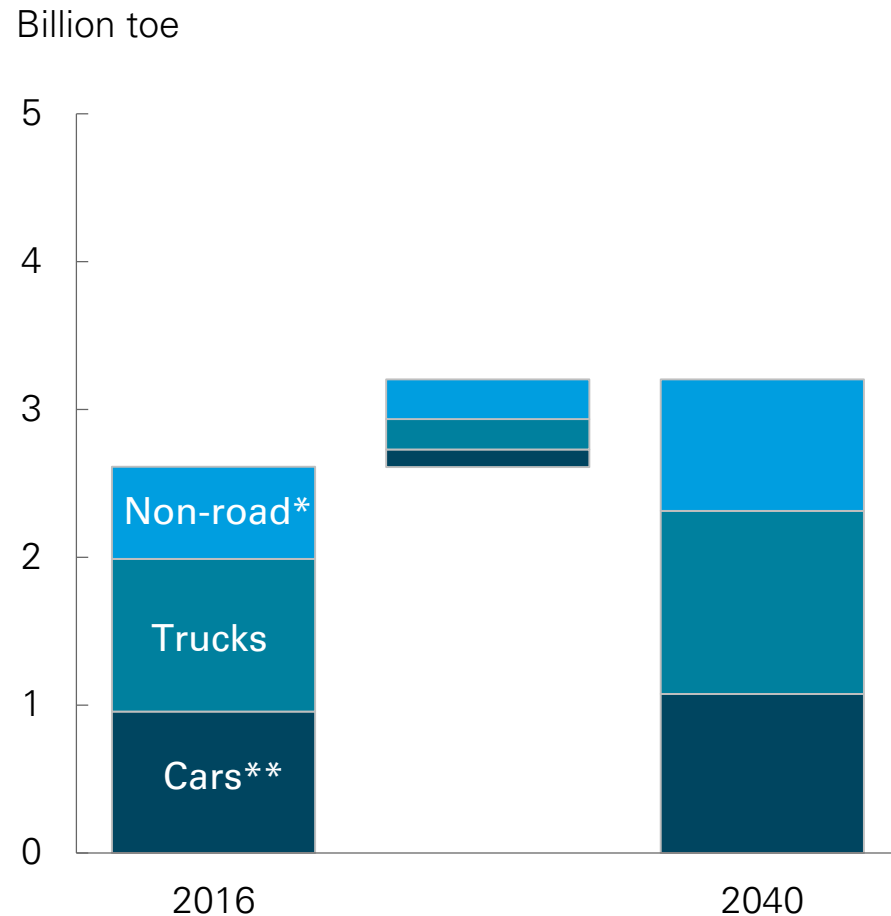


Growth of fuels used in transport slows...

Contributions to transport energy consumption growth



Transport energy consumption by mode



*Aviation, Marine and Rail

**Includes 2- and 3- wheelers



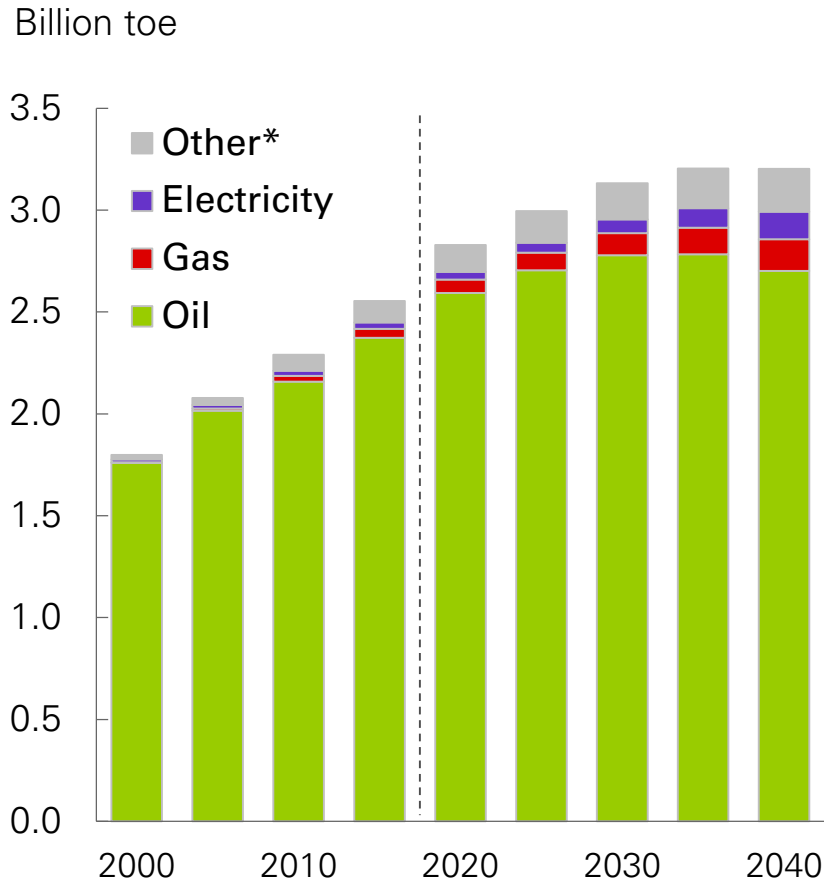
...as the impact of rising prosperity is offset by efficiency gains

- Increasing prosperity in developing economies causes the demand for transport to increase, with the impact on fuel demand largely offset by efficiency gains.
- In the ET scenario, global demand for both passenger and freight transport services more than double by 2040. These patterns are broadly consistent across road, aviation and marine. But the impact on transport fuel demand is largely offset by efficiency gains: energy used in transport increases by only 25% over the Outlook – far slower than the 80% increase during the previous 25 years – and plateaus towards the end of the Outlook.
- Within road transport, the impact from increased ownership and travel is offset by efficiency improvements, dampening the overall growth of fuel used by cars and motorbikes. Growth in fuel demand for trucking is stronger, with increasing freight activity and more modest efficiency gains causing the share of energy within transport consumed by trucks to increase.
- Energy consumption in aviation and marine transportation increase by broadly similar amounts, supported by the expansion in global GDP, with air passenger traffic growing particularly strongly.

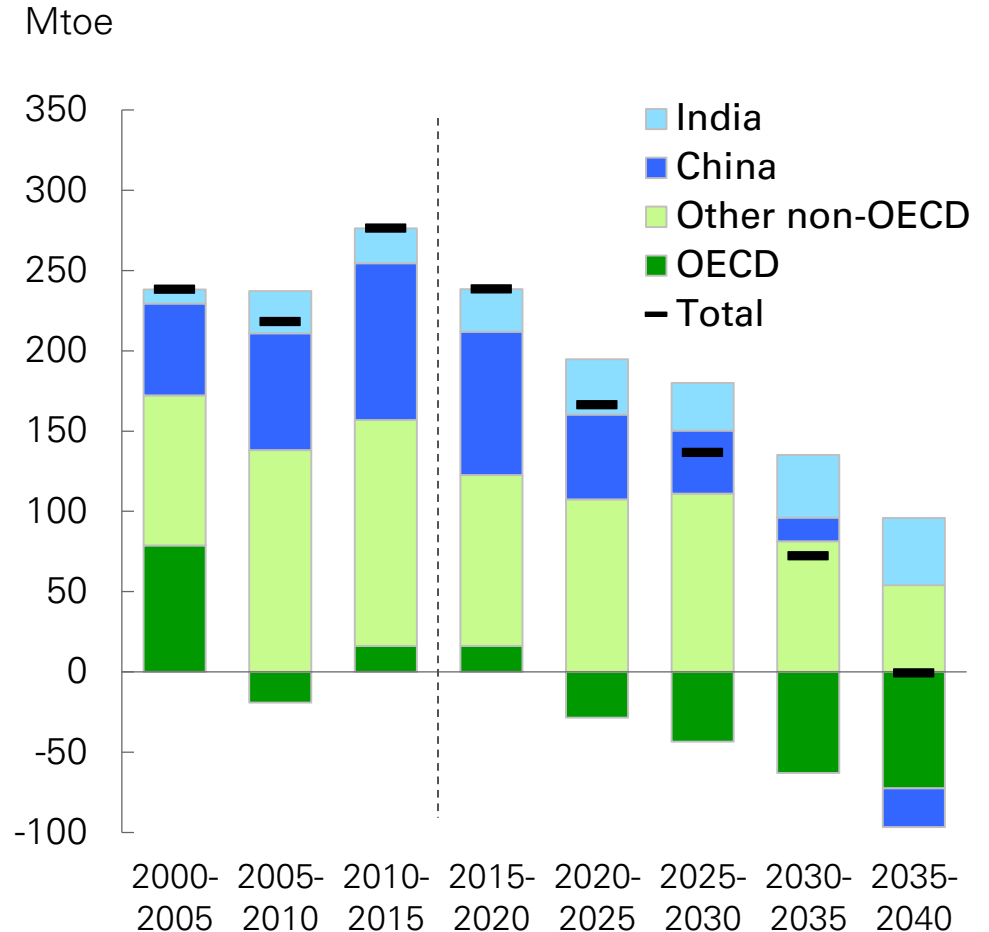


Transport demand continues to be dominated by oil...

Transport energy consumption by fuel type



Transport energy consumption growth by region



*Other includes biofuels, gas-to-liquids, coal-to-liquids, hydrogen



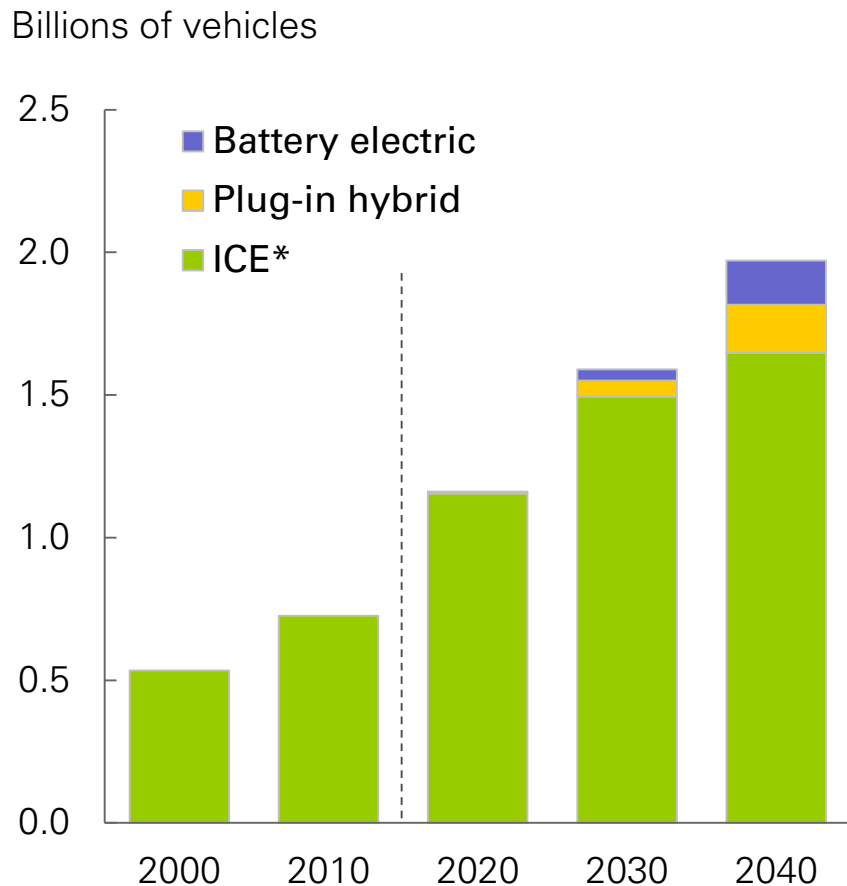
...despite increasing use of both natural gas and electricity

- The transport sector continues to be dominated by oil, despite increasing penetration of alternative fuels, particularly natural gas and electricity.
- In the ET Scenario, oil demand accounts for around 85% of total transport fuel demand in 2040, down from 94% currently. Natural gas, electricity and a mix of 'other' types of fuels are each projected to account for around 5% of transport fuel by 2040.
- Growth in natural gas is concentrated in the use of LNG in long-distance road haulage and marine transportation. In contrast, electricity usage increases most rapidly in passenger cars and light trucks (pp 42-45 outlines an alternative scenario in which electric cars are assumed to grow more rapidly than in the ET Scenario).
- 'Other' fuels are dominated by biofuels, with hydrogen accounting for only a small proportion of total fuel transport. The prospects for hydrogen, particularly towards the end of the Outlook and beyond, depend on the ability of hydrogen to compete against liquid fuels and electricity in fueling long-distance road haulage.
- All of the growth in transport fuel demand comes from developing economies, with China and India accounting for over half of the increase.

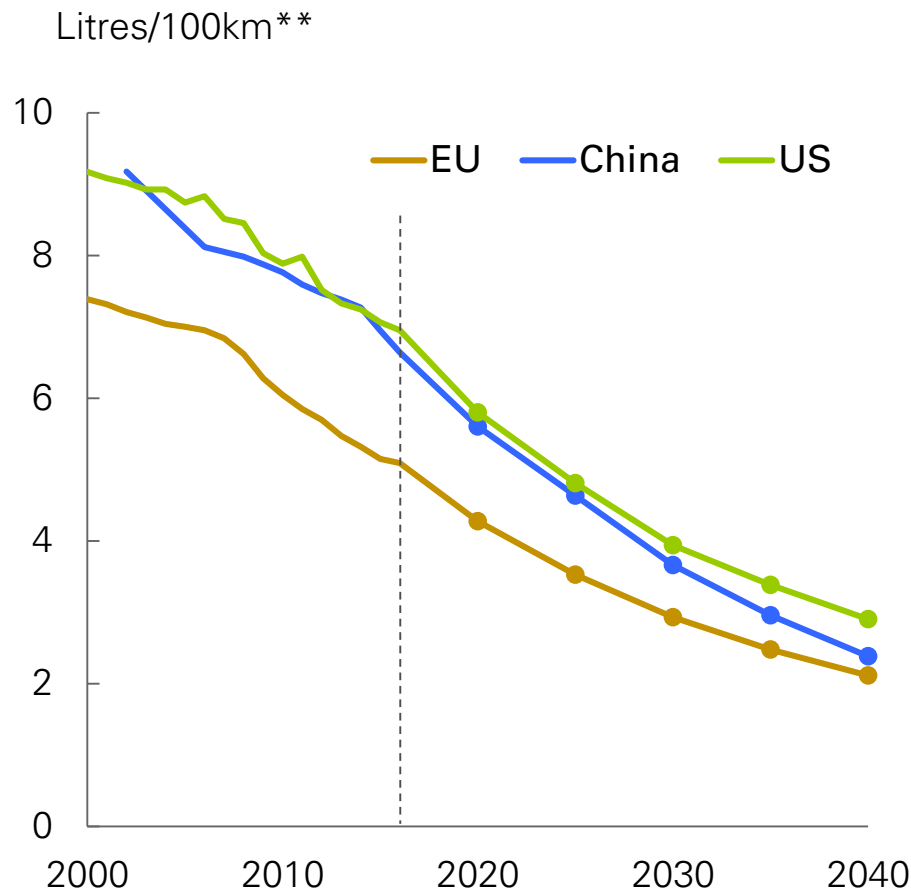


The passenger car parc grows substantially...

Passenger car parc by type



Fuel economy of new cars



*ICE vehicles includes hybrid vehicles which do not plug into the power grid

**Based on the NEDC (New European Drive Cycle), gasoline fuel



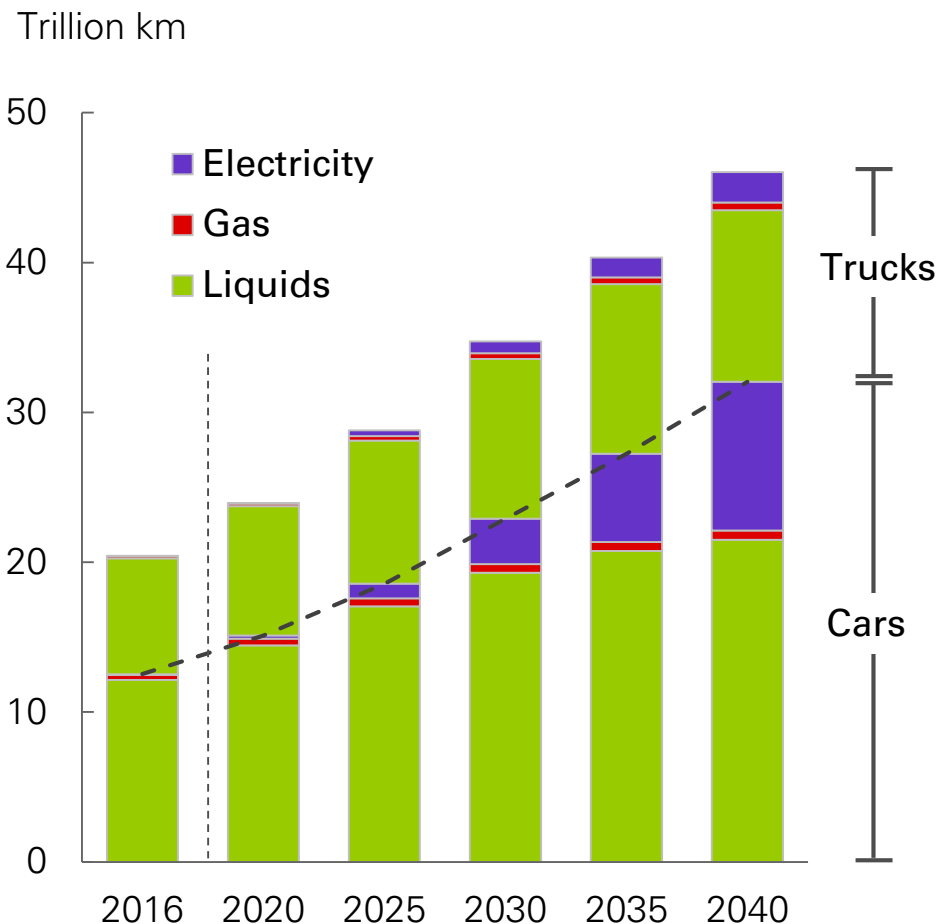
...with increased EVs and significant efficiency improvements

- The number of passenger cars on the planet increases substantially by 2040, with an increasing number of electric cars and a substantial improvement in vehicle efficiency.
- In the ET scenario, the passenger car parc nearly doubles to 2 billion cars by 2040, including more than 300 million electric cars. The increase in electric cars in the ET scenario is faster than in the base case in last year's Outlook (pp 112-113).
- There are two main types of electric cars: plug-in hybrids (PHEVs) and battery electric vehicles (BEVs), with roughly equal amounts of PHEVs and BEVs by 2040. PHEVs contain both a conventional internal combustion engine (ICE) and an electric motor, and run on a combination of oil and electricity from the grid. PHEVs are broadly equally powered by electricity and oil. In contrast, BEVs are powered solely by electricity.
- The efficiency of the global car parc improves by 2-3% p.a. during the Outlook, significantly faster than the past 15 years, driven by tightening regulations and government targets. In the EU, new cars in 2040 are likely to be around 70% more efficient than in 2000. A typical new ICE passenger car in the EU by 2040 consumes around 3 litres per 100km, compared with 5 litres today and 7 litres in 2000.

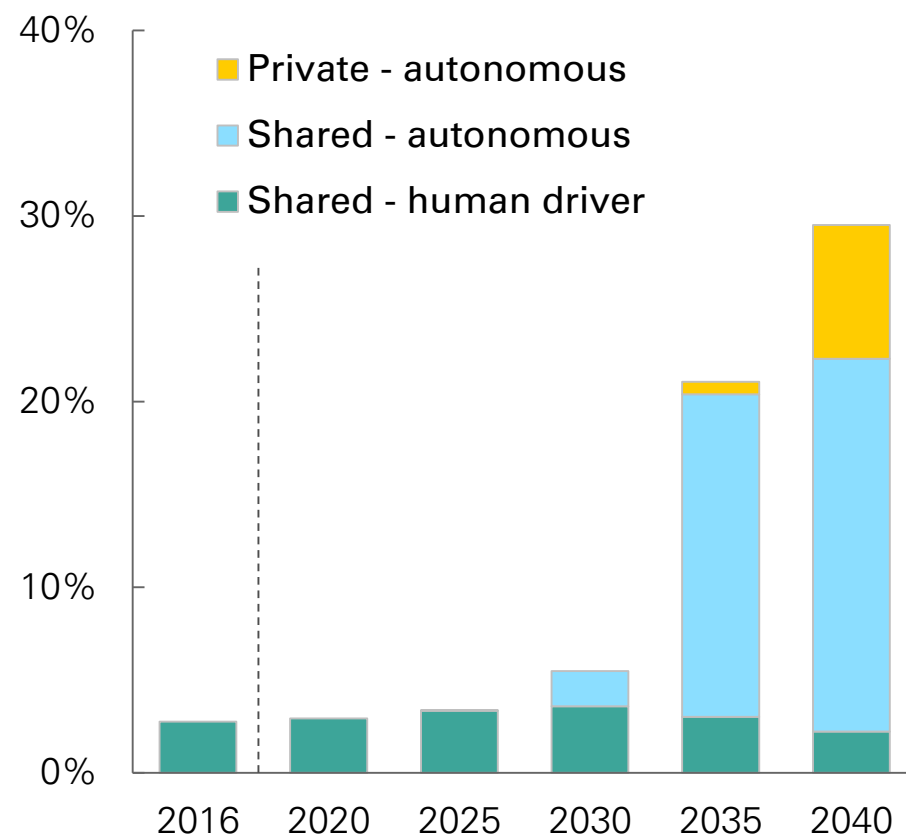


Road transport will be affected by the mobility revolution...

Vehicle kilometres (Vkm) by fuel type



New mobility share of total Vkm



Cars excludes 2- and 3- wheelers



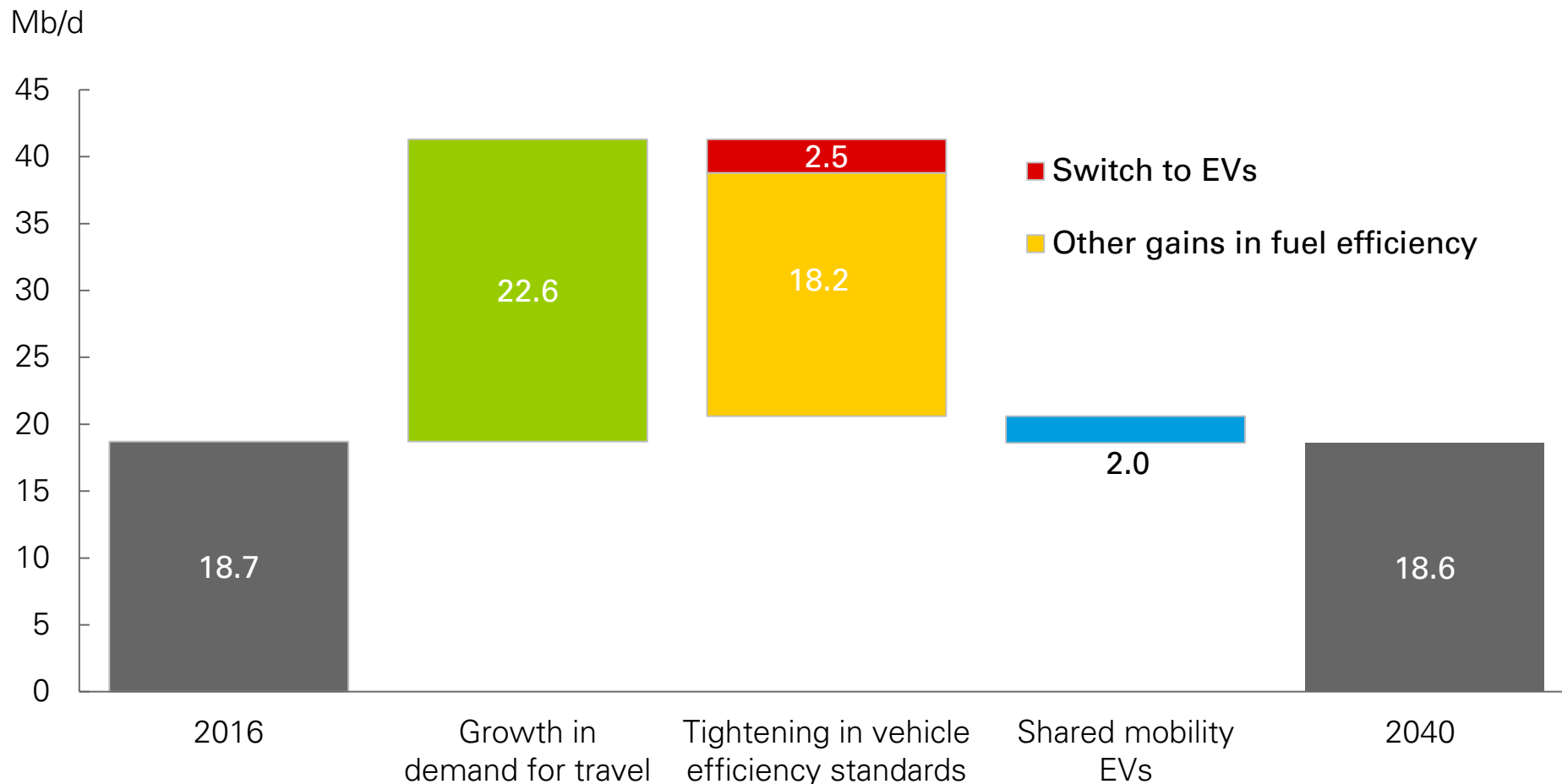
...of electric cars, shared mobility and autonomy

- Fuel demand within road transport is increasingly affected by the combined impact of: electric vehicles (EVs), shared mobility and autonomous driving.
- The importance of EVs is best measured by the share of Vkm powered by electricity, rather than by the number of EVs, since this takes account of: (i) different types of EVs (PHEVs and BEVs); and (ii) different intensities of usage due to shared mobility.
- In the ET scenario, by 2040 around 30% of passenger car Vkm are powered by electricity, significantly higher than the proportion of EVs (BEVs and PHEVs) in the global car parc of just over 15%. This higher share reflects the importance of EVs in shared mobility, where the lower costs per km of EVs make them more competitive than ICE cars, as shared-mobility cars are used much more intensively. In particular, the sharp fall in the cost of car travel associated with fully autonomous cars, which start to become available in the early 2020s, leads to a substantial increase in shared mobility (and use of EVs) in the 2030s.
- In the ET scenario, the penetration of electricity in the car market depends equally on the increasing number of EVs and the interaction of autonomy with shared mobility.
- The share of truck Vkm powered by electricity reaches 15% by 2040, concentrated within short-distance, light trucks.



Liquid fuel use in cars is broadly flat...

Changes in liquids demand from cars: 2016-2040





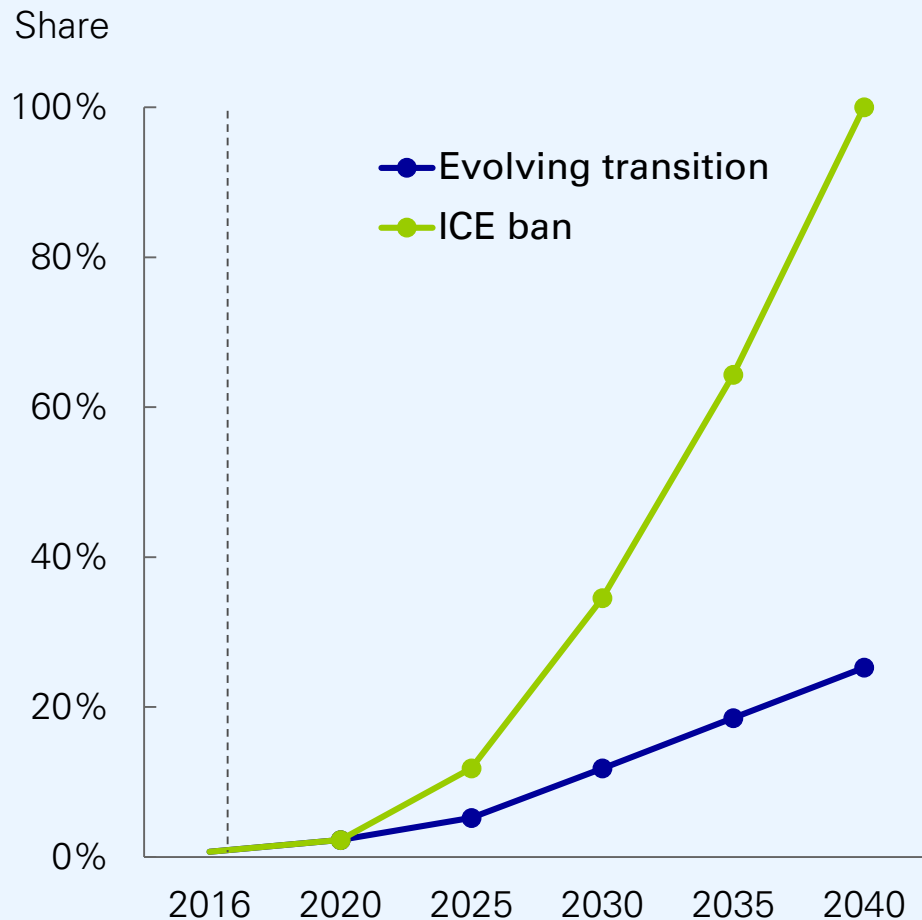
...with increased travel offset by tightening efficiency standards

- The outlook for liquid fuel consumption by passenger cars is determined by the increased demand for passenger car travel offset by tightening vehicle efficiency standards and the impact of increased share mobility.
- In the ET scenario, demand for travel by passenger cars more than doubles, largely due to increasing prosperity in developing countries.
- But the impact of increased car travel on liquid fuel demand is largely offset by the tightening in vehicle emission standards (pp 36-37). Car manufacturers can satisfy these emission standards by a combination of: changing the mix of ICE cars sold; selling more EVs; or making other efficiency improvements, such as light-weighting.
- Car manufacturers may choose to sell more EVs for a variety of other reasons, including meeting customer demands and long-term strategy. But for a given vehicle emission standard, if the proportion of EVs sold does increase, car manufacturers have less incentive to invest in other types of vehicle efficiencies. As such, the impact of more EVs on liquid fuel demand is likely to be largely offset.
- The projected growth in liquid fuel demand is also partly offset by the increased use of shared-mobility cars, since these are predominantly EVs.

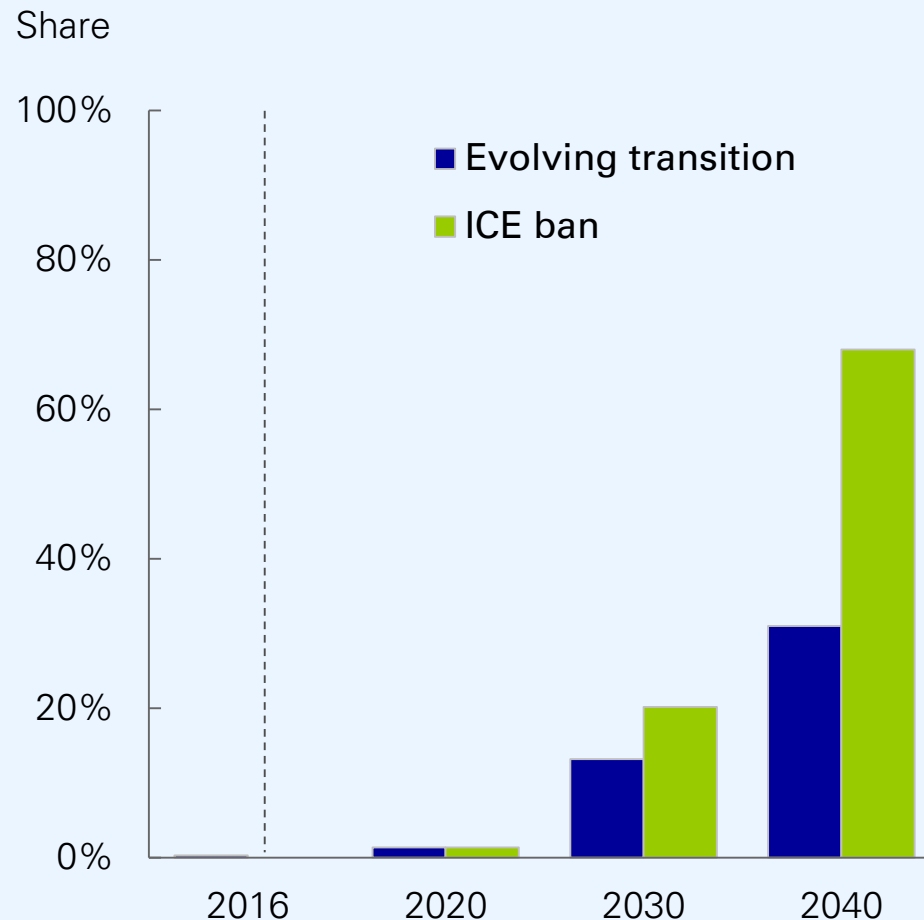


Alternative scenario: impact of faster growth in electric cars...

Electric car sales as a share of total car sales



Share of total passenger Vkm powered by electricity





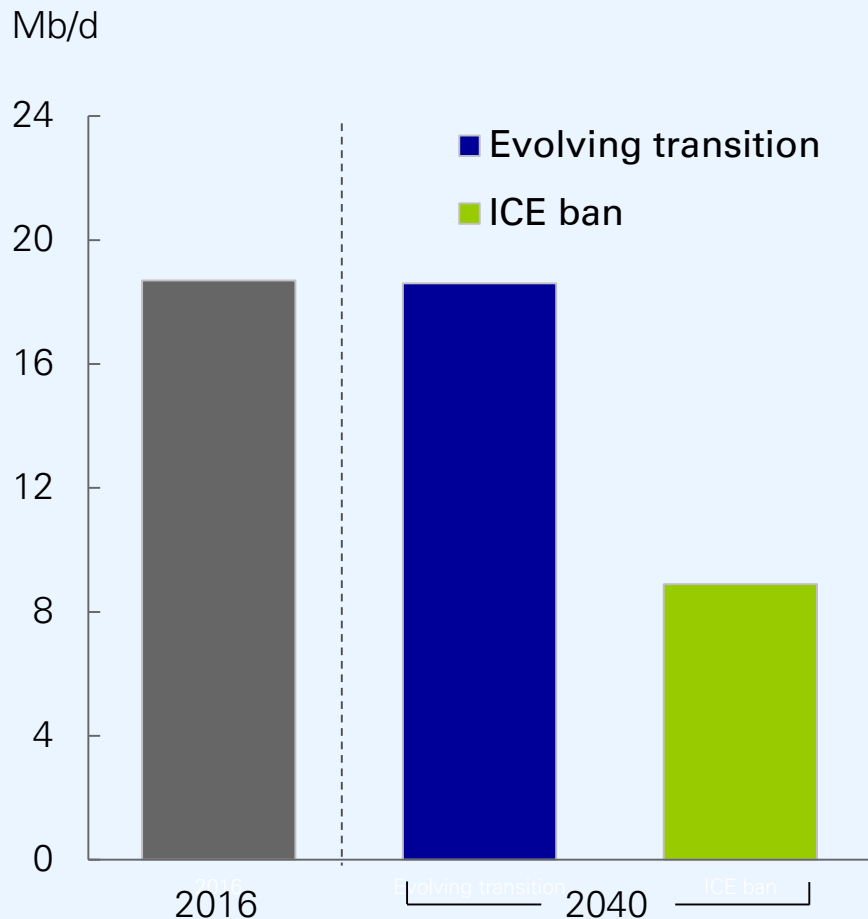
...caused by a worldwide ban on ICE car sales from 2040

- A key uncertainty surrounding the prospects for oil demand is the speed with which sales of electric cars increase over the Outlook. This depends on a number of factors, including government policy, technological improvements and social preferences, and as such is hard to predict with any certainty.
- To gauge the significance of this uncertainty, consider an alternative scenario in which governments impose a worldwide ban on the sale of all ICE (and PHEVs) cars from 2040 onwards, with the regulations gradually increasing, such that around a third of all cars sales in 2030 are BEVs, two thirds in 2035 and 100% in 2040.
- Under this alternative 'ICE ban' scenario, electricity powers around 20% of total passenger car Vkm in 2030 and two-thirds in 2040. This compares with nearly 15% and 30%, respectively, in the ET scenario.

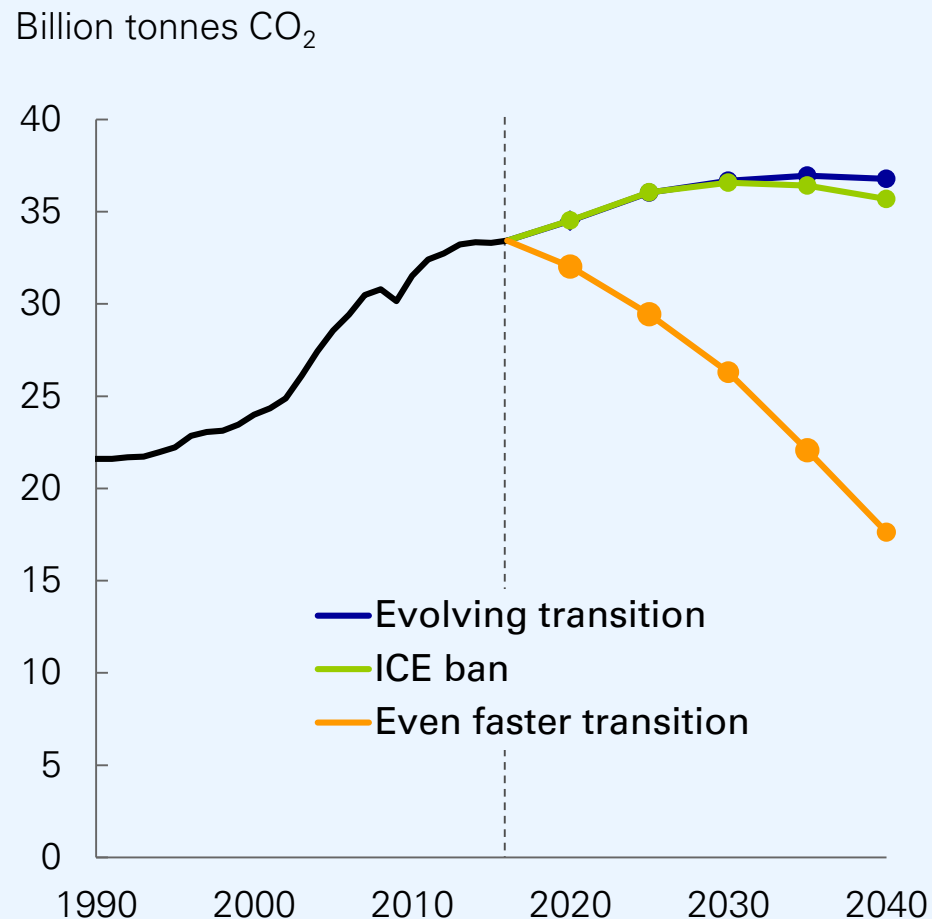


The ICE ban has a limited impact on both liquid fuel demand...

Passenger cars liquids demand



Carbon emissions from energy





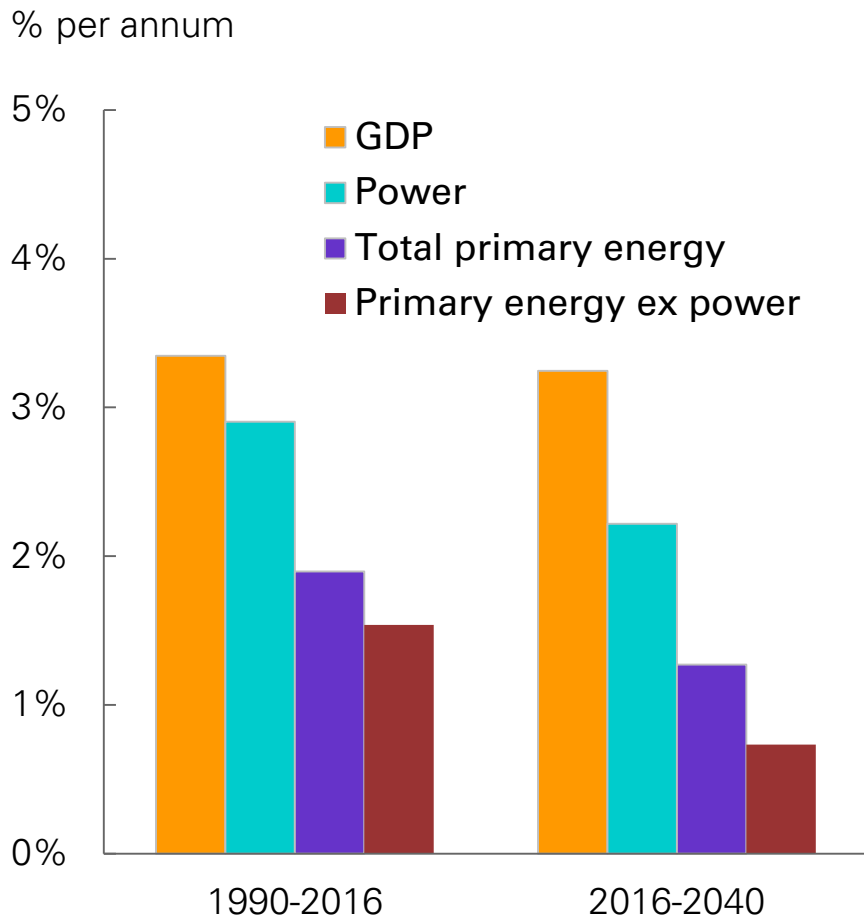
...and carbon emissions

- The impact of the 'ICE ban' scenario on liquid fuel demand depends on the extent to which vehicle emission standards are adjusted in the light of the ban.
- If emission standards are unchanged from the profile assumed in the ET scenario, the impact of the ICE ban on liquid fuel demand would be negligible, since the impact of the greater number of EVs would be offset by less investment in other forms of vehicle efficiency.
- But assuming emission standards are tightened by a corresponding amount, such that there is no offset from smaller efficiency gains, the ICE ban reduces liquid fuel demand by around 10 Mb/d relative to the ET scenario. Even so, the level of oil demand in 2040 in the 'ICE ban' scenario is higher than in 2016.
- The relatively small impact of the ICE ban on total oil demand means its impact on carbon emissions is also relatively limited. Even if the electricity used to power the additional EVs is assumed to be generated entirely by renewable energy and so leads to no additional emissions, carbon emissions in the 'ICE ban' scenario still increase by 7% over the Outlook, little different from the ET scenario, and far higher than in the 'even faster transition' scenario.

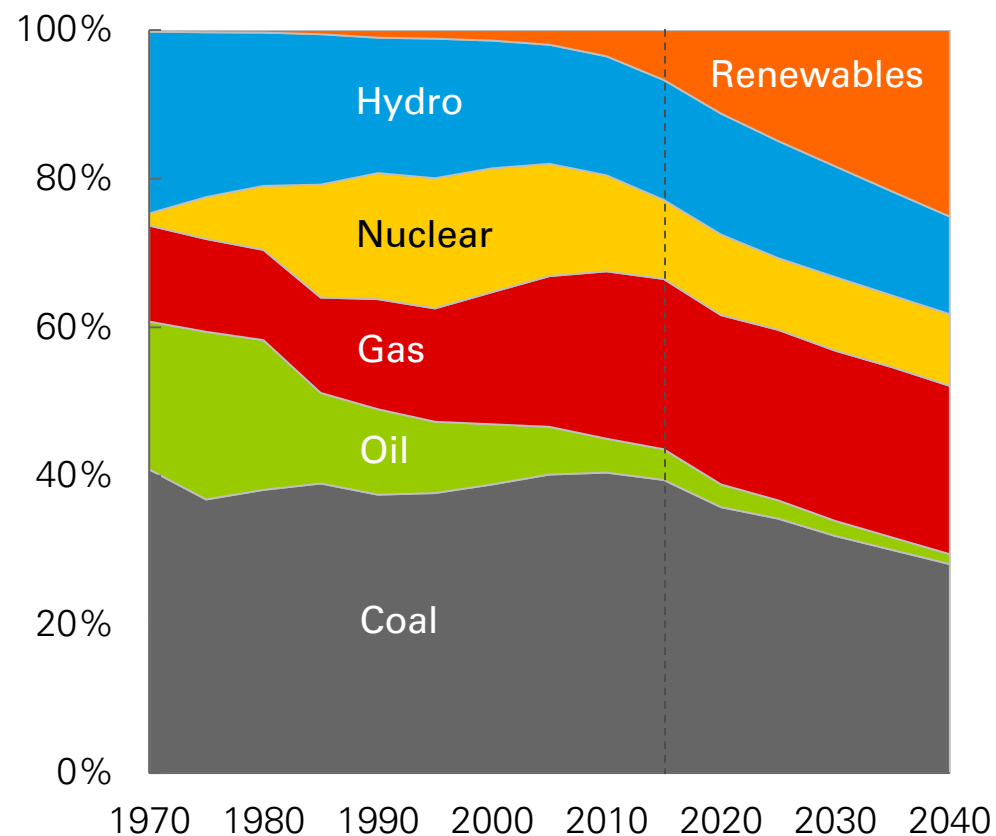


The world continues to electrify...

Growth of GDP, power and primary energy



Shares of total power generation





...with renewable energy playing an ever increasing role

- The world continues to electrify, with electricity consumption growing strongly.
- In the ET scenario, almost 70% of the increase in primary energy is used for power generation, with power demand growing three times more quickly than other energy.
- But the quickening pace of efficiency gains in the final use of electricity means that the relationship between economic growth and electricity consumption weakens over the Outlook, with this weakening particularly pronounced in the OECD.
- The mix of fuels used in power generation is set to shift materially, with renewable energy continuing to gain in importance. In the ET scenario, renewables account for around half of the increase in power and their share of total power generation increases from 7% today to around a quarter by 2040 (pp 94-95).
- The main loser is coal, which accounts for just 13% of the increase in power over the Outlook compared with more than 40% over the previous 25 years. Even so, coal remains the largest source of energy for power in 2040, with a share of almost 30%.
- The share of natural gas is projected to be relatively flat at a little over 20% during the Outlook, after rising gradually over much of the past 25 years.

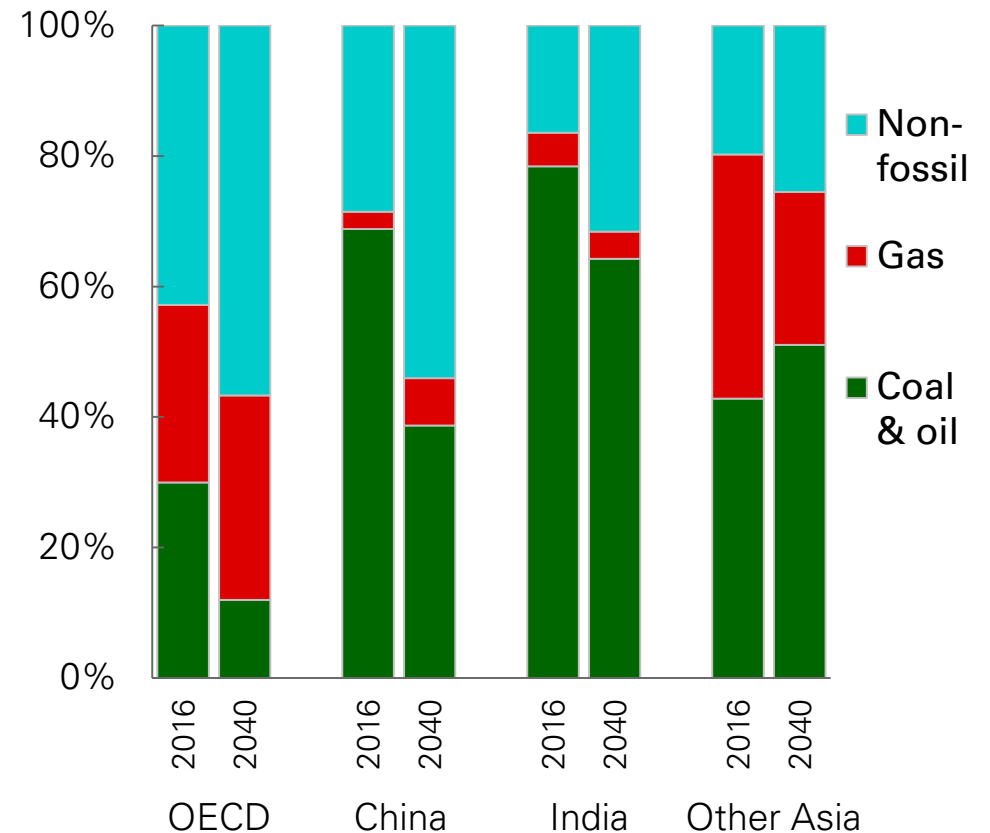
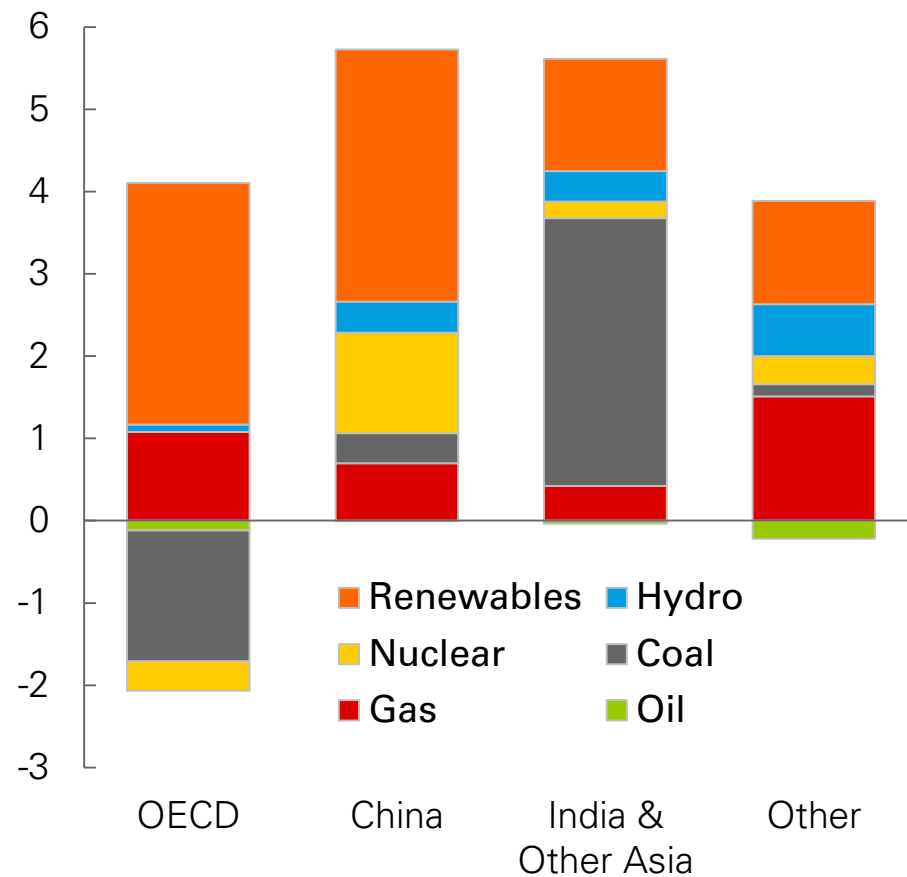


The increasing share of renewables is led by China and OECD...

Growth of power generation, 2016-2040

Shares of power generation, 2016 and 2040

Thousand TWh





...with coal still dominant in the rest of Asia

- The shifting mix of fuels used in global power generation reflects sharply different trends across regions.
- The increase in renewable power in the ET scenario is driven by the OECD and China, with coal-powered generation falling in the OECD and starting to decline in China from around 2030.
- By 2040, the share of non-fossil fuels in the OECD and Chinese power sectors is projected to be broadly similar, although the ratio of coal to gas remains much higher in China.
- In contrast, coal remains the dominant source of energy for power generation in the rest of Asia, accounting for the vast majority of the increase in power generation in the region over the Outlook.
- As a result, the pace of change in the structure of power generation in the rest of Asia is less pronounced than in China. In the ET scenario, the broad structure of the fuel mix in the Indian power sector in 2040 is broadly similar to the mix in China today.



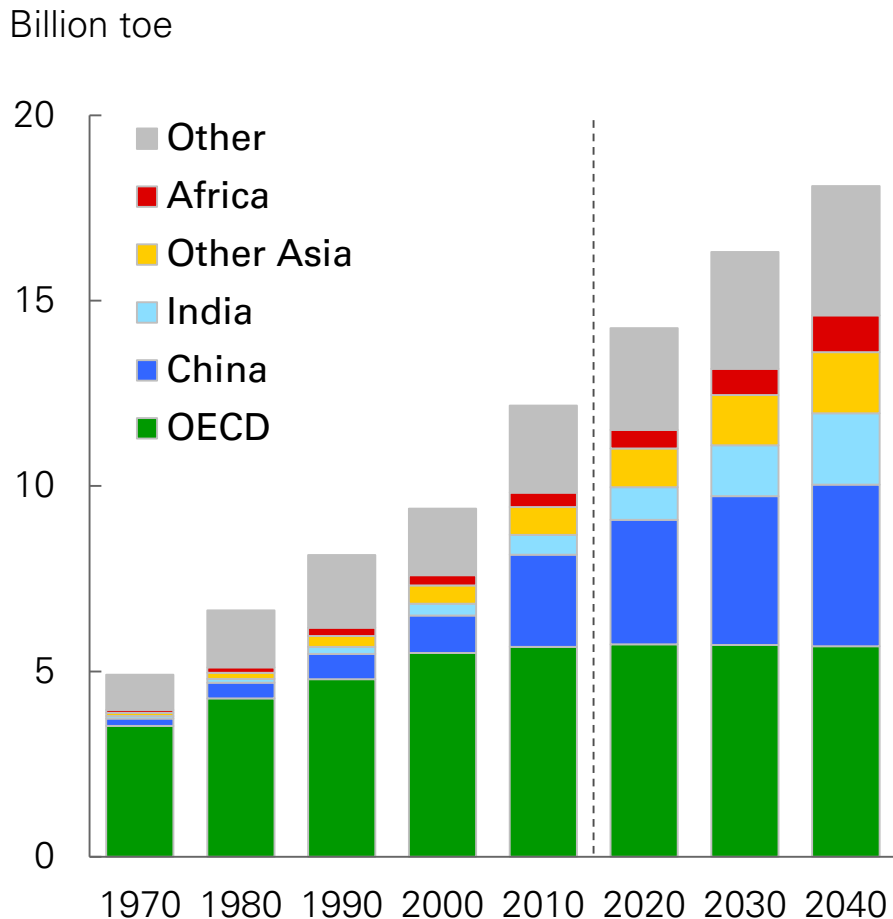
Region demand

- Overview
- China
- India
- Africa
- US
- EU

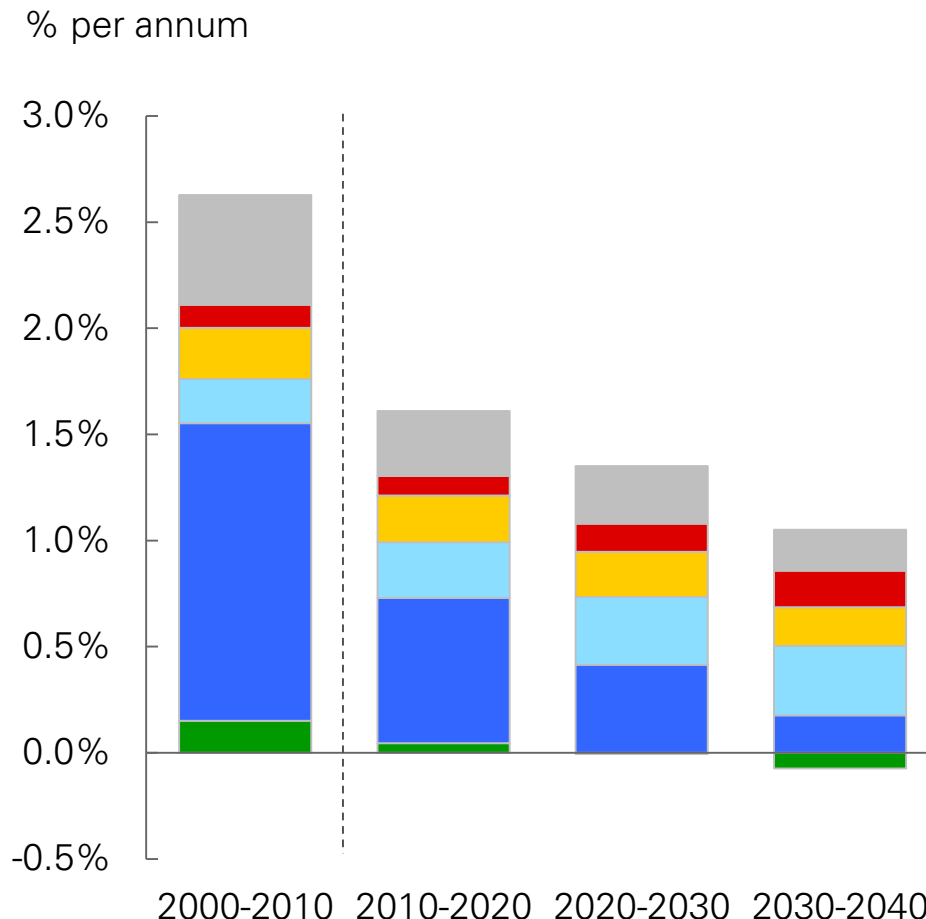


Growth in energy demand is driven by increasing prosperity...

Primary energy consumption by region



Primary energy growth and regional contributions





...led by fast-growing Asian economies

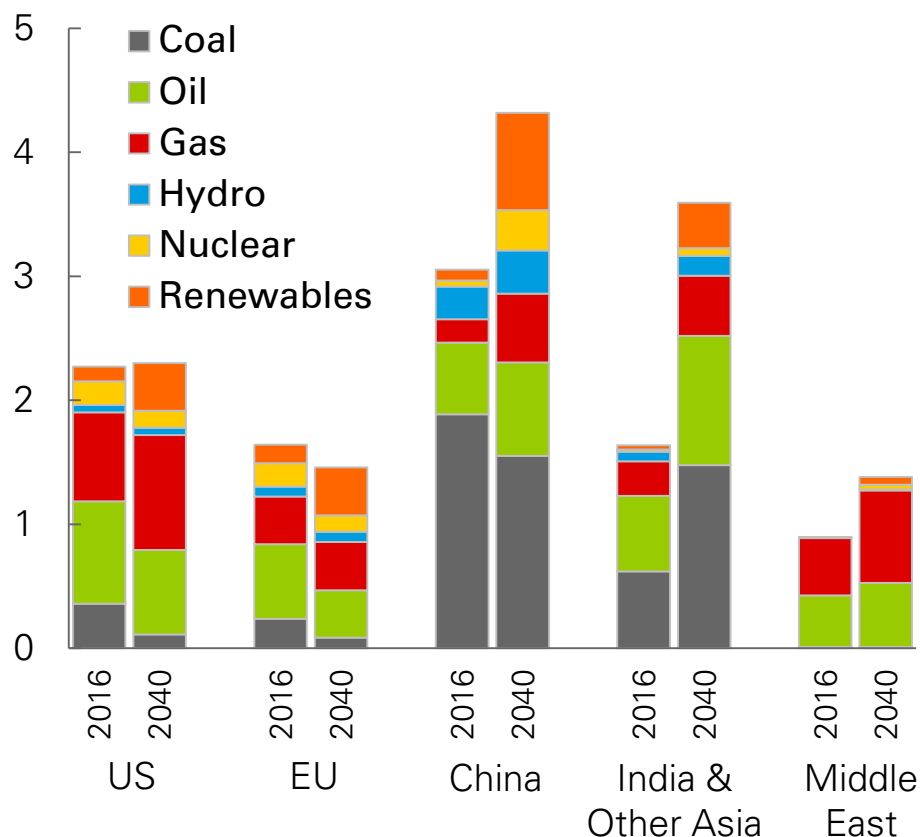
- Growth in global energy demand is driven by increasing prosperity and improving living standards in fast-growing emerging economies. Plentiful supplies of energy enable this increasing prosperity.
- In the ET scenario, the majority of the increased energy is consumed in Asia: with China, India and other non-OECD Asia accounting for around two-thirds of the growth. Energy demand within the OECD is flat.
- China and India each account for around a quarter of the increase in world energy over the Outlook, although this masks sharply contrasting trends. China's energy growth slows significantly as it transitions to a more sustainable pattern of economic growth. In contrast, the slowing in India's demand growth is less pronounced, underpinned by robust economic growth. As a result, by the second half of the Outlook, India emerges as the world's largest growth market for energy (pp 112-113).
- Africa also plays an increasingly important role in driving energy demand in the latter stages of the Outlook – contributing more to global demand growth in the final five years of the Outlook than China – supported by an increasing population together with some pick-up in productivity.



Differences in the fuel mix across regions...

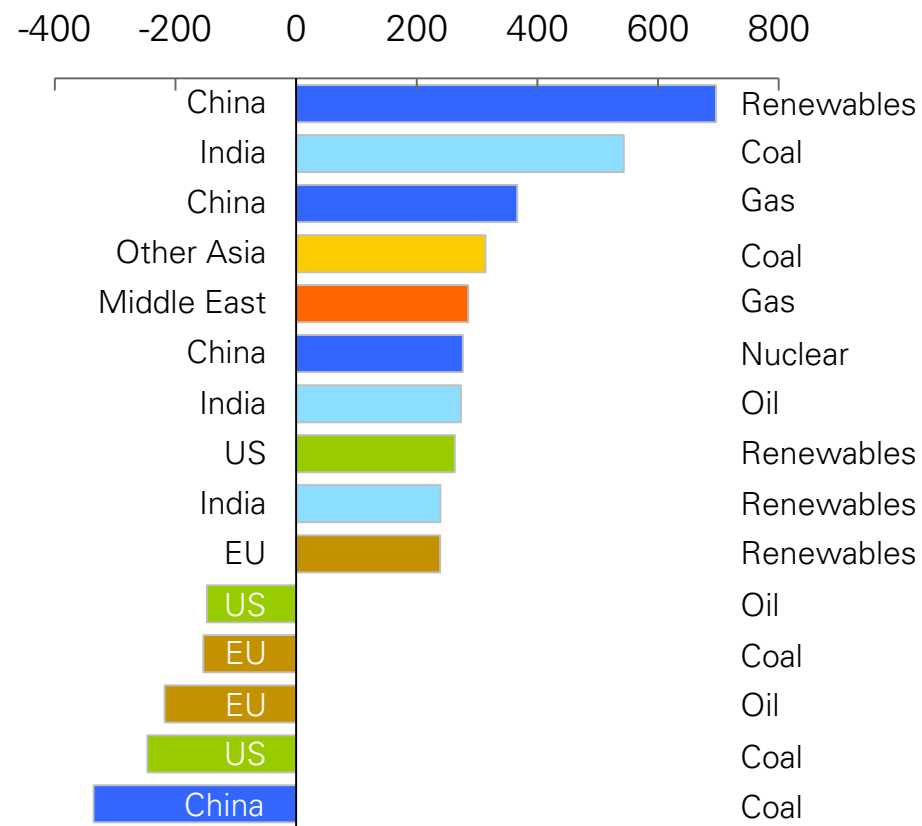
Primary energy demand by fuel and region

Billion toe



Changes 2016-2040[†] by fuel and region

Mtoe



[†]Ten largest increases and five largest declines



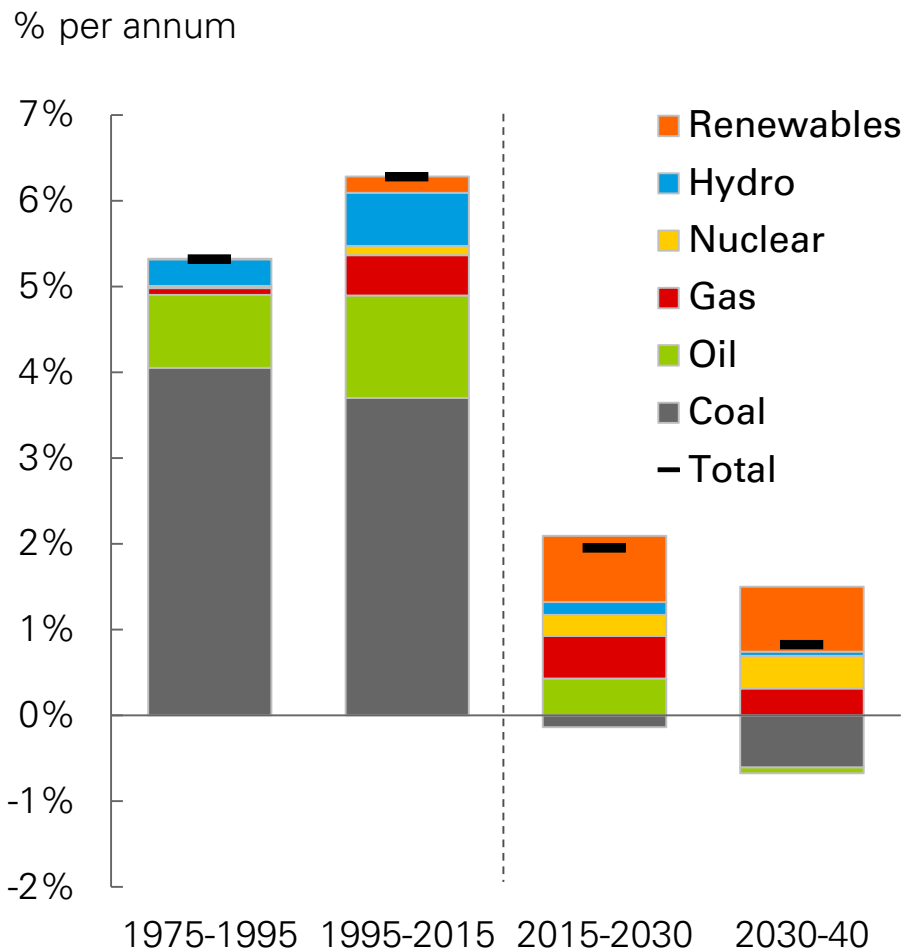
...have an important influence on the energy transition

- Differences in the fuel mix across regions, and the extent to which that mix changes over the Outlook, have an important bearing on the energy transition.
- The regions accounting for the majority of the growth in global energy demand: China, and India & other emerging Asia – all start with relatively coal-intensive fuel mixes.
- In the ET scenario, China's coal intensity declines sharply, with its overall coal consumption falling, more than offset by a large rise in renewable energy. Indeed, the largest growth of any energy source at a regional level is the increase in renewables in China.
- In contrast, the share of coal within India and other emerging Asia is largely unchanged, such that coal demand increases along with overall energy demand.
- The US and EU both start the Outlook with diverse fuel mixes and share similar trajectories of declining shares of coal and oil, offset by increasing use of renewables and, in the US, natural gas.
- The growth in Middle East energy demand is almost entirely met by an increase in consumption of natural gas.

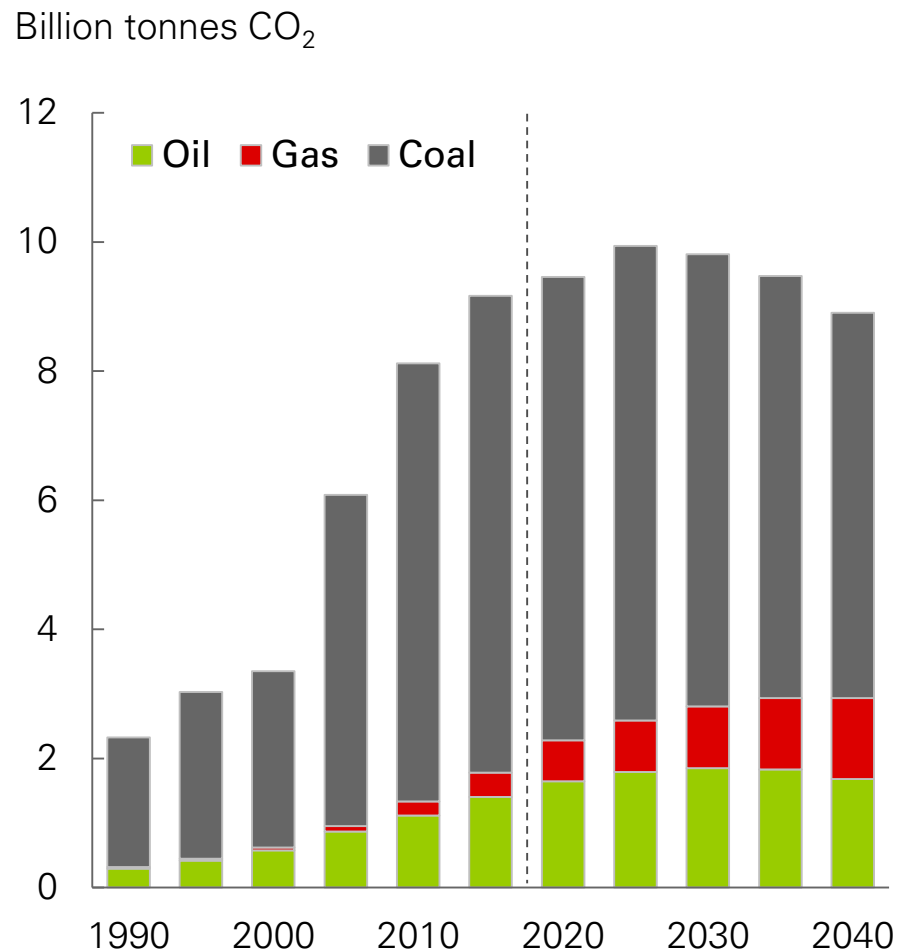


China's energy needs are changing: slower demand growth...

Primary energy demand growth and contributions by fuels



Carbon emissions by source





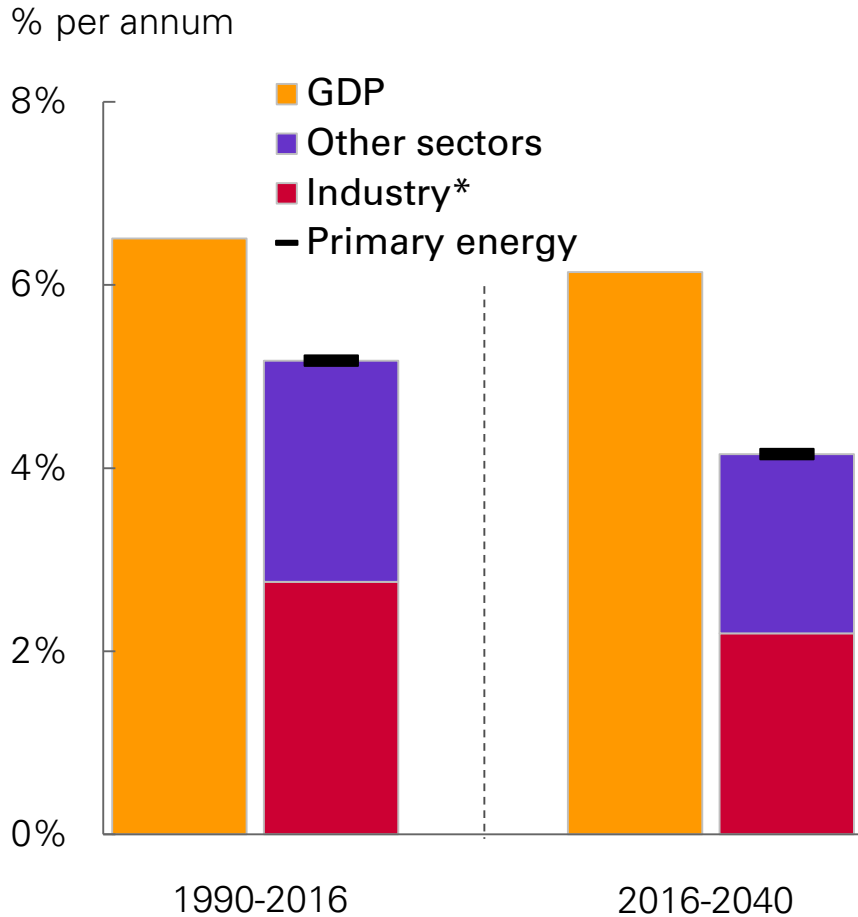
...and a shift towards lower carbon fuels

- China is the world's largest consumer of energy and has been the most important source of growth for global energy over the past 20 years. But as China transitions to a more sustainable pattern of growth, its energy needs change.
- In the ET scenario, China's energy demand is projected to grow by just 1.5% p.a., less than a quarter of its growth rate over the past 20 years. China's energy mix also changes significantly, driven by its shifting economic structure and its commitment to move to cleaner, lower carbon fuels.
- In particular, China's coal consumption is projected to fall over the Outlook, in sharp contrast to the past 20 years where it provided the vast majority of the energy used to power China's rapid industrialization. It seems increasingly likely that China's consumption of coal has peaked.
- In contrast, renewable energy, together with nuclear and hydro, account for over 80% of the increase in China's energy demand out to 2040. Renewables overtake oil to become the second largest energy source in China.
- In the ET scenario, slowing demand growth and the shift towards lower carbon fuels causes China's carbon emissions from energy use to peak in the mid-2020s.

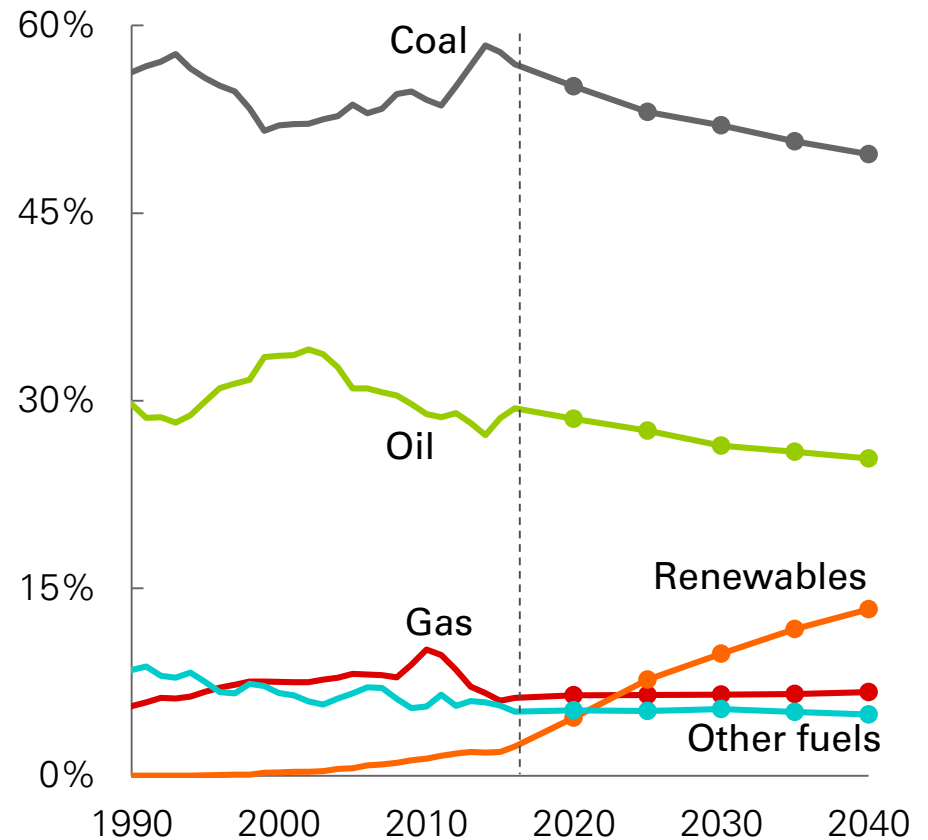


India emerges as the largest growth market for global energy...

Growth of GDP and primary energy



Shares of primary energy



*Excludes non-combusted fuels



...supported by robust economic growth

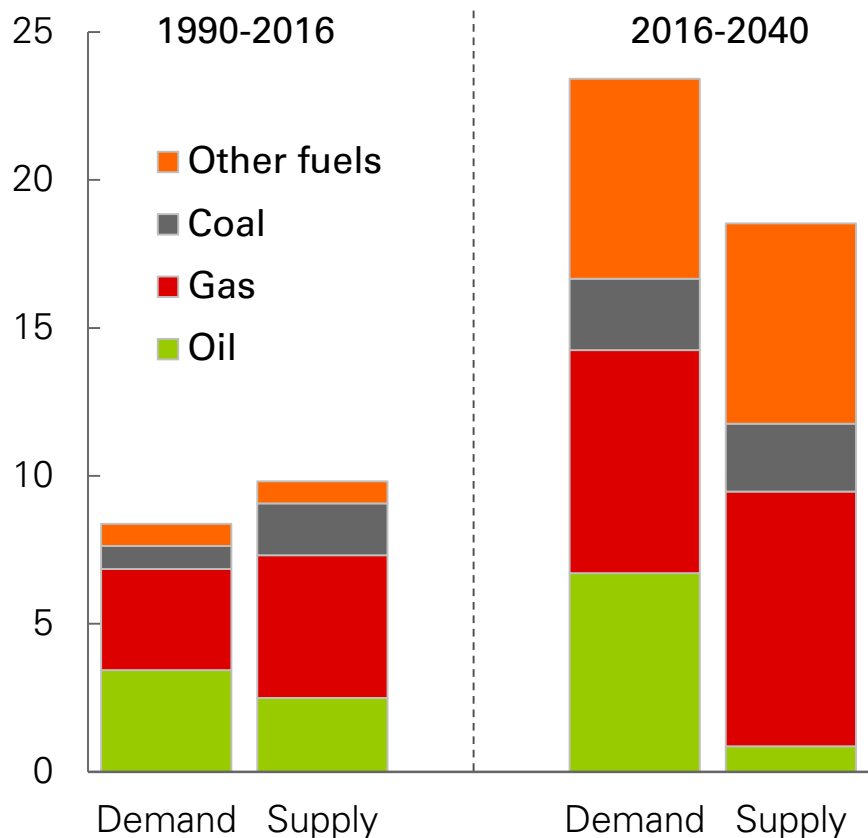
- India's footprint in global energy markets increases materially over the Outlook, with India emerging as the largest growth market for global energy.
- The rise in India's energy demand is supported by continued robust economic growth, partially offset by quicker declines in energy intensity. In the ET scenario, the pace of Indian industrialization slows relative to the past 25 years. But if India's sustained, strong economic growth is accompanied by an increasing shift to industrial activity, this could pose upside risks to energy demand.
- Coal continues to provide the main source of energy supporting India's economy, accounting for 45% of the increase in energy demand; over 70% of the increase in coal consumption feeds the power sector as India seeks to provide access to electricity to its entire population.
- Renewable energy grows rapidly over the Outlook, with particularly strong growth in solar energy.
- Gas consumption almost triples, with strong growth in industrial sector use, including as a feedstock for production of fertilizers. Growth of gas in power is less strong, held back by the continued dominance of coal and the rapid growth of renewables.



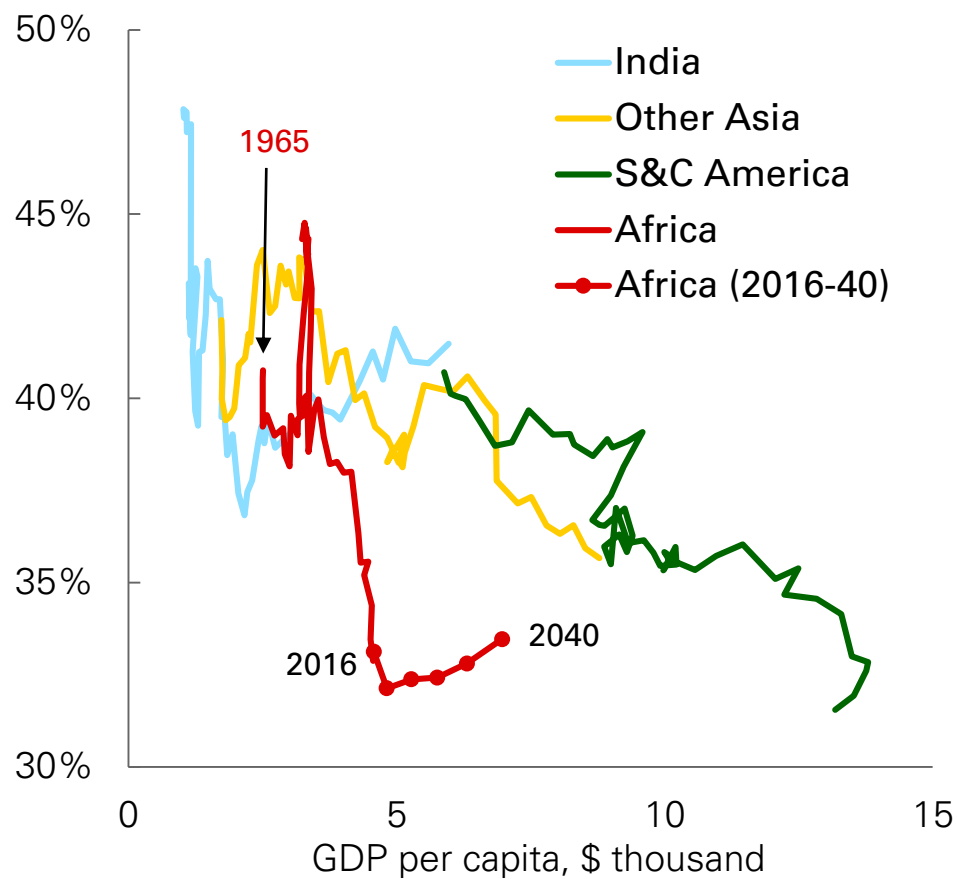
Africa plays an increasing role in global energy...

Energy supply and demand growth

Mtoe per annum



Industrial energy share* (1965-2016 unless stated)



*Includes non-combusted fuels



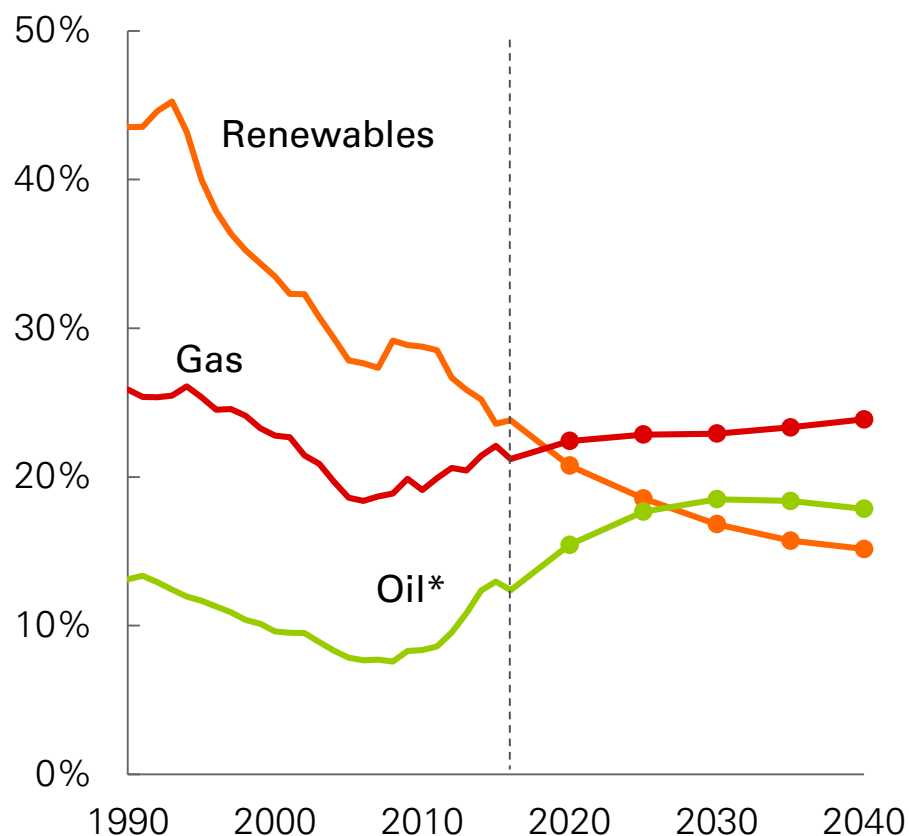
...but extent depends on productivity and industrialization

- Africa has an increasingly important bearing on global energy markets in the latter part of the Outlook and beyond.
- In the ET scenario, Africa accounts for around one-fifth of total energy demand growth in the final five years of the Outlook.
- Africa's role as a significant exporter of energy diminishes, with overall net exports declining as domestic consumption increases by more than production. A sharp reduction in the oil surplus is only partially offset by higher net exports of natural gas.
- Africa's economic development until now has been held back by low levels of industrialization and productivity. Reflecting that, the industrial share of energy consumption in Africa has been falling sharply since the early 1980s and is far lower than other developing economies at a similar stage of development.
- In the ET scenario, the industrial share of energy rises gradually as the level of industrialization picks up, but the precise profile is uncertain and will depend on a variety of factors including the efficiency of Africa's wave of urbanization over the next 25 years.

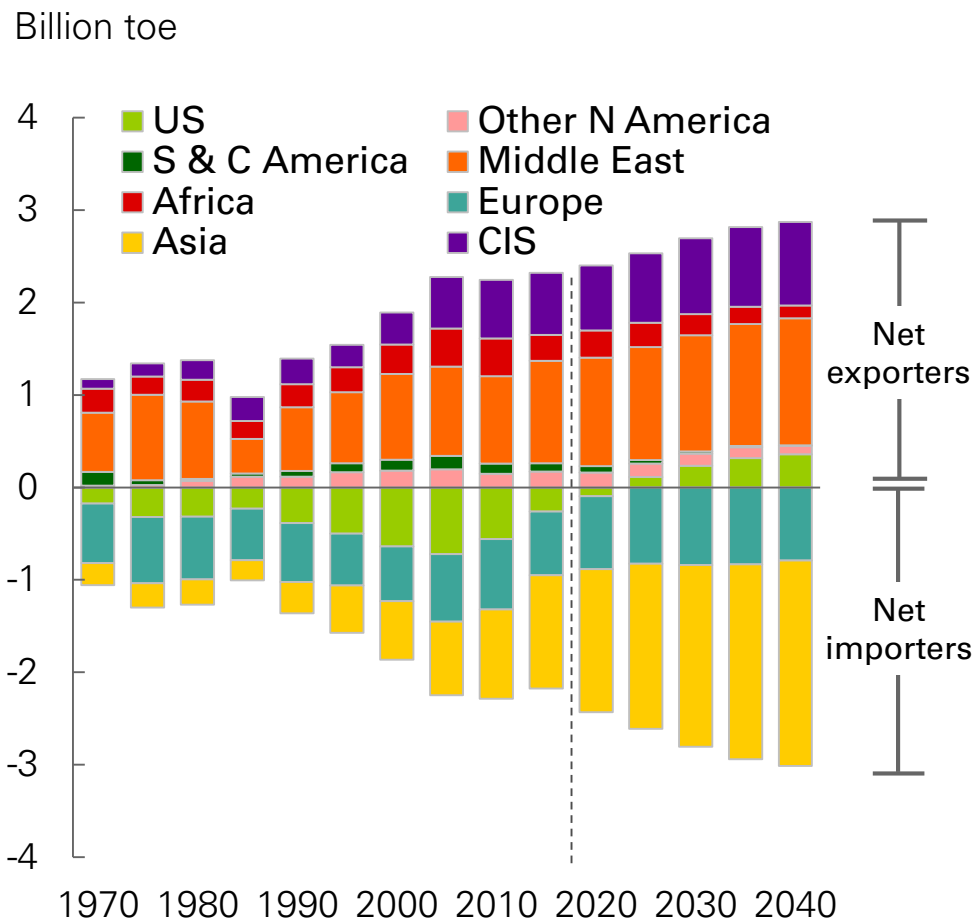


The US extends its lead in oil and gas production...

US shares of global production



Regional oil/gas imbalances



* Includes crude and NGLs



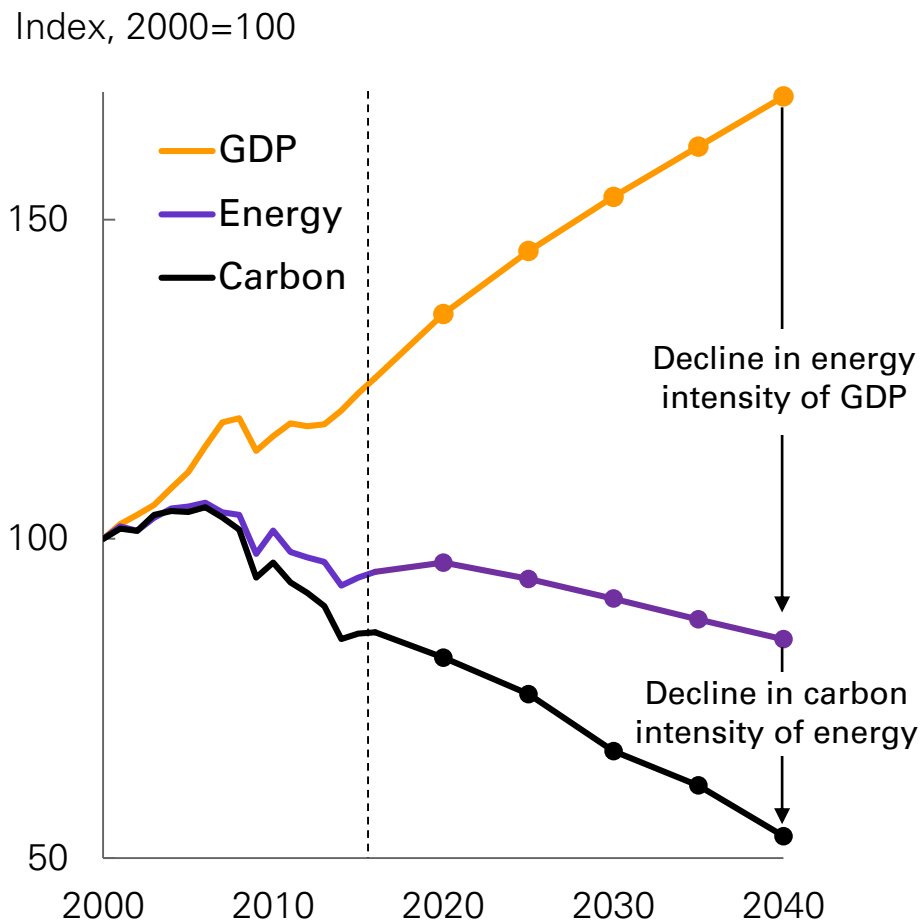
...but its share of global trade remains small

- The US enhances its position as the world's largest producer of oil and gas over the Outlook, but its net exports account for only a small fraction of world trade.
- In the ET scenario, the US share of global oil production (crude plus natural gas liquids (NGLs)) increases from about 12% today to about 18% by 2040. This is well above Saudi Arabia – the world's second largest producer – which has a market share of about 13% by 2040. For natural gas, the US lead is even more pronounced: accounting for 24% of total gas production in 2040, compared with Russia's share of 14%.
- But the US also remains the world's largest consumer of gas and second-largest consumer of oil. As such, in the ET scenario, its net exports account for only a relatively small share of overall world trade. In 2040, the US exports 360 Mtoe of oil and gas combined, equivalent to only around 9% of global trade in oil and gas in 2016, and less than half that of Russia (780 Mtoe in 2040) – the world's largest exporter of oil and gas.
- The US also loses its position as the largest producer of renewable energy, with its share of global production declining from 24% currently to around 15% by 2040. In contrast, China's share of renewables increases to around 30%.

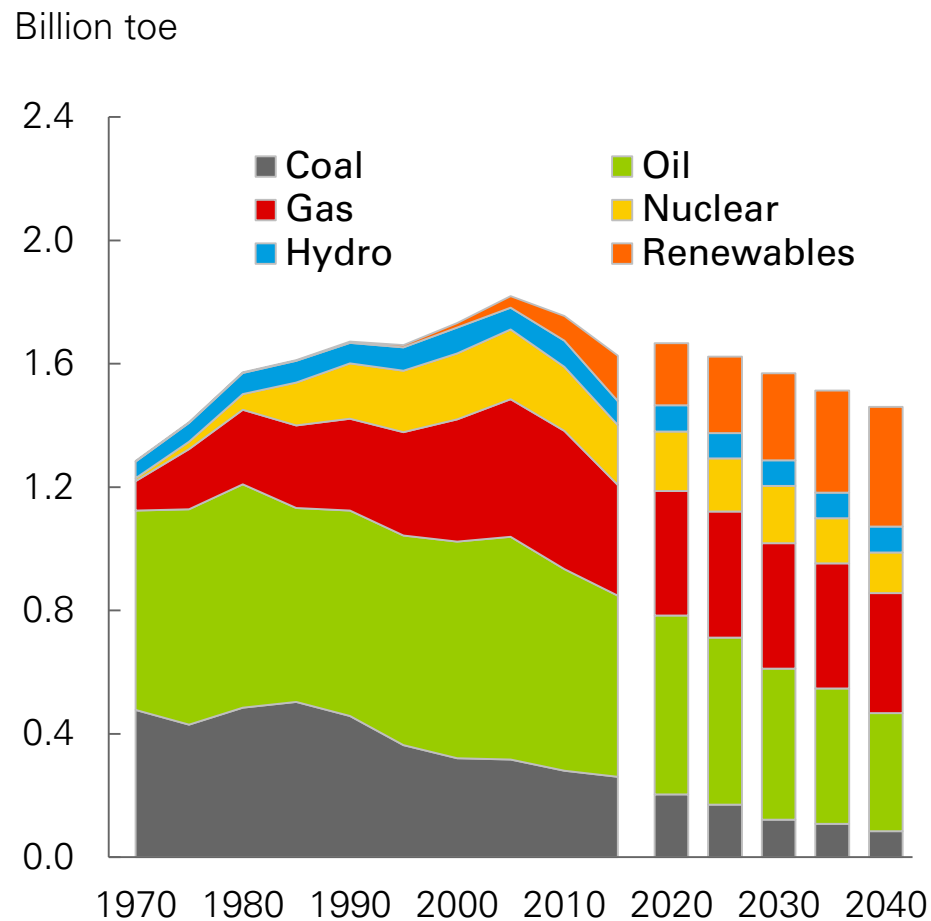


The EU leads the transition to a lower carbon economy...

GDP, energy and carbon emissions



Primary energy consumption





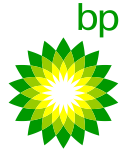
...through efficiency and shifting the energy mix

- The EU continues to lead the transition towards a low carbon economy.
- In the ET scenario, EU carbon emissions by 2040 are over 35% lower than in 2016 and the EU's carbon emissions per unit of GDP are almost half the world average. This transition is supported by a range of policies targeting energy efficiency and encouraging a shift towards lower carbon fuels.
- Improvements in energy intensity continue to play the largest role: in 2040, the EU consumes roughly the same amount of energy as it did in 1975, despite its level of GDP being more than three times bigger.
- A shift to a lower carbon fuel mix also plays an important role. Over the Outlook, oil consumption falls materially – driven by efficiency gains in road transport – as does coal consumption, as renewables account for an increasing share of power generation.
- By 2040, non-fossil fuels provide around 40% of EU energy demand, up from 25% in 2016 and considerably higher than the world average of 25%.



Demand and supply of fuels

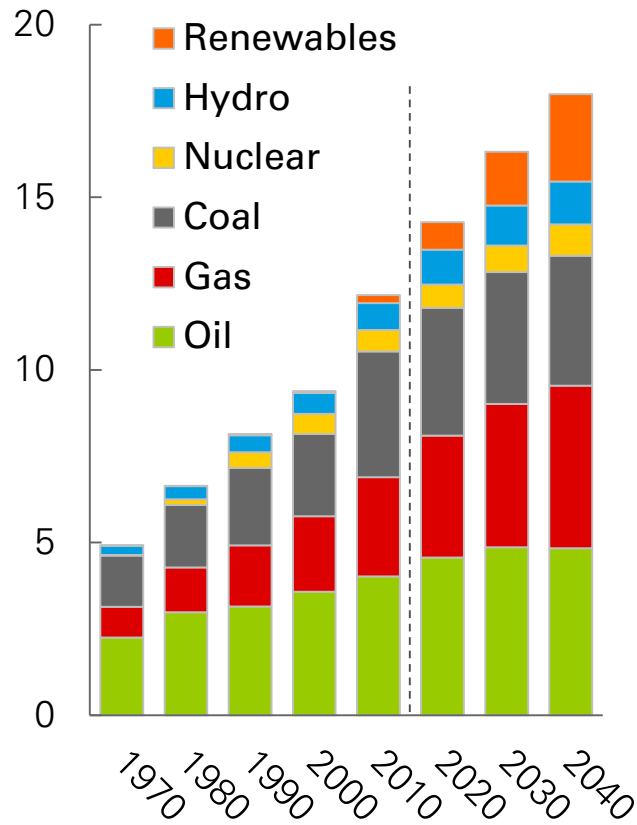
- Overview
- Oil
- Natural gas
- Coal
- Nuclear and hydro
- Renewables



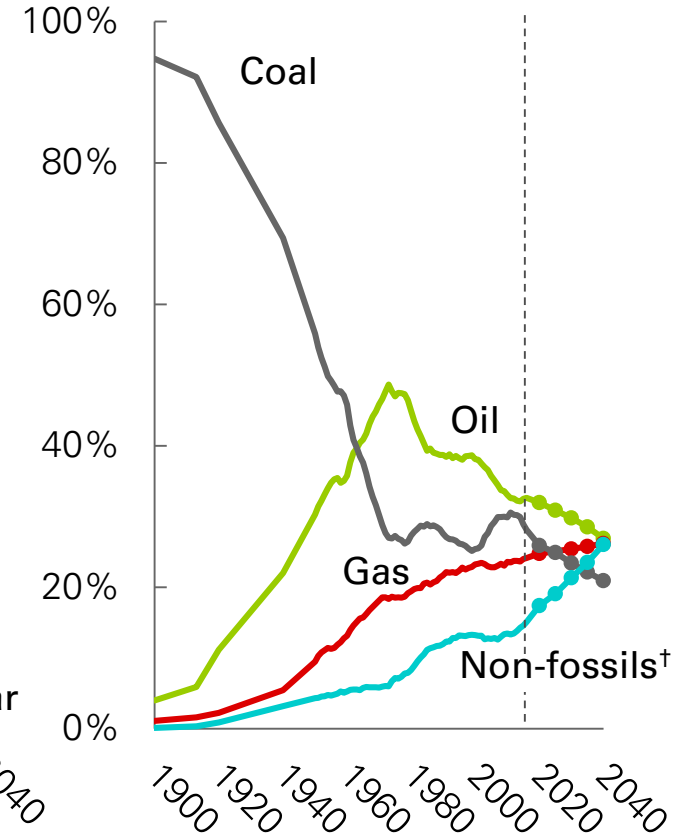
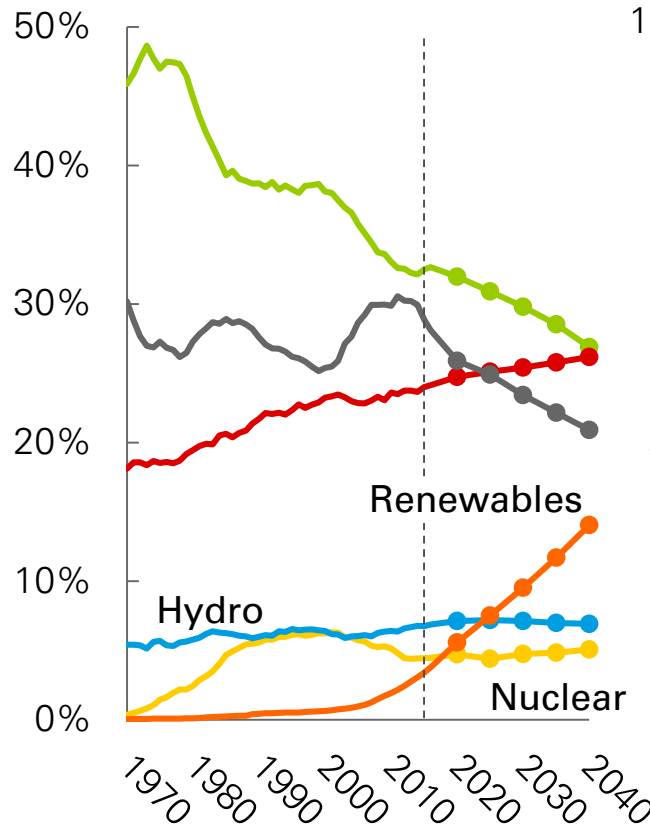
The transition to a lower carbon fuel mix continues...

Primary energy consumption by fuel

Billion toe



Shares of primary energy



† Non-fossils includes renewables, nuclear and hydro

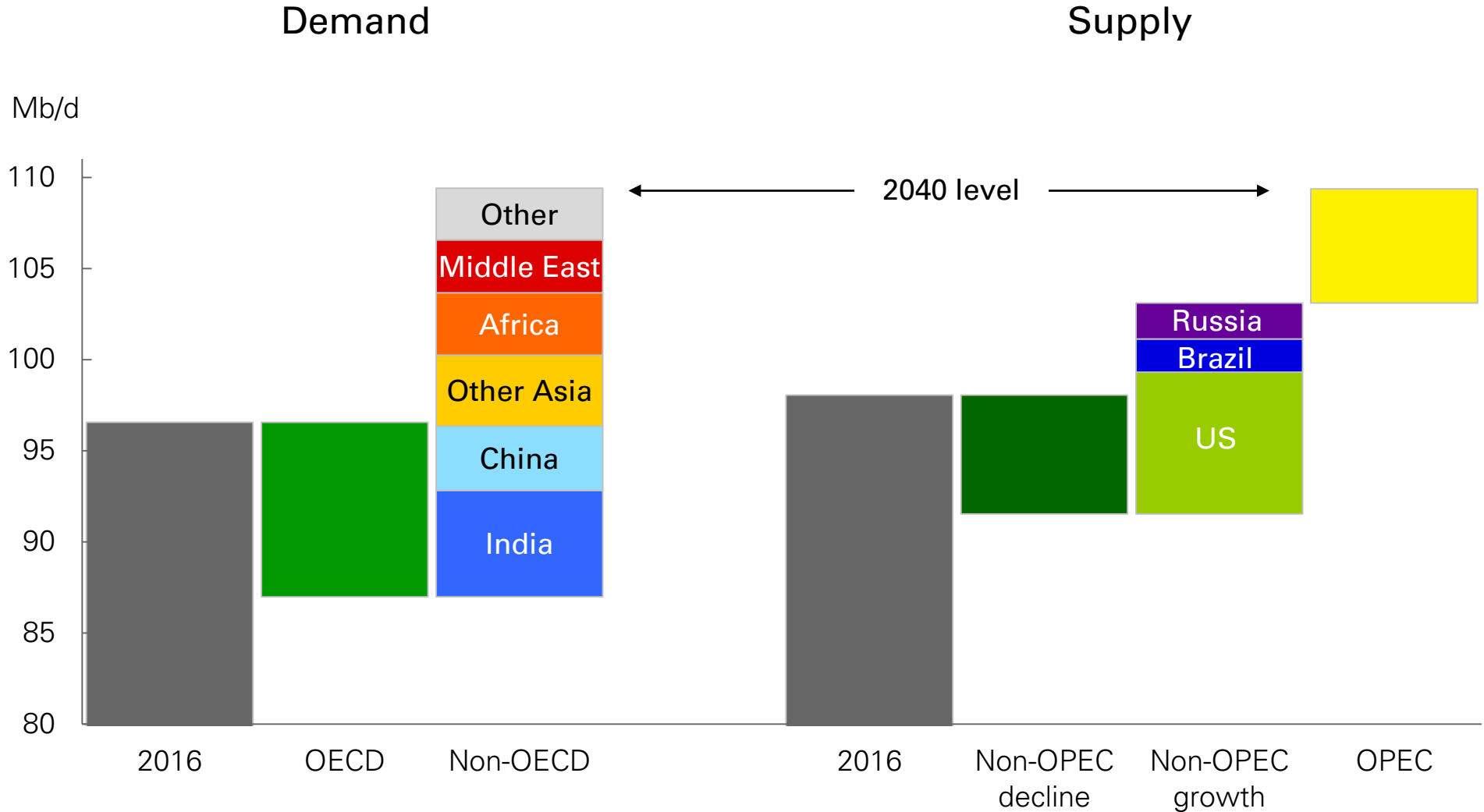


...with renewables the largest source of energy growth

- The transition towards a lower carbon fuel mix is set to continue.
- In the ET scenario, renewable energy is the fastest growing source of energy (7% p.a.), accounting for over 40% of the increase in energy supplies, the largest contribution of any energy source.
- The rapid growth in renewable energy contributes to a more diversified energy mix. By 2040 oil, gas, coal, and non-fossil fuels are projected to each provide around a quarter of the world's energy. This would be the most diversified fuel mix ever seen.
- Natural gas (1.6% p.a.) grows much faster than either oil or coal, with its share in primary energy overtaking coal and converging on oil by the end of the Outlook.
- Oil grows (0.5% p.a.) over much of the Outlook, although is projected to plateau in the final part of the Outlook.
- Coal consumption is broadly flat over the Outlook, with its share in primary energy declining to 21%, its lowest share since the industrial revolution.



Growing demand for liquid fuels in emerging economies...





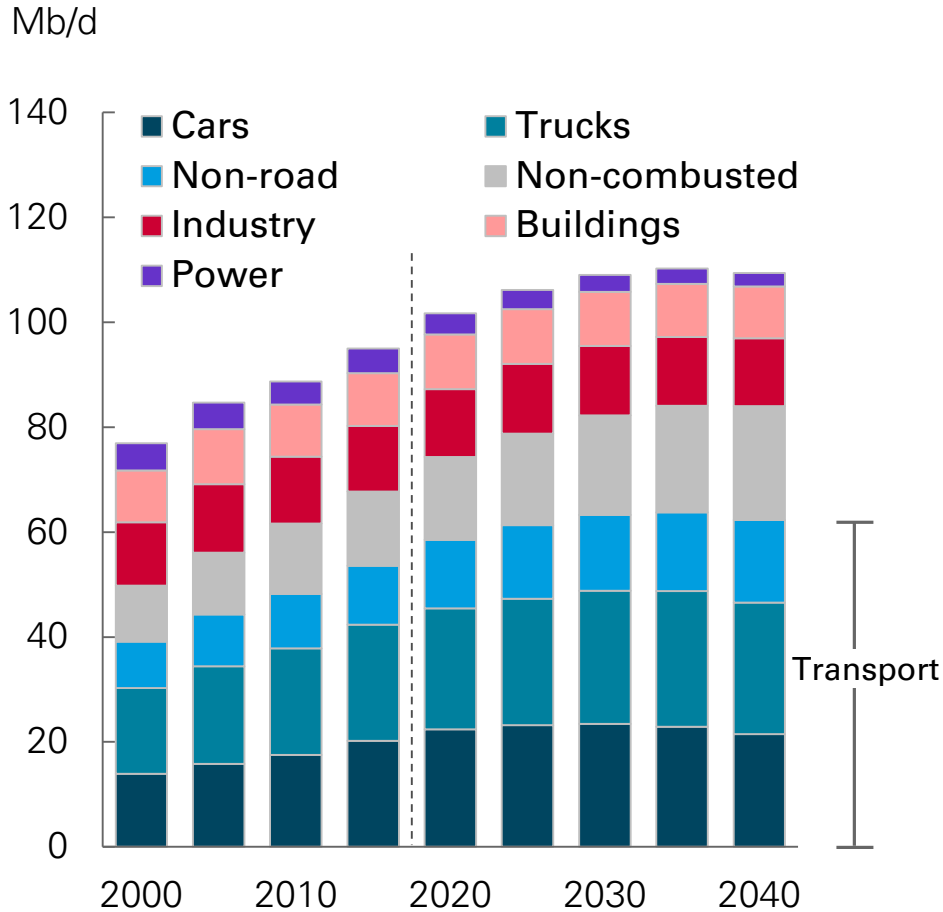
...is met by increased supply from the US and OPEC

- The global market for liquids expands over much of the Outlook, with growing demand from developing economies met by increased supply from low-cost producers.
- In the ET scenario, global demand for liquid fuels (oil, biofuels, and other liquid fuels) increases by around 13 Mb/d, reaching 109 Mb/d by 2040. Growth in liquids demand gradually wanes and plateaus towards the end of the Outlook.
- All of the demand growth comes from emerging economies, driven by rising prosperity, with India replacing China as the primary source of growth. OECD demand resumes its trend decline.
- Global liquids supply increases by a little less (11 Mb/d), reflecting the excess supply of liquids in 2016. Supply increases are driven initially by US tight oil, with OPEC taking over from the late 2020s, as Middle-East producers adopt a strategy of growing market share. OPEC output increases by around 6 Mb/d by 2040.
- Non-OPEC supply grows by 5 Mb/d, with the US accounting for more than all of the net growth, and higher output in Brazil and Russia partially offsetting declines in higher-cost, mature regions.

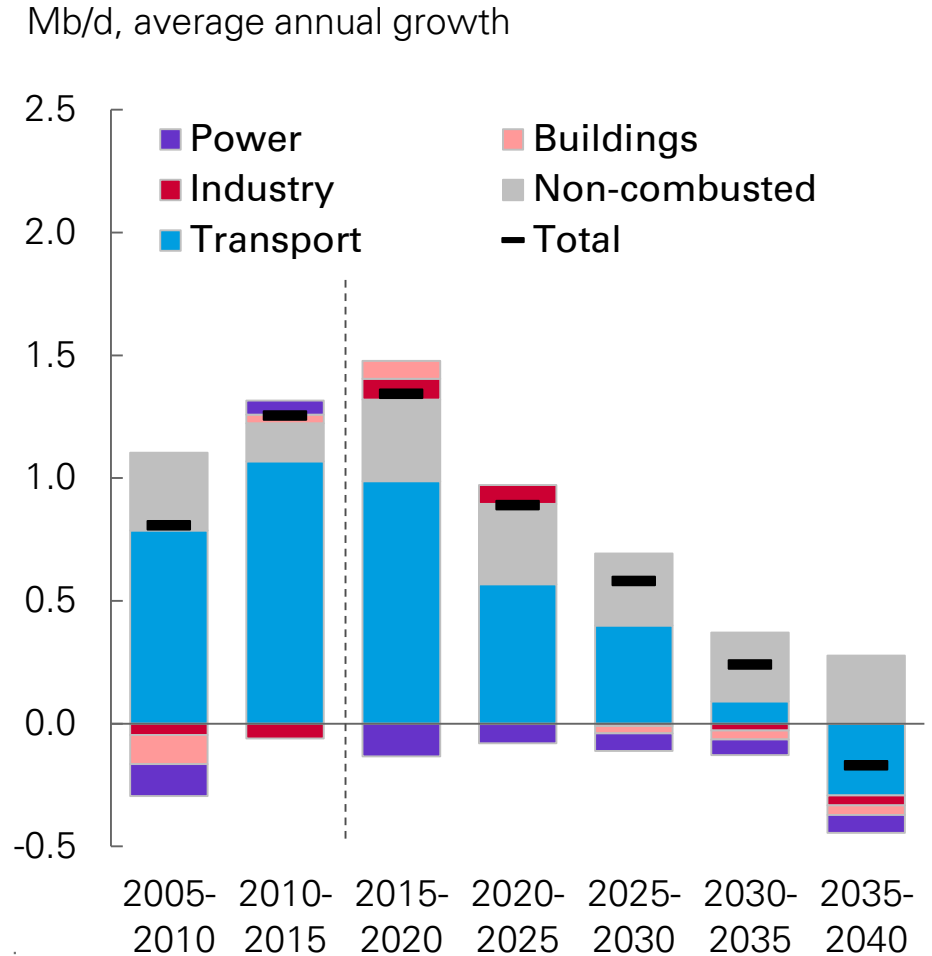


Liquids demand grows materially over the Outlook...

Liquids demand



Liquids demand growth



Cars include 2- and 3- wheelers. Trucks include most SUVs in North America.
 Non-road includes aviation, marine and rail



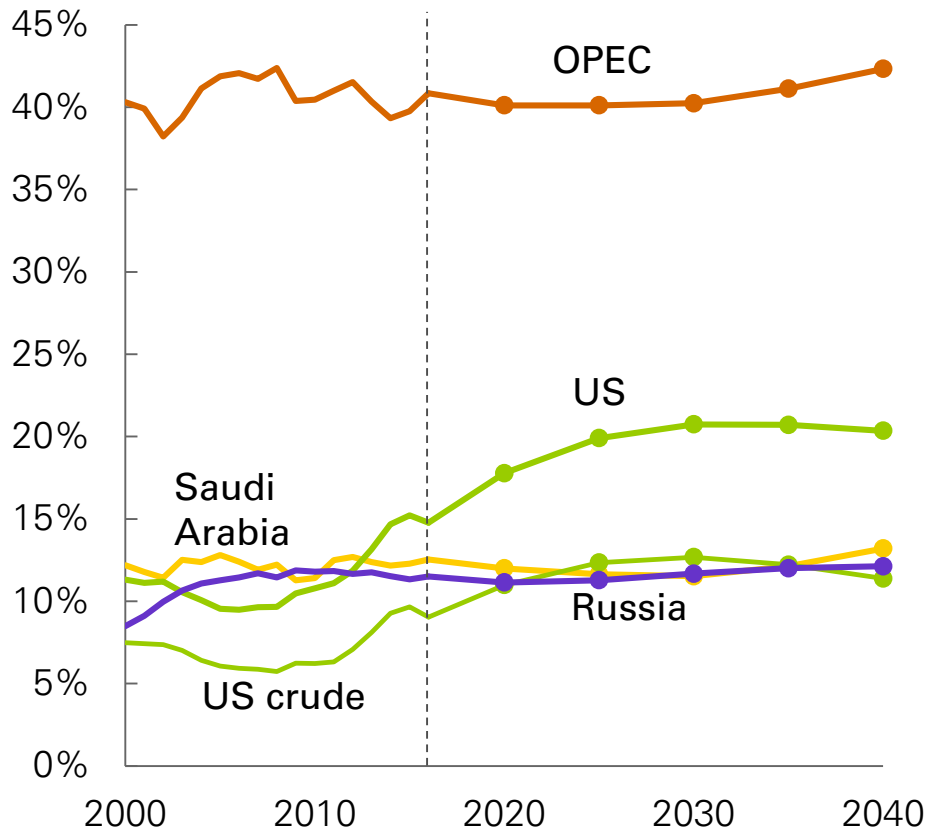
...but plateaus by the end

- Demand for liquid fuels grows over much of the Outlook, although in the ET scenario, the rate of growth gradually slows and plateaus in the later years.
- The transport sector continues to dominate global oil demand, accounting for more than half (8 Mb/d) of the overall growth in demand, with its share in total oil demand remaining relatively stable at a little over 55%. Within transport, non-road (4 Mb/d) and trucks (3 Mb/d) account for the majority of growth, with a smaller increase in cars and motorbikes (1 Mb/d) (pp 32-33).
- But the stimulus from transport demand gradually fades as the pace of vehicle efficiency improvements quickens and alternative fuels penetrate the transport system (pp 34-35). Liquid fuels used by the transport system stop growing towards the end of the Outlook.
- The non-combusted use of oil, particularly as a feedstock within petrochemicals, takes over as the main source of growth for liquids demand after 2030, reflecting the more limited scope for efficiency gains relative to transport. Over the Outlook as a whole, non-combusted uses of liquid fuels increase by 7 Mb/d (pp 28-29).

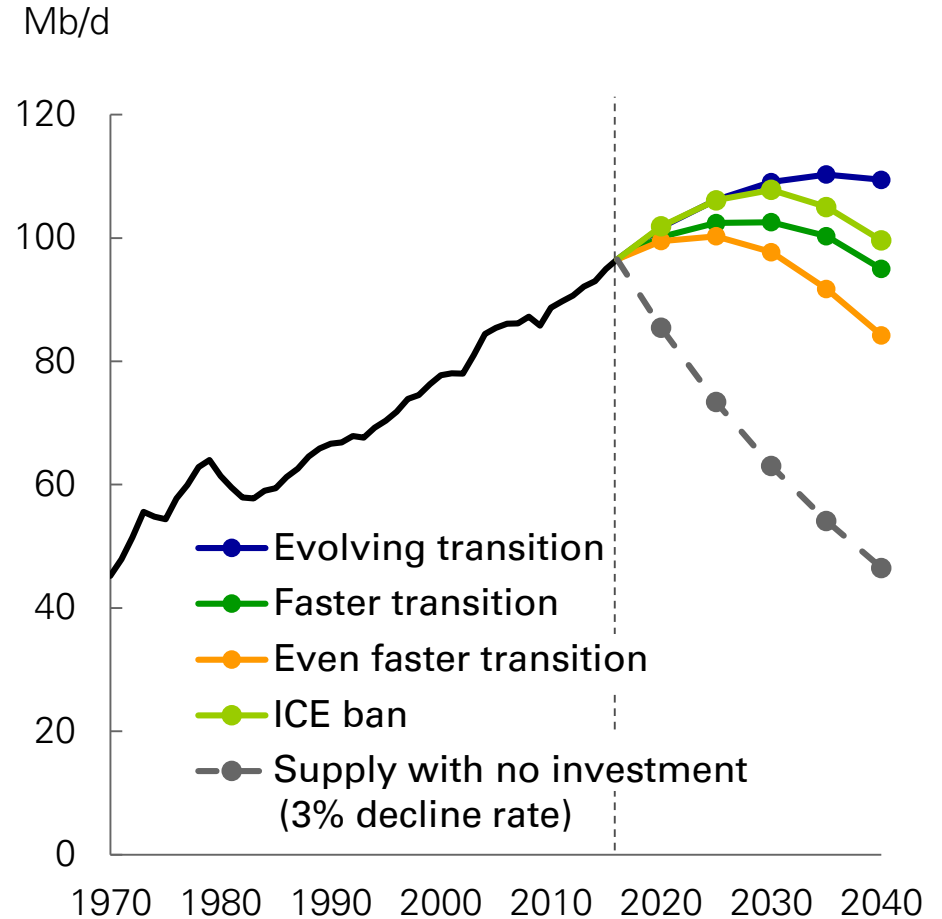


Global liquids supply growth is led by low-cost producers...

Share of world liquids supply



Demand and supply of liquid fuels





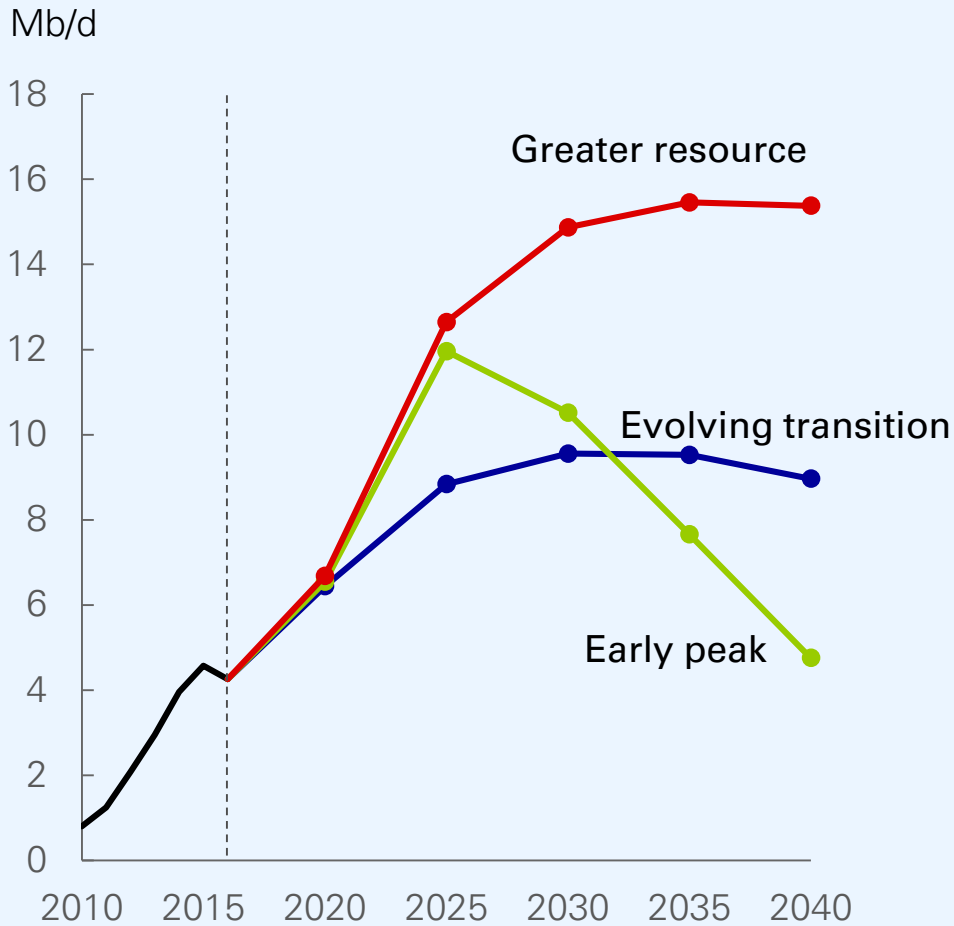
...with US becoming by far the largest producer of liquid fuels

- Growth in global oil production is driven by low-cost producers, especially US tight oil and Middle-East OPEC.
- Increases in oil production during the first part of the Outlook are dominated by US tight oil. In the ET scenario, total US liquids production, including natural gas liquids (NGLs), account for two-thirds of the increase in global supply during the first 15 years of the Outlook, plateauing at around 23 Mb/d in the early 2030s. The US is by far the largest producer of liquid fuels over the Outlook (some alternative scenarios for the speed and extent of growth in US tight oil are described on pp 76-77).
- In the final 10 years of the Outlook, production growth is increasingly driven by OPEC. The abundance of global oil resources is assumed to prompt OPEC members to reform their economies, reducing their dependency on oil and allowing them gradually to adopt a more competitive strategy of increasing their market share.
- For there to be sufficient oil supplies to be able to meet demand in any of the scenarios considered requires significant levels of new investment in oil production. If there were no new investment in oil production from today, and existing production declined at 3% p.a., global oil supplies would be around 45 Mb/d in 2040.

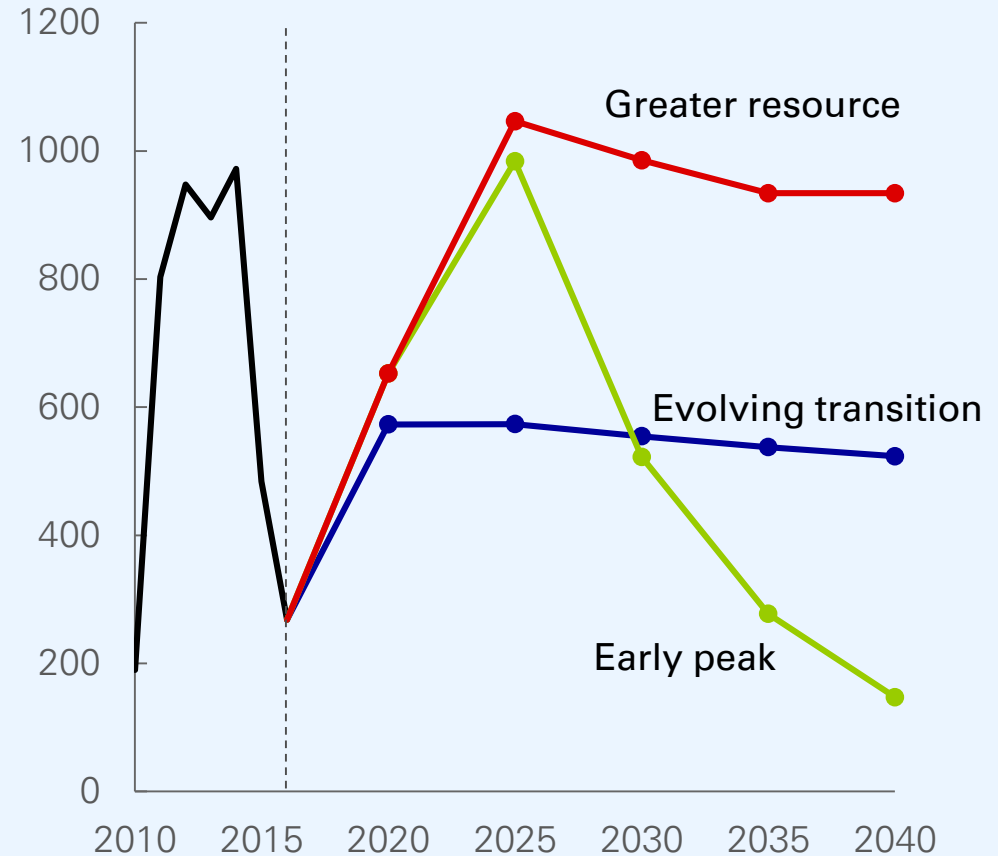


Alternative scenario: US tight oil could grow more rapidly...

US tight oil



Number of US oil rigs*



*In the four main producing regions:
Permian, Eagle Ford, Bakken and Niobrara



...and peak earlier or grow by more

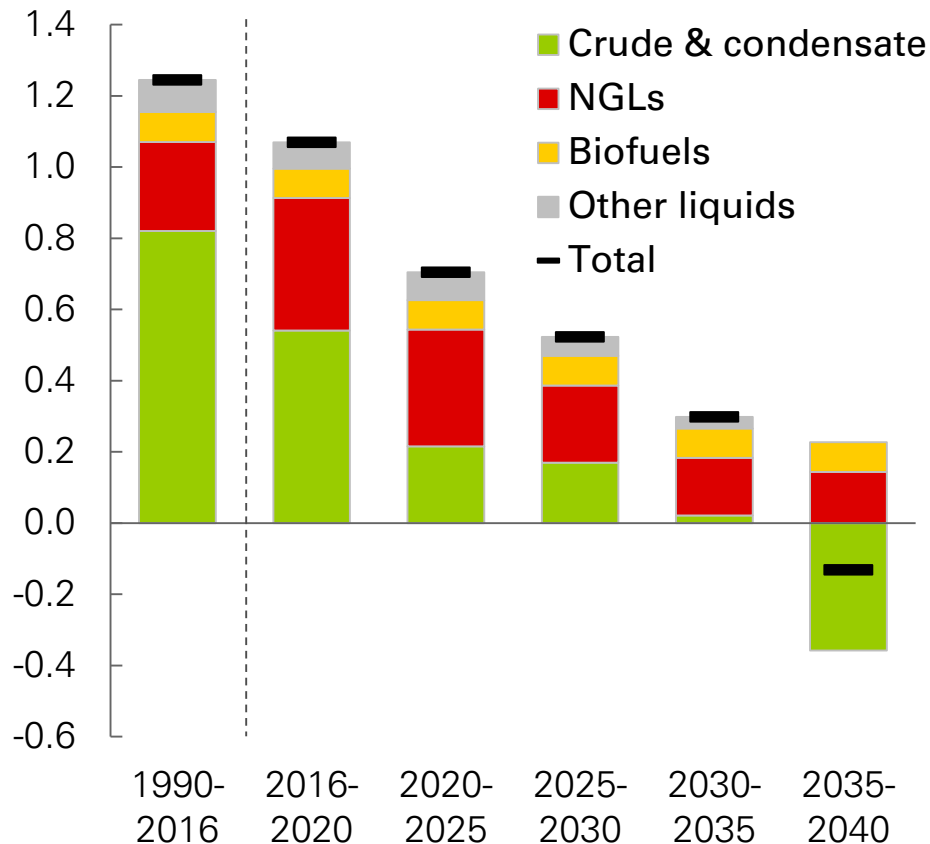
- There is significant uncertainty about the pace and duration of US tight oil growth, depending on the availability of finance and other inputs required to support rapid expansion, and on the total volume of resources that can be economically extracted.
- In the ET scenario, US tight oil grows by around 5 Mb/d, peaking at close to 10 Mb/d in early 2030s. This is consistent with the number of rigs remaining around current levels, productivity levels improving by around 40% over the next 10 years, and cumulative production between now and 2040 of around 70 billion barrels. But US tight oil could grow more rapidly or for longer than projected in the ET scenario.
- One possibility ('early peak' scenario) is that the availability of finance and resources allows a more rapid expansion. If the rig count doubled by 2025, for the same productivity profile, US tight oil would peak earlier at around 12 Mb/d, but would then decline more rapidly if the same total resource is extracted over the Outlook.
- Another possibility ('greater resource' scenario) is that recoverable resources are greater, perhaps enabled by stronger productivity gains. If cumulative production was 50% higher than in the ET scenario, US tight oil could potentially grow to around 15 Mb/d by 2030 and remain around that level for the rest of the Outlook.



Global refining is put under increasing pressure...

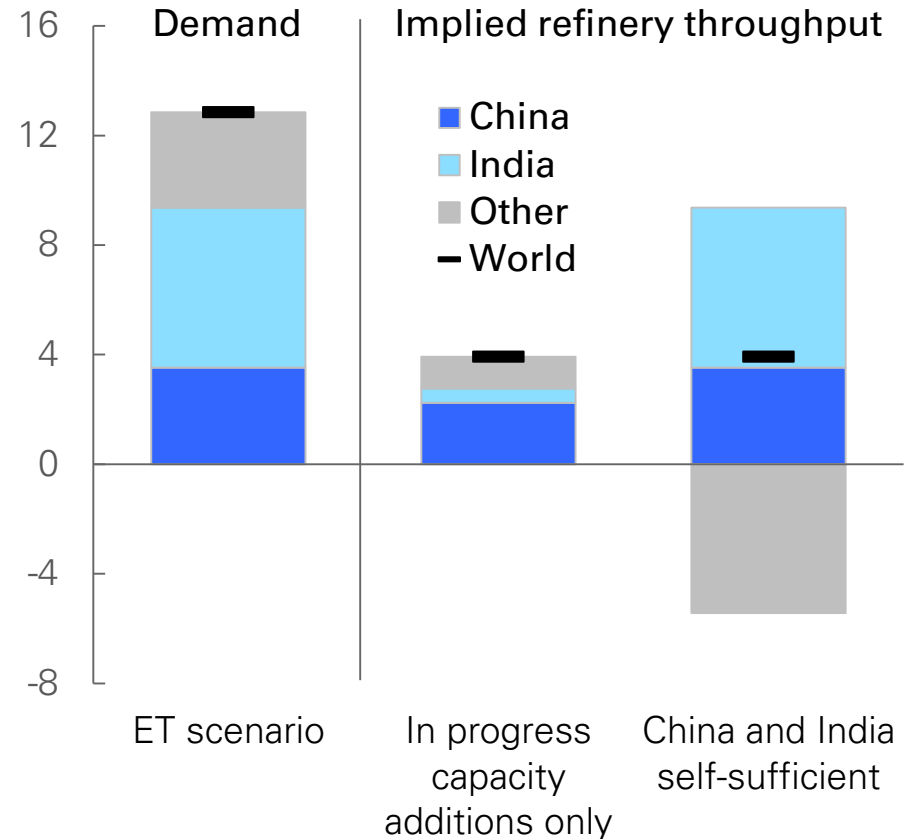
Global liquids supply growth

Mb/d, average annual growth



Refining throughput and demand growth, 2016-2040

Mb/d





...from weak demand growth and abundant NGLs

- Slower growth in liquids demand combined with continued growth of NGLs and biofuels puts pressure on global refining.
- In the ET scenario, liquid supplies grow by around 11 Mb/d, of which only 3 Mb/d is accounted for by crude and condensates which need to be refined, with the rest met by NGLs (6 Mb/d) and biofuels and other liquids (3 Mb/d).
- The gradual plateauing in product demand, combined with continuing steady growth in non-refined liquid supplies, causes refinery runs to peak in the mid-2030s.
- New refinery projects which are already planned or under construction for the next five years or so are sufficient to meet all of this additional throughput, implying no net new refining capacity is needed beyond that.
- However, in the past, many emerging economies, including China and India, have typically built refining capacity to meet (or exceed) their own demand growth. If just China and India were to continue that practice, this would imply that throughput in the rest of the world would need to fall by 5 Mb/d from today's levels. This would likely result in substantial refinery closures in mature markets such as Europe, OECD Asia and parts of North America.



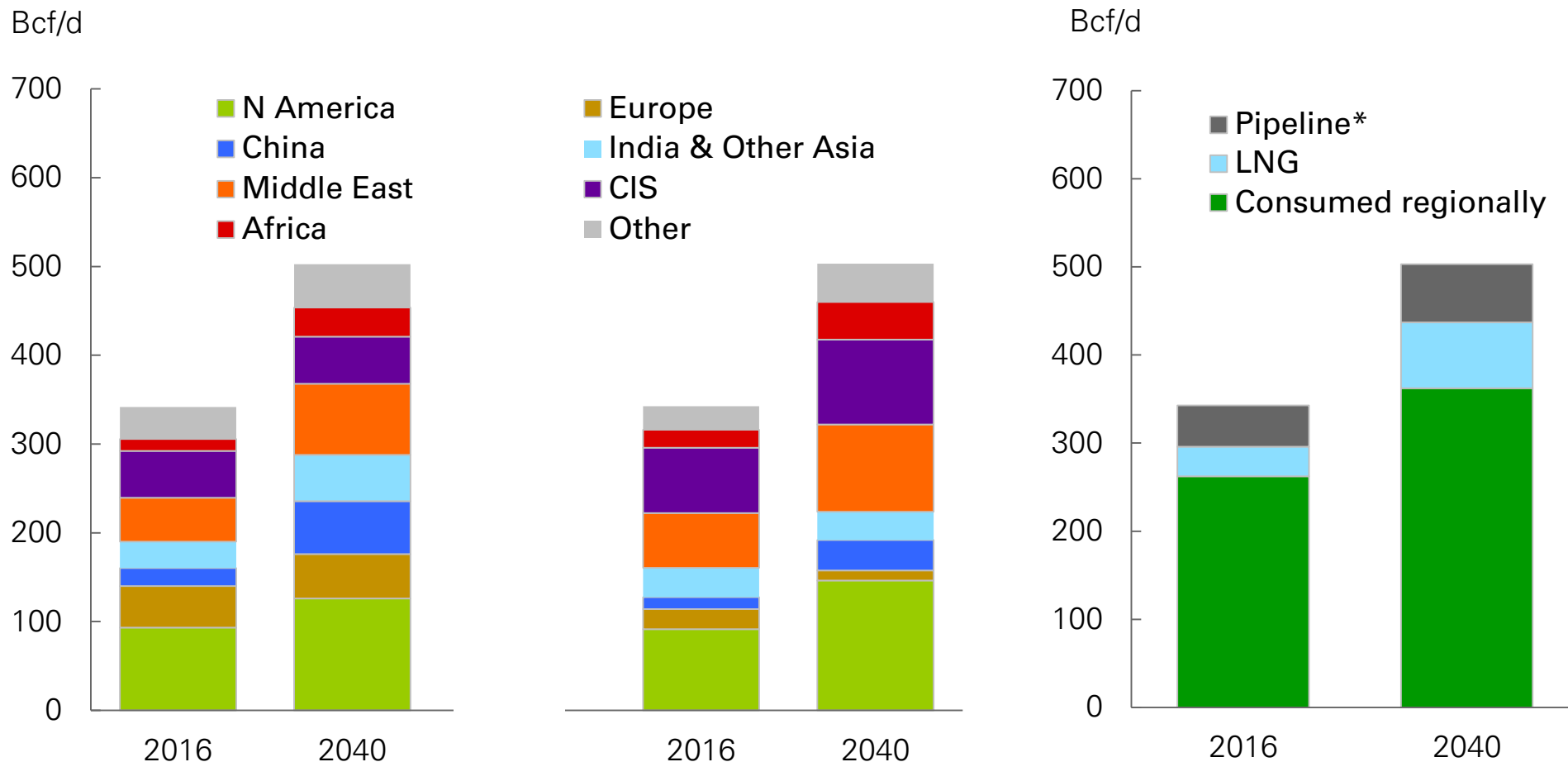
Natural gas grows strongly, with broad-based demand...

Natural gas

Consumption

Production

Trade



*Pipeline gas refers to inter-regional pipeline trade



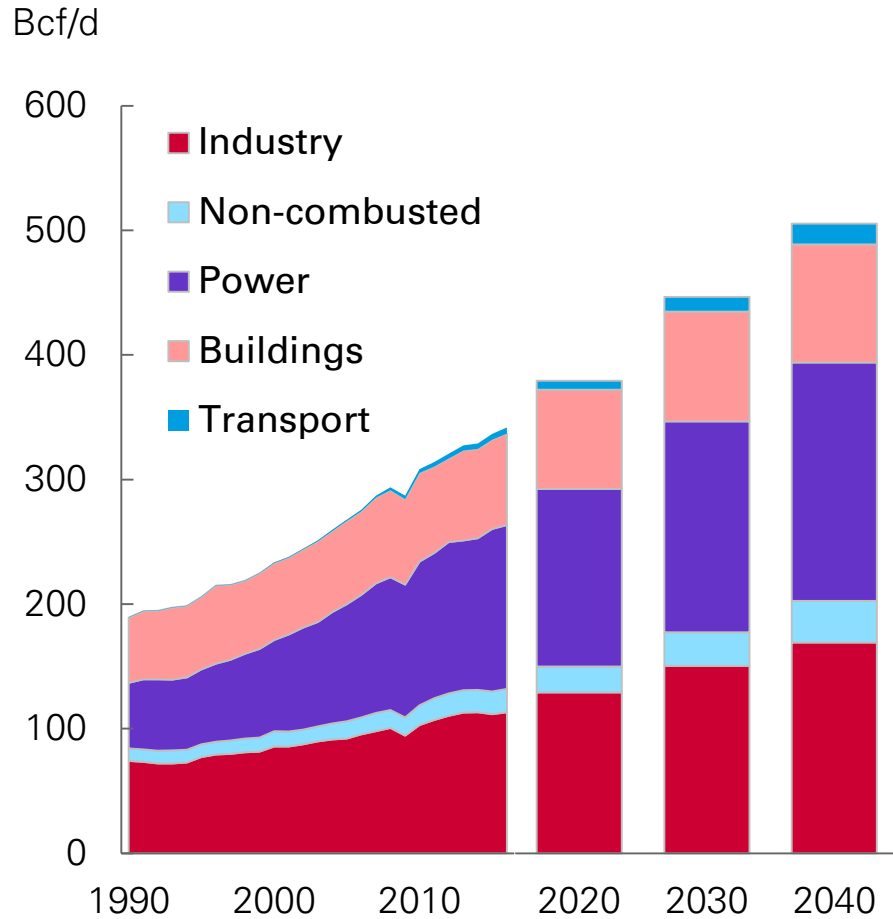
...low-cost supplies and increasing global availability

- Natural gas grows strongly, supported by broad-based demand, strong increases in low-cost supplies, and continuing expansion of supplies of liquefied natural gas (LNG) increasing the availability of gas globally.
- In the ET scenario, natural gas growth is supported by a number of factors: increasing levels of industrialization and power demand (particularly in emerging Asia and Africa); continued coal-to-gas switching (especially in China); and the increasing availability of low-cost supplies (in North America and the Middle East).
- The US and the Middle East (Qatar and Iran) contribute over half of the incremental production. By 2040, the US accounts for almost one quarter of global gas production, ahead of both the Middle East and CIS (each accounting for around 20%).
- Global LNG supplies more than double over the Outlook, with around 40% of that expansion occurring over the next five years. The sustained growth in global LNG supplies greatly increases the availability of gas around the world, with LNG volumes overtaking inter-regional pipeline shipments in the early 2020s.

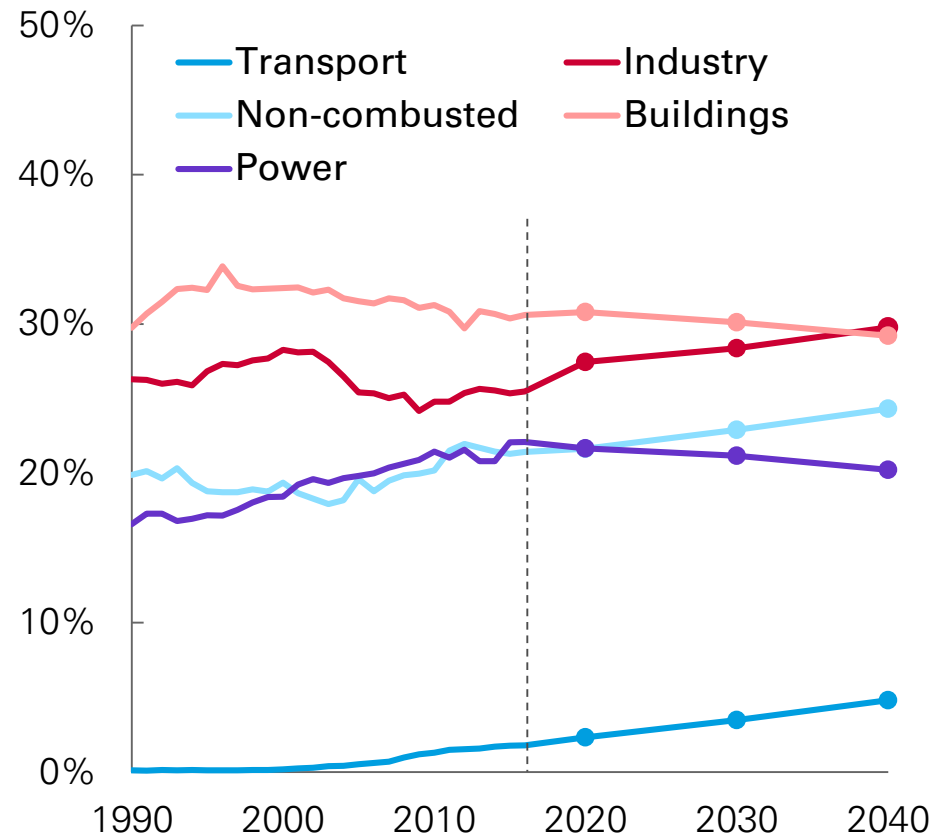


Growth in natural gas demand...

Gas consumption by sector



Gas share by sector





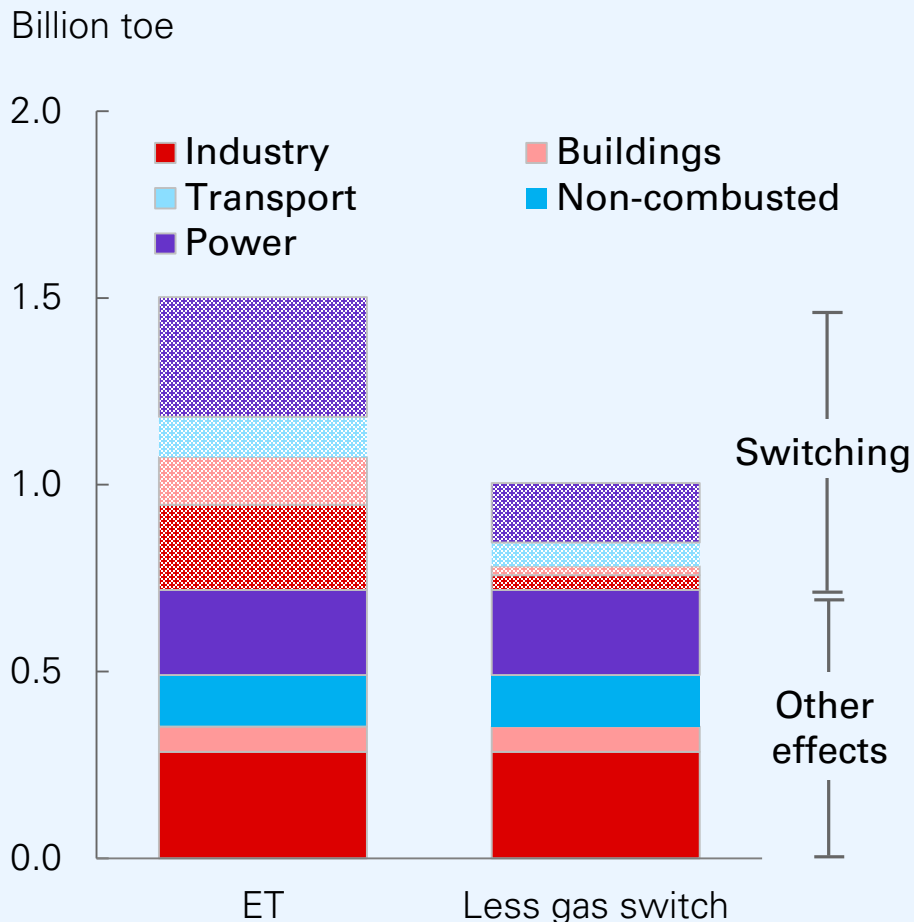
...is largely driven by industrial and power sectors

- Growth in natural gas demand is led by increases in industry and the power sector.
- In the ET scenario, growth in industrial use of gas including use in the non-combusted sector (70 Bcf/d) is supported by both continued industrialization in developing economies, together with gas gaining share as some countries in both OECD and non-OECD switch away from coal (pp 26-27).
- The increase in gas used by the power sector (59 Bcf/d) is driven by the overall growth in global power demand. The competing trends in renewables and coal demand means the share of gas within the power sector is relatively flat over the Outlook (pp 46-47).
- The growth of gas demand within buildings (21 Bcf/d) is less significant, reflecting that almost all of the incremental energy demand within buildings over the Outlook is for electricity to provide space cooling and power electrical appliances (pp 30-31).
- The fastest rate of growth of gas demand is in the transport sector as gas is increasingly used in trucking and marine transport. Although the increase in transport demand is small in absolute amount (11 Bcf/d), the share of gas within transport increases to almost 5% by 2040 (pp 34-35).

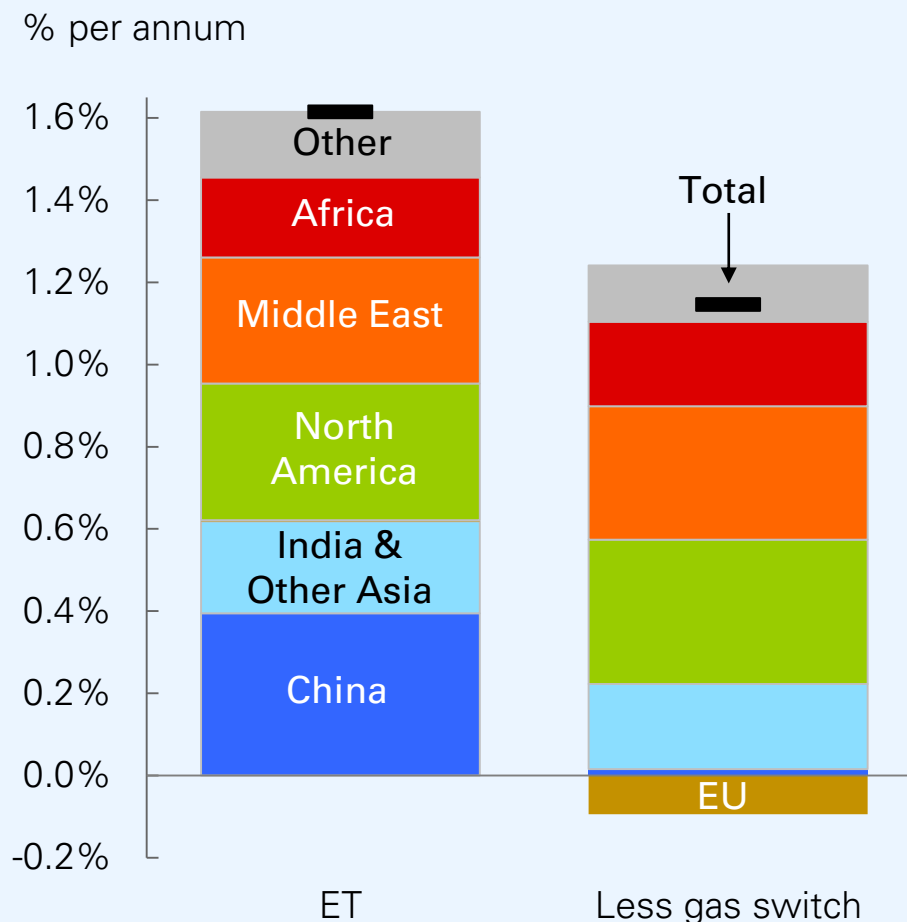


Alternative scenario: growth in natural gas could be slower...

Gas consumption increase
2016-2040



Gas consumption growth with
regional contributions, 2016-2040





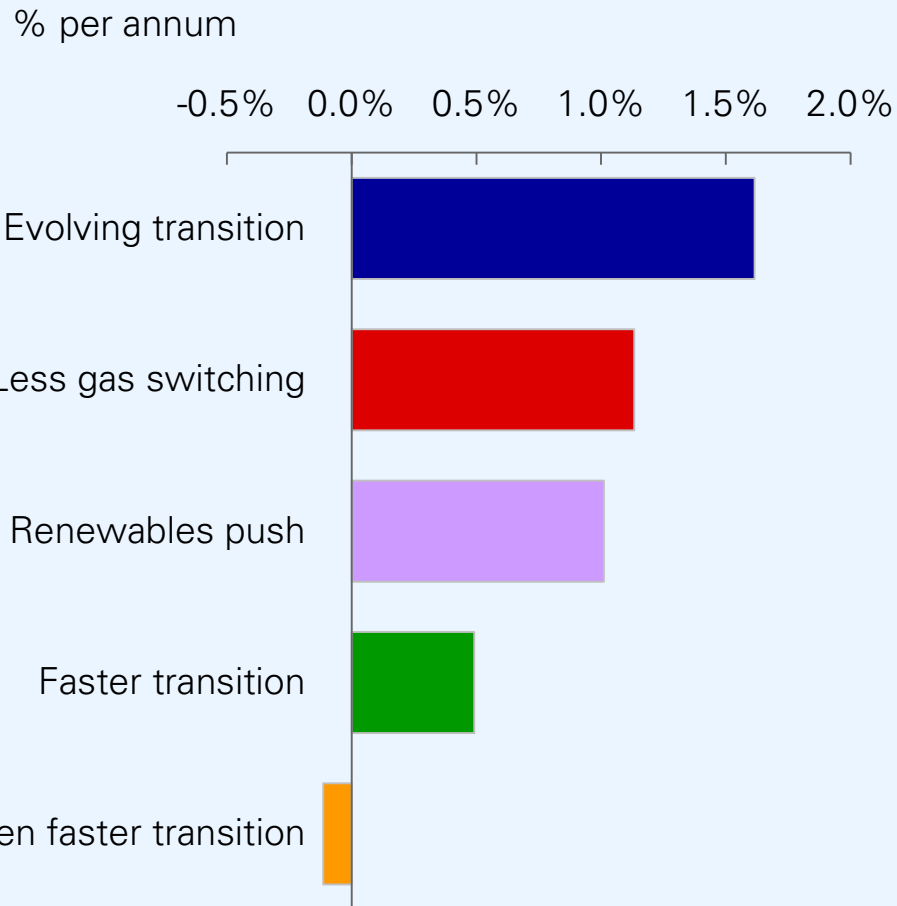
...if policies prompting coal-to-gas switching are weaker

- One way of analyzing the projected growth in natural gas is to separate it into two components: growth due to 'switching' i.e. gas gaining share relative to coal (and to oil in transport); and growth caused by 'other effects', mainly economic growth.
- In the ET scenario, around half of the growth in gas is due to 'switching'. Some of this switching is driven by the increasing availability of low-cost gas (e.g. US, Middle East), and some is due to policy measures promoting a shift to a lower carbon fuel mix (e.g. Asia, EU). One risk to the prospects for natural gas is that these environmental policy measures are less stringent than envisaged in the ET scenario.
- Consider an alternative scenario in which there is no coal-to-gas switching in the two regions in which policy plays the greatest role (Asia and the EU), as well as limited oil-to-gas switching in transport. The growth of natural gas in this 'less gas switch' scenario averages around 1.1% p.a. compared with 1.6% p.a. in the ET scenario.
- The weaker growth is concentrated in China which has a significant degree of coal-to-gas switching in the ET scenario, and, to a lesser extent, the EU. Gas growth in India and the rest of Asia is relatively unchanged.

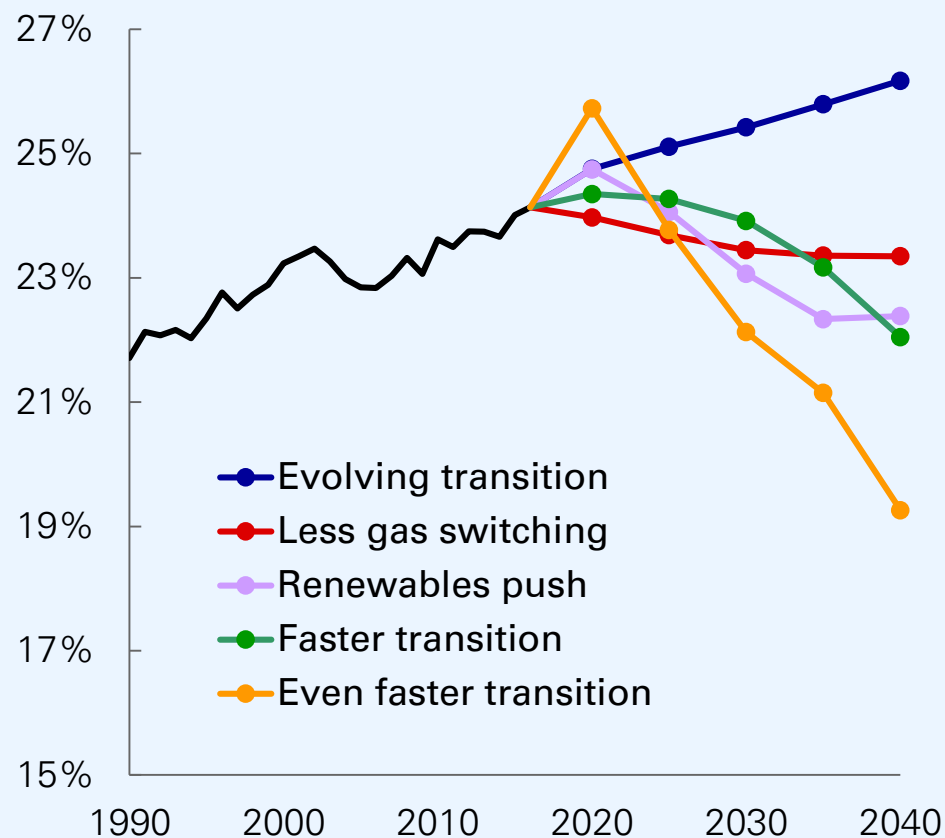


Prospects for gas demand could be dampened...

Gas demand growth 2016-2040



Gas share of primary energy 1990-2040



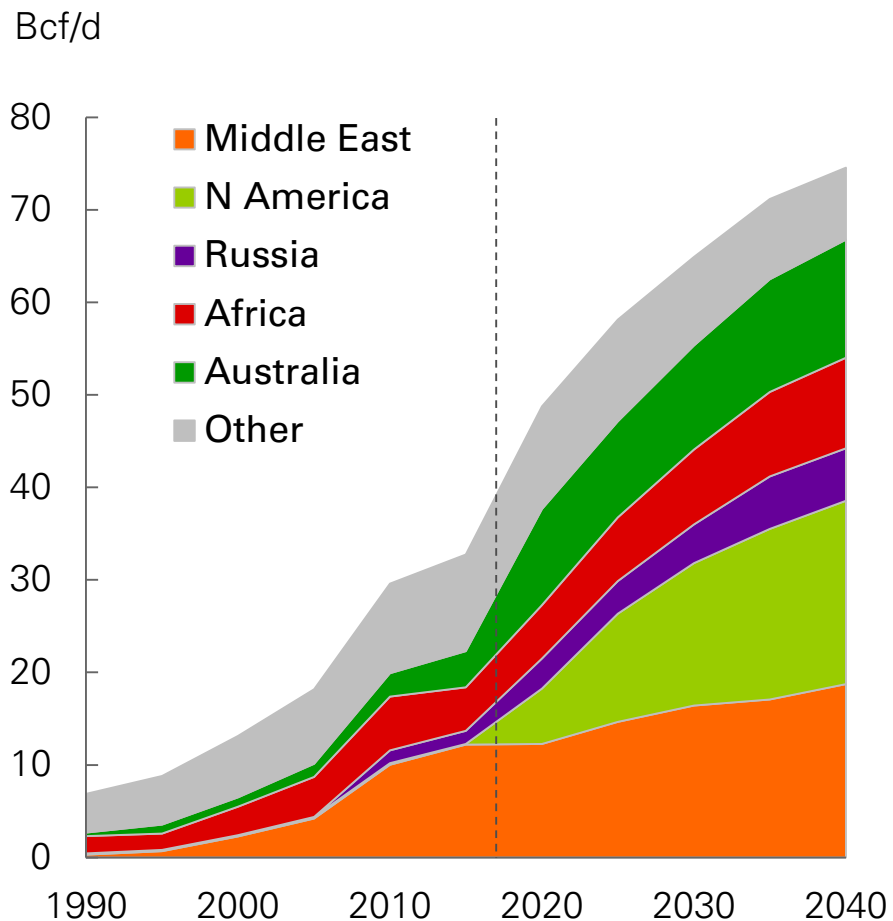


...by either weaker or stronger environmental policies

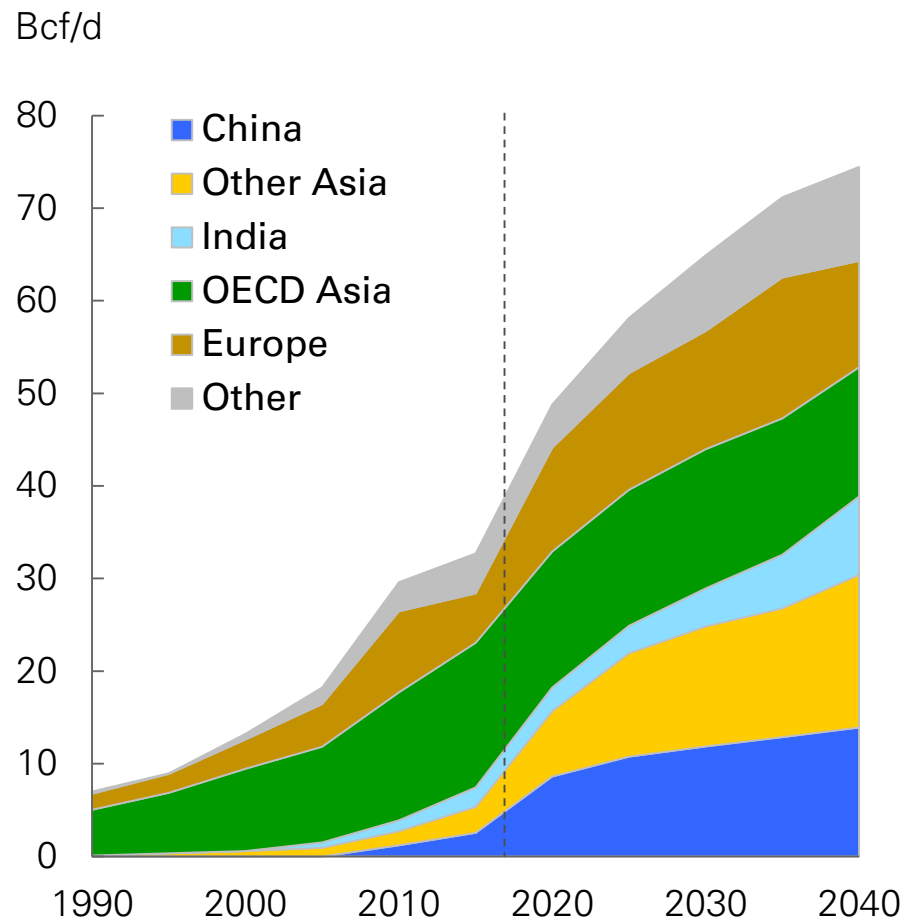
- The prospects for gas demand could be adversely affected by either weaker or stronger environmental policies. Weaker policies could dampen the shift away from coal towards natural gas as in the 'less gas switching' scenario, whereas stronger policies could encourage greater gains in renewables and energy efficiency.
- The 'renewables push' scenario assumes that the level of policy support for renewables persists around current levels for the entire outlook, crowding out gas (and coal) from the power sector (pp 98-99 describe the 'renewables push' scenario and its implications in more detail). Global gas demand grows by around 1% p.a. in the 'renewables push' scenario, similar to the 'less gas switching' scenario.
- The growth of gas demand is slower in the 'faster transition' and 'even faster transition' scenarios, reflecting the more comprehensive climate policies assumed in these scenarios, which lead to significant improvements in energy efficiency, as well as to a lower carbon fuel mix.
- The share of gas in primary energy falls in all of these alternative scenarios, relative to the current level, in contrast to the steady increase projected in the ET scenario.

LNG increases the global availability of gas...

LNG exports



LNG imports





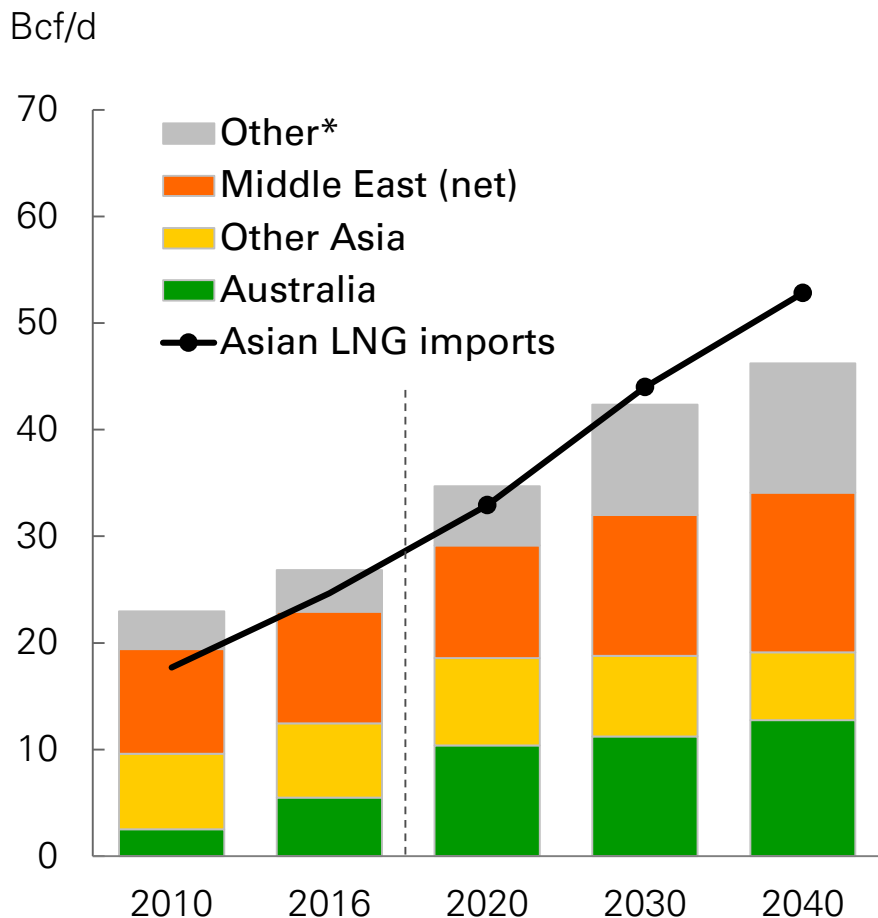
...with supply more than doubling, led by US and Qatar

- Global LNG supplies expand rapidly, leading to a more competitive, globally integrated gas market.
- In the ET scenario, LNG more than doubles over the Outlook. Much of that growth is concentrated over the next few years as a number of existing projects are completed, followed by slower increases over the remainder of the Outlook.
- LNG exports are dominated by the US and Qatar, which account for almost half of global LNG exports by 2040. But material increases are also projected in Australia, as existing projects are completed, in Russia and in East and West Africa.
- The increasing accessibility and competitiveness of gas associated with LNG helps to develop new and expanding markets, led by China together with some smaller Asian countries, such as Pakistan and Bangladesh. Europe remains a key market, both as a potential 'market of last demand' for surplus LNG cargoes and as a key hub of gas-on-gas competition between LNG and pipeline gas (pp 90-91).
- The mobility of LNG cargoes and their ability to be diverted in response to price signals causes the gas market to become increasingly integrated, with movements in global gas prices becoming more synchronized.

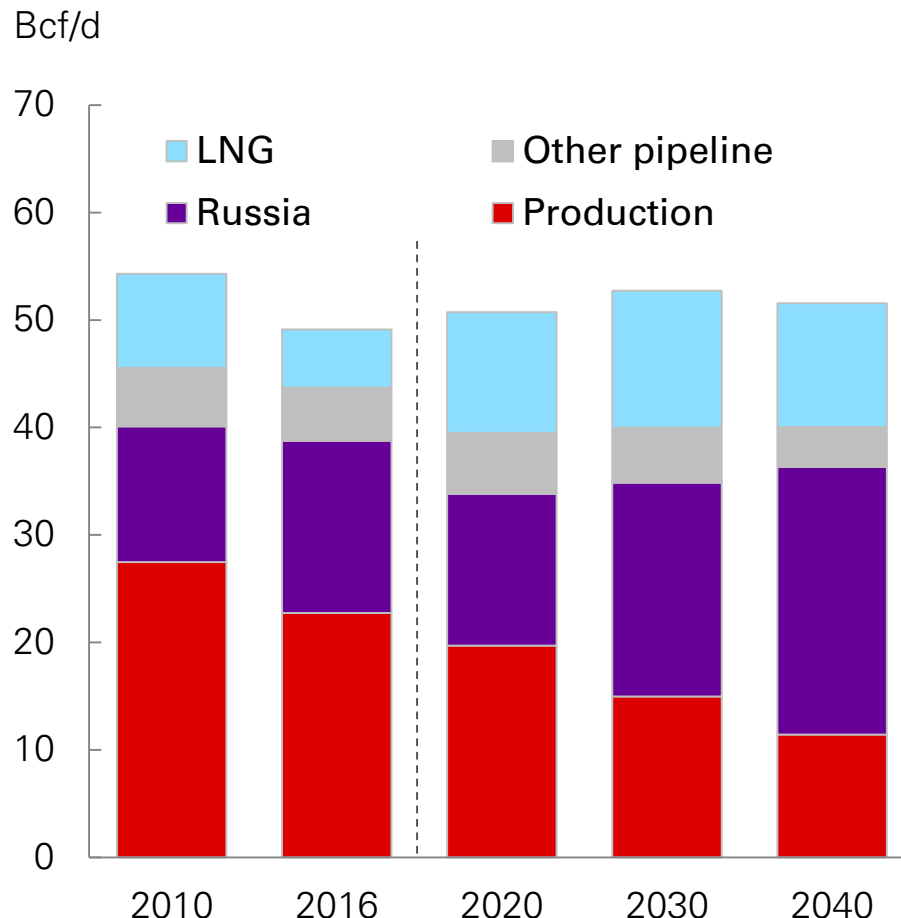


Developments in Asian and European LNG markets...

Asian LNG imports and LNG exports of regions 'close' to Asia



Gas supply to Europe



*Other includes Peru, Canada, East Africa, Angola, parts of West African and Russian gas supplies

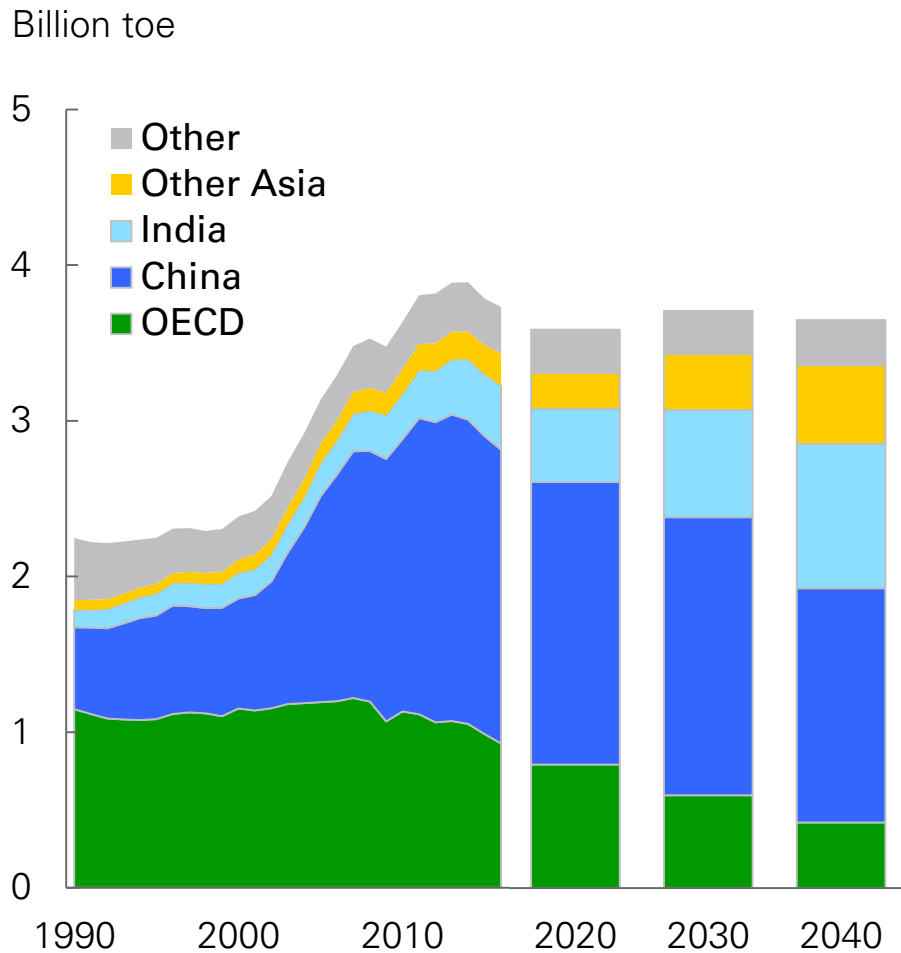


...will have an important bearing on global LNG trade

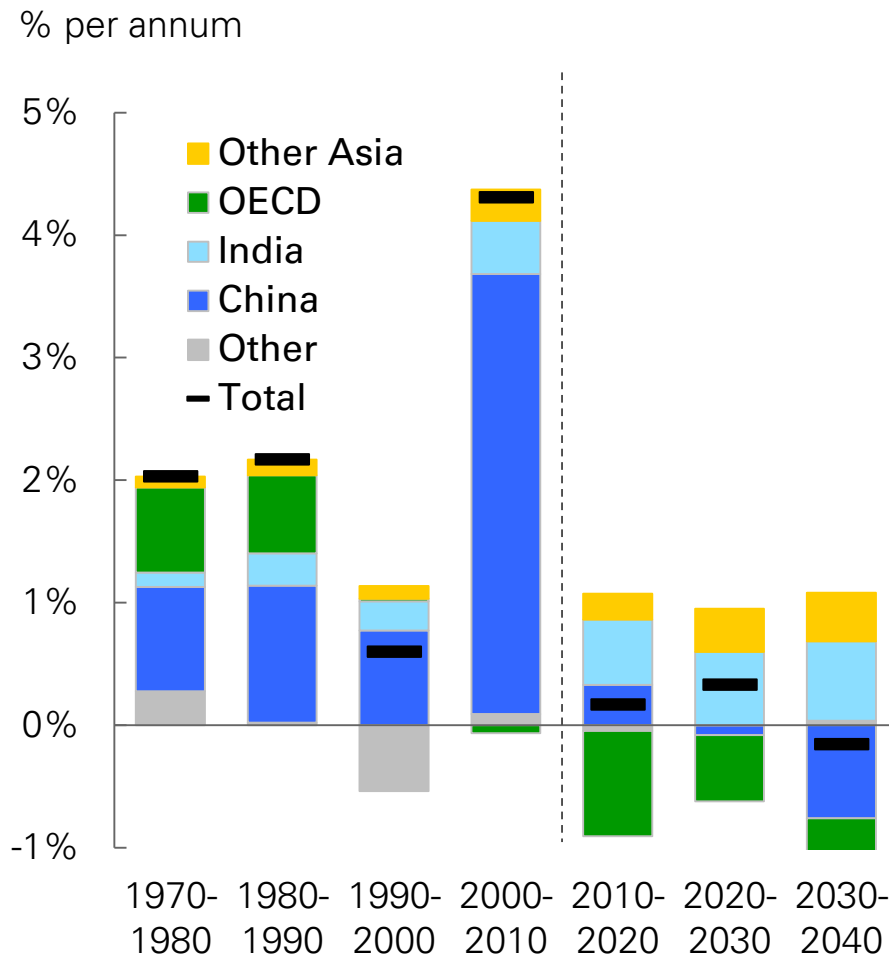
- Asia and Europe together account for the vast majority of LNG demand by 2040. As such, how these markets develop will have an important bearing on global LNG trade.
- One question is whether Asia will provide a market for significant volumes of US LNG. A comparison of total Asian LNG imports with LNG exports from regions which are closer to Asia than the US and so have lower shipping costs, suggests that, in principle, there may be relatively little need for Asia to import LNG cargoes from the US. However, in practice, both LNG sellers and buyers see value in diversifying their portfolios, and so significant quantities of US LNG are likely to be exported to Asia.
- In Europe, domestic gas production is set to roughly halve over the Outlook causing the share of imported gas in total consumption to increase from around half in 2016 to three-quarters by 2040. In the ET scenario, the development of a globally integrated gas market limits European concerns about becoming overly dependent on gas exports from Russia, allowing Russia to broadly maintain its share of European gas imports. As such, the share of Europe's total gas consumption met by Russian exports increases from around a third currently to almost half by 2040.

Global coal demand flatlines, with falls in China and OECD...

Coal consumption by region



Coal consumption growth and regional contributions





...offset by increases in India and other Asia

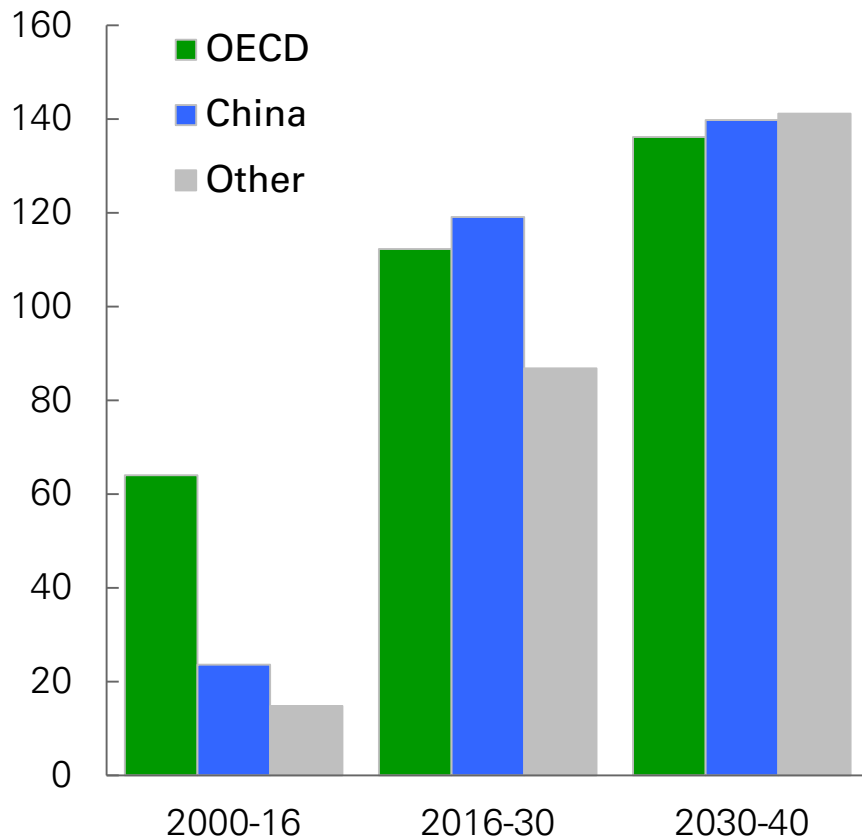
- Growth in global coal consumption slows sharply relative to the past, with falls in China and OECD offset to a greater or lesser extent by increasing demand in India and other emerging Asia.
- In the ET scenario, coal demand flatlines, in sharp contrast to the past 25 years, during which coal was the largest source of energy growth.
- Much of that slowing is driven by China, where coal consumption is broadly flat over the next 10 years or so, before declining thereafter. Even so, China remains the world's largest market for coal, accounting for 40% of global coal demand in 2040.
- Coal demand within the OECD declines, largely driven by environmental policies, except in the US where the availability of low-cost natural gas is the main factor driving out coal.
- In contrast, coal demand within India and other emerging Asian economies increases, as these economies continue to industrialize and electrify their economies. India is the largest growth market for coal, with its share of global coal demand more than doubling from a little over 10% in 2016 to around a quarter by 2040.



Renewables are the largest source of energy growth...

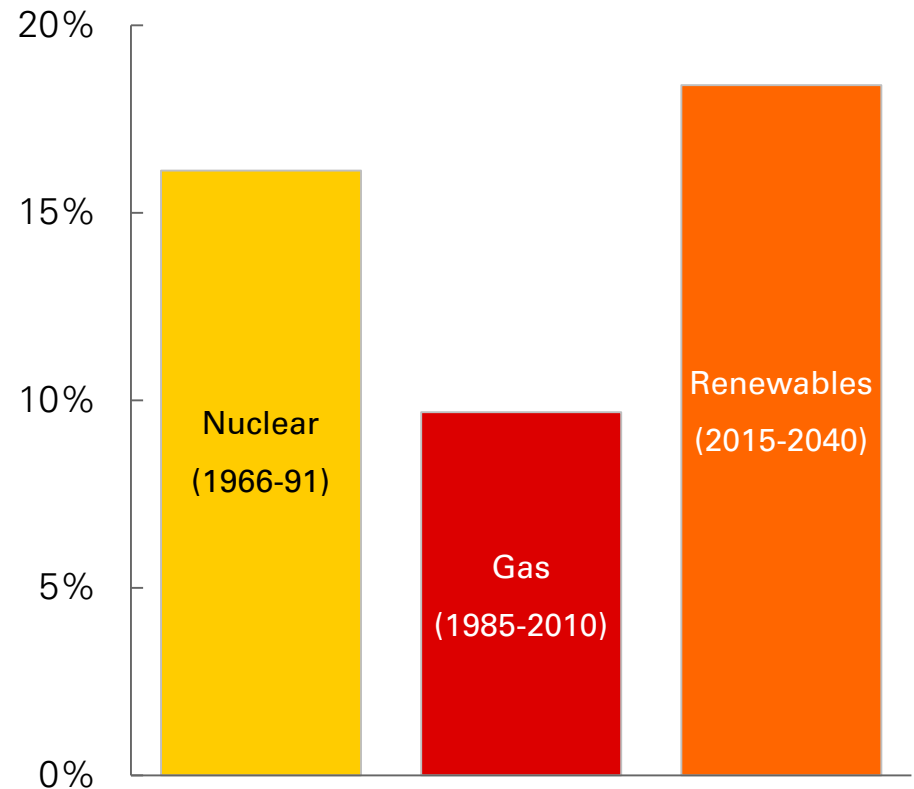
Growth of renewable power

TWh, average annual growth



Pace of power market penetration

Largest gains in market share over 25 years, %pts





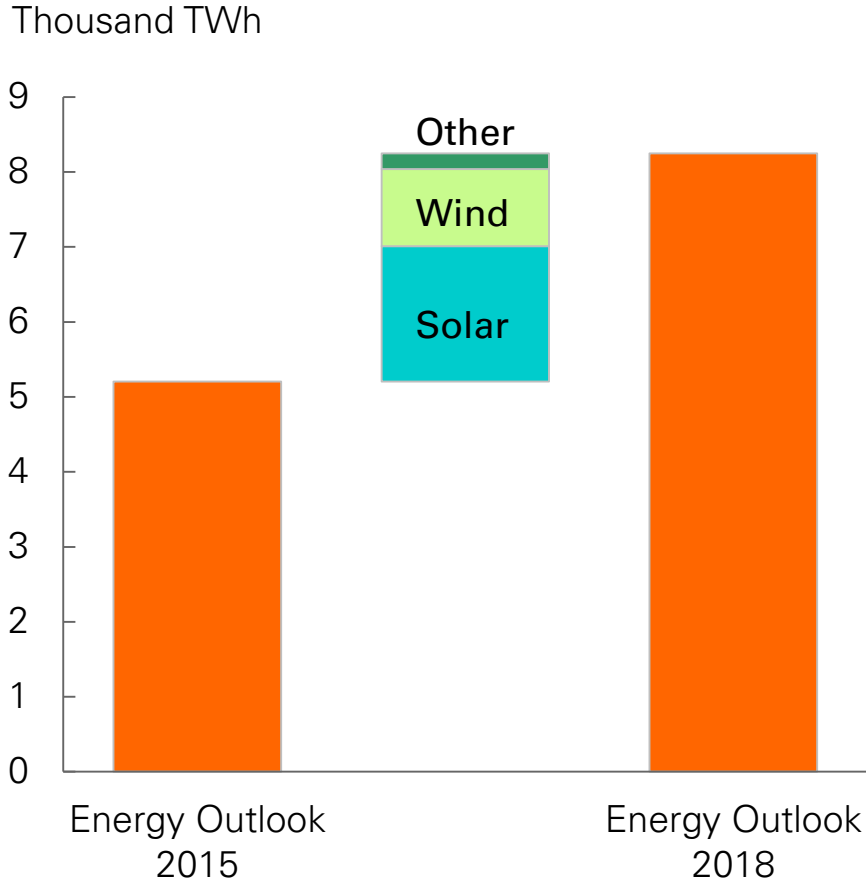
...gaining share in power at an unprecedented rate

- Renewable energy grows strongly, increasing its share within the power sector.
- In the ET scenario, renewables in power are the fastest growing energy source (7.5% p.a.), accounting for over 50% of the increase in power generation.
- The strong growth in renewable energy is enabled by the increasing competitiveness of wind and solar power. In the ET scenario, subsidies are gradually phased out by the mid-2020s, with renewable energy increasingly able to compete against other sources of energy, aided by a gradual rise in carbon prices and continued regulation supporting a shift to lower carbon energy (pp 98-99 outline an alternative scenario in which subsidies are maintained around current levels until 2040).
- The expansion in renewable energy is broad-based, with China and increasingly other parts of the developing world taking over from the EU as the main engine of growth. China is the largest source of growth, adding more renewable energy than the entire OECD combined; India becomes the second largest source of growth by 2030.
- The pace at which renewables gain share in power generation over the Outlook is faster than any other energy source over a similar period. The closest parallel is the rapid build-up of nuclear power in the 1970s and 1980s.

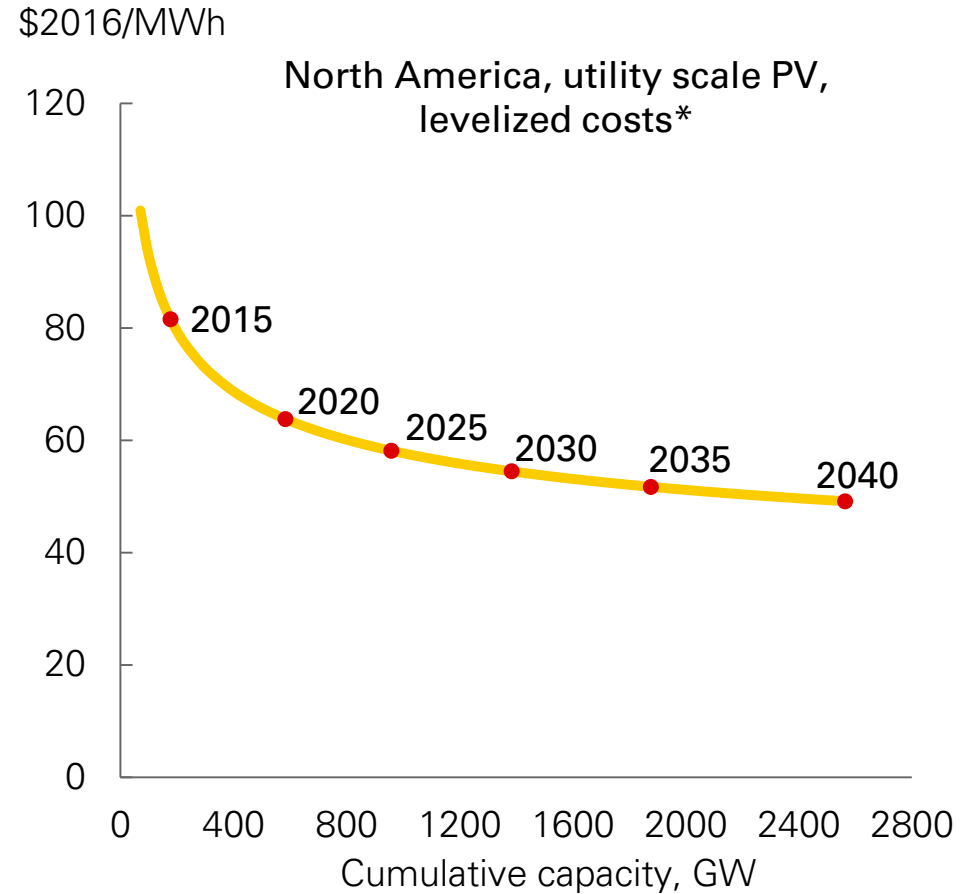


The outlook for renewables has increased significantly...

Change to the projected level of renewable power in 2035



Solar PV learning curve



*Cost per MWh of building and operating a plant over its lifetime. Excludes subsidies, tariffs and the cost of grid integration.



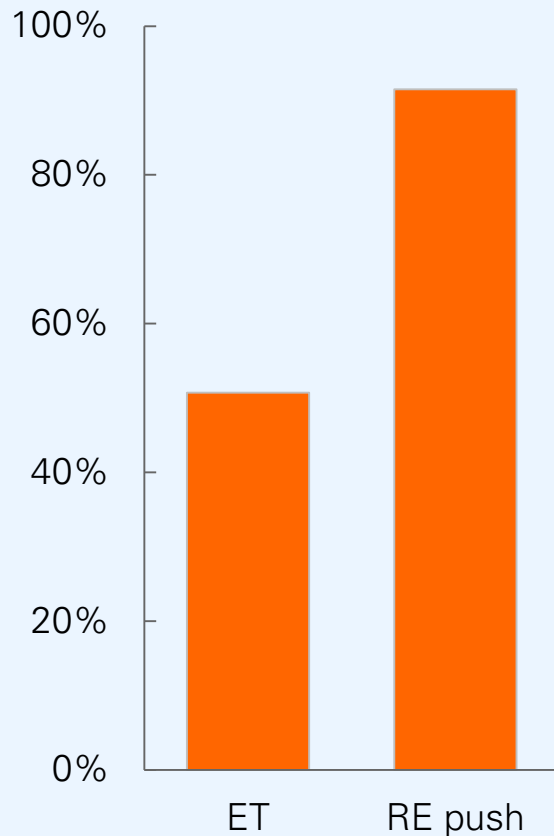
...due to faster technological gains and greater policy support

- The outlook for renewable energy has increased substantially in the past three Energy Outlooks, particularly the prospects for solar power.
- In the ET scenario, global solar power in 2035 is more than 150% higher than in the base case of the 2015 Energy Outlook. This reflects solar costs falling faster than anticipated, with solar energy now projected to be widely competitive by the mid-2020s – 10 years earlier than previously expected.
- The more rapid decline is partly due to faster technological gains, but also reflects stronger policy support, which enables solar energy to move more quickly down its 'learning curve'. The largest increases in solar energy are in China and India, where renewable energy receives significant levels of support over the medium term.
- In the ET scenario, solar costs continue to follow the learning curve, with module costs falling by around 24% with every doubling of cumulative capacity. The rate of decline of \$/MWh costs slows over the Outlook, as it takes longer to double the cumulative capacity and as module costs fall as a proportion of total costs.
- Some projects enjoying the best solar conditions and continued policy support will offer far lower prices than implied by this learning curve.

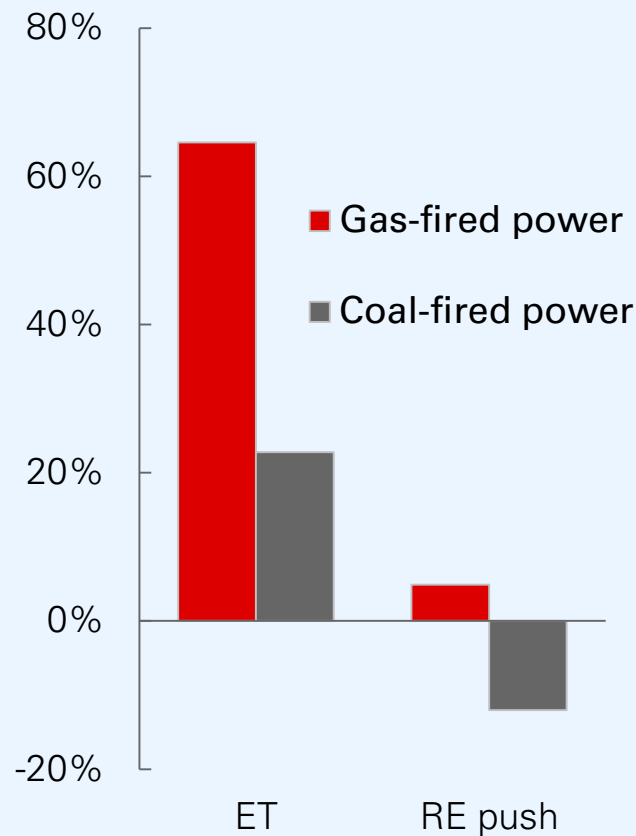


Alternative scenario: more sustained support for renewables...

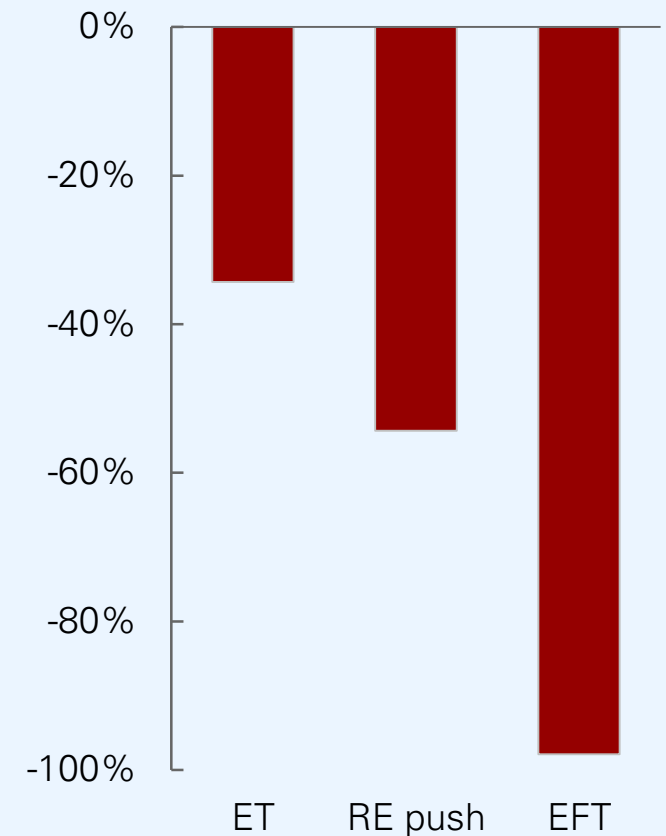
Renewables share of power growth, 2016-2040



Change in gas and coal power output, 2016-2040



Change in carbon intensity of power, 2016-2040





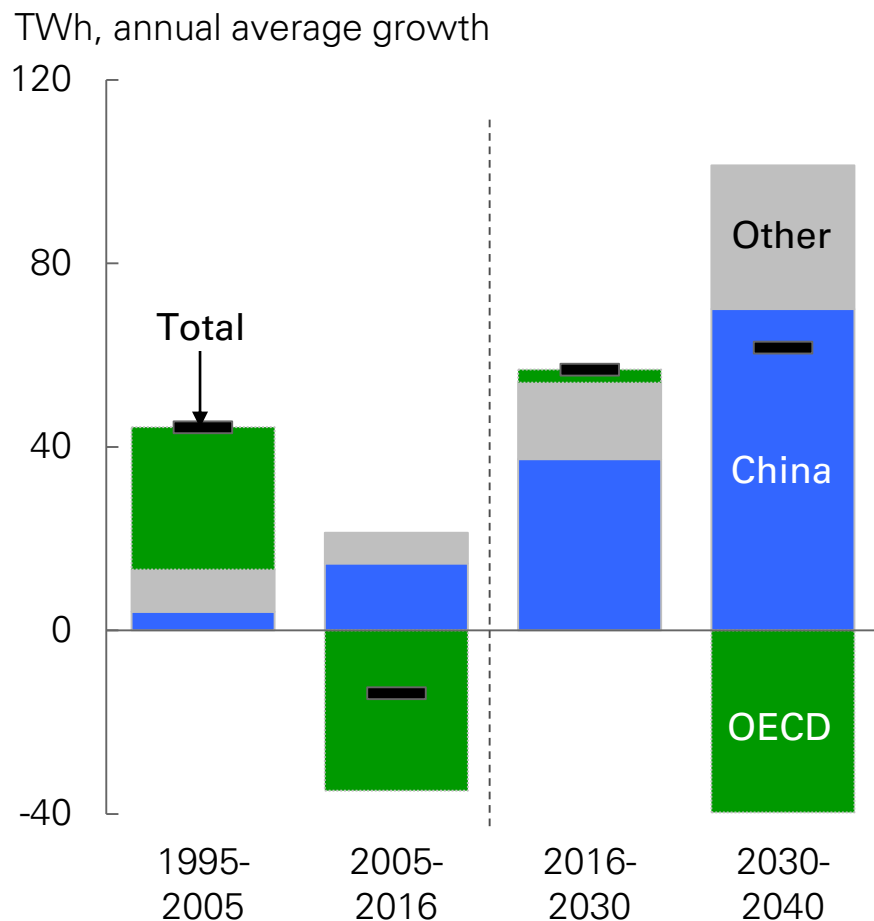
...leading to stronger growth

- The pace at which renewable energy penetrates the global power system depends partly on the size and persistence of government support. In the ET scenario, support for renewables is largely phased out by mid 2020s. We also consider an alternative scenario in which levels of government support per unit of capacity installed persists around current levels until 2040.
- In this alternative ‘renewables push’ scenario, renewables account for more than 90% of the growth in power demand over the Outlook, with the share of renewables within power reaching over 40% by 2040, compared with 25% in the ET scenario. The stronger growth in renewables crowds out coal and gas to a broadly equal extent.
- This stronger policy push to renewables reduces the carbon intensity of power relative to the ET scenario, although the reduction in the carbon intensity of power is only around half of that achieved in the ‘even faster transition’ (EFT) scenario (pp 106-107).
- This smaller improvement reflects that the ‘renewables push’ policy reduces carbon intensity only by supporting renewables, which has diminishing effectiveness as renewables grow within the power sector causing the cost of balancing intermittency issues to escalate. In contrast, as well as supporting renewables, high carbon prices in the EFT scenario also encourage more coal-to-gas switching and large-scale deployment of CCUS.

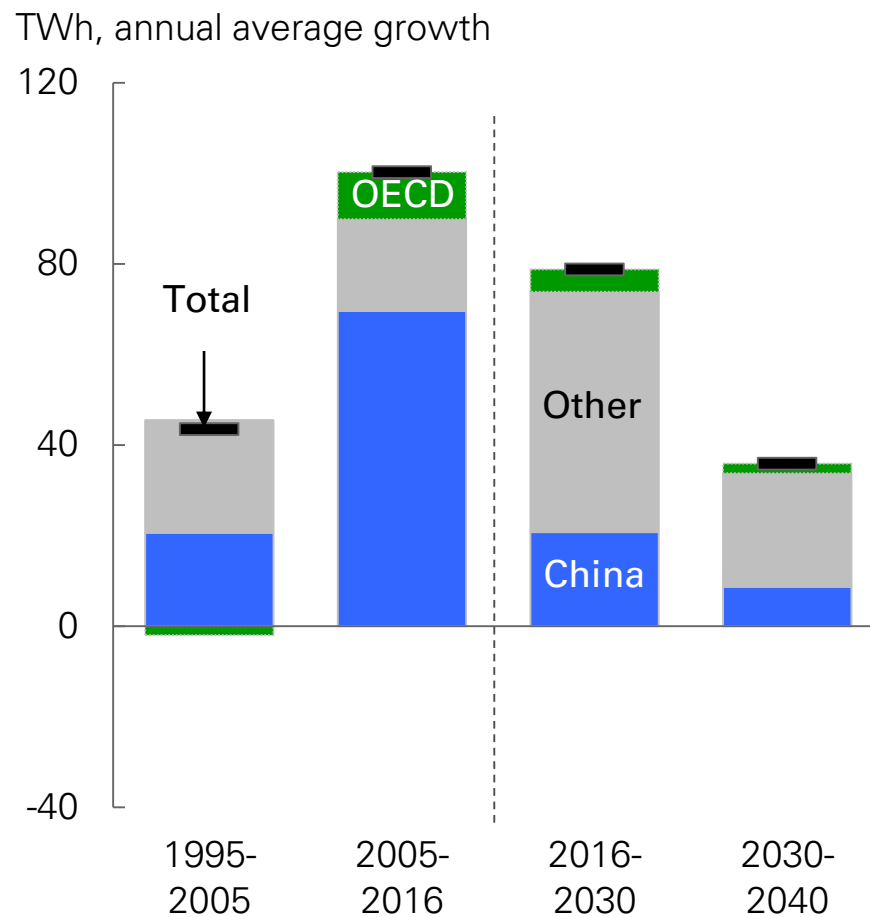


Nuclear and hydro power output increases...

Nuclear



Hydro





...driven by China and the rest of the developing world

- Nuclear and hydro power output continue to grow over the Outlook, although less rapidly than overall power generation, such that their shares within power decline.
- In the ET scenario, growth in nuclear energy (1.8% p.a., 59 TWh p.a.) is driven by China (51 TWh p.a.), which accounts for almost 90% of the total growth in nuclear energy. The share of nuclear energy within China's energy demand increases from 2% today to 8% by 2040.
- The overall growth in nuclear energy is dampened by declines in both the EU (-11 TWh p.a.) and US (-10 TWh p.a.) as aging nuclear plants are retired and not replaced.
- Growth in hydro power (1.3% p.a., 61 TWh p.a.) is more broadly based across developing economies. Although much slower than the rapid growth seen over the past few years, China contributes the largest increase (16 TWh p.a.), supported by growth in both South and Central America (13 TWh p.a.) and Africa (11 TWh p.a.).

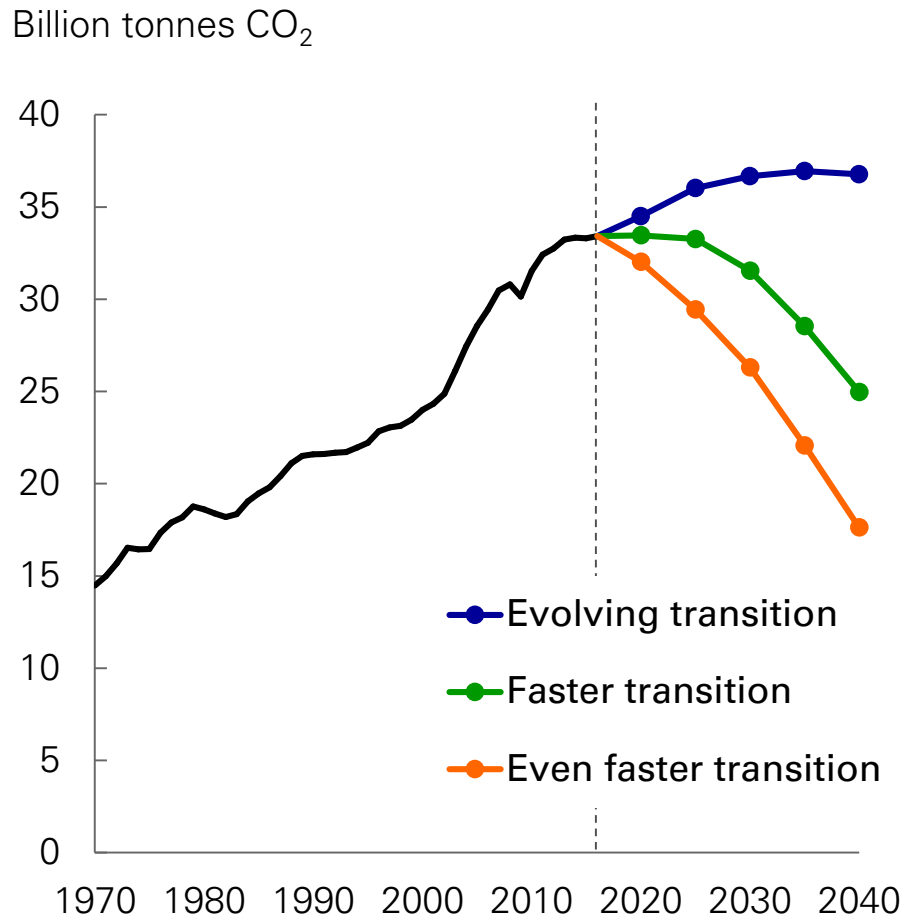


Carbon emissions

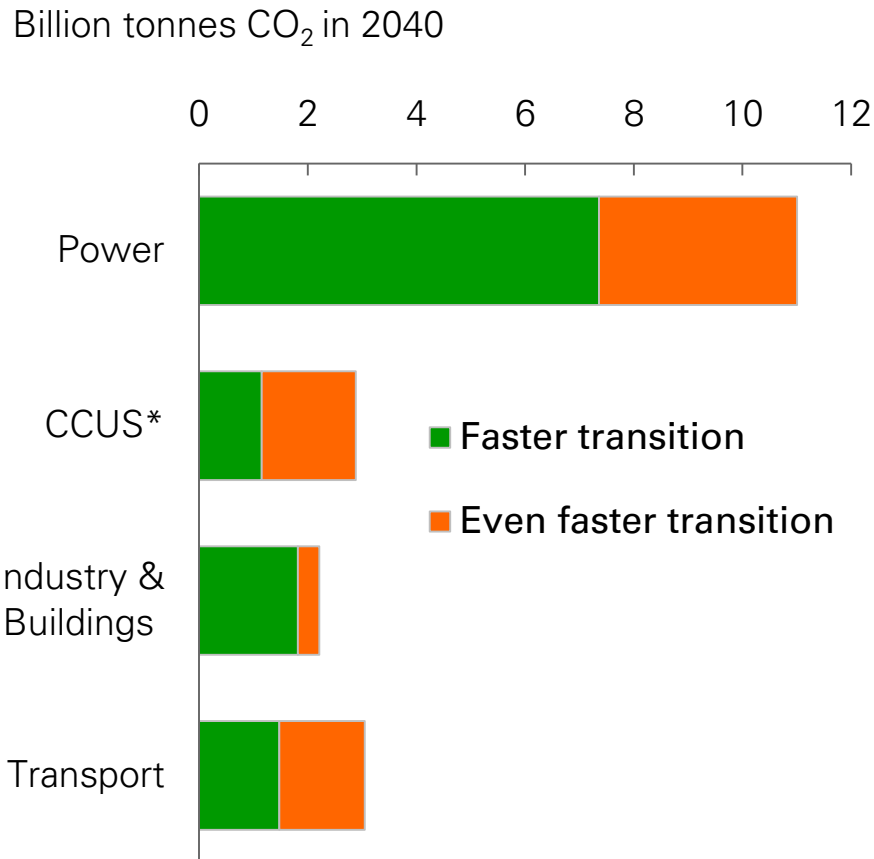


Carbon emissions continue to grow in the ET scenario...

Carbon emissions



Reductions versus ET scenario



*Carbon capture use and storage



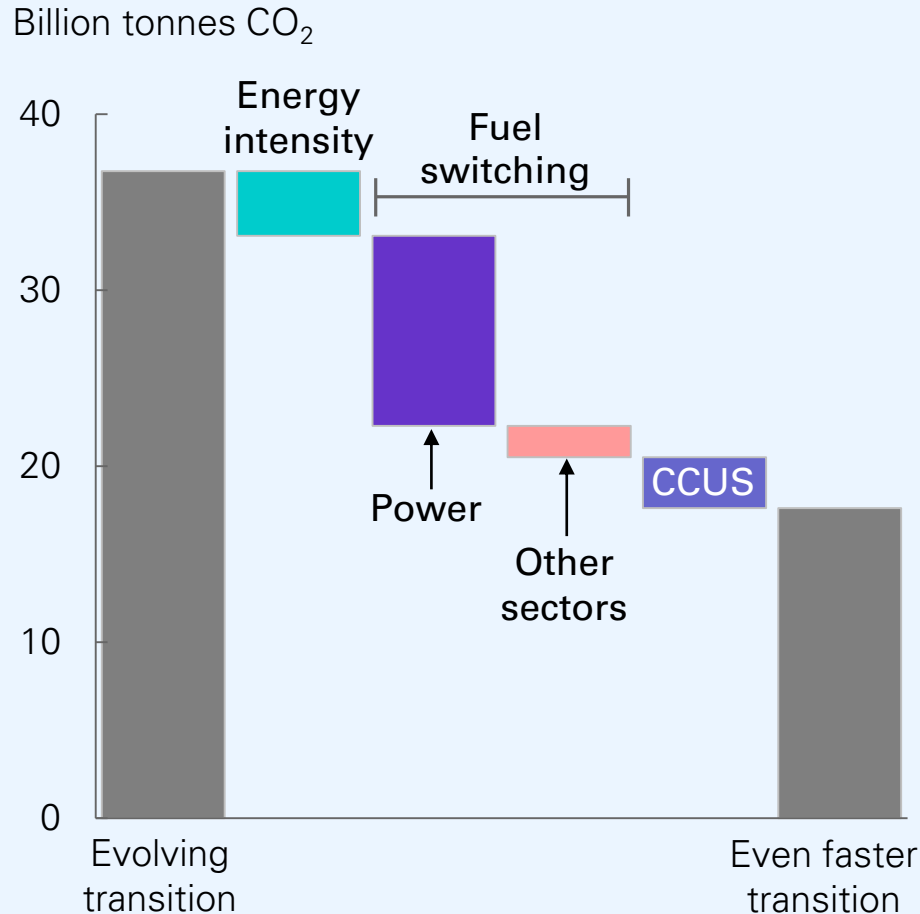
...highlighting the need for a more decisive break from the past

- In the ET scenario, carbon emissions from energy use grow through much of the Outlook, increasing by around 10% by 2040.
- This rate of growth is far slower than that seen in the past 25 years, when carbon emissions increased by 55%.
- Even so, the projected rate of growth is far higher than the sharp decline thought necessary to be consistent with achieving the Paris climate goals. This highlights the need for a more decisive break from the past than implied by the ET scenario.
- The 'even faster transition' (EFT) scenario follows the same broad decline in carbon emissions as the IEA's 'Sustainable Development Scenario', with emissions falling by almost 50% by 2040.
- Most of the additional abatement of emissions in the EFT scenario, relative to the ET scenario, emanates from the power sector, which is almost entirely decarbonized by 2040. The dominant role the power sector plays in bringing about a sharp fall in carbon emissions is a common feature across many of the external scenarios which have similar falls in carbon emissions.

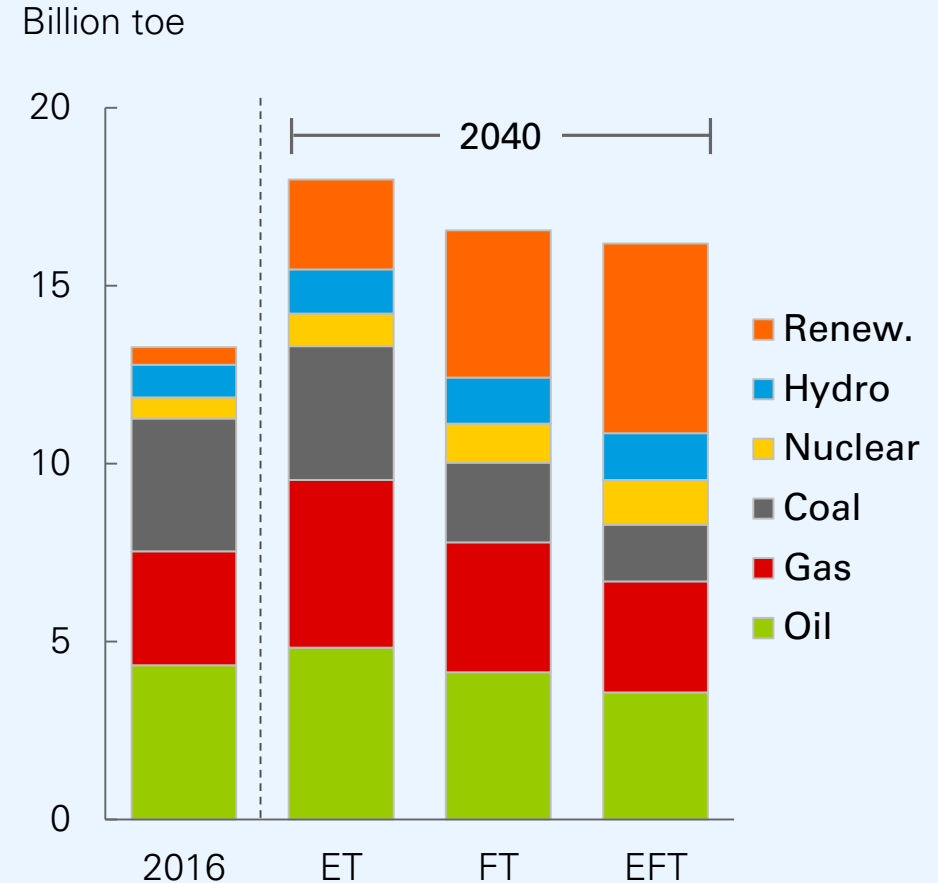


Alternative scenario: impact on global energy system...

Carbon emissions in 2040: EFT versus ET scenario



Primary energy consumption by fuel





...of a faster transition to a lower carbon economy

- The continuing growth of carbon emissions in the ET scenario highlights the need for an even more decisive break from the past if climate goals are to be met. This could have significant implications for the global energy system over the next 25 years.
- The EFT scenario illustrates one possible configuration of policies and outcomes achieving such a break, and is based on a sharp increase in carbon prices and a range of other policies designed to encourage more rapid gains in energy efficiency and greater fuel switching.
- Energy demand continues to grow in the EFT scenario, but at a slower rate reflecting the faster gains in energy efficiency. The higher carbon price also encourages greater use of carbon capture, use and storage (CCUS) in both industry and the power sector.
- The carbon intensity of the fuel mix in the EFT scenario is significantly lower than in the ET scenario. Renewables account for more than the entire growth in global energy, with their share within primary energy increasing to around a third by 2040.
- Even so, oil and gas together account for more than 40% of world energy in 2040.

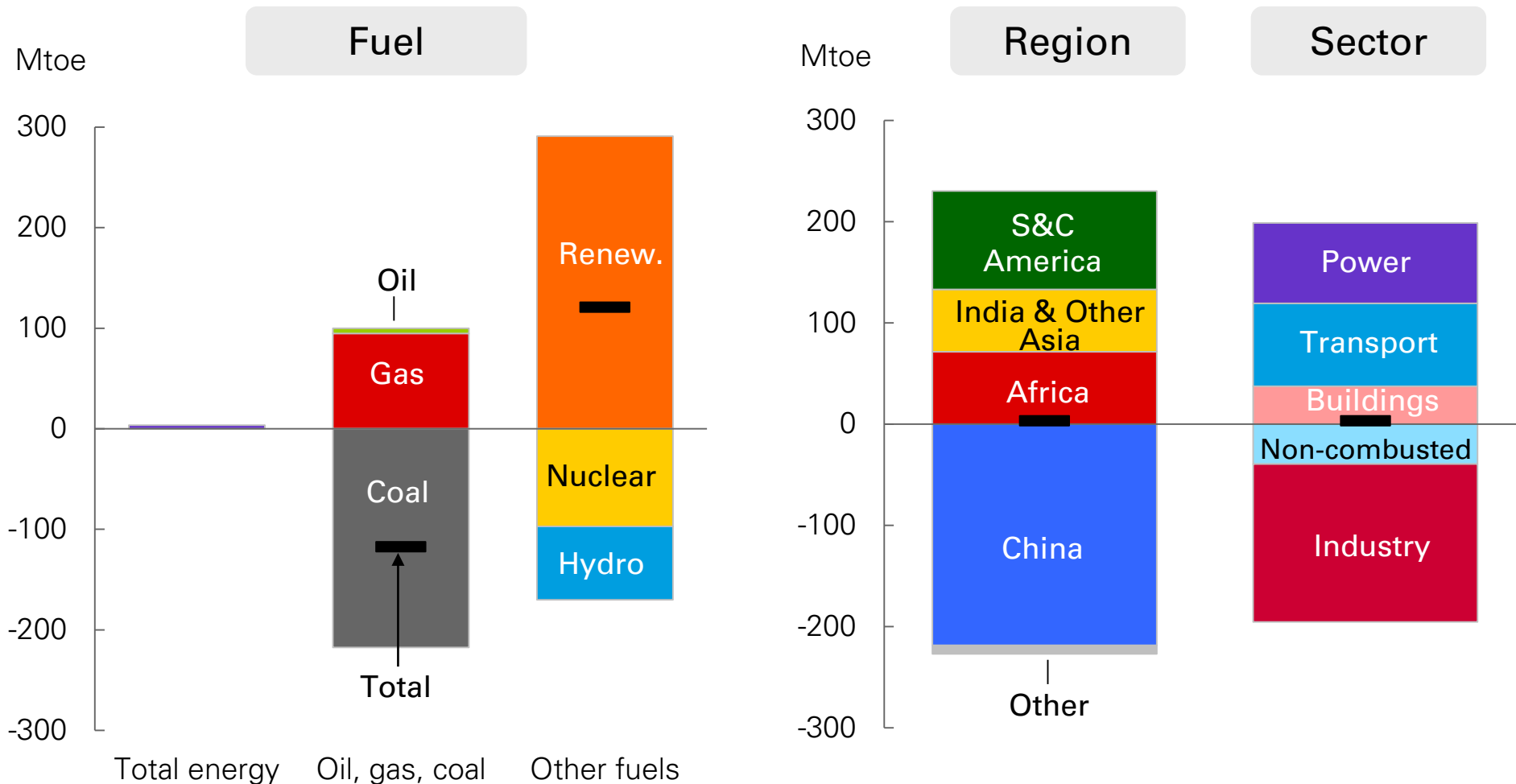


Comparisons



Comparing the ET scenario with last year's base case...

Difference in projected levels in 2035





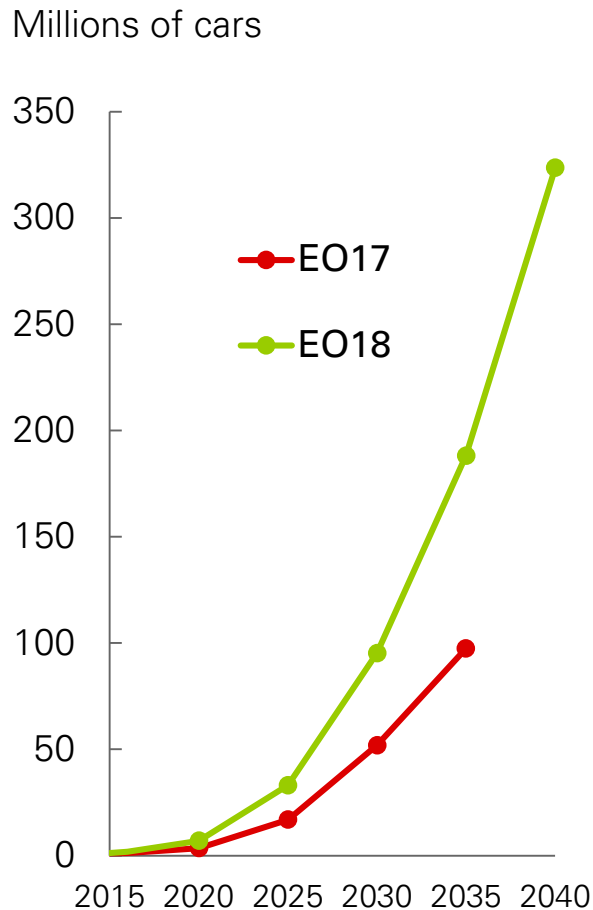
...overall energy demand is similar, but the fuel mix is different

- Comparing the ET scenario with the base case in last year's Energy Outlook, overall energy demand in 2035 is broadly similar, but there are some significant differences in the projected fuel mix.
- The largest difference is in the level of renewable energy, which is over 15% higher in 2035. The outlook for renewables has been materially increased in recent years, reflecting stronger policy support and quicker than expected falls in costs, particularly for solar energy (pp 96-97). The higher level of renewables is partially offset by a lower outlook for both nuclear and hydro energy.
- Global coal consumption in 2035 is lower, largely driven by developments in China. This is partially offset by higher levels of natural gas demand.
- By region, China's energy demand is almost 5% lower than in last year's base case, reflecting enhanced policies aimed at reducing energy intensity. This lower level of Chinese demand is largely offset by higher demand in other emerging markets, as industries migrate from China to cheaper, lower-income markets.
- By sector, the largest difference is the lower level of industrial energy demand, reflecting faster efficiency improvements, particularly in China.

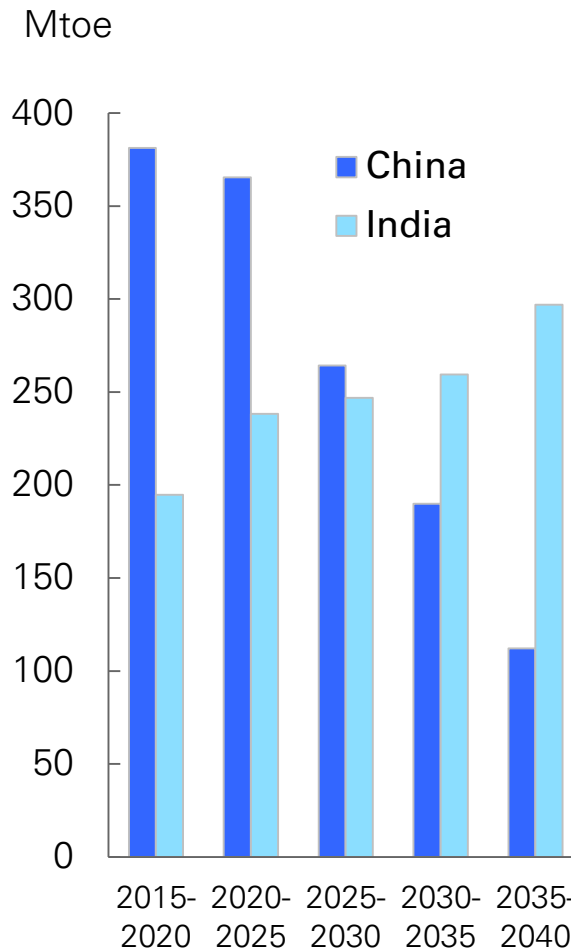


Extending the Energy Outlook to 2040...

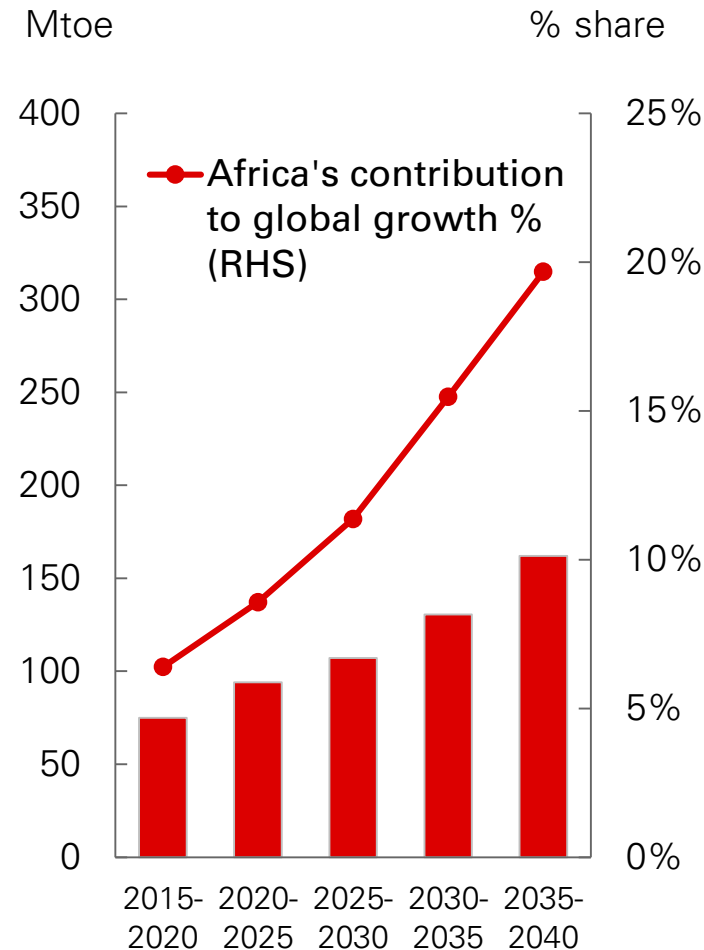
Electric cars*



Energy demand growth in China and India



Energy demand growth in Africa



*Includes plug-in hybrids



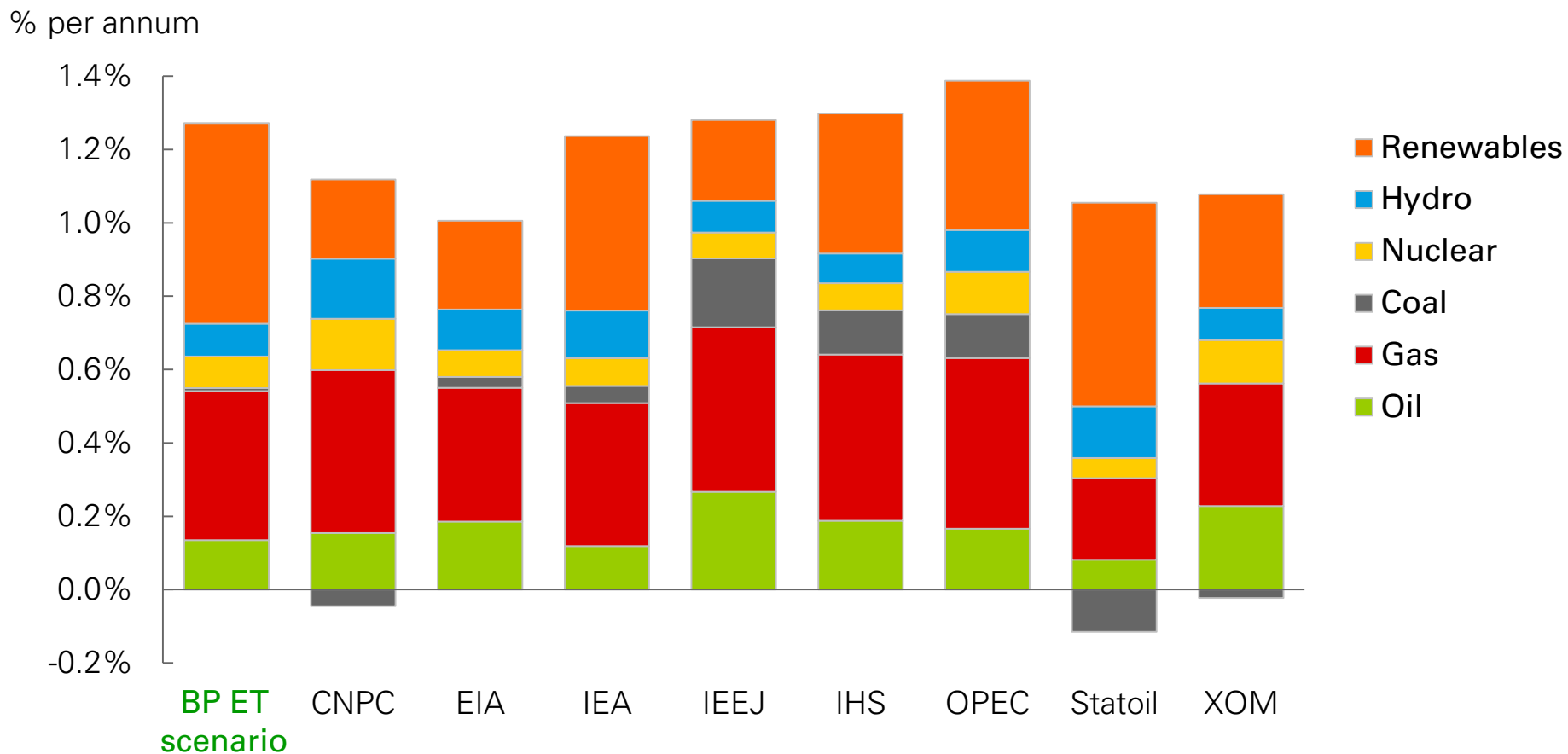
...highlights emerging trends in EVs, China vs India, and Africa

- Extending the Energy Outlook by five years to 2040 highlights several key trends.
- This is particularly the case for electric cars, where the growing size of the electric car parc means the number of electric cars added towards the end of the Outlook increases very rapidly. In the ET scenario, there are nearly 190 million electric cars by 2035, higher than the base case in last year's Outlook of 100 million. The stock of electric cars is projected to increase by a further 130 million in the subsequent five years, reaching around 320 million cars by 2040.
- Another trend that comes into sharper focus by moving out to 2040 is the shift from China to India as the primary driver of global energy demand. The progressively smaller increments in China's energy demand – as its economic growth slows and energy intensity declines – contrasts with the continuing growth in India. Between 2035 and 2040, India's demand growth is more than 2.5 times that of China, representing more than a third of the global increase.
- Africa's contribution to global energy consumption also becomes more material towards the end of the Outlook, with Africa accounting for around 20% of the global increase during 2035-2040; greater than that of China.



Comparing the ET scenario with other outlooks...

Contributions to growth of energy consumption, 2016-2040



Technical note: for ease of comparison outlooks have been rebased to a common set of data for 2016 taken from the BP Statistical Review. The IEA case shown is the New Policies Scenario, for IHS it is Rivalry Scenario and Statoil it is the Reform Scenario. The OPEC, EIA and IEEJ cases are each publication's reference case. For full sources and data definitions see pages 122 and 123.



...helps highlight areas of uncertainty

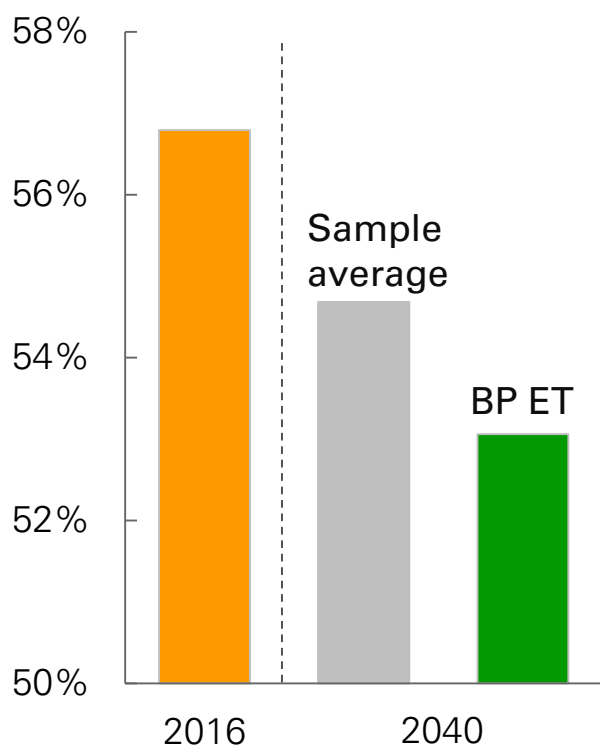
- Many organisations publish long-run energy projections and outlooks. Comparing the Energy Outlook with these alternative projections helps to highlight differences of view and areas of uncertainty.
- There are many different published outlooks and it is not possible to do a comprehensive survey. To aid the comparison, where possible the external scenarios selected are based on assumptions for policy, technology and social preferences most similar to those underpinning the ET scenario.
- All the outlooks in our sample show global energy demand continuing to grow, ranging from 0.9% p.a. to 1.4% p.a.. The ET scenario (at 1.3% p.a.) is toward the top of this range, although not far from the sample average of 1.2%.
- By fuel, all the outlooks have oil and gas growing over the next 25 years, although by a slower rate than in the past. In the ET scenario, oil and gas grow by a combined rate of around the average of the other outlooks. In contrast, the growth of renewables in the ET scenario (7% p.a.) is toward the top of the sample of outlooks.



There are a range of views within the outlooks including...

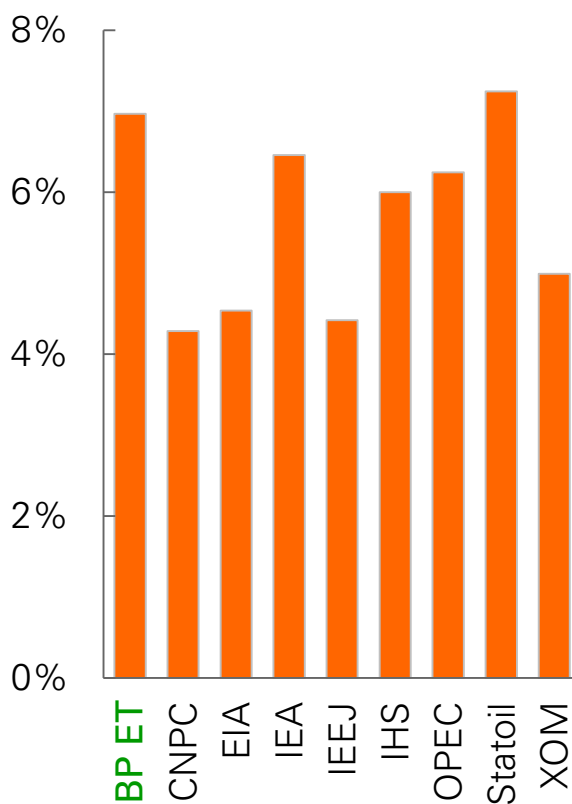
Global oil and gas demand

Share of primary energy



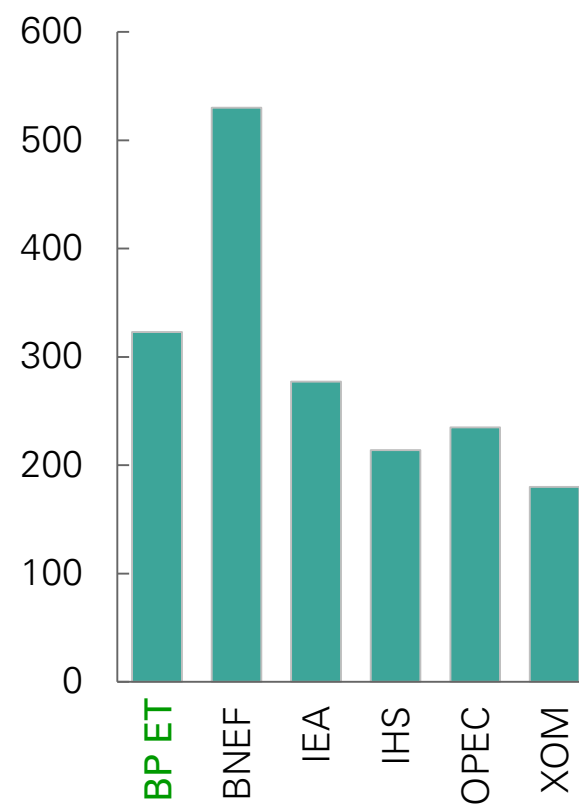
Renewables growth 2016-2040

% per annum



Electric vehicles in 2040

Millions



Technical note: not all outlooks in the original sample publish data at the level of detail required to create each chart. Where the data is unavailable we have removed the source from the sample. For EVs we have added BNEF who produce detailed EV analysis but do not cover all fuels at a global level so are not in the original sample.



...oil and gas, renewables and electric cars

- One area where there is a relatively narrow range of views is the combined growth of oil and gas. In the ET scenario, oil and gas grow at a combined rate of around 1% p.a., close to the average growth of outlooks within the sample. But because the overall growth of energy demand in the ET scenario is slightly higher than in the other outlooks, the share of oil and gas in primary energy by 2040 is somewhat lower.
- In contrast, growth of renewable energy in the ET scenario (7% p.a.) is quite a bit stronger than the average of the other outlooks (around 5.5% p.a.). It is hard to identify exactly the cause of this difference, but it is likely to reflect differences in views about the pace of technological improvements and the level of government support: both of which are very uncertain. This uncertainty is reflected in the dispersion in views of renewables growth across the outlooks being higher than for other forms of energy.
- There is also a range of views over the pace at which electric cars will increase, with projections ranging from less than 200 million vehicles to over 500 million in 2040. The ET scenario is towards the top end of this sample.



Annex

Key figures: Evolving transition scenario

<i>Macro</i>			Change (absolute)		Change (%)		Change (% per annum)	
	2016	2040	1990- 2016	2016- 2040	1990- 2016	2016- 2040	1990- 2016	2016- 2040
GDP (trillion US\$)	109	235	63	126	135%	115%	3.3%	3.2%
Population (billions)	7.4	9.2	2.1	1.7	40%	23%	1.3%	0.9%
GDP per capita (thousand US\$)	15	26	6	11	68%	74%	2.0%	2.3%
Energy intensity (toe per US\$m)	122	77	-54	-45	-31%	-37%	-1.4%	-1.9%
Net CO ₂ emissions (billion t CO ₂)	33.4	36.8	11.8	3.3	55%	10%	1.7%	0.4%

	Consumption (Mtoe)		Shares (%)		Change (Mtoe)		Change (%)		Change (% per annum)	
	2016	2040	2016	2040	1990- 2016	2016- 2040	1990- 2016	2016- 2040	1990- 2016	2016- 2040
Primary energy	13276	17983	100%	100%	5134	4707	63%	35%	1.9%	1.3%

<i>By fuel:</i>										
Oil	4336	4836	33%	27%	1183	500	38%	12%	1.2%	0.5%
Gas	3204	4707	24%	26%	1437	1502	81%	47%	2.3%	1.6%
Coal	3732	3762	28%	21%	1486	30	66%	1%	2.0%	0.0%
Nuclear	592	912	4%	5%	139	320	31%	54%	1.0%	1.8%
Hydro	910	1241	7%	7%	423	331	87%	36%	2.4%	1.3%
Renewables	502	2527	4%	14%	467	2025	1333%	404%	10.8%	7.0%

<i>End-use sector:</i>										
Transport	2662	3398	20%	19%	1194	735	81%	28%	2.3%	1.0%
Industry	5965	7843	45%	44%	2222	1877	59%	31%	1.8%	1.1%
Non-combusted	809	1277	6%	7%	340	468	73%	58%	2.1%	1.9%
Buildings	3840	5466	29%	30%	1378	1626	56%	42%	1.7%	1.5%

<i>of which:</i>										
Inputs to power	5584	8814	42%	49%	2614	3231	88%	58%	2.5%	1.9%



Key figures (continued)

	Consumption (Mtoe)		Shares (%)		Change (Mtoe)		Change (%)		Change (% per annum)	
	2016	2040	2016	2040	1990- 2016	2016- 2040	1990- 2016	2016- 2040	1990- 2016	2016- 2040
<i>By region:</i>										
North America	2789	2914	21%	16%	465	125	20%	4%	0.7%	0.2%
United States	2273	2299	17%	13%	307	26	16%	1%	0.6%	0.0%
S & C America	705	1085	5%	6%	374	380	113%	54%	2.9%	1.8%
Brazil	298	477	2%	3%	172	180	136%	60%	3.4%	2.0%
Europe	1902	1826	14%	10%	68	-75	4%	-4%	0.1%	-0.2%
EU	1642	1460	12%	8%	-30	-182	-2%	-11%	-0.1%	-0.5%
CIS	966	1020	7%	6%	-400	55	-29%	6%	-1.3%	0.2%
Russia	674	716	5%	4%	-191	42	-22%	6%	-1.0%	0.3%
Middle East	895	1382	7%	8%	631	487	239%	54%	4.8%	1.8%
Africa	440	1002	3%	6%	218	562	98%	128%	2.7%	3.5%
Asia Pacific	5580	8754	42%	49%	3779	3174	210%	57%	4.4%	1.9%
China	3053	4319	23%	24%	2370	1266	347%	41%	5.9%	1.5%
India	724	1921	5%	11%	529	1197	271%	165%	5.2%	4.2%
Other Asia	912	1671	7%	9%	618	709	210%	83%	4.5%	2.6%
World	13276	17983	100%	100%	5134	4707	63%	35%	1.9%	1.3%
OECD	5581	5583	42%	31%	795	2	17%	0%	0.6%	0.0%
Non-OECD	7695	12400	58%	69%	4340	4706	129%	61%	3.2%	2.0%



Definitions

Data

- Unless noted otherwise, data definitions are based on the BP Statistical Review of World Energy.
- Primary energy comprises commercially-traded fuels, and excludes traditional biomass.
- The primary energy values of nuclear, hydro and electricity from renewable sources have been derived by calculating the equivalent amount of fossil fuel required to generate the same volume of electricity in a thermal power station assuming a conversion efficiency of 38% (a global average for thermal power generation).
- Gross Domestic Product (GDP) is expressed in terms of real Purchasing Power Parity (PPP) at 2010 prices.

Sectors

- Transport includes energy used in road, marine, rail and aviation.
- Industry includes energy combusted in manufacturing; construction; the energy industry including pipeline transport; and for transformation processes outside of power generation.
- Non-combusted includes fuel that is used as a feedstock to create materials such as petrochemicals, lubricant and bitumen.
- Buildings includes energy used in residential and commercial building, plus agriculture, fishing and IEA's non-specified sector "Other".
- Power includes inputs into power generation (including combined heat and power plants).

Regions

- OECD is approximated as North America plus Europe plus OECD Asia.
- Other Asia includes all countries in non-OECD Asia excluding China and India.
- China refers to the Chinese Mainland.

Fuels

- Oil unless noted otherwise includes: crude; natural gas liquids (NGLs); gas-to-liquids (GTLs); coal-to-liquids (CTLs); condensate; and refinery gains.
- Liquids includes all of oil plus biofuels.
- Renewables unless otherwise noted includes wind, solar, geothermal, biomass, and biofuels and excludes large-scale hydro.
- Non-fossils includes renewables, nuclear and hydro.



Comparison and other key data sources

Comparison data sources:

BNEF: Bloomberg New Energy Finance, [Long-Term Electric Vehicle Outlook 2017](#), July 2017

CNPC: CNPC Economics & Technology Research Institute, [Energy Outlook 2050](#), 2017

EIA: US Energy Information Administration, [International Energy Outlook 2017](#), Washington, D.C., United States, September 2017

IEA: International Energy Agency, [World Energy Outlook 2017](#), Paris, France, November 2017

IEEJ: Institute of Energy Economics Japan, [Outlook 2018 - Prospects and challenges until 2050](#), Tokyo, Japan, October 2017

IHS: IHS Markit, [Rivalry: the IHS Markit view](#), July 2017

OPEC: Organization of the Petroleum Exporting Countries, [World Oil Outlook 2040](#), October 2017

Statoil: [Energy Perspectives 2017](#), May 2017

XOM: ExxonMobil, [2018 Outlook for Energy: A View to 2040](#), February 2018

Other key data sources:

BP p.l.c., [BP Statistical Review of World Energy](#), London, United Kingdom, June 2017

International Energy Agency, [Energy Balances of Non-OECD Countries](#), Paris, France, 2017

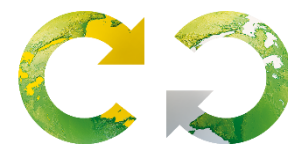
International Energy Agency, [Energy Balances of OECD Countries](#), Paris, France, 2017

UN Population Division, [World Population Prospects: The 2017 Revision](#), New York, United States, 2017



Disclaimer

This presentation contains forward-looking statements, particularly those regarding changes to the fuel mix, global economic growth, population and productivity growth, energy consumption, energy efficiency, mobility developments, policy support for renewable energies, sources of energy supply and growth of carbon emissions. Forward-looking statements involve risks and uncertainties because they relate to events, and depend on circumstances, that will or may occur in the future. Actual outcomes may differ depending on a variety of factors, including product supply, demand and pricing; political stability; general economic conditions; demographic changes; legal and regulatory developments; availability of new technologies; natural disasters and adverse weather conditions; wars and acts of terrorism or sabotage; and other factors discussed elsewhere in this presentation. BP disclaims any obligation to update this presentation. Neither BP p.l.c. nor any of its subsidiaries (nor their respective officers, employees and agents) accept liability for any inaccuracies or omissions or for any direct, indirect, special, consequential or other losses or damages of whatsoever kind in connection to this presentation or any information contained in it.



BP Energy Economics

Brought to you by the team that produces
the BP Statistical Review of World Energy
and the BP Energy Outlook.