2017

World Oil Outlook 2040

Organization of the Petroleum Exporting Countries

World Oil Outlook

2040

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OPEC is a permanent, intergovernmental organization, established in Baghdad, Iraq, on 10–14 September 1960. The Organization comprises 14 Members: Algeria, Angola, Ecuador, Equatorial Guinea, Gabon, the Islamic Republic of Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela. The Organization has its headquarters in Vienna, Austria.

Helferstorferstrasse 17
A-1010 Vienna, Austria
www.opec.org

ISBN 978-3-9503936-4-4

Report citation: Organization of the Petroleum Exporting Countries. 2017 OPEC World Oil Outlook. October 2017. Available from: http://www.opec.org.

Download: All the data presented in this Outlook is available at www.opec.org.

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Foreword

The past year has been an historic one for OPEC and the global oil industry. Since publication of the World Oil Outlook 2016 in early November last year, the oil market has undergone significant change and transition. It has been a period where the rebalancing of the global oil market has gathered vital momentum, buoyed by a number of important factors.

In Vienna, at the 171st Meeting of the OPEC Conference on 30 November 2016, OPEC Member Countries agreed on production adjustments for an initial period of six months, beginning 1 January 2017. This was followed on 10 December 2016, by the decision of 11 non-OPEC producing nations who also agreed to voluntary production adjustments over the same time period. The focus for all nations was to accelerate the drawdown of the stock overhang and bring the oil market rebalancing forward. These adjustments by a total of 24 participating nations, now known as the 'Declaration of Cooperation', have since been renewed to the end of March 2018.

The landmark decisions were the result of extensive consultations among OPEC Member Countries, and between OPEC and non-OPEC producing nations, as well as with consumers and the broader international community, about the strategic urgency of restoring sustainable oil market stability in a collective manner. It is evident that this major commitment to production adjustments has been central to the rebalancing process that the market has undergone this year.

For OPEC Member Countries and participating non-OPEC countries there have been unprecedented high conformity levels to the production adjustments throughout the year. In turn, this has helped with the destocking process, both onshore and offshore. For example, at the beginning of this year OECD commercial oil inventories were around 340 million barrels (mb) above the five-year average, but by September the level had fallen to just below 160 mb. Moreover, industry data suggests that crude in floating storage has also fallen by an estimated 50 mb since June this year.

There is now global recognition that without such adjustments by OPEC and non-OPEC nations, the market would have experienced further extreme volatility, which would have had far-reaching negative consequences for producers, consumers, investors, the industry and the global economy at large.

The positive conformity story needs to be also placed alongside healthy oil demand growth, which is set to increase by close to 2 million barrels a day (mb/d) from the first to the second half of 2017. This has also aided the overall rebalancing process.

The importance of this development, specifically in terms of helping to achieve sustainable market stability, is evidently vital across all timeframes. While the focus for many is naturally on the short-term, we need to remember that the short-, medium- and long-terms are all interlinked. None can be viewed in isolation. Stability today is crucial for stability tomorrow given that the oil industry remains very much a growth business, with oil continuing to be a fuel of choice for the foreseeable future.

This year's WOO underlines these linkages, as well as taking on board the various shifting industry dynamics in terms of both supply and demand, considering developments in the global

economy, and examining a diverse range of industry challenges and opportunities. These include evolving technologies, policies, energy efficiency and sustainable development and the shifting energy mix. All this enables the WOO to provide a detailed medium- and long-term oil market analysis by sectors and regions.

From the perspective of the global economy, there is an expectation that growth will generally accelerate over the medium-term from 3.1% in 2016 to 3.7% by 2022, driven by faster expansion across the board. This includes improving conditions in the OECD, an expected swift recovery in India's growth, positive momentum in Developing countries and improving geopolitical stability in Eurasia. In the longer term, global growth in the period from 2016-2040 is expected to average 3.5% per annum (p.a.), with most of this driven by Developing countries.

Alongside an ever-expanding global population and the critical importance of reducing energy poverty, these growth rates mean energy demand is expected to increase by close to 100 million barrels of oil equivalent a day (mboe/d) between 2015 and 2040. Renewables are anticipated to see the highest annual growth rate – at 6.8% p.a. – although by 2040 their overall share of the energy mix is still expected to be only 5.4%, given their low initial base. OPEC is greatly supportive of the ongoing development of renewables and many of our Member Countries have vast solar and wind resources, with significant investments being made in these areas.

While oil is expected to see a drop in its share of the energy mix over the forecast period, it is expected to remain the fuel with the largest share, at just over 27% by 2040. Natural gas sees growth throughout the period and by 2040 its share is slightly more than 25%. It is interesting to observe that oil and gas combined is still expected to make up over 52% of the global energy mix by 2040.

In regards to oil demand, the medium-term period 2016–2022 shows an anticipated increase of 6.9 mb/d, rising from 95.4 mb/d to 102.3 mb/d. This corresponds to an average annual increase of close to 1.2 mb/d. The outlook for long-term oil demand growth is slightly more optimistic than in last year's WOO, reaching 111.1 mb/d by 2040, although average growth slows to around 300,000 b/d between 2035 and 2040 on the back of anticipated efficiency improvements, a further tightening of energy policies, as well as decelerating GDP and population growth.

On the supply side, total non-OPEC liquids in the medium-term are estimated to grow by 5 mb/d, from 57 mb/d in 2016 to 62 mb/d in 2022, a higher level than in the WOO 2016. Of this growth, 3.8 mb/d is incremental supply from the US alone. After 2022, non-OPEC growth begins to slow, peaking in 2027 at 63.8 mb/d, before declining to 60.4 mb/d by 2040.

Thus, the long-term focus for additional liquids demand remains on OPEC. In terms of crude, it is estimated that OPEC will need to supply an additional 7.7 mb/d in the period 2020-2040. For all OPEC liquids, the figure is 10.5 mb/d. Moreover, the share of OPEC crude in global oil supply is expected to increase from 34% in 2016 to 37% in 2040.

Looking at the refining sector, around 7.6 mb/d of new global capacity additions is forecast by 2022, which grows to just below 20 mb/d by 2040. The majority of these capacity additions will likely be located in developing regions, in line with oil demand growth. Almost 50% of refinery

additions are expected to occur in the Asia-Pacific, led by China and India, while the Middle East is anticipated to account for just below 20% of additions.

At the same time, a significant amount of closures are forecast to be required if depressed refining margins are reversed. Around 2.5 mb/d of closures are estimated by 2022, which could be followed by more than 4 mb/d of additional closures after 2022. The majority of these closures are likely to take place in developed countries, whose refining sectors are likely to feel pressure from stagnating and declining oil demand.

Of course, the anticipated expansion in both the upstream and downstream, as well as the midstream, will require significant investments. This year's WOO sees overall investment requirements of $10.5 trillion in the period to 2040. However, the recent crude oil price crash has led to nearly one trillion dollars in investments being frozen or discontinued, and many hundreds of thousands of jobs lost.

While the Outlook sees investments picking up slightly in 2017 and in 2018, it is clear that this is not anywhere close to past levels. The recent investments are also more evident in short-cycle rather than long-cycle projects, which are the industry's baseload. It is vital that this be rectified so that a lack of investments today does not lead to a supply shortage in the future.

OPEC Member Countries remain committed to supporting investments – in new upstream capacity, in the maintenance of existing fields and infrastructure, in the construction of the necessary pipelines, and in the building and expansion of oil terminals and refineries. However, it is essential that such investments have the right enabling environment, with the central pillar being sustainable market stability. This is the principal focus of the 'Declaration of Cooperation'.

The WOO 2017 also explores a variety of other issues such as energy policies, with climate change and energy efficiency developments at the fore, as well as new technologies. It also considers various sensitivity cases related to the uncertainties surrounding economic developments, the level and speed of penetration of alternative vehicles, the rate of adoption of energy efficiency measures across various oil demand sectors and the development of non-OPEC supply.

In terms of climate change, let me stress that all 14 OPEC Member Countries have signed the Paris Agreement and eight of them have ratified it. At OPEC, we recognize the need to use energy efficiently and to continually look to develop and adopt cleaner energy technologies in the future, such as carbon capture and storage, among many others. We are continually looking to advance the environmental credentials of oil, both in its production and use.

It is vital, however, to remember that implementation of the Paris Agreement should continue to be guided by the principles and provisions provided for in the United Nations Framework Convention on Climate Change. In particular, the unique situation of developing countries – including those developing countries dependent on oil – should be given the priority it deserves.

As with all previous editions, this year's WOO is a valuable and informative reference tool, one that underscores the Organization's commitment to data transparency, and to the enhancement of dialogue and cooperation. This commitment has been particularly relevant over the past year, with the ongoing collective efforts of OPEC and participating non-OPEC producers to return balance and stability to the market. In this regard, we hope to achieve a new framework for permanent and long-standing cooperation among oil producing countries, as well as other interested stakeholders, in order to continue to discuss and collaborate on issues of the kind that can be viewed in this year's WOO.

In closing, I would like to recognize the hard work and commitment of all those members of staff at the OPEC Secretariat who have been involved in producing this WOO. They are the vital cogs that enable the Organization to publish such a comprehensive outlook; one that we believe is vital not only to OPEC, but to all industry stakeholders. Their efforts should be applauded.

Mohammad Sanusi Barkindo
Secretary General

Executive Summary

2017: road to adjustment

Since the publication of the World Oil Outlook (WOO) 2016 in November last year the market has experienced significant changes that have had an impact on medium- and long-term estimates. This is particularly evident from the supply viewpoint, with OPEC's decisions taken in Algiers (28 September 2016) at the 170th (Extraordinary) Meeting of the OPEC Conference and then in Vienna (30 November 2016) at the 171st Meeting of the OPEC Conference, seeing its Member Countries implement a production adjustment with a target of 32.5 million barrels a day (mb/d) with effect from 1 January 2017. Moreover, the subsequent OPEC and non-OPEC Declaration of Cooperation through the Ministerial Meetings in Vienna (10 December 2016 and 25 May 2017) embraced a production adjustment of 1.2 mb/d for OPEC, together with a production adjustment of around 0.6 mb/d from participating non-OPEC producing countries. The decisions were focused on accelerating the ongoing drawdown of the stock overhang, which is now well underway, as a means to help bring the oil market rebalancing forward.

The world is experiencing an era of demographic change

Future developments in energy and oil markets will be driven by number of factors. The critical ones include population growth, changing demographics, the assumed path of economic growth, policy changes, technology advancements and energy and oil prices. For population growth, this is expected to expand at an unprecedented low rate compared to the previous century. Moreover, the growth rate is anticipated to see a further deceleration as the outlook moves to 2040. At the same time, the world continues to age as fertility rates decline and people live longer across the world. In addition, more people are moving from country-to-country, as well as increasingly to urban areas.

Global population is estimated to increase from 7.3 billion in 2015 to 9.2 billion in 2040. The additional 1.8 billion people will mainly come from Developing countries. In the Organization for Economic Co-operation and Development (OECD) region, population is forecast to increase by 116 million people in the period to 2040 partly supported by immigration. The share of the global working age population (that is, individuals aged between 15 and 64 years) peaked in 2012, following a steady increase since 1970. Individuals aged 65 or more are anticipated to account for 14% of the world population in 2040, up from today's level of 8%. Children are estimated to represent 22% of the population by 2040, down from 26% today.

Population by region

millions

	Levels				Growth
	2015	2020	2030	2040	2015–2040
OECD	1,280	1,313	1,363	1,397	116
Non-OECD	6,068	6,444	7,137	7,759	1,692
World	**7,348**	**7,757**	**8,500**	**9,156**	**1,808**

Long-term economic growth will be driven by Developing countries, with growth in the OECD constrained by weaker demographics

Against this background, in the Reference Case, global gross domestic product (GDP) between 2016 and 2040 is expected to increase at an average rate of 3.5% p.a. Most of the global growth will be driven by the Developing countries, which on average are expected to grow by 4.5% p.a. during this period on the back of higher labour productivity growth and a more optimistic demographic outlook.

Long-term real GDP growth rates in the Reference Case *% p.a.*

	2016–2022	2022–2030	2030–2040	2016–2040
OECD	2.1	2.1	2.0	2.0
Non-OECD	4.7	4.6	4.0	4.4
World	**3.5**	**3.6**	**3.3**	**3.5**

The global economic picture will change in the long-term

The size of the global economy in 2040 is estimated to be 226% that of 2016. Developing countries are estimated to account for three-quarters of the global GDP growth over the forecast period. Furthermore, one of every two additional $ (2011 purchasing power parity (PPP)) of GDP is expected to come from China and India.

In 2016, OECD America accounted for 20% of global GDP, OECD Europe and China were both at 18%, and India was at 7%. By 2040 the share of OECD America is anticipated to drop to 16% and that of OECD Europe to 12%. On the other hand, China's contribution to the global economy is forecast to increase to 23%. Even more remarkable is the case of India. Its weight in terms of global GDP is expected to increase to 16%.

Energy policies and technological development drive energy efficiency and emission reductions

The evolution of energy markets over time is significantly impacted by government policies, which are used as mechanisms to stimulate change beyond purely market-driven forces. The current trend is expected to lead toward a long-term global convergence that focuses on energy efficiency and the increased adoption of clean modes of energy, including renewables. Moreover, policies are also expected in terms of energy poverty eradication measures in developing countries.

Among the visible long-term global energy policy trends is the increasing penetration of electric vehicles (EVs), the tightening of fuel emissions standards, and the desulphurization in the road transportation, marine and aviation sectors.

Technology will continue to shape the energy industry as a whole, and the oil industry, in particular

It can be expected that technical advancements will continue to evolve and change the future energy panorama. For example, the current development of renewable energies and the of

introduction of EVs as a replacement for ICE vehicles are strong signs of trends. Elsewhere, highly resistant fibres in conjunction with oil-based resins are already replacing traditional metal-based materials in the case of latest-generation airplanes, to highlight another state-of-the-art development. And in the field of oil discovery and exploration, technical development has always played a decisive role since early onshore drilling, through the large-scale development of offshore and, today, tight oil reserves.

Driven by expansion in Developing countries, global energy demand is set to increase by 35% over the period 2015–2040

Reflecting the underlying assumed developments of the key drivers, total primary energy demand is forecast to increase by 96 mboe/d between 2015 and 2040, rising from 276 mboe/d to 372 mboe/d. In relative terms, this represents a 35% increase compared to the base year of 2015, with an average annual growth rate of 1.2 % during the forecast period.

Total primary energy demand by region

mboe/d

	2015	2020	2030	2040
OECD	110.0	113.5	113.6	112.0
Non-OECD	166.0	184.7	225.8	259.6
Total world	**276.0**	**298.2**	**339.4**	**371.6**

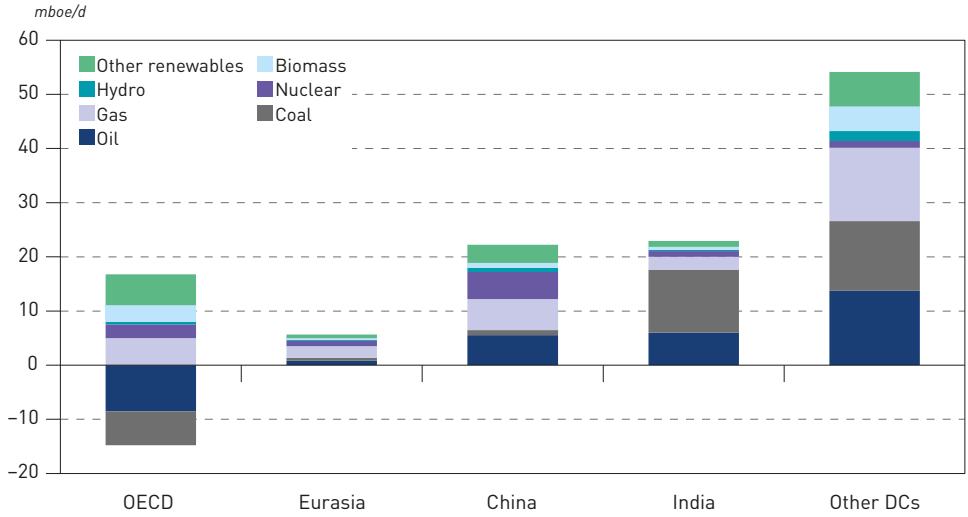
This significant global energy demand growth is, however, unequally distributed among major regions and country groupings. Energy demand in Developing countries is expected to grow at an average rate of 1.9% p.a. over the period 2015–2040. This is in sharp contrast to an average growth rate of 0.1% p.a. projected for the OECD and 0.9% p.a. for Eurasia. The key reasons for this variation are the different prospects that exist among major country groups in terms of population growth, urbanization rates and expansion in economic activity.

India and China are the two largest contributors to future energy demand

Within the grouping of Developing countries, India and China are the two nations with the largest additional energy demand over the forecast period, both in the range of 22–23 mboe/d. It should be noted, however, that for the first time recent projections see India as the single largest contributor to future energy demand, followed by China and other countries. However, this change in the leading position is primarily the result of the downward revisions made for China, compared to the Reference Case, rather than a more positive outlook for India.

There are two main reasons for this change. The first has to do with the modified prospects for economic activity in these countries, which have mainly resulted in downward revisions for China's GDP growth compared to last year. The second reason is more policy-oriented. Recent signals and specific actions being undertaken by China – such as the closure of several inefficient coal power plants, the cancellation of plans to build new power plants and the rapid expansion of renewable energy sources – have raised the credibility of government endeavours to combat domestic pollution problems, contribute to efforts to reduce global emissions and use

Regional energy demand growth by region, 2015–2040



energy more efficiently. As a result, overall energy demand in China by 2040 has been reduced by more than 3 mboe/d in the WOO 2017, compared to last year's projections.

Gas contributes most to future energy demand growth

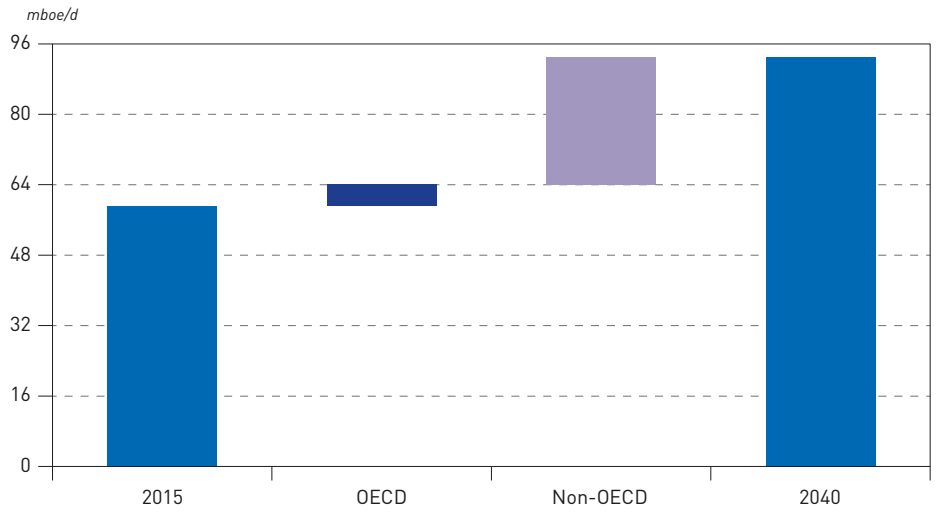
At the global level, the largest contribution to future energy demand is projected to come from natural gas. In absolute terms, demand for gas will increase by almost 34 mboe/d, reaching a level of 93 mboe/d by 2040. Its share in the global energy mix will increase by a significant 3.6 percentage points.

World primary energy demand by fuel type

	Levels *mboe/d*				Growth *% p.a.*
	2015	2020	2030	2040	2015–2040
Oil	86.5	92.3	97.9	100.7	0.6
Coal	78.0	80.7	85.8	86.2	0.4
Gas	59.2	65.2	79.9	93.2	1.8
Nuclear	13.5	15.8	20.1	23.8	2.3
Hydro	6.8	7.5	9.0	10.3	1.7
Biomass	28.0	30.1	34.0	37.3	1.2
Other renewables	3.8	6.6	12.9	20.0	6.8
Total world	**276.0**	**298.2**	**339.4**	**371.6**	**1.2**

The majority of the energy demand growth in the 2015–2040 period comes from non-OECD countries with around 29 mboe/d, while the rest (some 5 mboe/d) is located in the mature markets of OECD countries. Strong population growth in most developing countries, combined with robust economic development, leads to demand growth for gas in all the relevant sectors: power generation, industry, as well as the residential and commercial sectors. The increasing availability of gas on the global market due to the expansion of liquefied natural gas (LNG) production is also set to contribute to the high growth rates for this energy source.

Global gas demand outlook, 2015 and 2040



Renewables are projected to record the fastest growth rate, but oil and gas are still expected to supply more than half of global energy needs by 2040

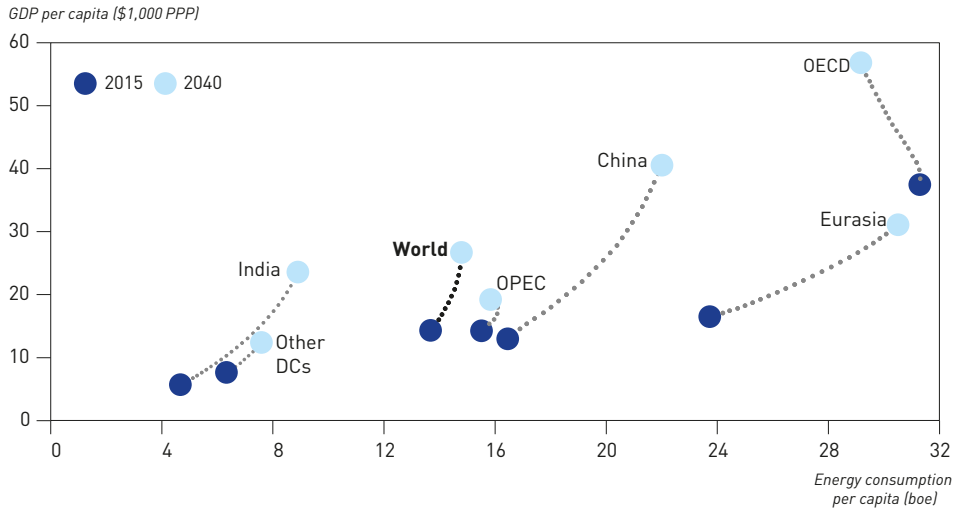
Other renewables – consisting mainly of wind, photovoltaic, solar and geothermal energy – is projected to be by far the fastest growing energy type. It is estimated to have an average annual growth rate of 6.8% over the forecast period. Its share is expected to increase by 4 percentage points by 2040. However, given that its current base in the global energy demand mix is rather low, at about 1.4%, the share of other renewables is still anticipated to be below 5.5% by 2040, despite its impressive growth.

Oil and coal are projected to grow at much lower rates of 0.6% and 0.4% p.a., respectively. Despite these relatively low rates, fossil fuels will retain a dominant role in the global energy mix, although with a declining overall share. Indeed, the share of fossil fuels in the global energy mix stood at 81% in 2015. This is set to decline to below 80% by 2020 and then drop further to under 78% by 2030. It is estimated to reach 74% by 2040. It should be noted, however, that oil and gas together are still expected to provide more than half of the world's energy needs over the forecast period, with their combined share relatively stable between 52–53%.

Energy poverty remains a critical issue

Rapid economic expansion in the developing world, particularly in developing Asia, has lifted millions of people out of poverty and enlarged the middle class base, prompting an increase in energy access. In 2015, average energy consumption in the Developing countries had almost tripled compared to 1970, with the gap to the OECD clearly narrowing.

Energy consumption per capita versus GDP at PPP per capita, 2015–2040



Nevertheless, the gap is still wide and energy poverty remains a critical issue. In specific regions, such as India and Africa, energy consumption per capita is still very low, underscoring the challenge related to energy poverty. Strong political commitment and resolute support from the global community is required to ensure that modern energy services are universally accessible and affordable.

Medium-term oil demand growth remains healthy

The medium-term oil demand outlook for the period 2016–2022 shows an increase of 6.9 mb/d, rising from 95.4 mb/d to 102.3 mb/d. This corresponds to a healthy average annual increase of almost 1.2 mb/d. Demand in Developing countries is expected to be strong, increasing from 43.2 mb/d in 2016 to 49.6 mb/d in 2022.

Globally, oil demand has been revised upwards by 2.24 mb/d in 2022 compared to the WOO 2016. This revision includes the upward shift to the baseline (+1.2 mb/d) in 2016. In addition, in this year's WOO, OECD regional oil demand is expected to grow until 2019, before the trend reverses. In last year's publication, OECD demand grew only until 2017.

IMO regulations are expected to impact the pattern of medium-term demand growth

One of the most important impacts on medium-term oil demand growth patterns will be the introduction of new International Maritime Organization (IMO) regulations. In particular,

oil demand growth in 2020 is expected to be higher, at almost 1.4 mb/d. This is due to a combination of two factors.

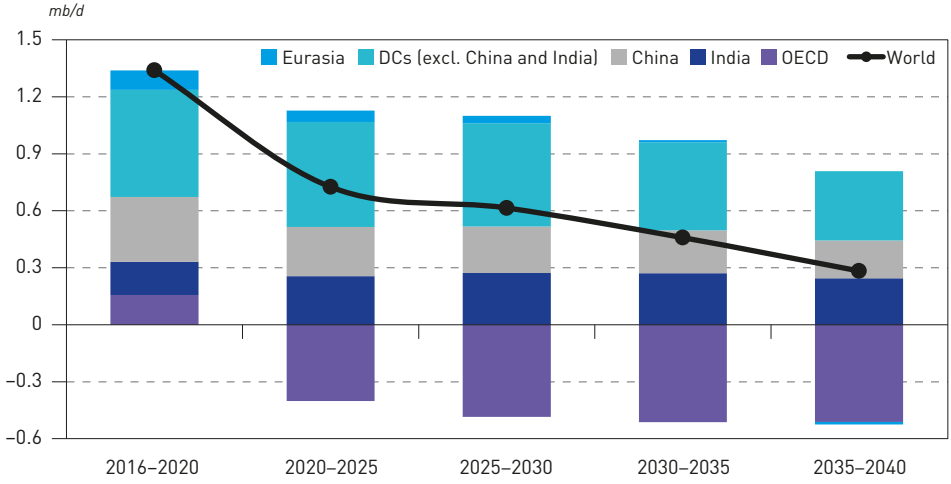
The primary reason is the need for additional refinery runs to provide required fuels that lead to a surplus of high sulphur fuel oil (HSFO) volumes priced at a discount. It is assumed that these will mainly be absorbed by the power generation sector. Furthermore, higher demand growth is also a direct consequence of volumetric processing gains related to switching from fuel oil to diesel.

On the refining side, it is assumed that the first step the global refining system takes will be to leverage its flexibility in producing diesel and low sulphur fuel oil (LSFO) without increasing overall refinery runs. However, the nature of the required processing changes leads to a need to process additional crude. Given that refiners will move to produce more distillate fuel, which could be blended with off-spec fuel oil, increasing runs are most likely to be seen in the regions with complex refining systems. US refiners are natural candidates for additional runs due to their high complexity. At the same time, potential exists also in Europe, where refining capacity is under-utilized. Further possibilities for additional production can be viewed in the Middle East and parts of Asia-Pacific, such as India.

Oil demand increases by 15.8 mb/d to reach 111.1 mb/d by 2040, but demand growth decelerates

Long-term oil demand is expected to increase by 15.8 mb/d, rising from 95.4 mb/d in 2016 to 111.1 mb/d in 2040. Demand in the OECD region is anticipated to show a significant decline of 8.9 mb/d over the forecast period. Driven by an expanding middle class, high population growth rates and stronger economic growth potential, Developing countries' oil demand is expected to increase by almost 24 mb/d. China is anticipated to continue to be the largest oil consumer over the forecast period, adding 6 mb/d to reach 17.8 mb/d by 2040. India will be the region with

Average annual oil demand growth in the Reference Case



the second largest overall demand growth, adding 5.9 mb/d between 2016 and 2040. Indian demand growth is also set to witness the fastest average growth of 3.6% p.a.

Long term global oil demand growth is forecast to decelerate steadily, falling from an annual average of around 1.3 mb/d during the period 2016–2020 to only 0.3 mb/d every year between 2035 and 2040. This deceleration is a result of slowing GDP growth, assumed oil price increases, a structural shift of economies towards a more service-oriented structure, efficiency improvements as a result of tightening energy efficiency policies and/or technological improvements, and oil facing strong competition from other energy sources.

Light products will satisfy more than half of the long-term oil demand growth, while demand for gasoil/diesel has been revised downward

Light products (ethane/liquefied petroleum gas (LPG), naphtha and gasoline) are expected to satisfy more than 50% of global demand growth in the period to 2040; 8.5 mb/d out of a total demand growth of 15.8 mb/d. Demand for middle distillates is anticipated to increase by 6.8 mb/d during the forecast period, while that for heavy products increases only marginally by 0.5 mb/d.

Jet/kerosene is the fastest growing fuel in the Outlook and diesel/gasoil remains the most important product category. However, compared to last year, long-term diesel/gasoil demand growth has been revised downwards.

Sectoral oil demand in the Reference Case *mb/d*

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
Road	43.0	45.4	46.8	47.7	48.2	48.4	5.4
Aviation	6.0	6.6	7.2	7.8	8.4	8.9	2.9
Rail & dom. waterways	1.8	1.9	2.0	2.1	2.1	2.2	0.4
Marine Bunkers	3.8	4.2	4.7	5.0	5.2	5.4	1.5
Transportation	**54.6**	**58.1**	**60.6**	**62.5**	**63.9**	**64.9**	**10.3**
Petrochemicals	12.6	13.4	14.3	15.0	15.9	16.5	3.9
Other Industry	12.5	13.0	13.3	13.6	13.7	13.7	1.2
Industry	**25.2**	**26.4**	**27.6**	**28.6**	**29.6**	**30.2**	**5.1**
Resid./Comm./Agr.	10.5	10.9	11.4	11.7	12.0	12.1	1.7
Electricity generation	5.1	5.3	4.8	4.6	4.2	3.9	–1.2
Other uses	**15.6**	**16.2**	**16.1**	**16.3**	**16.2**	**16.0**	**0.4**
World	**95.4**	**100.7**	**104.3**	**107.4**	**109.7**	**111.1**	**15.8**

This downward revision is on the back of three main factors. The first factor relates to the IMO regulations. Bearing in mind several uncertainties related to the specifics of the implementation of IMO regulations, this year's expectation is that less residual fuel will be substituted with diesel than previously forecast. The second factor relates to the road transportation sector. The so-called 'diesel scandal' and its scars, together with a higher than previously expected penetration of electric vehicles (EVs), has resulted in a further downward revision for diesel/gasoil demand. Finally, a faster than expected oil demand decline in other sectors, such as residential/commercial/agriculture and electricity generation, where diesel plays an important role, also contributes to the downward revision for this product.

The transportation sector will remain the main consumer of oil products

Most of the demand for oil is used for transportation purposes (road, aviation, marine, rail and domestic waterways). It is the sector where oil continues to face the weakest competition from alternative fuels. Between 2016 and 2040, the transportation sector accounts for two out of every three additional barrels consumed. Nevertheless, demand growth is foreseen to decelerate on the back of efficiency improvements driven by technological developments, a tightening of energy policies and a relatively low (albeit increasing) penetration of transportation fuelled by natural gas and electricity.

Oil use for industrial purposes (petrochemicals and other industry) is also expected to increase, though at a slower pace than in the transportation sector. Oil consumed for other uses is forecast to grow marginally, particularly because demand in electricity generation is projected to decline, hence, offsetting some growth in other sectors. Energy poverty alleviation measures, coupled with rising income and urbanization levels, will continue to foster a switch away from traditional fuels to oil-based products.

Most demand growth comes from the road transportation sector, followed by petrochemicals and aviation

The road transportation sector is currently the largest contributor to global oil demand. In 2016, this sector represented 45% of total demand at 42.8 mb/d. Substantial growth is expected in the long-term with an additional 5.4 mb/d up to 2040, when it reaches 48.3 mb/d. In fact, one out of every three new barrels between 2016 and 2040 is anticipated to come from the road transportation sector.

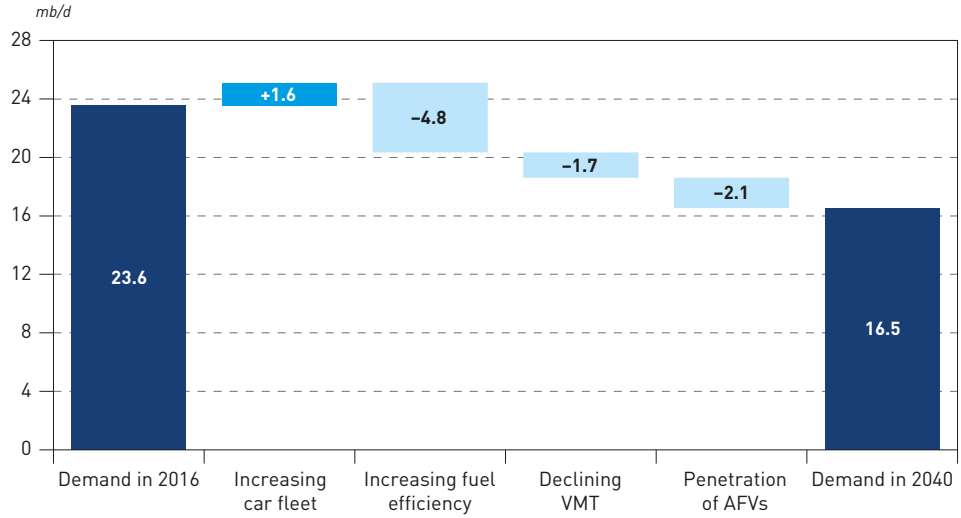
Significant growth is also expected for the petrochemical sector where demand is estimated to increase by 3.8 mb/d during the forecast period. Aviation is the fastest growing sector driven by a rapidly expanding global middle class, particularly in developing countries, as well as the increasing penetration of low cost carriers. It is foreseen that demand in this sector will increase by 2.9 mb/d over the forecast period.

Expanding global car fleet outweighs improving efficiencies and increasing penetration of alternative fuel vehicles, but OECD an outlier

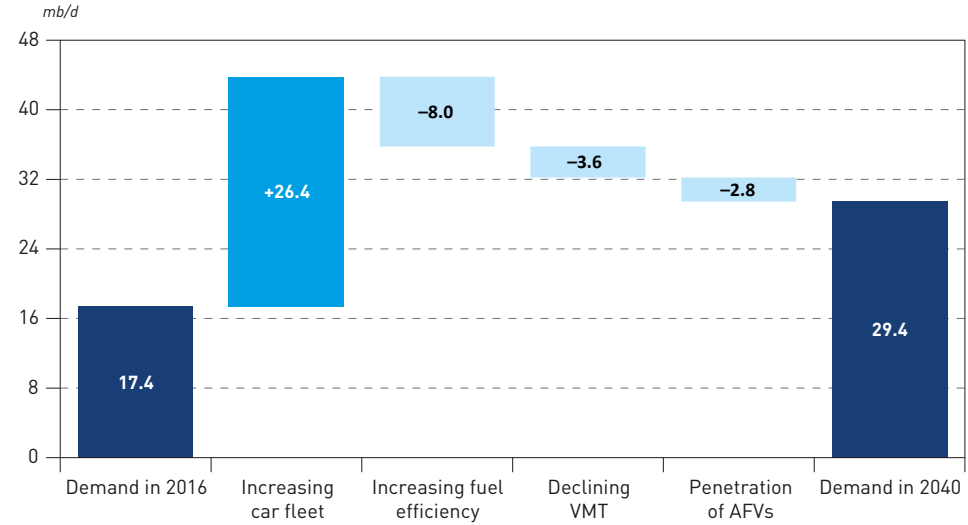
Demand in the road transportation sector is anticipated to increase by 5.4 mb/d over the forecast period. However, there is a clear differentiation between the expected sectoral demand pattern in the OECD region and that in Developing countries. In the former, sectoral demand is anticipated to drop by 7.2 mb/d. In the latter, it is estimated to increase by 12.2 mb/d.

In the OECD, the moderate increase in the car fleet would, all other things being equal, add around 1.6 mb/d to sectoral demand. However, efficiency improvements as a result of a further tightening of emission reduction policies, technological developments, changing driving behaviour and the increasing penetration of alternative fuel vehicles, particularly EVs (including plug-in hybrid electric vehicles and battery electric vehicles) and, to a lesser extent natural gas and fuel cells, is expected to significantly shrink sectoral demand.

Demand in road transportation in the OECD, 2016 and 2040



Demand in road transportation in the Developing countries, 2016 and 2040



In Developing countries, the picture is rather different. The massive increase in the car fleet would, all other things being equal, increase sectoral demand by 26.4 mb/d over the forecast period. Increasing efficiency, changing driving behaviour and the penetration of alternative fuel vehicles, particularly EVs in China and India, will only partially curb demand growth.

Non-OPEC supply shows strong growth in the medium-term, slowing thereafter

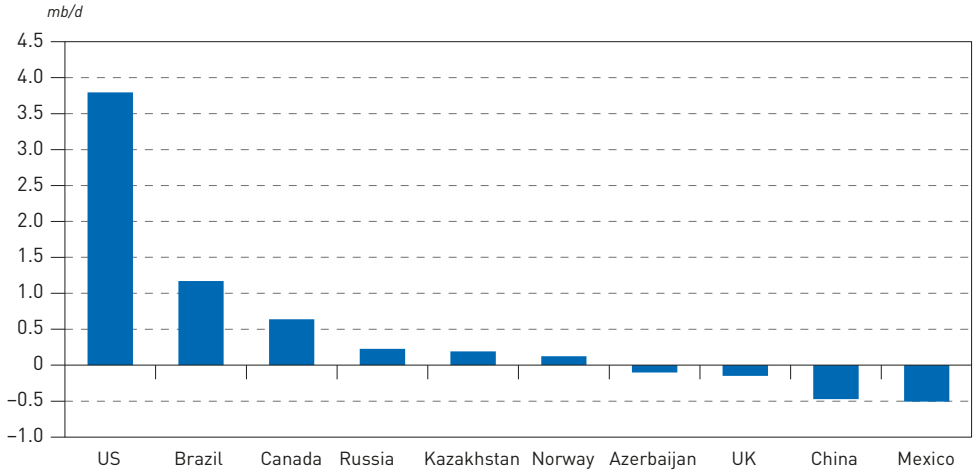
Non-OPEC supply in the Reference Case is forecast to grow from 57 mb/d in 2016 to 62 mb/d in 2022. Of this, 3.8 mb/d, or 75%, stems from US oil production alone, with the tight oil sector expected to continue its recovery after its dramatic 2016 slump. Brazil and Canada are the other significant contributors to supply growth, meaning incremental non-OPEC production is heavily focused on the Americas. While this WOO's medium-term outlook is more optimistic than last year's projected growth, the long-term forecast is largely unchanged. Total non-OPEC supply is projected to decline by 0.3 mb/d in the 2020–2040 period, with US tight oil production estimated to peak in the latter half of the 2020s.

Long-term liquids supply outlook in the Reference Case

mb/d

	2016	2017	2020	2025	2030	2035	2040
US & Canada	18.1	18.9	21.4	23.8	23.9	23.2	22.1
of which: tight crude	*4.5*	*5.1*	*5.7*	*8.7*	*8.8*	*8.3*	*7.3*
OECD	**24.8**	**25.5**	**27.7**	**30.0**	**29.7**	**28.7**	**27.2**
DCs, excl. OPEC	**16.0**	**16.0**	**16.1**	**16.7**	**16.4**	**15.9**	**15.3**
Eurasia	**14.0**	**14.1**	**14.5**	**14.4**	**14.6**	**14.8**	**14.9**
Processing gains	**2.2**	**2.2**	**2.3**	**2.4**	**2.6**	**2.8**	**3.0**
Non-OPEC	**57.0**	**57.7**	**60.7**	**63.6**	**63.5**	**62.3**	**60.4**
Crude	*42.0*	*42.2*	*43.6*	*45.2*	*44.3*	*42.4*	*39.9*
NGLs	*7.7*	*7.9*	*8.7*	*9.2*	*9.1*	*8.7*	*8.2*
of which: unconv. NGLs	*2.2*	*2.2*	*2.5*	*3.2*	*3.3*	*3.1*	*2.9*
Other liquids (incl. biofuels)	*5.1*	*5.4*	*6.0*	*6.7*	*7.5*	*8.4*	*9.2*
Total OPEC supply	**38.8**	**38.7**	**40.4**	**41.0**	**44.1**	**47.6**	**50.9**
OPEC NGLs	5.9	6.0	6.4	7.0	7.7	8.3	8.9
OPEC other liquids	0.2	0.3	0.3	0.5	0.5	0.5	0.6
OPEC crude	*32.7*	*32.4*	*33.7*	*33.5*	*35.9*	*38.8*	*41.4*
Stock change	**0.5**	**-0.3**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**
World supply	**95.8**	**96.5**	**101.1**	**104.5**	**107.6**	**109.9**	**111.3**

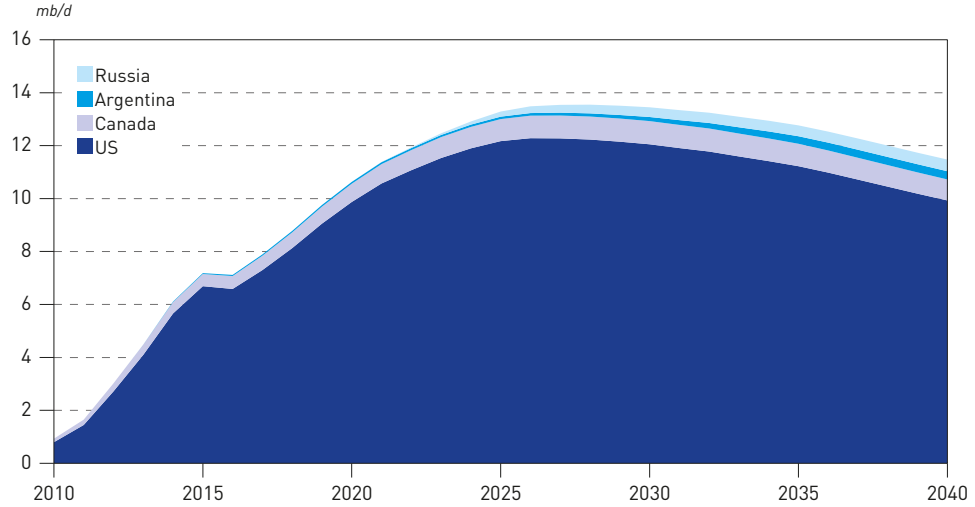
Select contributors to non-OPEC total liquids change 2016-2022



US tight oil is by far the most important contributor to non-OPEC supply, but peaks after 2025

Non-OPEC supply growth is overwhelmingly driven by higher tight oil production, predominantly in the US and to a lesser extent elsewhere. This growth is heavily front-loaded, as drillers seek out and aggressively produce barrels from sweet spots in the Permian and other basins. As such, global tight oil grows 4.8 mb/d in the 2016–2022 period, mostly in the US, but the WOO also assumes some growth in Canada, Argentina and Russia – before peaking after 2025

Global tight oil supply outlook in the Reference Case



and then declining modestly from around 2030. As in previous reports, no tight oil volumes are expected from other countries outside of these four.

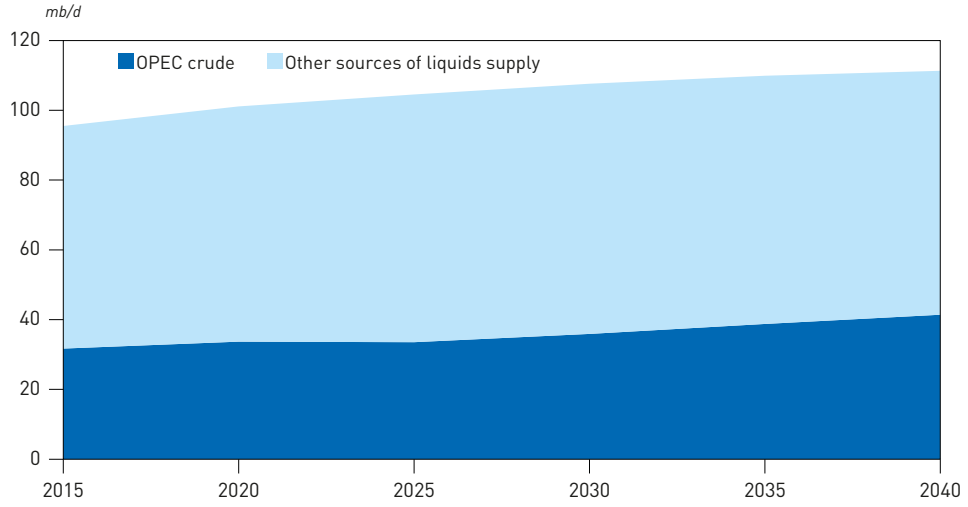
Tight oil's increasing importance shows up in higher implied decline rates

A simple calculation of implied decline rates shows that around 4.4 mb/d or 7% of non-OPEC production is 'lost' on a yearly average in the 2018–2028 period. This is not to be confused with observed decline rates, which when last analyzed by the OPEC Secretariat, were seen to average 5.4% for non-OPEC countries. This means that a substantial 5 mb/d of new non-OPEC production needs to come online each year, a counter-intuitively high number and vastly overshadowed by headline growth in US tight oil. The higher decline rate implied in this calculation may stem from US tight oil's increasing importance in non-OPEC supply and its innate characteristics of high initial production rates, followed by a rapid decline.

Demand for OPEC crude is quite flat until 2025 and then rises sharply

In the Reference Case, demand for OPEC crude stays relatively flat at just over 33 mb/d until 2025, after which US tight oil is projected to peak, and with it overall non-OPEC supply. Thereafter, the call on OPEC crude production rises steadily, reaching 41.4 mb/d in 2040, or up 8.8 mb/d from 2016. This would imply OPEC's share of global oil production (including not only crude, but also all other liquids), would rise from 40% in 2016 to 46% in 2040.

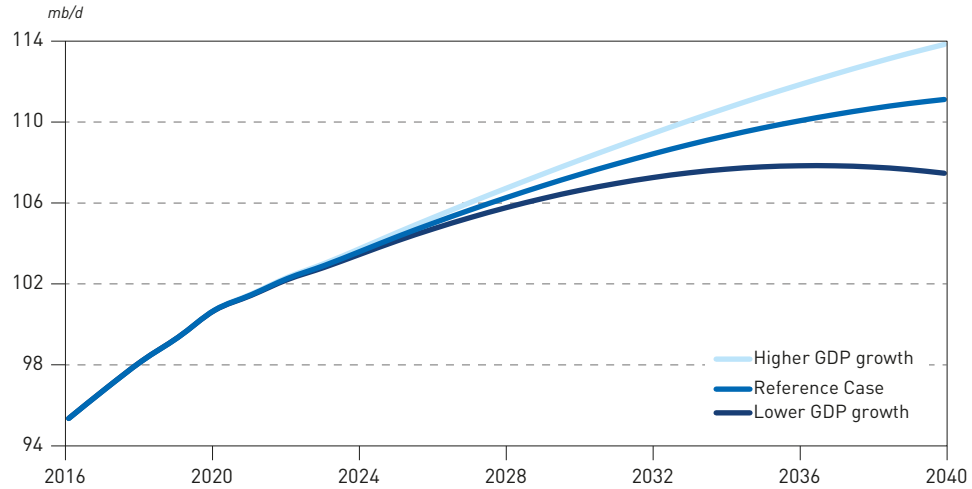
OPEC crude and other sources of liquids supply in the Reference Case



Uncertainty emerging from economic developments is in the range of 6 mb/d by 2040

The energy market, and in particular the oil market, is clouded with uncertainties that stem from a wide variety of sources, including alternative views on economic developments; the level and speed of penetration of alternative vehicles; and, the speed of adoption of energy efficiency measures across various sectors of oil demand.

World oil demand in the economic growth sensitivities



Addressing the issue of economic developments, two alternative sensitivities were developed: higher GDP growth (HG) and lower GDP growth (LG). The HG sensitivity assumes that the average GDP growth for the forecast period is 3.6% p.a. This is the result of additional labour productivity gains and employment growth due to further efforts to improve human capital and promote labour market participation. In the LG sensitivity, the average GDP growth for the forecast period is assumed at 3.3% p.a. This is the result of an increasing move towards protectionism that limits trade and migration.

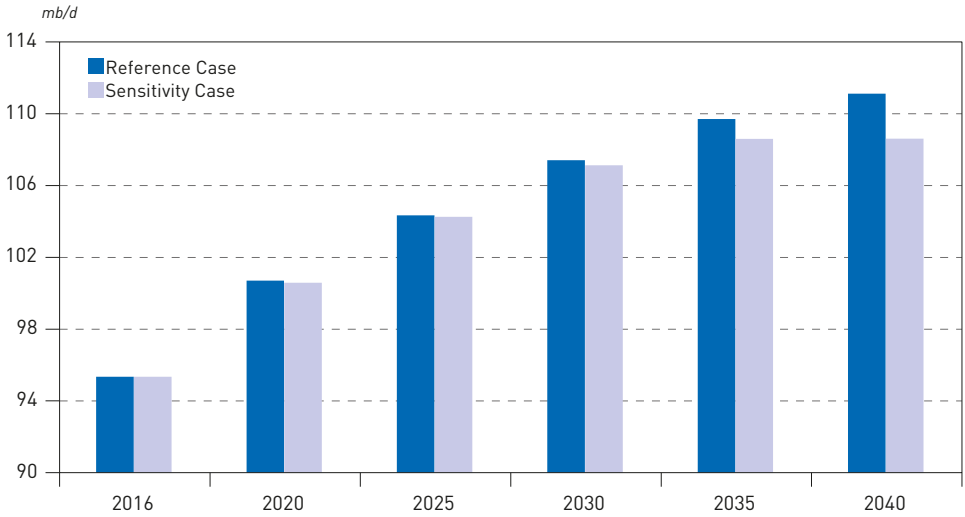
In the case of the HG, global oil demand reaches 113.8 mb/d in 2040. The LG sees demand at 107.5 mb/d in the same year. This implies that the overall uncertainty emerging from the economic developments is in the range of around 6 mb/d in 2040. Moreover, it is important to highlight that the uncertainty is skewed to the downside.

Faster penetration of EVs has the potential to reduce oil demand to 108 mb/d by 2040

Focusing on the penetration of EVs in the passenger car segment, a alternative sensitivity has been developed: the Sensitivity Case. In this sensitivity, a more optimistic view is taken on the penetration of EVs with the assumption that annual EV sales reach 80 million by 2040. This would mean that three out of every five cars sold in 2040 would be electric.

Under the assumption that the increasing EV penetration in the passenger car segment in the Sensitivity Case spreads, at least partially, to commercial vehicles, particularly in the medium-duty segment, oil demand in 2040 is reduced by 2.5 mb/d compared to the Reference Case, to total 108.6 mb/d. Moreover, global oil demand is estimated to plateau around this level in the second half of the 2030s.

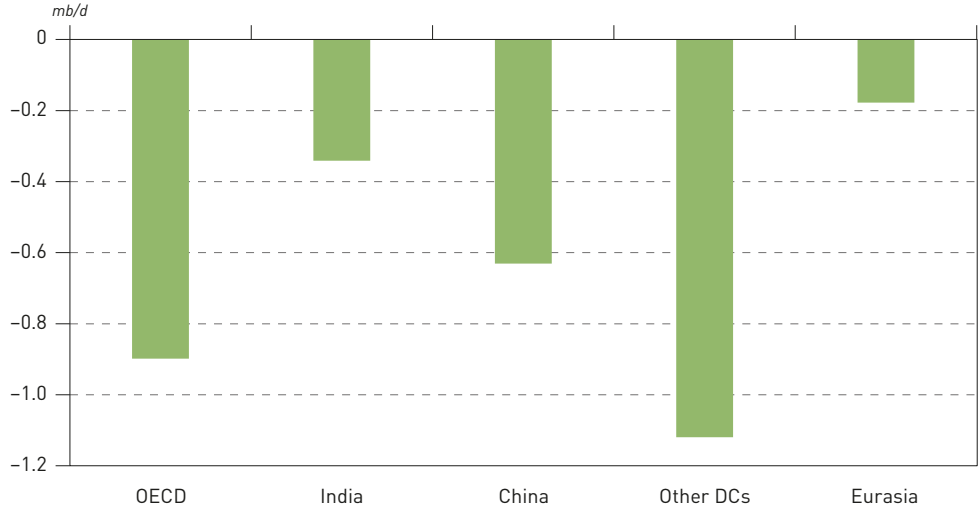
Oil demand in the Reference Case and the Sensitivity Case



Energy efficiency improvements could impact future oil demand in a similar way to the economy and EVs

Improvements in energy efficiency have long been recognized as a key element of policies focused on reducing emissions. Therefore, an alternative sensitivity – Accelerated Efficiency (AE) case – was developed assuming somewhat more aggressive efficiency improvements than those incorporated in the Reference Case. It is important to note, however, that the rates of efficiency improvements assumed in the AE case do not fully explore the potential for

Oil demand reduction compared to Reference Case in 2040, by region



improvement that exists in the oil sector. On the contrary, they in fact represent the moderate levels that are plausibly achievable if policymakers and technology work together in an orchestrated way in the decades to come.

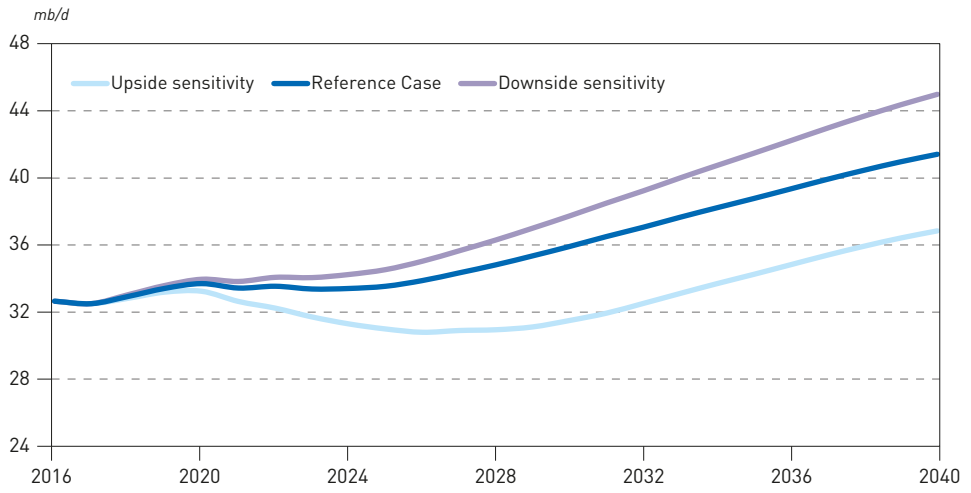
Compared to the Reference Case, the overall demand reduction in the AE case is 3.2 mb/d by 2040. The larger part of this reduction, around two thirds, is assumed to take place in Developing countries where a higher potential for efficiency improvements exists. Assumed efficiency improvements in China would translate into some 0.6 mb/d lower oil demand than in the Reference Case while India contributes another 0.3 mb/d. Because of the high overall level of oil demand in the group of Other DCs, the potential demand reduction in this region is more than 1 mb/d. The corresponding demand decline in Eurasia and OECD is 0.2 mb/d and 0.9 mb/d, respectively.

These estimates clearly show that the net effect of an orchestrated push for even moderate improved efficiencies across all sectors of oil demand is comparable to the impact of alternative economic developments, as well as to the much discussed impact of a potential faster penetration of electric vehicles.

Upside potential to non-OPEC supply could curb demand for OPEC crude by 4.6 mb/d in 2040

To reflect supply uncertainties, alternative non-OPEC supply sensitivities were also examined – both to the upside and the downside. These are explicitly constructed as a function of country-specific factors, including technology, regulation, taxation, innovation and others. The upside sensitivity shows greater potential, with 1.3 mb/d more non-OPEC oil production achieved by 2022, widening to around 4.6 mb/d in the long-term. By contrast, the downside sensitivity sees non-OPEC supply around 0.5 mb/d lower by 2022, widening to 3.6 mb/d by 2040.

Upside/downside sensitivities: impact on demand for OPEC crude



Based upon the upside sensitivity for non-OPEC supply, the demand for OPEC crude is reduced to a low of around 31 mb/d in the latter half of the 2020s, before US tight oil peaks and demand for OPEC crude rises again. By 2040, demand for OPEC crude increases significantly to 36.8 mb/d, albeit still 4.6 mb/d lower than in the Reference Case.

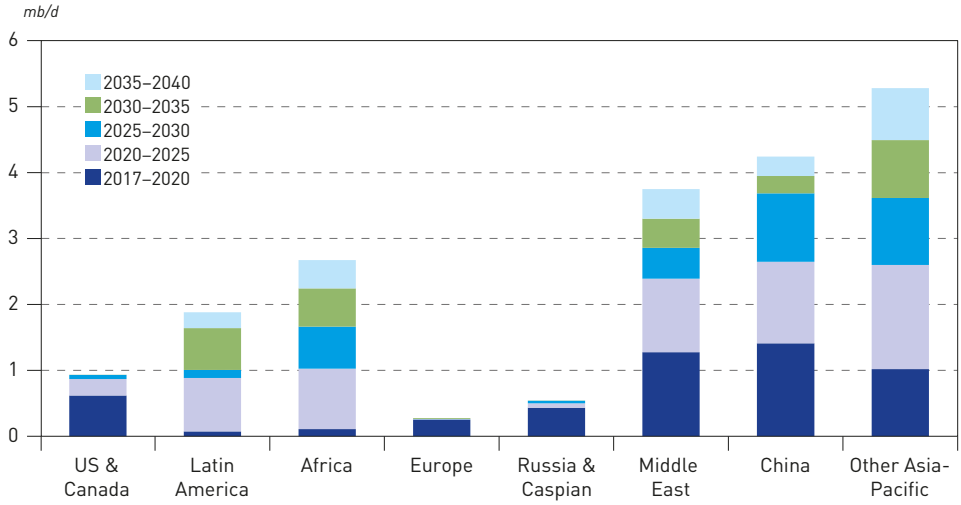
The effect of the downside sensitivity for non-OPEC supply is less pronounced. The demand for OPEC crude remains relatively flat at just over 33 mb/d in the medium-term horizon. Thereafter, it rises steadily, topping 40 mb/d in the early 2030s and reaching 45 mb/d by 2040. This is some 3.6 mb/d higher than in the Reference Case, and a full 8.1 mb/d higher than in the upside sensitivity estimate.

The majority of new refining capacity expansion set to be located in Developing countries, led by the Asia-Pacific and the Middle East

Around 7.6 mb/d of new refining capacity is likely to come online between 2017 and 2022, while 19.6 mb/d of new refining capacity is expected between 2017 and 2040. The majority of the new capacity is anticipated to be located in developing regions supported by growing oil demand. In the long-term, around half of the overall refining capacity (9.5 mb/d) is estimated to be added in the Asia-Pacific, while new capacities in the Middle East are expected to total around 3.7 mb/d, or some 20% of the total. Combined refining capacity additions in Latin America and Africa are estimated to be around 4.5 mb/d, or almost 25% of the total. At the same time, in the long-term new builds in developed regions are estimated at below 2 mb/d, which equates to less than 10% of the global additions.

It is also important to recognize that the projected long-term additions are driven more by the shift in global demand from industrialized regions to developing regions (mostly the Asia-Pacific) than by outright global demand growth itself. In addition, these new refineries in

Crude distillation capacity additions in the Reference Case, 2017–2040

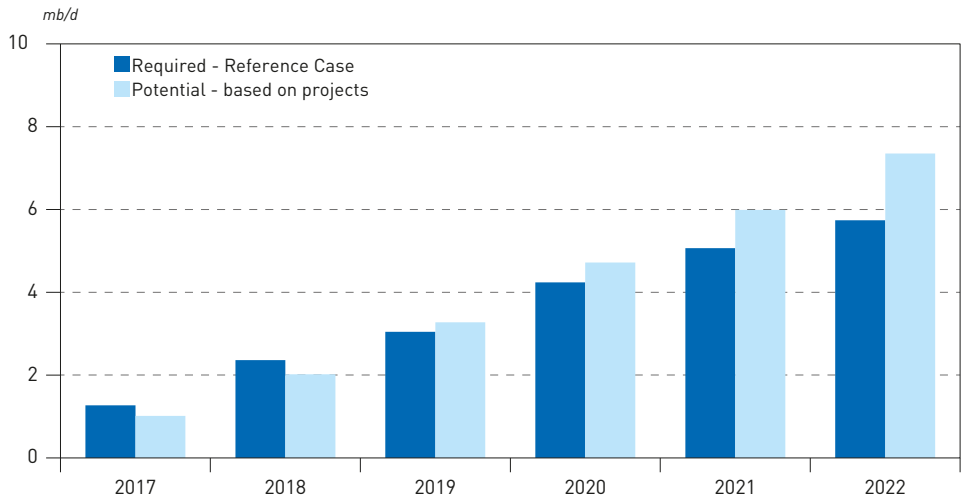


developing regions will compete with existing facilities in the US & Canada, Europe and Russia & Caspian as demand in those regions flattens before starting to decline.

Medium-term refining expansion points to increasing competition and the need for refinery closures

Based on assumptions for capacity expansion and 'creep' capacity additions, the potential incremental crude runs average approximately 1.2 mb/d p.a. This leads to cumulative potential incremental runs of 7.4 mb/d in the period to 2022. Compared to the refining potential, annual global demand growth in the six years from 2016–2022 is projected to average almost 1.2 mb/d p.a. However, close to 15% of the growth is covered by incremental supplies from biofuels, natural gas liquids (NGLs) and other non-crude streams. This leaves a little under 85%, or around 0.95 mb/d p.a. on average, to come from crude-based refined products. The net result is an outlook where incremental refinery output potential and incremental refinery product demand are projected to be closely in balance through to 2018, but thereafter, a gap progressively opens up, starting with exceptionally high additions in 2019. Consequently, the cumulative 7.4 mb/d refinery production potential is around 1.6 mb/d in excess of the 5.75 mb/d that refineries are projected to be required to produce by 2022.

Additional cumulative refinery crude runs, required and potential***



* *Required: based on projected demand increases.*

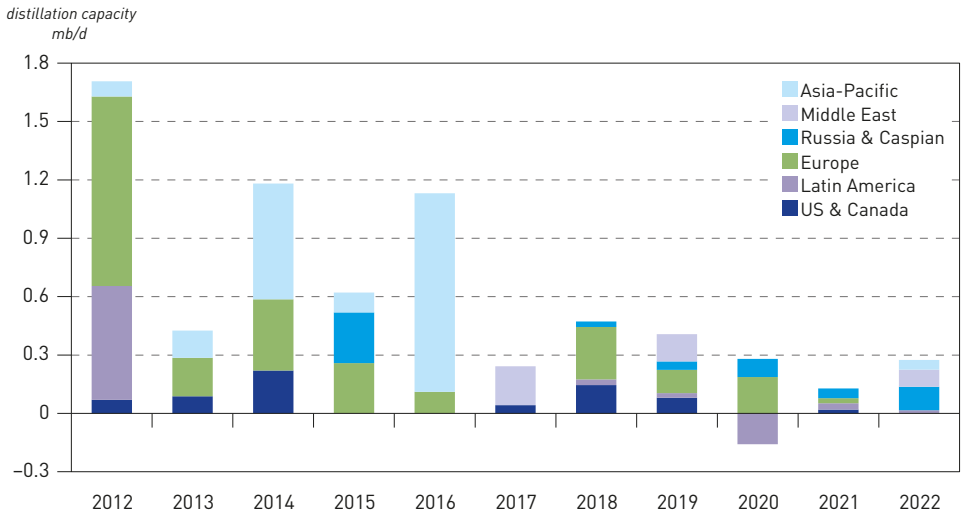
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

On a regional basis, developed regions such as the US & Canada, Russia & Caspian and Europe show capacity surplus in 2022, mostly due to declining demand. In addition, the Middle East is also projected to see a considerable surplus by 2022, based on the intention to increase product exports. This could lead to higher competition in product markets and lower overall refinery utilization, which, as a consequence, could lead to capacity closures, especially in developed regions.

Capacity closures will be needed in the medium- and long-term in order to avoid falling refinery utilization rates

A total net closure level of 2.5 mb/d is estimated for the period 2017–2025. This is based on announcements and the refinery capacity considered at risk of closure by virtue of a recent sale or other announcements. The majority of the closures are expected to occur in developed regions, led by Europe (around one third of the total estimated closures). Based on the modelling results, further refinery closures of around 4–5 mb/d across the world's regions are estimated as a potential requirement over the long-term. This has to be added to the 2.5 mb/d already built into the modelling base capacity for 2017–2025, indicating that total closures of somewhere in the range of 6–8 mb/d are needed from 2017–2040. This equates to an annual average rate of 0.25–0.35 mb/d for the period 2017–2040, a level that is in line with the 0.3 mb/d average included for 2017–2025. While closures in industrialized regions can be expected to continue, it is also clear that significant closures will be required in other regions if efficient levels of refinery operations are to be achieved and maintained.

*Net refinery closures, recent and projected, by region**

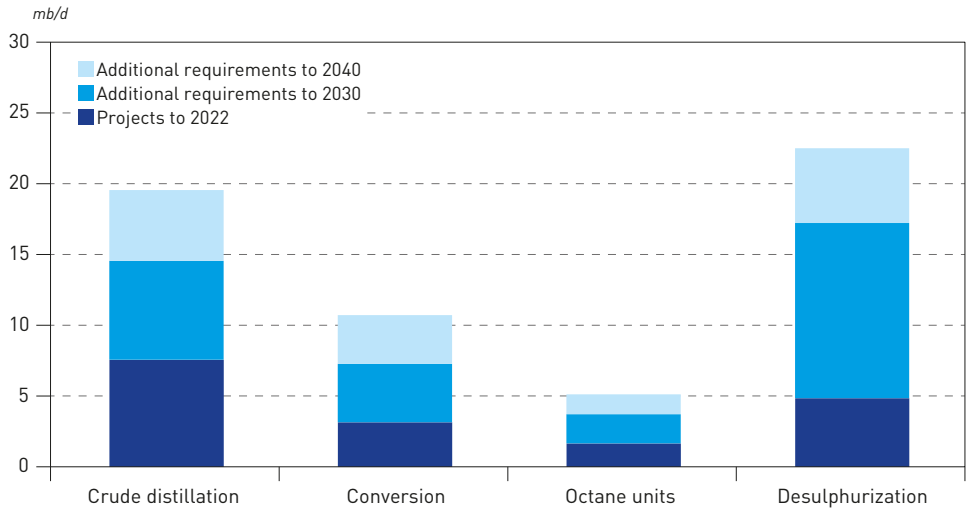


* *No closures are expected in Africa.*

Due to increasing demand for clean and high quality products, secondary capacity additions have become a key gauge of the refining sector's capability to meet demand

All major projects for new refineries and large expansions comprise complex facilities with high levels of upgrading, desulphurization and related secondary processing. At the global level, projections indicate the need to add some 10.7 mb/d of conversion units, 22.5 mb/d of desulphurization capacity and just above 5 mb/d of octane units in the period to 2040. The high levels of secondary processing additions, relative to new distillation capacity, are driven by the expected long-term growth in demand for light low-sulphur products, combined with flat to declining residual fuel demand.

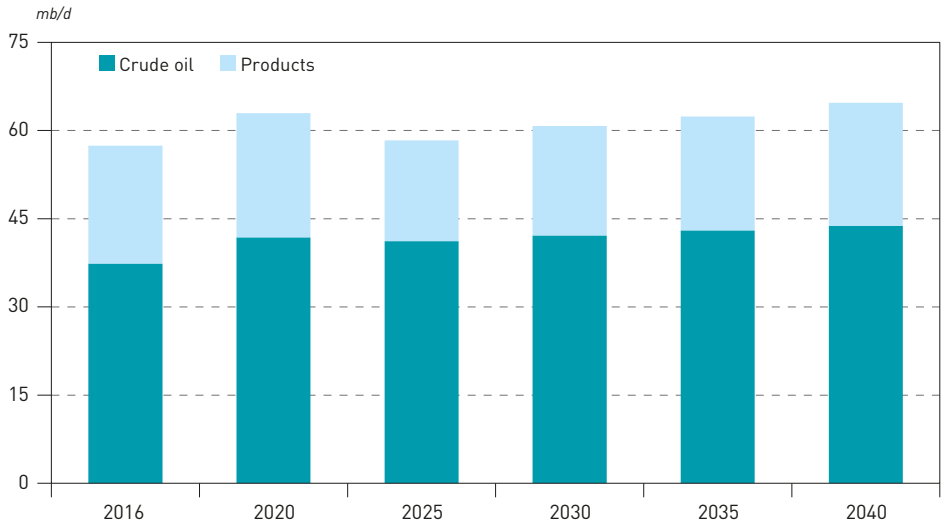
Global secondary capacity requirements by process type, 2017–2040



Long term global oil trade is set to increase gradually with the Middle East playing a significant and expanded role in crude and products

The anticipated rather sharp changes in crude trade between 2016 and 2020 stem mainly from developments in the US & Canada region. As oil production in the US & Canada increases, it is expected that crude exports rise significantly to world markets. Although a net-importing region, the US & Canada is estimated to export an appreciable share of its

Inter-regional crude oil and products exports, 2016–2040



production, as a large portion of the crude produced is light-sweet (notably tight oil) and sold at a premium to high-sulphur and heavier grades, while US refineries process mainly medium and heavy grades. At the same time, imports to the US & Canada are also expected to increase in the period to 2020 as most refineries in the US are complex and capable of converting low-quality and highly-discounted crude into high-value products such as diesel and gasoline.

In the period post-2020, the international crude trade is estimated to drop slightly by 2025, as more regions are expected to use more crude locally in newly installed refining units, for example, in Latin America and Africa, as well as the Middle East. Thereafter, global trade increases gradually, in line with growing liquids demand, resulting predominantly in increasing exports from the Middle East and imports to the Asia-Pacific. The overall crude and condensate trade in 2040 is estimated to be just below 44 mb/d. On the product side, the trade volumes drop significantly between 2020 and 2025 as the refining system in product-importing regions expands, which reduces somewhat the need for refined product imports.

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Key assumptions

Key takeaways

- Global population is estimated to increase from 7.3 billion in 2015 to 9.2 billion in 2040. The additional 1.8 billion people will mainly come from Developing countries, particularly from the Middle East & Africa and India. In the Organisation for Economic Co-operation and Development (OECD) region, population growth is supported by immigration.
- In parallel, population growth is anticipated to continue decelerating and the world to continue ageing. By 2040, global population growth is expected to only average 0.7% per annum (p.a.) and the share of the working age population is estimated to drop to 64%. In the OECD, the picture is gloomier as this share is anticipated to fall below 60%.
- The world economic growth dynamic has accelerated noticeably in 2017, with the global Gross Domestic Product (GDP) forecast now at 3.6%. This encouraging momentum has also become more balanced, with all major economies now showing positive growth for 2017. This GDP growth trend is expected to continue in 2018 at around similar levels.
- In the medium-term (2016-2022), global GDP growth is forecast to gather further momentum stabilizing at around 3.6–3.7% p.a. Growth in the OECD region is also expected to improve and stabilize at around 2.2% p.a. China is assumed to continue the process of restructuring its economy, while India's growth is forecast to improve after the impact of the demonetization of its economy.
- In the long-term (2016–2040), global GDP is expected to increase at an average rate of 3.5% p.a. Most of the global growth will be driven by Developing countries. These countries are expected to grow, on average, by 4.5% p.a. during this period, on the back of higher labour productivity growth and a more optimistic demographic outlook.
- The total size of the global economy in 2040 is estimated to be 226% that of 2016. Developing countries are expected to account for three-quarters of the global GDP growth over the forecast period. Furthermore, one of every two additional $ (2011 Purchasing Power Parity (PPP)) of GDP is anticipated to come from China and India, which combined are forecast to represent almost 40% of the global GDP in 2040.
- The evolution of energy markets over time is significantly impacted by government policies. The current trend is expected to lead towards a long-term convergence that focuses on energy efficiency, the increasing adoption of clean modes of energy and a tightening of fuel emissions standards.
- The Reference Case assumes an evolutionary development of technology and energy policy in the long-term. Overall, energy policies and technological development are expected to continue driving energy efficiency and emission reductions.

1.1 Introduction

Since the publication of the World Oil Outlook (WOO) 2016 in November last year, the market has experienced significant changes that have had an impact on medium- and long-term estimates.

From the supply viewpoint, OPEC's decisions taken in Algiers (28 September 2016) at the 170th (Extraordinary) Meeting of the OPEC Conference and then in Vienna (30 November 2016) at the 171st Meeting of the OPEC Conference, saw its Member Countries implement a production adjustment of 32.5 million barrels a day (mb/d) with effect from 1 January 2017. Moreover, the subsequent OPEC and non-OPEC Declaration of Cooperation through the Ministerial Meetings in Vienna (10 December 2016 and 25 May 2017) embraced a production adjustment of 1.2 mb/d for OPEC, together with a voluntary production adjustment of 0.6 mb/d from 11 participating non-OPEC producing countries (now 10 following Equatorial Guinea joining OPEC on 25 May 2017). The decision was focused on accelerating the ongoing drawdown of the stock overhang, bringing the oil market rebalancing forward and ensuring that much-needed investments return to the industry.

The ORB averaged around $43/b between July and September 2016, it then climbed to $51.6/b in December and reached $53.3/b in February 2017. However, the resilience of US tight oil supply put downward pressure on the oil price in the months that followed. Following the May OPEC and non-OPEC Ministerial Meeting and the corresponding extension of the voluntary production adjustments up to March 2018, the oil price recovered to average over $53/b in September this year.

These developments have evidently impacted expectations for non-OPEC supply growth for 2017 to the upside. While in OPEC's July 2016 Monthly Oil Market Report (MOMR) non-OPEC supply in 2017 was estimated to decrease by 0.1 mb/d (–0.14 mb/d for the US), in the October 2017 MOMR, the expectation switched to growth of 0.7 mb/d (+0.61 mb/d in the US). The impact can also been seen in the US rig count. According to latest Baker Hughes' weekly report, the US drilling rig count has almost doubled since the low point in May 2016. Expectations for a return to steady non-OPEC supply growth are also underpinned by other indicators such as the bottoming-out of upstream costs, renewed upstream investment, specifically in the US tight oil sector and a renewed interest in mergers and acquisitions (M&A).

At the same time, the upward trend observed by the oil price post-May OPEC and non-OPEC Ministerial Meeting is also the result of more optimistic expectations from the demand side. In OPEC's July 2017 MOMR, global oil demand growth in both 2017 and 2018 was estimated at 1.3 mb/d. The latest estimates look more promising. OPEC's October 2017 MOMR now projects an oil demand increase for these years of around 1.4 mb/d.

From the demand point of view, the main development has been the increasing sales of electric vehicles (EVs). Driven by declining battery costs and government support, battery electric and plug-in hybrid electric vehicles (PHEVs) continue to penetrate the market, particularly in the Organisation for Economic Co-operation and Development (OECD) region and China. The latest information shows that the number of EVs on roads around the world rose to two million in 2016. Furthermore, six countries have achieved an EV market share above 1% of their total

passenger car sales, with Norway being the highest globally where EVs have a 29% market share. However, it should not be forgotten that EVs currently account for less than 0.2% of the overall passenger fleet.

In October last year, the new International Maritime Organization (IMO) MARPOL Annex VI Global Sulphur Cap regulation to limit bunker fuel sulphur content to 0.5% was adopted with January 2020 as the implementation date. In last year's WOO it was assumed that the implementation date would be 2025. Given the short period of time until 2020, the response of the marine bunkers sector to this new regulation remains somewhat uncertain at this stage. Switching to diesel, using low sulphur fuel oil, installing scrubbers or even switching to liquefied natural gas (LNG) are options for ship owners. In this Outlook, this issue is analyzed in detail.

The OPEC Secretariat continues to closely monitor all these developments and, with this report, sheds light on a plausible outlook. Furthermore, the WOO 2017 also includes sensitivity analysis on key factors to account for medium- and long-term oil market uncertainties. Finally, on a technical note, it should be mentioned that the report reflects the current membership status of OPEC. Since the WOO 2016 was published last year, the Organization has added a new Member Country (Equatorial Guinea) as already mentioned, and Indonesia has suspended its membership. Therefore, throughout the report, when OPEC is referred to, it includes the current 14 Member Countries. It is also important to highlight that the WOO 2017 is fully consistent with OPEC's October 2017 MOMR as the base for its medium- and long-term projections.

1.2 Demographic assumptions

The world is experiencing an era of demographic change. Global population is growing at an unprecedented low rate compared to last century and the forecast is for a further deceleration. At the same time, the world continues to age as fertility rates decline and people live longer across the world. In addition, more people are moving from country-to-country, as well as increasingly to urban areas. The future of the global economy and the energy outlook will be heavily determined by these global demographic trends.

Based on the United Nations (UN) Population Division's 2015 Revision of World Population Prospects, the global population is estimated to increase from 7.3 billion in 2015 to 9.2 billion in 2040 (Table 1.1). The additional 1.8 billion people will mainly come from Developing countries, particularly from the Middle East & Africa and India. In the former, the population is anticipated to increase from 1 billion in 2015 to 1.7 billion in 2040. In the latter, it is expected to expand from 1.3 billion to 1.6 billion. The situation in China, however, is rather different. It is expected that the population will peak in 2028 at around 1.42 billion and then start a slow decline to 1.4 billion by 2040.

In the OECD region, an additional 116 million people are forecast in the period to 2040, with most coming from OECD America. This region sees an additional 92 million partly as a result of immigration. OECD Europe is also expected to witness an increase, albeit smaller, with the addition of 24 million people. In OECD Asia Oceania, the population is estimated to plateau during the next decade and then start to decline. In Eurasia, the population is expected to peak in 2022 and then decline, particularly in Russia.

Table 1.1
Population by region

millions

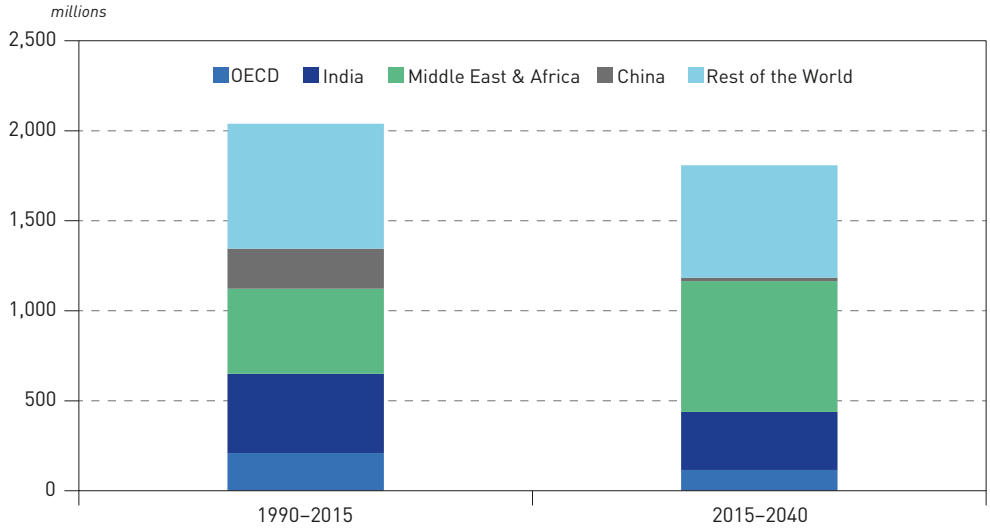
	Levels						Growth
	2015	2020	2025	2030	2035	2040	2015–2040
OECD America	507	529	550	568	585	599	92
OECD Europe	560	568	574	578	582	584	23
OECD Asia Oceania	213	215	216	216	215	214	0
OECD	**1,280**	**1,313**	**1,340**	**1,363**	**1,382**	**1,397**	**116**
Latin America	438	458	476	492	506	517	79
Middle East & Africa	1,001	1,129	1,267	1,412	1,566	1,727	726
India	1,311	1,389	1,462	1,528	1,585	1,634	323
China	1,384	1,411	1,423	1,424	1,417	1,404	20
Other Asia	1,128	1,199	1,264	1,323	1,375	1,420	291
OPEC	464	514	565	617	670	726	262
Developing countries	**5,726**	**6,101**	**6,458**	**6,796**	**7,119**	**7,426**	**1,700**
Russia	143	143	141	139	136	133	–11
Other Eurasia	198	201	202	202	201	200	2
Eurasia	**342**	**344**	**343**	**341**	**337**	**333**	**–8**
World	**7,348**	**7,757**	**8,141**	**8,500**	**8,838**	**9,156**	**1,808**

Sources: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, DVD Edition, OPEC Secretariat estimates.

The changing population growth dynamics are observed in Figure 1.1. While in the previous 25 years (1990–2015) India added 440 million people to the global population, in the next 25 years (2015–2040) its growth contribution is estimated to decline to 323 million. Similarly, in the earlier period China and the OECD added 223 and 210 million people, respectively, but they are only expected to add 20 million and 116 million in the subsequent one. On the other hand, population growth in the Middle East & Africa is expected to accelerate. Between 1990 and 2015 the region added 472 million people. In the next 25 years, 726 million are expected to be added.

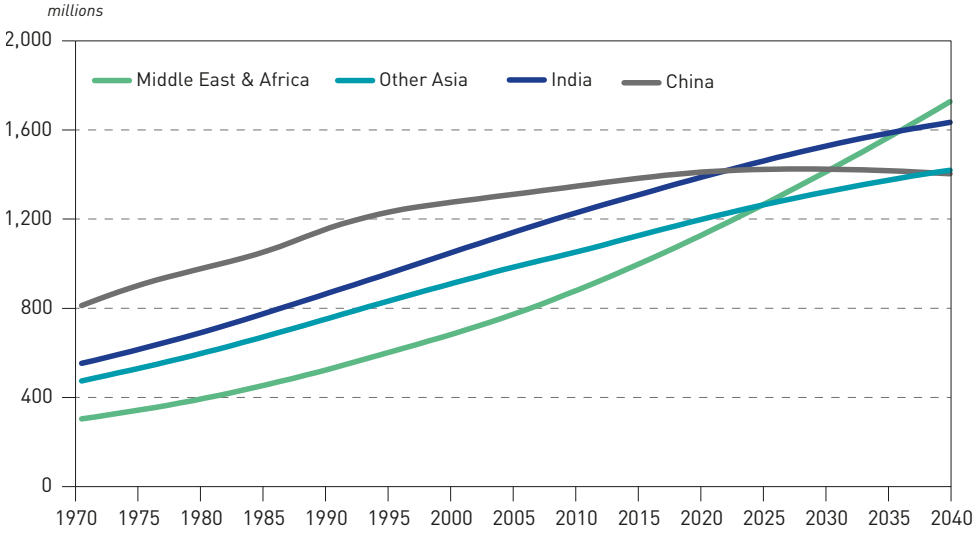
These population changes will mean that the ranking of the regions will shift significantly in the next 25 years, particularly in Developing countries. As shown in Figure 1.2, since 1970 China has been the most highly populated region, followed by India, Other Asia and the Middle East & Africa. However, in 2022, India is expected to overtake China as the most populated

Figure 1.1
Population growth 1990–2015 versus 2015–2040



Sources: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, DVD Edition, OPEC Secretariat estimates.

Figure 1.2
Population trends in developing Asia and Middle East & Africa



Sources: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, DVD Edition, OPEC Secretariat estimates.

Box 1.1

Habitat III: the future urban agenda

Urbanization is a transformational trend that alters humanity's relationship with itself and with the planet. By 2040, it is estimated that over 5.7 billion people will be living in urban areas, accounting for over 63% of the global population. This shift toward a more urban global population has profound implications for a wide range of economic and social issues.

The need to better understand the opportunities, as well as the challenges related to urbanization, such as congestion, poverty, quality of life, environmental degradation and climate change, among other issues, together with economic, social and creative advantages offered by the cities, was the reason for the conference, Habitat III, that was held in Quito, Ecuador, from 17–20 October, 2016. This was the third conference in a series that began in 1976 that has looked to strengthen the global political commitment to the sustainable development of towns, cities and other human settlements by means of the so-called New Urban Agenda (NUA), a document that sets the global strategy around urbanization for the following two decades.

The NUA is a non-binding agreement for UN member states to guide efforts around urbanization for a wide range of actors for the next 20 years, including country, city and regional leaders, international development funders, UN programmes and civil society. Moreover, the NUA provides an important platform for the world's urban development policymakers to review current progress and practices and consider opportunities for change. In addition, the NUA will have a significant impact on the development priorities and programmes financed by the World Bank, regional development banks and others, and by governments engaging in their own bilateral funding.

The UN says that the NUA that emerged from Habitat III is a resource for every level of government, from national to local; for civil society organizations; the private sector; constituency groups; and for all who call the urban spaces of the world 'home' to realize this vision. It adds that it represents a shared vision for a better and more sustainable future, one in which all people have equal rights and access to the benefits and opportunities that cities can offer, and in which the international community reconsiders the urban systems and physical form of urban spaces to achieve this. It calls the NUA "a paradigm shift" based on the science of cities, laying out standards and principles for the planning, construction, development, management, and improvement of urban areas.

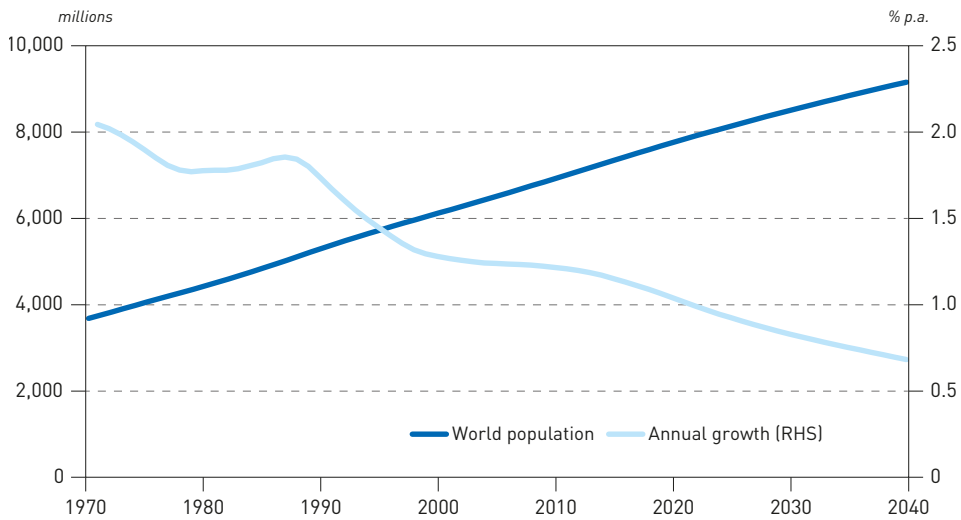
The Habitat III conference underscored that a well-planned and well-managed urbanization strategy can be a powerful tool for sustainable development in both developing and developed countries. It also emphasized the importance of better understanding urbanization in terms of resources, specifically those related to energy. It is evident that that the future evolution of urbanization could have a material impact on the future evolution of energy.

region. The impressive population growth in the Middle East & Africa means that it is estimated to surpass Other Asia in 2025 and China in 2030. Finally, by 2036, it is anticipated to become the most populated global region. Declining population in China implies that by 2039, Other Asia assumes third position.

Another interesting observation is that, as mentioned earlier, global population is expected to increase by 1.8 billion between 2015 and 2040. This corresponds to an average growth of 0.9% p.a. However, analyzing the data shows that population growth will decelerate further in the years to come (Figure 1.3). In 1970, the global population was expanding at around 2% p.a. By 2000, growth had dropped to 1.3% p.a. and this fell further to 1.1% p.a. in 2015. Looking ahead, global population growth is anticipated to continue its decline so that by 2040 it will only average 0.7% p.a. Sociologists often argue that declining population growth rates are a result of women's empowerment due to improved access to education and labour opportunities, better reproductive health and family planning programmes.

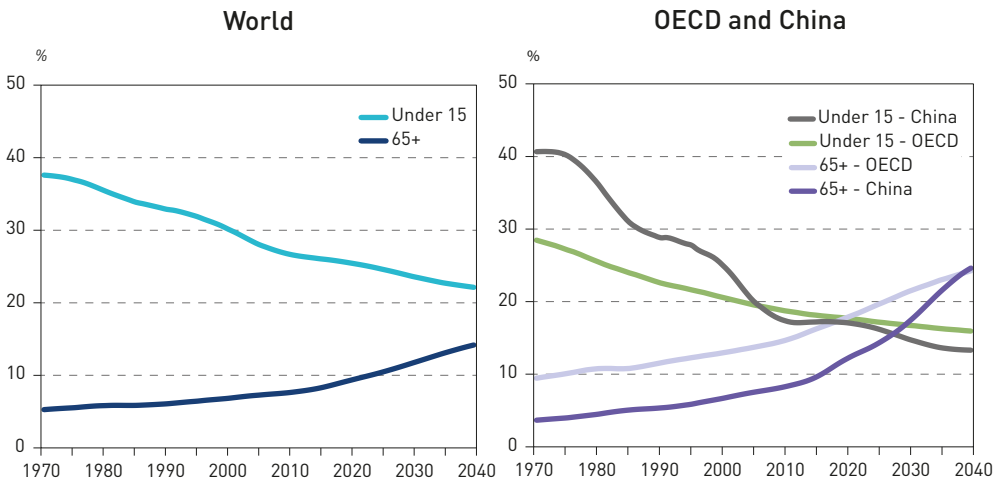
In parallel with the slowdown in population growth, the world continues to age. In fact, the share of the working age population (that is, individuals aged between 15 and 64 years old) in terms of the total global population peaked in 2012, following a steady increase since 1970. In 2012, two out of every three people in the world were of a working age. In 2040, it is estimated to be less than 64%. In the OECD, the picture is gloomier as this ratio is anticipated to fall below 60%.

Figure 1.3
Total population and annual growth



Sources: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, DVD Edition, OPEC Secretariat estimates.

Figure 1.4
Age structure in the world and in the OECD region and China



Sources: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, DVD Edition, OPEC Secretariat estimates.

The share of the working age population declines because the share of individuals aged 65 or more is expected to increase and the share of children – aged under 15 – is forecast to steadily decline. As shown in Figure 1.4, individuals aged 65 or more are anticipated to account for 14% of the world population, up from today's level of 8%. Children are estimated to represent 22% of the population by 2040, down from 26% today. Moreover, the total number of children is not expected to grow and remain fairly stable, around two billion, in the last 15 years of the forecast period.

In China and the OECD the ageing phenomenon is even more striking. In both regions by 2040, the share of children is forecast to be lower than that of individuals aged 65. In 2040, one out of every four Chinese and OECD nationals will be of retirement age. The number of children is expected to fall by 51 million and 10 million between 2015 and 2040, respectively. At the other extreme, the demographic trends in the Middle East & Africa are distinctly different. Individuals aged 65 or more are anticipated to account for only 5% of the population, while children are expected to represent 61% in 2040.

1.3 Economic growth

Economic growth is one of the main drivers behind energy (and oil) demand. As such, robust assumptions made for the short-, medium- and long-term outlook are essential for a credible market analysis. Higher economic growth rates are, in general, associated with higher energy demand. However, the two variables appear to have decoupled somewhat in recent years,

Box 1.2

The Millennial generation

It is evident that a new generation of young educated people, often with different consumption and living patterns, distinct vehicle ownership preferences, as well as an environmental friendly attitude, compared to previous generations, is taking shape globally. They are the so-called 'Millennials'. The birth years defining this generation corresponds to the beginning of the 1980s through to the end of 1990s and according to the Pew Research Centre, this generation accounts for around 27% of the global population or about two billion people.

During their formative years, the vast majority of Millennials, particularly in developed countries, have had access to the Internet. The connectivity of older generations is much lower and Millennials are also usually more connected to technology than previous generations. They feel comfortable with technology, given that they have largely grown-up with it and social media, using new tools as a natural and integral part of life and work.

Another interesting characteristic of Millennials is that they have grown-up marked by the global financial crisis of 2008. It is said that the event has influenced the behaviour of this generation. For example, the event may have caused this generation to postpone some important milestones like purchasing a home or car and delaying marriage, as well as more of a focus on the need to study and obtain training to have access to better job prospects.

Shifting views on transportation

Millennials are more likely to live in urban and walkable neighbourhoods and they seem to be more open to non-driving forms of transportation. They tend to be less car-focused than previous generations, and their transportation behaviour continues to change in ways that reduce the desire to drive, but increase transportation demand. This suggests that this generation tends to drive less than previous generations, but is likely to use more public transportation, as well as multiple modes of travel like carpooling and ride-sharing platforms. It could be said that Millennials view cars as more perfunctory – they are a form of transportation, rather than a status symbol.

Millennials are also the first generation to fully embrace mobile Internet-connected technologies, which are rapidly spawning new transportation options. A variety of new technologies have recently appeared that allow other transportation services, from car sharing to traffic tracking applications in real time. New forms of transport have also emerged, such as Zipcar, RelayRides, Car2Go, Lyft and Uber. These are examples of how technology has been able to shift perceptions in this generation. The 'shared mobility' concept has Millennials at the front of the adoption curve.

These trends and their evolution will need to be monitored closely and will no doubt have an impact on the thinking of car manufacturers, transportation businesses and oil companies in the years and decades ahead.

particularly in the OECD region, as a result of efficiency improvements, structural shifts in the economic structure and technological developments.

Current status and short-term perspectives

The world economic growth dynamic has accelerated noticeably, with global GDP now forecast at 3.6% in 2017. This compares to a five-year average growth from 2012–2016 of 3.2%. This encouraging momentum has also become more balanced, with all major economies now showing positive growth for 2017. This trend is expected to continue, with GDP growth in 2018 standing at 3.5%, only slightly below the 2017 growth level.

There are a number of significant supporting factors for this positive development including the ongoing accommodative monetary policies, improving global trade and the Chinese Government's continued growth-related assistance. There is also India's major structural reforms, which despite negatively impacting the economy in the first half of 2017 (1H17), are forecast to lift growth in the 2H17, as well as in 2018 and beyond. Moreover, the rebalancing of the oil market throughout 2017 and its positive effect on the economies of both producers and consumers has proven to be another important factor helping lift global economic growth above the levels of previous years. A significant contribution to the better growth momentum has come from the OECD group of countries. For this region, GDP growth in 2017 stands at 2.2%, compared to a five-year average from 2012–2016 of 1.8%. In 2018, OECD growth is forecast at 2.1%. Within OECD America, in 2017 the US has benefitted from labour market improvements and rising consumer confidence. Notable challenges remain in the US political sphere and there remain some uncertainties in respect to the monetary policy decisions of the US Federal Reserve (Fed) and their impact on economic growth.

In OECD Europe, the Euro-zone's recovery has continued in 2017, with improvements in peripheral economies and further solid expansion in Germany and France. This positive development was largely supported by falling unemployment levels, rising exports and ongoing monetary support from the European Central Bank (ECB). In OECD Asia Oceania, Japan's growth momentum in 2017 continued as the economy benefited from ongoing monetary stimulus, some fiscal support and structural reforms. South Korea has also benefitted from improving exports and strengthening domestic.

The largest economies in non-OECD Asia continue to grow at high levels. China's growth in the 1H17 was better-than-expected, although the 2H17 started on a softer note as export growth weakened amid slower demand from Asia. Private consumption has remained healthy in 2017, but real estate activity also slowed notably in 2H17. Looking ahead, challenges are expected to mainly come from issues related to the financial sector, the already high and continually rising debt levels in the private sector and from local governments. Growth is forecast to reach 6.7% in 2017 and then decelerate to 6.3% in 2018.

India's GDP growth momentum in the 1H17 slowed as a result of its demonetization programme, which removed about 90% of India's currency in circulation, as well as due to some uncertainty with regards to the implementation of the Goods and Services Tax (GST) in July 2017. However, it is expected that GDP growth rates will rebound in the 2H17 and 2018, led by

a recovery in consumption after the GST introduction and as the economy digests the effects of demonetization. Supported by easier financial conditions, economic growth is forecast to grow by 6.9% in 2017 and then jump to 7.5% in 2018.

In Latin America, the development of its largest economy, Brazil, has shown signs of improvement in 2017. In the second quarter of 2017 (2Q17) the economy moved out of a recession-cycle that had lasted more than three years. The improvement came on the back of the first acceleration in private consumption in more than two years, as well as rising trade levels. However, challenges remain, specifically in terms of still declining investments and uncertainties in the political landscape. The Middle East and Africa, as well as OPEC Member Countries, have been positively impacted in 2017 by some easing in fiscal consolidation, a recovery of oil production in some countries, and generally improving and less volatile oil prices.

In Russia, GDP posted growth reported the highest rate of quarterly growth since 2013. It should also be noted that household consumption posted growth in 1Q17, after two consecutive years of contraction. The broad-based improvement in the economy seen over the first eight months of 2017 is reflected in the anticipated 1.8% y-o-y GDP growth. For 2018, GDP is forecast to remain around the same level.

Medium-term prospects

Table 1.2 shows the economic growth assumptions in the Reference Case in the medium-term (2016–2022). It should be highlighted that the WOO incorporates October's MOMR GDP growth estimates for 2016, 2017 and 2018. Overall, it is observed that global GDP growth gains momentum towards the second half of the medium-term forecast period stabilizes at around 3.6–3.7% p.a.

It can be seen that growth in the OECD region is also expected to improve and stabilize at around 2.2% p.a. In the OECD America, growth is anticipated to improve steadily driven by strong consumer spending as wage growth takes off and the anticipation of a looser fiscal policy, but also a further recovery in energy-related investments. In OECD Europe GDP growth is forecast to stabilize around 1.8–1.9% p.a. as the current recovery phase consolidates, labour market conditions improve and fiscal policy expands. However, the debt overhang partially limits further growth. In OECD Asia Oceania growth is expected to decelerate to 1.5% p.a. by 2022 on the back of a shrinking labour force and a rising old-age dependency ratio.

In Developing countries, growth is also assumed to improve and reach 5.0% p.a. in the last two years of the medium-term period. Positive momentum is expected to come from improving economic conditions in Latin America, with the current recession in some of the region's countries overcome. Recovery in commodity prices and domestic reforms will also likely support regional growth. Similarly, in the Middle East & Africa, growth is assumed to accelerate in the medium-term as many macroeconomic challenges are overcome and stability is achieved. India's growth is also forecast to improve after the impact of the demonetization of the economy leads to a growth reduction of 0.5 percentage points in 2017, compared to 2016. In the medium-term, GDP growth is anticipated to hold at 7.4% p.a. This is a result of improving labour productivity as major reforms are implemented, but also on the back of a rapidly

Table 1.2
Medium-term annual real GDP growth rates in the Reference Case *% p.a.*

	2016	2017	2018	2019	2020	2021	2022
OECD America	1.5	2.1	2.3	2.3	2.5	2.8	2.7
OECD Europe	1.9	2.4	2.0	1.8	1.9	1.9	1.8
OECD Asia Oceania	1.8	2.0	1.7	1.6	1.6	1.5	1.5
OECD	**1.7**	**2.2**	**2.1**	**2.0**	**2.1**	**2.2**	**2.2**
Latin America	–1.1	1.5	2.0	2.5	2.8	3.1	3.3
Middle East & Africa	2.5	2.8	2.7	2.9	3.2	3.5	3.6
India	7.9	6.9	7.5	7.6	7.4	7.4	7.4
China	6.7	6.7	6.3	5.9	5.8	5.7	5.6
Other Asia	4.4	4.7	4.4	4.2	4.2	4.2	4.1
OPEC	1.4	2.1	2.3	2.5	2.7	3.1	3.2
Developing countries	**4.6**	**4.9**	**4.9**	**4.9**	**4.9**	**5.0**	**5.0**
Russia	–0.2	1.8	1.6	1.7	2.0	2.2	2.3
Other Eurasia	2.3	3.2	2.8	2.6	2.7	2.7	2.8
Eurasia	**0.8**	**2.4**	**2.1**	**2.1**	**2.3**	**2.4**	**2.5**
World	**3.1**	**3.6**	**3.5**	**3.5**	**3.6**	**3.7**	**3.7**

growing labour force. Growth in Developing countries is also expected to be supported by higher commodity (including oil) prices. OPEC Member Countries' growth is expected to accelerate from 1.4% in 2016 to 3.2% in 2022.

China is assumed to continue the process of restructuring its economy that allows for a smooth deceleration, with economic growth expected at 5.6% in 2022. This level of growth has not been seen in the country since the late 1970s, with the exception of the 1989–1990 period, following the collapse of the Soviet bloc and centrally planned economies. In Eurasia, improving geopolitical stability, together with a recovery in domestic demand, results in an acceleration of economic growth, which goes from 0.8% in 2016 to 2.5% by 2022.

Compared to last year's medium-term GDP growth estimates from the WOO 2016, in general, it can be observed that the figures have not been revised significantly, especially in the second half of the forecast period. However, short-term revisions have been applied to specific regions. In OECD Europe, Russia and Other Eurasia, the short-term economic picture looks more optimistic than in July 2016.[1] On the other hand, India (due to the demonetization process initiated in November 2016) and the Middle East & Africa show a slightly gloomier outlook.

Long-term prospects

In the long-term, economic growth is driven mainly by technological development and demographic trends. In the Reference Case, global GDP between 2016 and 2040 is expected to increase at an average rate of 3.5% p.a. As mentioned in the medium-term (2016–2022) economic activity is estimated to increase at an average rate of 3.5% p.a. In the rest of the 2020s, increasing labour productivity is anticipated to promote higher average growth of 3.6% p.a. In the 2030s, lower employment growth, coupled with lower labour productivity growth, is expected to reduce average global GDP growth to 3.3% p.a.

Table 1.3
Long-term annual real GDP growth rates in the Reference Case *% p.a.*

	2016–2022	2022–2030	2030–2040	2016–2040
OECD America	2.4	2.6	2.4	2.5
OECD Europe	1.9	1.8	1.7	1.7
OECD Asia Oceania	1.6	1.4	1.2	1.4
OECD	**2.1**	**2.1**	**2.0**	**2.0**
Latin America	2.6	3.2	2.6	2.8
Middle East & Africa	3.1	3.8	3.7	3.6
India	7.4	7.1	6.2	6.8
China	6.0	5.0	3.7	4.7
Other Asia	4.2	3.8	3.5	3.8
OPEC	2.6	3.2	3.2	3.1
Developing countries	**4.9**	**4.8**	**4.1**	**4.5**
Russia	1.9	2.7	2.4	2.3
Other Eurasia	2.7	3.0	2.6	2.7
Eurasia	**2.2**	**2.8**	**2.5**	**2.5**
World	**3.5**	**3.6**	**3.3**	**3.5**

Overall, most of the growth in the next 24 years is expected be driven by labour productivity. It accounts for almost three-quarters of the global growth. Regionally, disparities are observed in the sources of growth. For most of the regions, growth is mainly driven by labour productivity. This is particularly true for China, Other Eurasia and Russia. For some other regions, such as the Middle East & Africa and OPEC, low labour productivity growth is compensated by high employment growth. It should also be noted that a declining working age population significantly limits growth potential in countries and regions such as China, Russia and OECD Asia Oceania.

Growth in the OECD region averages 2.0% p.a. over the period 2016–2040. Despite a marginally declining working age population, an increasing participation rate and improving labour productivity support growth prospects. In fact, the participation rate is highest in OECD countries, particularly in OECD Asia Oceania, mainly because of high female participation. Further female participation and potentially the increasing participation of older individuals, as a result of increasing pressure on the social security systems and/or increasing retirement age, will likely see a marked increase in the participation rate and in turn support growth potential.

Within the OECD region, OECD America leads growth prospects with an average growth of 2.5% p.a. While in OECD Europe and OECD Asia Oceania increasing economic activity is limited by a declining working age population, the economic outlook in OECD America will be supported by expanding employment, particularly due to immigration. In fact, in OECD America net migration between 2016 and 2040 is expected to total around 35 million. Under a broad conservative assumption, GDP growth in the region – without immigration – would be reduced from 2.5% p.a. during the forecast period to at least 2.2% p.a. This would correspond to a loss in GDP of around $2.8 trillion (2011 PPP).

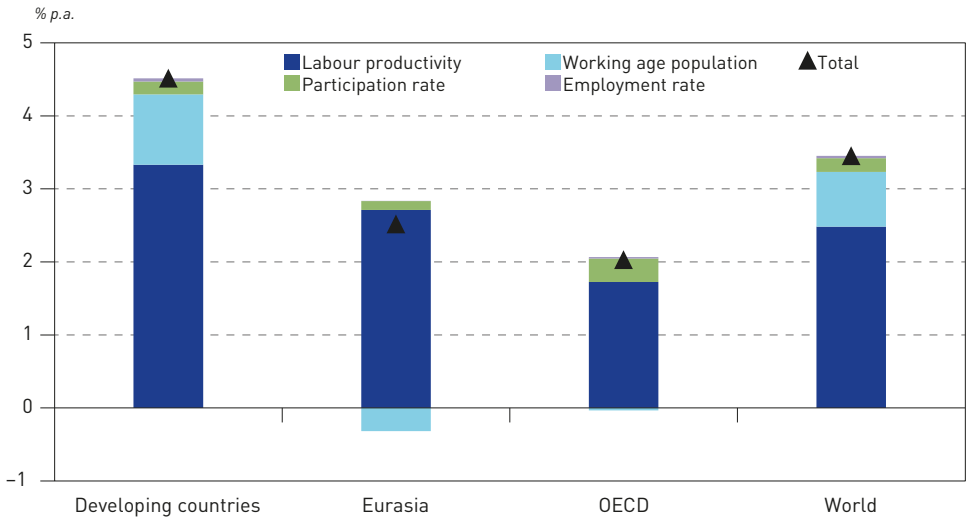
Most of the global growth will be driven by Developing countries in the period to 2040 (Table 1.3). These countries are expected to grow, on average, by 4.5% p.a. during this period on the back of higher labour productivity growth and a more optimistic demographic outlook. Within Developing countries, India is expected to be the fastest growing at an average growth of 6.8% p.a. This is driven by a rapidly expanding working age population (additional 237 million between 2016 and 2040). China follows with 4.7% p.a. However, its growth decelerates steadily as working age population declines so that in the last decade of the forecast period it averages only 3.7% p.a. and even falls below 3.4% in the final couple of years. Growth in Other Asia and OPEC remains strong driven mainly by labour productivity growth and an increase in the working age population, respectively.

For Latin America, it is expected that the economic downturn experienced in the last couple of years will limit growth in the medium-term. However, in the 2022–2030 period, growth is expected to gain momentum as labour productivity improvements accelerate. Beyond this, in the last decade of the forecast period the gloomier employment growth picture somewhat limits economic perspectives. Overall, the economy in Latin America is expected to expand by 2.8% p.a. during the forecast period. In Middle East & Africa growth remains strong on the back of a favourable demographic outlook, with growth averaging 3.6% p.a. over the forecast period. The regional working age population is anticipated to increase by a massive 483 million over the forecast period.

In Eurasia the economic growth outlook is limited by an unfavourable demographic picture, particularly in Russia, where the working age population is expected to decline steadily. However, anticipated strong labour productivity gains will support growth (Figure 1.5). Overall, GDP growth is forecast to average 2.5% p.a. in the long-term, with Russia at 2.3% p.a. and Other Eurasia at 2.7% p.a.

This year's GDP growth assumptions differ slightly with respect to last year's as a result of updated short-term figures, as well as due to an upgraded methodology. For the world,

Figure 1.5
Long-term GDP growth rates (2016–2040) by components



average GDP growth for the period 2016–2040 in this year's WOO is very similar to the WOO 2016. However, there are important differences for some regions. Growth prospects for the Middle East & Africa have been revised upwards so that the average annual growth in the forecast period is almost 0.4 percentage points (pp) higher. The previous forecasting methodology did not fully capture the growth potential arising from expanding employment. Long-term growth in Russia was revised up partly due to better medium-term prospects.

On the flip side, average annual long-term growth in China was revised down by almost 0.2 pp under the new methodology. India's growth was revised marginally downwards by 0.1 pp for the forecast period. However, the growth pattern this year is different with a more optimistic outlook for the 2020s, and then a more pessimistic for the 2030s compared to last year's report.

The assumed GDP growth figures imply that the total size of the global economy in 2040 will be 226% that of 2016. In particular, world GDP is forecast to increase by $136.6 trillion (2011 PPP), expanding from $108.4 trillion (2011 PPP) to $245 trillion (2011 PPP). Developing countries are estimated to account for three-quarters of the global GDP growth over the forecast period. Furthermore, one of every two additional $ (2011 PPP) of GDP are expected to come from China and India.

In 2016, OECD America accounted for 20% of global GDP, followed by OECD Europe and China, both with 18%, then Other Asia with a relative weight of 9% and India with 7% (Figure 1.6). The expected much higher growth of Developing countries in the long-term means that the weight

Figure 1.6
Distribution of the global economy

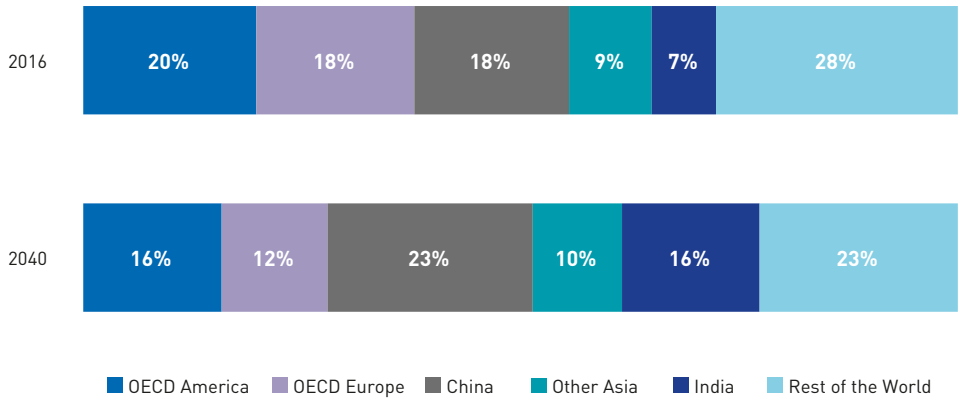
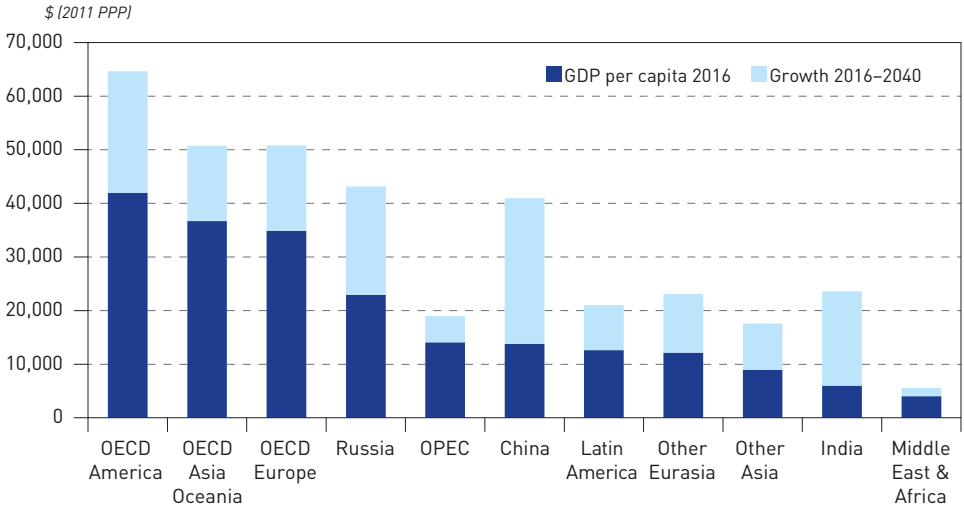


Figure 1.7
Real GDP per capita in 2016 and 2040



of OECD America is estimated to drop to 16% and that of OECD Europe to 12% by 2040. On the other hand, China's contribution to the global economy is forecast to increase by over 5 percentage points to 23%. Even more remarkable is the case of India. Its weight in the global GDP is expected to increase by more than 8 percentage points to 16%.

Despite the fact that there will be major regional shifts in the economic picture in the next 24 years and the GDP composition is anticipated to change significantly, the picture for average income (measured as GDP per capita) does not vary significantly. OECD America is forecast to remain as the region with the highest GDP per capita, followed by OECD Asia Oceania, OECD Europe and Russia (Figure 1.7). Additionally, the Middle East & Africa remains the region with the lowest income per head. The main changes are anticipated to occur in China and India. China's income levels are expected to triple and reach around $40,900 (2011 PPP) in 2040, a level comparable with that of OECD America today. GDP per capita in India is estimated to increase four-fold in the forecast period, with the country overtaking Other Asia, Other Eurasia, Latin America and OPEC. Overall, global average income is expected to increase by 83%, from $14,586 (2011 PPP) in 2016 to $26,765 (2011 PPP) in 2040.

1.4 Policy assumptions

The evolution of energy markets over time is significantly impacted by government policies, which are often used as mechanisms to stimulate change beyond purely market-driven forces. When forecasting the long-term energy outlook, there are many unknown variables, including when and which future policies may be enacted. Therefore, the Reference Case takes into account various energy policies that are already enacted, while accepting that the policy process is evolutionary in nature and susceptible to change over time.

Every year, the WOO projections are updated to reflect the impact of previously enforced policies and newly enacted ones, as well as taking into account the current debate on energy issues. As such, the following is an overview of policy developments and observable policy trends that have taken place since the publication of the WOO 2016; with the acknowledgment that policies are constantly changing, and therefore, policy developments need to be proactively and continuously monitored.

The end of 2016 culminated in a unified global action to address climate change, with the early enforcement of the Paris Agreement from COP 21 at the end of 2015. The landmark accord signifies recognition amongst all participating countries – in varying degrees of development – of their mutual interest and shared responsibility toward environmental conservation. The Agreement follows the Sustainable Development Goals (SDG) that were endorsed in 2015, particularly SDG 7, Affordable and Clean Energy, and SDG 13, Climate Action. Consequently, policymakers in most energy consuming and producing countries, and developed and developing economies, are taking on policy measures to attempt to simultaneously meet and balance their individual energy security, energy efficiency, economic development, poverty alleviation and other national priorities, whilst adhering to the global environmental accord.

This development trend is expected to lead toward a long-term global convergence focused on energy efficiency, clean modes of energy, including renewables, a tightening of fuel

emissions standards, and energy poverty eradication measures among developing countries. All 14 OPEC Member Countries have signed the Agreement and eight have already ratified it, with Member Countries actively seeking opportunities to promote energy efficiency and renewables within their own borders, while exchanging best practices to achieve sustainable development and reduce their carbon footprint. OPEC Member Countries remain committed to ensuring stable and reliable access to energy resources, which is of vital importance to global economic development.

Among the visible long-term global energy policy trends is the increasing penetration of EVs, the tightening of fuel emissions standards, and desulphurization in the road transportation, marine and aviation sectors. Various governments are utilizing both financial and non-financial mechanisms to stimulate paradigm shifts in the direction of meeting these targets as part of their energy and environmental agenda. For example, many governments are pushing the rollout of EVs, with subsidies and incentives; diesel-fuelled vehicles are increasingly facing bans in various cities across the globe; and sulphur limits are tightening in the automotive transportation and maritime sectors worldwide. This will evidently have implications for both oil producers and refiners. In terms of refining, the impetus lies on the sector to adapt to the changes imposed on refined products, as diesel demand in particular will be facing slower growth than previously anticipated.

1.4.1 Regional policies

US policies

It should be noted that on 1 June 2017, US President Donald Trump stated that "in order to fulfil my solemn duty to protect America and its citizens, the US will withdraw from the Paris climate accord." It remains to be seen how this will impact the accord in the long-term, but the European Union (EU), China and India have subsequently reaffirmed their support for the agreement. Moreover, many US businesses, as well as US states, have also since come out in support of sticking with the Paris Agreement.

Energy security continues to rank high on the political agenda in the US, as well as other major energy consuming nations. Changes in US energy policy direction have been at the forefront of uncertainties after the transition to the new US Presidential Administration at the end of 2016. What is clear is that the new Administration has set out its aims to bolster energy security and spur job creation, particularly in unconventional oil and gas, coal and US manufacturing industries. President Trump's 'America First Energy Plan' emphasizes his Administration's intentions to support US energy production.

To promote its energy priorities, the new Administration has taken advantage of the Congressional Review Act, which enables newly elected presidents to review the policies enacted by their predecessors at the end of the latter's presidential term. Alongside withdrawal from the Paris Agreement, President Trump has also ordered a series of changes to other energy-related policies, including a 31% budget cut and 'Regulatory Freeze Pending Review' on the US Environmental Protection Agency's (EPA) policies. This includes the elimination of the Clean Power Plan (CPP), in fulfilment of his promise to revive the

American coal industry. The CPP is an Obama-era policy that aims to reduce US greenhouse gas (GHG) emissions from coal-fired and natural gas power plants by 32% by 2030. The Administration has also said it intends to lift a Department of Interior moratorium covering new coal mining leases on federal lands.

Moreover, the Administration has also stipulated a review of 2022–2025 fuel economy standards for passenger vehicles and Renewable Fuels Standards (RFS) on transportation fuels, as well as rescinding the US Interior Department's planned issuance of minimum standards for hydraulic fracturing activities on federal laws.

While the US is experiencing unprecedented energy policy uncertainty, beyond its withdrawal from the Paris Agreement it remains to be seen how many will materialize. Considering the complex nature of the US legislative process, policy changes are anticipated to take time to be enacted and for the impact of the changes to come to fruition. Therefore, for the purpose of this outlook, currently enacted US policies are incorporated in the analysis. However, the OPEC Secretariat continues to vigilantly monitor US policy developments, and will take note of concrete policy actions as they evolve.

The US is undergoing a possible examination of fuel efficiency and emissions standards, while other parts of the world, including the EU, China and India, continue to move forward with fuel efficiencies and vehicle electrification plans.

European Union policies

Overall, the EU's energy policies are three-pronged; energy security, energy affordability, and sustainability. In order to achieve these objectives, the EU has set out individual medium- to long- term targets for the years 2020, 2030, and 2050. Within the 2020 strategy, the bloc aims to decrease GHGs by 20%, increase the share of renewables in its energy mix to at least 20% of consumption, and improve energy efficiency by 20% (compared with 1990 levels). By 2030, the EU intends to reduce GHGs by 40%, achieve a level of 27% renewables in its energy mix, and reach an energy efficiency target of 27% by 2030. Moreover, these goals are intended to pave the way to meet the Energy Roadmap 2050 goal of achieving an 80–95% reduction in GHG emissions by 2050. According to the EC, these goals are realistic as 2015 data shows that total EU emissions are already estimated to be 26% below 1990 levels.

The European Commission (EC) intends to introduce proposed legislation effective post-2020 on heavy-duty vehicle (HDV) emissions, which would require carbon dioxide (CO_2) emissions from new HDVs to be certified, reported and monitored. These plans are aligned with the EU's Nationally Determined Contribution (NDC) within the Paris Agreement to activate at least a 40% reduction in GHG emissions by 2030 compared to 1990 levels.

The EC is also targeting the residential sector to meet its energy efficiency goals, with the EC proposal in November 2016 for an update to the Energy Performance of Buildings Directive. Among its objectives, the proposal aims to see all new buildings in the bloc to be "nearly zero energy buildings"[2] by the end of 2020, while new public buildings would need to meet the

regulation by 2018. Additionally, the directive requires EU countries to carry out energy efficient renovations on at least 3% of its governmental buildings.

China's policies

China is also moving toward its overall goal of achieving cleaner air by way of the launch of several policies. China's State Council, in its 13th Five-Year Plan released in early 2017, announced plans to reduce sulphur dioxide (SO_2) emissions by 15% by 2020 compared to 2015 levels; cap overall energy consumption at 5 billion tonnes of coal equivalent by 2020; increase the share of public transportation to 30% of total traffic in major cities by 2020; and, stimulate the transition to cleaner fuels.

China's clean energy plans also extend beyond the road transportation sector. The government has announced plans to reduce coal consumption in Beijing by a further 30% in 2017, and ban small coal-fired boilers. The ban is expected to reduce coal consumption to below 7 million tonnes (mt) of coal in 2017, compared to around 22 mt in 2013. The aim is to have coal account for less than 58% of China's total energy consumption by 2020, compared to 62% in the previous plan. The country plans to increase natural gas consumption to 10% of its total energy mix by 2020, from around 6% currently.

According to China's National Energy Administration's (NEA) five-year plan for the power industry, the nation is targeting 2,000 gigawatts (GW) of electricity generating capacity by 2020, of which 55% would come from coal, 16% from solar and wind and 5.5% from natural gas. The NEA also intends to eliminate or delay at least 150 GW of coal-fired power projects between 2016 and 2020. Although the new ceiling for coal in power generation is higher than the previous five-year plan level of 960 GW, coal's total share in China's power generation mix is set to be reduced to slightly over 50%, compared to around two-thirds of total power generation in the previous plan.

Additionally, the country is advancing with its plans for the establishment of a national emissions permit system in the industrial sector by 2020. This is expected to begin with a pilot programme for emissions permits to be rolled out on power generators and paper mills in Beijing, Hebei and Tianjin by the end of 2017.

From the supply viewpoint, in April 2017, the China National Offshore Oil Corp. (CNOOC) offered 22 blocks covering an area of 47,270 km^2 in the South China Sea to foreign companies, with terms more favourable to foreign investors. This includes allowing companies without exploration experience to bid, as long as CNOOC remains the operator. The results of the tender, which closed on 15 September 2017, are yet to be announced but are expected to generate interest from domestic and foreign investors.

India's policies

Similarly, India continues to advance its clean fuel policy drive, both in the road transportation and bunkering sectors. At the end of March 2017, the Supreme Court ruled in favour of a nation-wide mandatory application of the Mass Emission Standard for Bharat Stage-IV (Euro 4) fuel standards beginning on 1 April 2017. The plans are expected to be enacted within the

medium-term as India pushes forward with the aim of 'leap-frogging' to Bharat Stage VI (Euro 6) standards nationwide by 2020. The fuel standard reform will put further downward pressure on diesel demand following the Supreme Court's ban on all diesel cars over ten years old in New Delhi.

Looking ahead, in working toward meeting its 'climate action plan' to reduce emission intensity by 33–35% by 2030, over 2005 levels, and boost clean energy in power generation to 40%, India also plans to reach 100% sales penetration of EVs by 2030, and aims to build infrastructure for charging stations and battery-swapping programmes.

Furthermore, to cut the country's carbon footprint, the government aims to raise the use of natural gas in its energy mix. To enhance the competitiveness of LNG, the Indian Government reduced LNG tax in the 2017–2018 fiscal year to 2.5% instead of 5% previously.[3] A total of $7.5 billion is set to be invested in the eastern region of the country for the purpose of achieving this target, through the development of LNG terminals, distribution networks and pipelines.

The Indian Government launched the Hydrocarbon Exploration and Licensing Policy (HELP) in May 2017 with the goal of attracting investment in its upstream sector. The policy streamlines the exploration licensing process by providing a single license for investors to explore for both conventional and unconventional oil and gas resources. It also grants companies freedom in pricing and the marketing of oil and natural gas produced from new fields, allows for the online submission of interest for exploration blocks without waiting for a formal bid round, and provides an 'easy to administer' revenue-sharing contract model.

OPEC Member Countries' policies

Energy efficiency and climate change mitigation is also a top priority for OPEC Member Countries, which is well aligned with their shared aspirations for providing reliable access to energy resources and achieving economic diversification. These commitments are demonstrated by their signing of the Paris Agreement, as well as concrete plans in the field of renewable energy. Many OPEC Member Countries have vast sources of solar and wind, and significant investments are being made in these fields. Moreover, a number of OPEC Member Countries are promoting projects that look to develop and adopt cleaner energy technologies, such as carbon capture and storage (CCS).

For example, in Saudi Arabia, the nation's National Transformation Plan 2020, issued in mid-2016, lays out plans for increasing the share of renewable energy in the national energy mix to 4% by 2020. In the same vein, Ecuador continues to make strides in emissions reductions with the commissioning of the Coca Codo Sinclair hydroelectric plant last November, which will increase the role of renewables in the nation's energy mix to 90%, from 85% previously. Iran in its sixth Five-Year Development Plan envisions construction of 5 GW of new renewable capacity (on top of more than 300 megawatt (MW) available now). Significant expansion is also planned in Algeria, which targets an additional 22 GW of renewable electricity capacity to be available by 2030 (above the current capacity of around 150 MW). The United Arab Emirates (UAE)'s Supreme Petroleum Council (SPC) passed ADNOC's 2030 strategy and five-year business plan in November 2016, which sets out plans to introduce energy efficiency

enhancement measures that will increase energy efficiencies by 10% by 2020. Similarly, Qatar, Nigeria, Angola and Kuwait have made investments in renewable energy, and aim to harness the power of solar energy.

OPEC Member Countries are also experiencing reform in their respective energy sectors. For example, Saudi Arabia has been making progress toward achieving its Saudi National Vision 2030, with the much anticipated announcement of its initial public offering (IPO) of a share of Saudi Aramco in 2018. The IPO is expected to be the largest in the world, and would be in line with the National Transformation Plan of 2020. Meanwhile, neighbouring Qatar lifted its 2005 moratorium on development of the North Field, which Qatar Petroleum has indicated could increase gas production by 10% as it would add 2 billion cubic feet per day of gas exports. Elsewhere in the Middle East, Iran's parliament passed a five-year economic development plan at the beginning of this year, which makes room for an increase in foreign investment. The plan permits the government to access an annual average of $30 billion of foreign financing, in addition to $15 billion of annual foreign direct investment in Iran, and up to $20 billion of foreign investment managed with local partners. Nigeria is also moving toward attracting foreign investment in its energy sector; particularly gas. Nigeria's draft National Gas Policy also seeks to end gas flaring by 2020.

Mexico's policies

Mexico is forging ahead with its energy reform process, which was initiated in 2013. In December 2016, it held the fourth and final call of round one of the upstream bidding process, which was not previously open to private companies for almost 80 years. The auction saw eight of the ten blocks receive bids, and 13 companies were awarded offshore exploration and production rights in the Gulf of Mexico. Australia's BHP won a separate bidding to jointly develop the Trion deep-water field with Mexico's national oil company (NOC) Pemex. Mexican Government officials have indicated their expectation for the deep-water contracts to ultimately result in additional oil production of 900,000 b/d. These are long-term projects, however, and may require up to a decade to generate production. Furthermore, further regulatory work is anticipated in the areas of safety and environment, as well as onshore and offshore infrastructure development. Mexico's energy market liberalization process has also extended to the fuel sector, with foreign participants entering the nation's diesel and gasoline market. The fuel liberalization process was initially programmed to begin in January 2018, but was expedited to January 2017 with the intention of having completely liberalized prices by 2018.

Brazil's policies

In Brazil, following the energy reform passed by Congress in October 2016, policymakers plan to ease regulations in order to attract investments. These reforms include allowing private companies to be sole operators of the offshore reserves, easing local content requirements, and permitting foreign investment access in offshore oil fields. According to ANP, Brazil's regulator, 300 offshore wells are expected to be operational by 2027, culminating in an additional 2 mb/d of oil production, on top of today's levels of about 2.5 mb/d. The reforms in Brazil are already bearing fruit, with Shell's announcement in November 2016 that it would step up investment in the country, promising to spend $10 billion over the next five years.

Meanwhile, in efforts to reduce debts and attract investment, in September 2016 Petrobras cut planned investments by 25% for the 2017–2021 period in an effort to reduce debts and revitalize investor confidence. Petrobras committed up to $74.1 billion in capital spending for the 2017–2021 period instead of the previous $98.4 billion allocation announced previously for the 2015–2019 plan. Additionally, the government launched auctions for electricity and infrastructure projects with the aim to attract investments and revive the economy.

1.4.2 Cross-national policy developments

Over the last year, a number of cross-national policies have been enacted, particularly in the transportation sector. At the C40 Meeting of Urban Leaders on 30 November 2016 in Mexico City, the mayors of the cities of Paris, Mexico City, Madrid and Athens announced that they would ban all diesel vehicles by 2025 and "commit to doing everything in their power to incentivize the use of electric, hydrogen and hybrid vehicles". The cities aim to address local air pollution by way of the ban, and also tackle traffic congestion. Correspondingly, Norway, Sweden, Belgium and the Netherlands are also aiming to ban both diesel and gasoline engines by 2025–2030. London is also introducing penalty fees of £12.50 to polluting vehicles entering Ultra-Low Emission Zones in central London from April 2019, with the penalty set to extend to all vehicles by 2021.

Tightening road transportation fuel specifications are also a trend in Africa. The African Refiners Association (ARA) supported a measure in March 2017 to implement the AFRI-4 specification on lower sulphur limits in gasoline and diesel by 2020, and the AFRI-5 specification by 2030. The AFRI-4 specification limits sulphur levels in gasoline to 150 parts per million (ppm), which is half of the current AFRI-3 standard, and reduces the sulphur limit in diesel to 50 ppm. This compares to the current level of 600 ppm.

Emissions reductions have also become a global trend in other parts of the transportation sector, primarily in marine and aviation transportation. The IMO decided in October 2016 to cut global sulphur emission limits for marine fuels from 3.5% to 0.5% by 2020, rather than deferring compliance to 2025, as was previously expected. Consequently, ship operators are faced with the choice to either switch to cleaner, more expensive bunker fuels, such as low-sulphur fuel oil, diesel, liquefied petroleum gas (LPG) or LNG, or invest in emissions cleaning systems such as exhaust gas cleaning systems ('scrubbers'), which clean the emissions post-combustion. The IMO policy is expected to dramatically modify the sectoral product demand outlook, which is explored further in Chapter 3. There is potential for LNG bunkering to develop as a means to meet the IMO regulations – if the necessary investments in infrastructure are made.

Decarbonization plans are also underway in the aviation sector. The International Air Transport Association (IATA) aims for an average improvement in fuel efficiency of 1.5% p.a. from 2009–2020, a cap on net aviation CO_2 emissions (carbon-neutral growth) from 2020, and a reduction in net aviation CO_2 emissions of 50% by 2050, compared to 2005 levels.

These plans are in line with the UN's International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) pact. The implementation

of this was agreed by its 191 member states in October 2016, with the goal of achieving a voluntary reduction of 80% in the aviation sector's carbon CO_2 growth in the period 2021–2026. From 2027, the reduction is intended to become mandatory.

1.5 Technology assumptions

The energy industry as a whole, and the oil industry, in particular, are very much dependent on technology that has shaped the way in which energy is produced, as well as consumed around the world. Each step on the industry's evolution has been marked by scientific discoveries and their appropriate technical application. Technology has always been the key to multiply human dynamism and it is evident that it continues to undergo rapid advances in several areas across the energy spectrum, in particular, in the renewables arena.

In the oil industry, in less than a decade, two important technology developments have advanced on the supply and demand sides: the innovative combination of directional drilling and hydraulic fracturing ('fracking') – leading to the advent of tight oil, particularly in the US – and substantial improvements to battery technology creating a new mobility segment of EVs.

It can be expected that these technical advancements will continue to evolve and change the future energy panorama. The current development of renewable energies and the of introduction of EVs as a replacement for internal combustion engine (ICE) vehicles are strong signs of trends, for example. Elsewhere, highly resistant fibres in conjunction with oil-based resins are already replacing traditional metal-based materials in the case of latest-generation airplanes, to highlight another state-of-the-art development. And in the field of oil discovery and exploration, technical development has always played a decisive role since early onshore drilling through the large-scale development of offshore and, today, tight oil reserves.

The present oil and energy outlook has, therefore, to consider technological developments in view of their impact on energy provision and energy efficiency.

Evolutionary development

In general, the energy industry is mature and global. A large number of vehicles and power plants already exist and a broad range of products satisfying today's needs in developed and emerging countries are commercialized every day. Less developed regions form an important potential market for the future expansion of power, mobility, petrochemicals and, in general, energy demand in a similar way. Any significant change requires, therefore, a major effort, or substantial advantage, for newly competing goods and technologies.

However, even a comparably fast and 'disruptive' innovation needs to penetrate new sales in the case of shorter term units (for example, vehicles) or replace existing power and chemical plants usually intended for decades-long service. Together with the typical start-up of new technologies from a very low base, both aspects delay the impact of even quickly embraced innovations. In some cases, however, even a share in the lower single digits may already have a notable impact and shift the market balance as, for example, tight oil has shown.

Efficiency improvements have been an important aspect in the energy sector for a long time. Increasing efficiency means lower energy consumption and, hence, a reduction of the ongoing expenses. On the other hand, efficiency advencements usually require investment in more sophisticated and, therefore, more expensive technology. Apart from the energy costs, financial costs of these investments also play an important role and together define the feasibility of introducing more advanced technology. The current low interest rate level in many countries encourages such investments. In recent years, however, not only have efficiency improvements played an important role, but also the increasing tendency to look for additional energy sources, mainly renewable ones.

Nevertheless, for the Reference Case an evolutionary development of existing technologies is the appropriate and straightforward approach. The WOO assumes a steady advance of engineering capabilities until the end of the timeframe. A corresponding overview of the main technology assumptions used in the Reference Case is presented below.

Conventional and renewable power generation

Conventional power generation continues to play an important role in view of primary energy consumption. In the past decades, a significant shift towards coal has caused oil to lose most of its share in this sector. The latest generation supercritical coal-fired power plants reach an electric efficiency of around 45%, which will be difficult to increase substantially in the future. On the other hand, natural gas also constitutes an important energy source for power generation, usually through gas turbines. Today's large combined cycle power plants (CCPT) are the most efficient ICEs, reaching more than 60% net electric efficiency. This is already close to the thermodynamic limit of the underlying process, which cannot be surpassed. The expected further increase in combustion temperature and optimized adaption of working gas and steam cycles may further increase overall efficiency by a few per cent, but no leaps can be expected in the future. Nevertheless, they are expected to remain by far the least CO_2-emitting fossil power plants.

In view of the limited potential for future improvements of fossil power plants, a significant change in long-term planning towards renewables has appeared as a strategy to reduce GHG emissions. Important investments, mainly pushed by substantial direct and indirect subsidies, have been made to develop new technologies in this area that will be able to compete with traditional fossil energy sources in the future. In general, the specific investment costs and accordingly the power generation costs of several renewables – mainly wind and solar – have declined more quickly than expected a decade ago.

In the case of wind, technical improvements toward higher efficiencies refers mainly to the improved usability of low-speed, as well as high-speed wind. In the case of solar the focus is on the efficiency increase of the employed solar cells. Together with the still ongoing up-scaling of the production process of such wind turbines and photovoltaic (PV) cells, it can be expected that costs will decline further in the foreseeable future.

Onshore wind is already competitive in some areas when compared to fossil power production, and Germany's last call for bids for offshore wind farms albeit not to be completed earlier than 2022 – gave results without a subsidy offer. The specific power generation costs of PV have

decreased in an impressive manner over the past decade, making small-scale power generation 'beyond the metre' now increasingly attractive. The technology potential of concentrating solar power (CSP), on the other hand, is more limited the part of the plant that converts the heat produced by concentrating mirrors is based on already mature steam turbines. Moreover, the large mirror arrays may mainly benefit from scaling effects only.

It should not be overlooked, however, that wind and solar as the main drivers of renewables still bear the disadvantages of a limited (wind) or non-existent (solar) baseload capability. Battery storage systems remain expensive although strong efforts are being undertaken to further bring down battery costs. Feasible storage solutions combining a high round-trip efficiency with low costs are still not available despite a broad range of propositions. Their development, however, is by far the most important key technology to ensure the success of renewable power production.

An unintended consequence of renewable power production is that powerful transmission lines must be constructed over unprecedented distances. In the past, in most cases, power plants were built where consumers reside. However, wind and solar are often not available in sufficient quantities or with satisfactory reliability at the point of consumption. Windmills, for example, have been up-sized continuously to take advantage of the accompanying scaling effects and are now often located far away from populated areas. To deliver the generated power, substantial technical progress had to be made in the development of long-distance direct current systems, as well as buried high-voltage cables. While the first reduces the transmission losses, the latter reduces the environmental impact and raises public acceptance. The lack of such lines can cause a severe sub-utilization of the installed power, reducing the associated capacity factor. This is currently the case for wind power in several areas of Europe and China. Therefore, the Reference Case also takes into account such side-effects impacting the straightforward up-scaling of renewable power.

Despite the appearance of renewables, fossil fuels are expected to remain essential to satisfying world's energy demand in a secure and reliable way. Oil and gas will last for a long time, as will coal. CCS, as well as carbon capture and utilization (CCU) may reduce GHG emissions, mainly CO_2, associated with the use of these energy sources and provide an additional path to limit global warming while maintaining a reliable and proven energy base. CCS and CCU may provide a substantial contribution to fulfil the commitments of the Paris Agreement.

The fact that natural gas has the lowest specific CO_2 emission of all fossil fuels and the efficient operation of CCPs makes them interesting candidates for CCS and CCU. Only around one-third of CO_2 must be captured even when compared to the most advanced super-critical coal-fired power plants. Both technical and financial expenses drop to a fraction.

CO_2 is increasingly used for modern enhanced oil recovery (EOR) technologies to maintain the production of already mature oil and gas fields. The positive experience with re-injecting CO_2 into oil wells over several decades suggests that CCS is a safe and technically viable strategy to reduce the carbon footprint of the oil producing and oil producing industry.

An almost completely CO_2-free energy source is nuclear energy. Hence, the Reference Case also considers technical advances for nuclear power, currently undergoing further

development mainly in China. The country's ambitious five-year plan foresees not only a significant build-up in nuclear capacity, but also technical progress towards inherently safe third and fourth generation reactor types. In the event of a serious failure, these reactors no longer rely completely on the active intervention of dedicated components – as, for example, mechanically introduced neutron absorbers – but the reactor is kept under control based on physical laws.

Residential and industrial sectors

In addition to the power generation, the residential and industrial sector should also be taken into account given that it requires significant energy just to produce heat at various temperatures. Examples range from heating and hot water in households, through dairy and juice plants that need heat for pasteurizing purposes, up to the broad range of needs for the chemical and petrochemical industries, where heat is an essential element for running the required chemical reactions.

An established strategy to reduce overall energy consumption is combined heat and power generation (CHP) where waste heat from power generation is efficiently used to cover thermal energy requirements. The typical set-up of a gas or diesel reciprocating engine, as well as industrial gas turbines, is to run in a heat-driven manner (the requested thermal power defines the load of the overall system). In past years, renewable energy has also been able to gain a larger share in this area with the implementation of innovative Organic Rankine Cycle (ORC) plants based on, for example, solid biomass. Efforts have been made to increase the power generation efficiency of all CHP plants as the general energy market development shifts towards energy of higher value (basically power instead of heat).

Contrary to traditional practice – where power is generated from heat – other developments can be seen in countries with abundant electric power. They have already pushed heat pumps for space heating and hot water production, displacing oil and natural gas furnaces. In the future, low and mid-temperature heat pumps may use renewable power and further increase energy efficiency, even in the case of mid-temperature industrial applications.

Transportation sector

Large units are well suited for stationary power generation, however, they cannot be used for mobile applications. To this effect, ICEs were developed more than 100 years ago. Until today, they remain not only the most common vehicle drive, but also the main driver for oil consumption. While the dominance of these engines will remain untouched for a long time, the current discussion about electric mobility underlines how technical advances have the potential to change the energies landscape.

Technology will evidently continue to play a very important role in the road transportation sector. The appearance of battery electric vehicles (BEVs) puts pressure on the automotive sector to accelerate technical developments towards cleaner and more fuel-efficient ICEs. Some progress has been made, but significant potential remains especially in the case of passenger vehicles.

Nonetheless, powertrain electrification is already a reality for passenger cars and encompasses hybrid electric vehicles (HEVs), PHEVs, as well as BEVs. While HEVs use the ICE as the only power source, PHEVs can also consume electricity to replace at least a part of conventional fuel, awarding them at least a partial zero-emission capability in urbanized areas. The Reference Case assumes that battery costs will decrease faster than expected only a few years ago. Future PHEVs will also benefit from declining costs as is the case for BEVs. The ability to incorporate larger batteries in PHEVs at moderate prices may provide a solution to the most important setbacks of BEVs: their enormous upfront battery costs and their limited range. Even so, ICE powered vehicles will remain the cheapest. Consequently, the Reference Case assumes that conventional powertrain technology option will continue to dominate the fleet.

The mobility discussion has recently included the topics of car sharing and carpooling. Both concepts have the potential to reduce the number of vehicles, but not necessarily the amount of passenger kilometres travelled. As the vehicles' average occupation time increases, faster vehicle replacement is required as these vehicles reach their usable lifetime earlier. A side-effect may, therefore, be an acceleration of the fleet towards, on average, more modern and hence more fuel-efficient and less polluting vehicles. Innovative platforms on the Internet allow an unprecedented efficiency in view of managing a fleet of shared vehicles to provide the user with car availability close to conventional car ownership.

While in past years the passenger vehicle segment has enjoyed rapid technical development, large commercial vehicles with heavy-duty diesel engines were already at a far higher efficiency than passenger vehicle ICEs. Hence, the Reference Case assumes here only little improvement. However, some shift towards LNG may occur.

Air transport is a rapidly growing transport sector and relies exclusively on oil-based fuel (apart from a few flights to demonstrate the feasibility of certain biofuels). Commercial airplanes are today solely equipped with flight gas turbines, which are already far more efficient than two decades ago. However, there is still some potential for improvements. Introducing material compounds as, for example, carbon fibre reinforced composites, as well as innovative wing designs will reduce hull and wing weight substantially while decreasing induced air resistance. Apart from optimizing the load factor of airplanes, serious attempts are underway to make air traffic control and navigation more efficient to diminish the actually flown distance. As security is the overwhelming aspect of air traffic, such innovations, however, may take some time.

Slow technical advancements are also the case for large marine engines. They already have the advantage of scaling effects because of their size, and they are a mark of the ICE's efficiency record that has been achieved at a very moderate pace over several decades. Consequently, the potential for future ICE improvements is substantially limited in the marine sector. Other innovations as, for example, hull innovations and air lubrication are more promising and may contribute several per cent to fuel saving in the future.

Oil production and the growing importance of IT

Efficiency improvements and innovative technologies not only reshape the demand side of the energy business; several important developments are underway on the supply side as well.

Directional drilling in combination with hydraulic fracturing, for example, granted access to oil resources formerly considered uneconomic. The collected technical and operational experience, mainly in the US, will likely be further expanded to improve drilling and fracturing efficiency and bring down production costs. Although often criticized as harmful to the environment through the use of hazardous chemical additives for fracturing and venting or incomplete combustion of associated gases, current technology improvements target these issues and are expected to provide solutions in the near future. The reduced thickness of the considered oil-containing geological layers requires efficient seismic equipment to optimize access and exploitation of the tapped resources.

The ever-increasing computing power of modern IT equipment, together with the ongoing data collection in view of geological and geophysical characteristics of a large part of the earth's crust, assist in improving the exploration of new reserves, as well as the supervision of existing oil ones. Innovative imaging methods as, for example, multi-dimensional seismic methods and real-time seismic, are important to achieve these goals. The general movement towards integrating a broad variety of data sources to provide an overall and detailed picture, so-called Big Data strategies, may also play an increasing role in the future for the oil and gas industry.

Closely related is maintaining – and in some cases increasing – the production of what was considered even a decade ago a mature oil field by means of EOR. This is an important asset for oil producing countries. While early EOR used mainly water to drive out more of the contained oil, now CO_2 is also used and may form the single most important CCU application. This prevents the liberation of GHGs into the atmosphere during oil production and, hence, helps to reduce the CO_2 footprint of the petroleum industry as a whole. Formerly unused by-products that were vented, flared or returned to the production well, are now guided towards economic use. Incorporating renewable energy to provide steam and power for exploitation and transport will likely play an increasing role, although it starts from a considerably low level.

In summary, it can be concluded that, despite the technical efforts of replacing fossil sources by renewables, they will remain the dominant source of energy in the foreseeable future. Technical advances do not only benefit renewables, but help to raise energy efficiency as a whole. For example, even with batteries becoming cheaper, conventional ICE powered vehicles can take advantage by means of hybrid technologies. An important aspect is that the far smaller CO_2 footprint of oil and gas when compared to coal makes these energy sources more suitable in view of GHG emissions than commonly assumed. Reducing CO_2 emissions further can be achieved by CCS and CCU, which may possibly provide a more economical solution than renewables in several cases.

Energy demand

Key takeaways

- Total primary energy demand is forecast to increase by 96 million barrels of oil equivalent per day (mboe/d) between 2015 and 2040, rising from 276 mboe/d in 2015 to 372 mboe/d by 2040. In relative terms, this represents a 35% increase compared to the base year of 2015 and an average annual growth rate of 1.2 % during the forecast period.
- Energy demand in Developing countries is set to increase by 88 mboe/d from 2015–2040 compared to energy demand growth of close to 6 mboe/d in Eurasia and around 2 mboe/d in OECD regions.
- Within Developing countries, India and China are the two countries with the largest energy demand additions during the forecast period, both in the range of 22–23 mboe/d.
- The largest contribution to future energy demand is projected to come from natural gas. In absolute terms, demand for gas is expected to increase by almost 34 mboe/d, reaching a level of 93 mboe/d by 2040.
- Other renewables – consisting mainly of wind, photovoltaic, solar and geothermal energy – is projected to be by far the fastest growing energy type with an average annual growth rate of 6.8% over the forecast period. It is estimated to gain a share of 4 percentage points during this period.
- Fossil fuels will retain a dominant role in the global energy mix, although with a declining overall share.
- Oil and gas, combined together, are expected to continue to provide more than half of the global energy needs over the forecast period. Their combined share remains relatively stable between 52–53%.
- Coal demand is projected to peak sometime around 2035 at levels below 87 mboe/d.
- Nuclear energy is projected to grow on average by 2.3% p.a. and increase from 13.5 mboe/d in 2015 to 23.8 mboe/d in 2040. This is estimated to add 1.5% to the share of nuclear energy in global energy demand by 2040 when it is forecast to reach 6.4%.
- Hydropower is projected to grow from 6.8 mboe/d in 2015 to 10.3 mboe/d in 2040.
- Total consumption of biomass is projected to rise by an average of 1.2% p.a. from 2015–2040, or from 28 mboe/d in 2015, to 37.3 mboe/d.
- The gap in energy per capita consumption between developing and OECD countries is forecast to remain wide. Therefore, energy poverty remains a critical issue.

2.1 Major trends in energy demand

The global energy system, the backbone of economic and socio-demographic developments around the world, is currently at a crossroads with several forces and drivers at play. One of these is the factor of energy production costs. In the past year, since the last Outlook was published in November 2016, several signs of a continuing reduction in costs have been evident. This was especially the case for electricity generation by solar and wind energy. In the upstream oil sector, industry has seen a further decline in costs driven primarily by technology improvements and the application of best practices in tight oil production. This has had some spill-over effects in other areas. Elsewhere, natural gas prices in most markets have also remained at lower levels.

Another factor has been the shifting energy policies in consuming countries. Energy issues are evidently high on the agenda of the new US Administration, though more time is needed to evaluate the implications of its shift in policy direction, especially in terms of long-term trends. It remains to be seen to what extent the Administration's declared intentions to revive the US coal industry, open up federal lands for oil and gas production, provide support to the nuclear industry and expand the country's pipeline system will change the overall energy scene in North America.

Moreover, it remains unclear how the formal withdrawal of the US from the Paris Agreement will play out as opposition to this decision is taking shape both domestically and globally. Within the US, several states, cities, institutions and companies have said they will continue to pursue measures driven by climate change concerns. Similarly, in reaction to the decision of the US to withdraw from the Paris Agreement, several other regions countries – led by the EU, China and India – have stated their intention to intensify efforts to reduce emissions.

In regards to policies, the decision of the IMO to limit sulphur content in marine fuels as of January 2020 has also contributed an element of uncertainty to future energy use. The decision, adopted in October 2016, is clouded with uncertainties regarding its implementation and raises questions about the potential implications it may have on oil and energy markets.

The past year has also seen continued intensive discussions about the future of transportation. All major car manufacturers continue to expand the number of models that rely on alternative engines, especially BEVs. In early July 2017, for example, Volvo was the first major car manufacturer to announce that every model in its range will have electrified powertrain available from 2019. Separately, the UK and France announced their intentions to phase out pure internal combustion engine cars as of 2040. At the same time, various new studies, reports and news articles about the growth of car sharing business models, 'autonomous' vehicles and new transport services have been appearing almost daily, leading to increasing questions about the future of transportation. In addition, there are the numerous discussions between policymakers, local authorities and the automobile industry about the future of diesel cars, especially in large cities.

The list of factors to be considered should also include, among others, the current state of the global economy and prospects for economic development, fading financial stimulus from central banks and pricing issues for oil and natural gas, each with more or less direct/indirect implications for future energy demand. One other factor that should not be overlooked is the

trend towards decelerating growth in global carbon emissions resulting from a decoupling of the link between economic growth and emissions. Bearing in mind the limited availability of data, some preliminary estimates indicate that global emissions during 2016 remained broadly unchanged compared to 2015. Although it is premature to speak of a reversal in global emissions, the fact is that increasing efficiency improvements in energy use and energy transformation, as well as the growing share of renewable energy, all play an increasing role in shaping the links between economic developments and emissions.

Taking into account all these developments, as well as the assumed prospects for economic growth, socio-demographic trends and other factors described in Chapter 1, total primary energy demand is forecast to increase by 96 mboe/d between 2015 and 2040, rising from 276 mboe/d in 2015 to 372 mboe/d by 2040 (Table 2.1). In relative terms, this represents a 35% increase compared to the base year of 2015, with an average annual growth rate of 1.2 % during the forecast period.

This significant growth in global energy demand is, however, unequally distributed among major regions and country groupings. Energy demand in Developing countries is expected to grow

Table 2.1
Total primary energy demand by region

	Levels *mboe/d*				Growth *%p.a.*	Share of global energy demand *%*			
	2015	**2020**	**2030**	**2040**	**2015–2040**	**2015**	**2020**	**2030**	**2040**
OECD America	56.0	57.5	58.0	57.6	0.1	20.3	19.3	17.1	15.5
OECD Europe	35.7	36.9	36.2	35.3	0.0	12.9	12.4	10.7	9.5
OECD Asia Oceania	18.3	19.0	19.3	19.2	0.2	6.6	6.4	5.7	5.2
OECD	**110.0**	**113.5**	**113.6**	**112.0**	**0.1**	**39.9**	**38.0**	**33.5**	**30.1**
China	62.7	69.0	79.7	84.9	1.2	22.7	23.1	23.5	22.9
India	16.8	20.6	30.4	39.7	3.5	6.1	6.9	9.0	10.7
OPEC	19.8	21.5	26.9	31.3	1.9	7.2	7.2	7.9	8.4
Other DCs	44.5	50.3	62.8	75.7	2.1	16.1	16.9	18.5	20.4
DCs	**143.8**	**161.5**	**199.9**	**231.7**	**1.9**	**52.1**	**54.2**	**58.9**	**62.4**
Russia	13.9	14.3	15.6	16.5	0.7	5.0	4.8	4.6	4.4
Other Eurasia	8.3	9.0	10.3	11.4	1.3	3.0	3.0	3.0	3.1
Eurasia	**22.2**	**23.3**	**25.9**	**27.8**	**0.9**	**8.0**	**7.8**	**7.6**	**7.5**
Total world	**276.0**	**298.2**	**339.4**	**371.6**	**1.2**	**100**	**100**	**100**	**100**

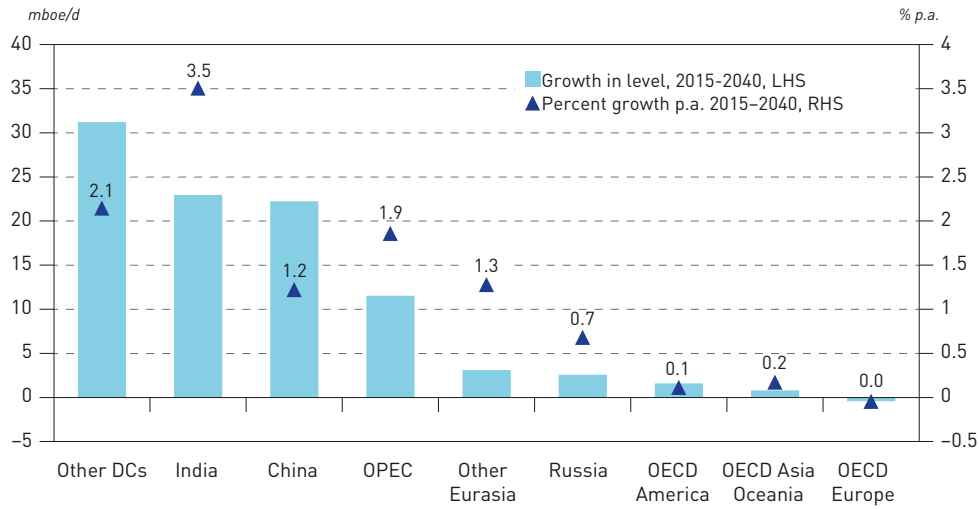
at an average rate of 1.9% p.a. over the period 2015–2040. This is in sharp contrast with an average 0.1% p.a. growth rate projected for the OECD and 0.9% p.a. for Eurasia. The key reasons for this variation are the different prospects that exist among the major country groups in terms of population growth, urbanization rates and growth in economic activity. On average, Developing countries are forecast to post a real GDP growth rate of 4.5% p.a. (on a PPP basis) over the 2015–2040 period compared with an average 2% p.a. growth in the OECD. Varying prospects in respect to population growth are even more pronounced with the majority of the additional population by the end of the forecast period living in Developing countries (1.7 billion people out of a 1.8 billion total increase). Moreover, a large group of people in the Developing countries are expected to gain access to modern energy services for the first time during the forecast period. In contrast to this, OECD countries are at a more mature and saturated stage of development, and thus have a much lower rate of population growth and thus a lower potential for energy demand growth. Eurasia as a region stands somewhere in between. With prospects for average GDP growth at 2.5% p.a. and a marginally declining population, its energy demand is set to increase at rates slightly below the global average.

In terms of the actual quantity of energy demand in Developing countries, this is set to increase by 88 mboe/d from 2015–2040 compared to energy demand growth of close to 6 mboe/d in Eurasia and around 2 mboe/d in OECD regions. Within Developing countries, India and China have the largest additional energy demand during the forecast period, both in the range of 22–23 mboe/d. It should be noted, however, that recent projections see India as the single largest contributor to future energy demand for the first time, followed by China and other countries.

There are two main reasons for this change. The first has to do with the modified prospects for economic activity in these countries, which have resulted in mainly downward revisions for China's GDP growth compared to last year's WOO. The second reason is more policy-oriented. Recent signals and specific actions being undertaken by China – such as the closure of several inefficient coal power plants, the cancellation of plans to build new power plants and the rapid expansion of renewable energy sources – have raised the credibility of government efforts to combat domestic pollution problems, contribute to efforts to reduce global emissions and use energy more efficiently. As a result, overall energy demand in China by 2040 has been reduced by more than 3 mboe/d this year, compared to last year's projections.

In terms of shares, Developing countries are anticipated to consume more than 62% of global energy demand by 2040, compared to the current share of around 52%. Despite the highest growth in energy demand being in India, China is projected to retain the largest share of global energy demand, on a country basis, with around 23% over the entire period. India's share of energy demand is estimated to increase from around 6% in 2014 to almost 11% in 2040, registering the largest gain in overall share. The second largest gain in share (more than 4 percentage points) is projected for the group of countries named 'Other DCs' which consists of a wide range of developing countries at various stages of development. In fact, this is a group with the highest contribution to additional energy demand (of more than 31 mboe/d between 2015 and 2040). An increasing share in global energy demand is also projected for OPEC. However, the change is at a much more moderate level – in the range of around 1 percentage point.

Figure 2.1
Growth in primary energy demand by region, 2015–2040



The shares of other major regions in global energy demand are projected to decline. For the OECD, the share of total world energy demand is forecast to decrease from about 40% in 2015 to 30% in 2040, while Eurasia's share is expected to decrease marginally from slightly above 8% in 2015 to around 7.5% in 2040. These projections are driven by the future outlook for demographics, economic growth, changes in the structure of national economies, technology and policy developments, as discussed in detail in Chapter 1.

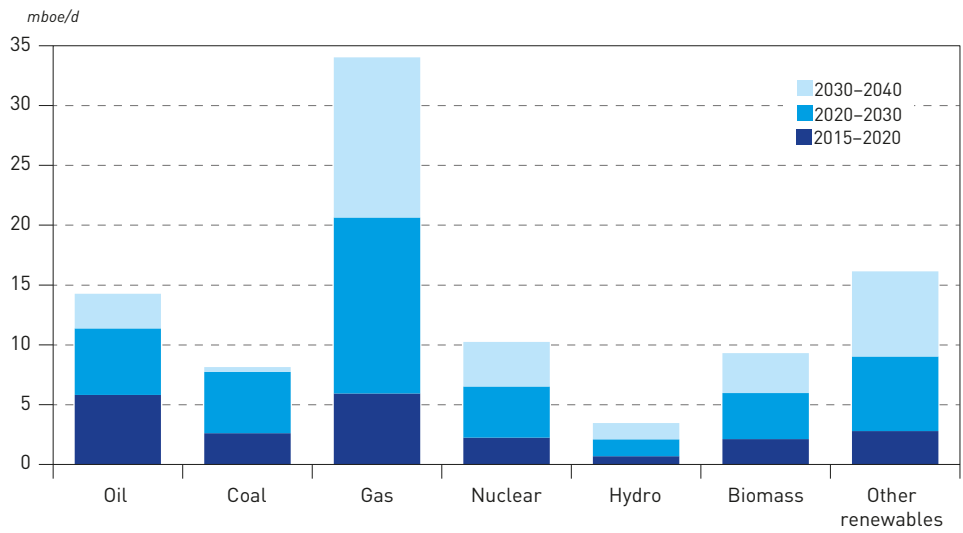
Besides shifts in regional energy demand, significant changes in the global energy industry are also expected in terms of its mix. Trends from past years – such as the rapid growth of renewable energy, the expansion of gas, moderate growth in oil demand and slowing growth or even declining demand for coal in several regions – are set to continue changing the future energy mix towards a less carbon-intensive one, as summarized in Table 2.2 and Figure 2.2.

At the global level, the largest contribution to future energy demand is projected to come from natural gas. In absolute terms, demand for gas is estimated to increase by almost 34 mboe/d, reaching a level of 93 mboe/d by 2040. Accordingly, its share in the global energy mix is also anticipated to increase significantly by 3.6 percentage points. This represents the second largest increase in fuel shares, only behind other renewables. This fuel category – consisting mainly of wind, photovoltaic, solar and geothermal energy – is projected to be by far the fastest growing energy type with an average annual growth rate of 6.8% over the forecast period. It is estimated to gain a share of 4 percentage points during this period. However, its current base is rather low, contributing around only 1.4% to the global energy demand. Hence, the share of other renewables will still be below 5.5% by 2040, despite its impressive growth.

Table 2.2
World primary energy demand by fuel type

	Levels *mboe/d*				Growth *% p.a.*	Fuel shares *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
Oil	86.5	92.3	97.9	100.7	0.6	31.3	30.9	28.8	27.1
Coal	78.0	80.7	85.8	86.2	0.4	28.3	27.0	25.3	23.2
Gas	59.2	65.2	79.9	93.2	1.8	21.5	21.9	23.5	25.1
Nuclear	13.5	15.8	20.1	23.8	2.3	4.9	5.3	5.9	6.4
Hydro	6.8	7.5	9.0	10.3	1.7	2.5	2.5	2.6	2.8
Biomass	28.0	30.1	34.0	37.3	1.2	10.1	10.1	10.0	10.0
Other renewables	3.8	6.6	12.9	20.0	6.8	1.4	2.2	3.8	5.4
Total	**276.0**	**298.2**	**339.4**	**371.6**	**1.2**	**100**	**100**	**100**	**100**

Figure 2.2
Growth in energy demand by fuel type, 2015–2040



The second fastest growing energy source is projected to be nuclear energy that is considered by many countries as a way to reduce CO_2 emissions and address the issue of energy security. In the Reference Case, nuclear energy is estimated to meet more than 10 mboe/d of additional energy demand to 2040, contributing more than 6% to the global energy mix by the end of the forecast period. The overall expected increase in nuclear energy (in terms of additional energy demand) will almost triple the incremental contribution of hydropower and also surpass those increases coming from biomass (including primary solid biofuels, industrial and municipal waste, liquid biofuels, biogases and charcoal) and coal (Figure 2.2).

It is to be noted that, at the global level, all major fuel types record positive growth in the Reference Case over the forecast period. Alongside the outstanding average growth rate of 6.8% projected for other renewables, gas, nuclear and hydropower grow at levels of around 2% p.a. on average while biomass is seen as growing at a rate of 1.2% p.a., close to the global average of all energy types. Contrary to these energy sources, oil and coal are projected to grow at much lower rates of 0.6% and 0.4% p.a., respectively. Despite these relatively low rates, fossil fuels will retain a dominant role in the global energy mix, although with a declining overall share. Indeed, the share of fossil fuels in the global energy mix stood at 81% in 2015. This is estimated to decline below 80% by 2020 and then drop further to under 78% by 2030 to reach a share of 75.4% by 2040.

The trend of declining share of fossil fuels is led by coal, which is set to lose more than 5 percentage points, followed by oil whose share is expected to decline by more than 4 percentage points. This progressive shift away from coal and oil towards gas and renewables is a reflection of ongoing policies to address climate change concerns. The declining share of oil in the energy mix is mainly the result of tightened fuel efficiency standards across most countries of the world. Examples of such measures include Corporate Average Fuel Economy (CAFE) and Corporate Average Fuel Consumption (CAFC) standards in the US and India, respectively, the Energy Efficiency Directive in the EU and the Federal Sustainable Development Strategy in Canada, among others. Moreover, a gradual increase in the penetration of alternative vehicles (as discussed in more detail in Chapter 3) also plays a role. In the case of coal, the loss in its share in the overall energy mix has mainly been driven by its substitution by natural gas and renewable electricity, which are more environmentally acceptable alternatives. Moreover, it is worth mentioning that this year's Reference Case sees coal demand peaking sometime around 2035. It is the only primary energy source expected to see peak demand at the global level.

2.2 Regional primary energy demand

In principle, the major global trends in energy demand already outlined are also clearly present at the regional level. However, there are also some variations and specifics that become obvious at a more granular regional level. Firstly, there are quite significant differences in the current structure of energy demand across major regions. Clearly, these differences become more pronounced if more specific country groupings are considered. Secondly, future trends also vary according to the regional definitions used, which reflect such issues as their level of economic development, natural resource endowments and population demographics.

Starting with the three major country groupings, OECD, Developing countries and Eurasia, Tables 2.3–2.5 show the primary energy demand by fuel type for these regions. Comparing the

Table 2.3
OECD primary energy demand by fuel type

	Levels *mboe/d*				Growth *% p.a.*	Fuel shares *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
Oil	41.5	42.2	37.8	32.9	–0.9	37.7	37.2	33.3	29.4
Coal	20.0	18.5	16.0	13.7	–1.5	18.1	16.3	14.1	12.3
Gas	27.5	28.9	31.1	32.5	0.7	25.0	25.5	27.4	29.0
Nuclear	10.5	11.3	12.3	13.0	0.9	9.5	9.9	10.8	11.6
Hydro	2.5	2.6	2.8	3.0	0.7	2.2	2.3	2.5	2.6
Biomass	6.2	6.9	8.1	9.3	1.6	5.7	6.1	7.1	8.3
Other renewables	2.0	3.1	5.4	7.7	5.6	1.8	2.7	4.8	6.9
Total	**110.0**	**113.5**	**113.6**	**112.0**	**0.1**	**100**	**100**	**100**	**100**

Table 2.4
Developing countries primary energy demand by fuel type

	Levels *mboe/d*				Growth *% p.a.*	Fuel shares *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
Oil	40.0	44.7	54.2	62.0	1.8	27.9	27.7	27.1	26.8
Coal	54.1	58.1	65.4	68.0	0.9	37.7	36.0	32.7	29.3
Gas	21.3	25.5	36.9	48.2	3.3	14.8	15.8	18.5	20.8
Nuclear	1.5	2.7	5.6	8.2	7.1	1.0	1.7	2.8	3.5
Hydro	3.9	4.4	5.6	6.7	2.2	2.7	2.7	2.8	2.9
Biomass	21.2	22.6	25.1	27.1	1.0	14.7	14.0	12.5	11.7
Other renewables	1.8	3.4	7.2	11.6	7.7	1.3	2.1	3.6	5.0
Total	**143.8**	**161.5**	**199.9**	**231.7**	**1.9**	**100**	**100**	**100**	**100**

Table 2.5
Eurasia primary energy demand by fuel type

	Levels *mboe/d*				Growth *% p.a.*	Fuel shares *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
Oil	5.0	5.4	5.8	5.8	0.6	22.4	23.2	22.5	20.8
Coal	3.9	4.0	4.4	4.5	0.5	17.7	17.4	17.1	16.1
Gas	10.5	10.7	11.8	12.6	0.7	47.4	46.2	45.6	45.4
Nuclear	1.6	1.8	2.1	2.6	1.9	7.2	7.7	8.3	9.3
Hydro	0.5	0.5	0.6	0.7	1.0	2.3	2.3	2.3	2.4
Biomass	0.6	0.7	0.8	1.0	1.7	2.8	2.9	3.1	3.4
Other renewables	0.0	0.1	0.3	0.7	12.3	0.2	0.3	1.1	2.6
Total	**22.2**	**23.3**	**25.9**	**27.8**	**0.9**	**100**	**100**	**100**	**100**

base 2015 data indicates that there are noticeable differences in the importance of the three main fossil fuels across these regions: oil has the largest share in the energy mix in the OECD region (38%), followed by gas (25%). Coal is the most prominent fuel in Developing countries (38%), followed by oil (28%). In Eurasia, gas accounts for 47% of the energy mix, followed by oil (23%). These are largely an indication of the availability of each fossil fuel across the three regions, in addition to the role that the transportation sector has in some regions, especially the OECD, which evidently shifts the share of oil.

Moreover, differences in the current energy mix are not only limited to fossil fuels. Wide differences also exist for the contribution of nuclear energy and biomass to the overall energy mix. Nuclear energy contributes almost 10% to energy demand in the OECD, while its share in Eurasia is around 7%. In contrast, its share in Developing countries is just 1%. Biomass, on the other hand, contributes a much higher share to energy needs in Developing countries – almost 15% – than in the other two major regions. This is due to the fact that biomass is still the primary source of energy for individuals living in rural areas in many developing countries, often accounting for more than 90% of a household's energy consumption.

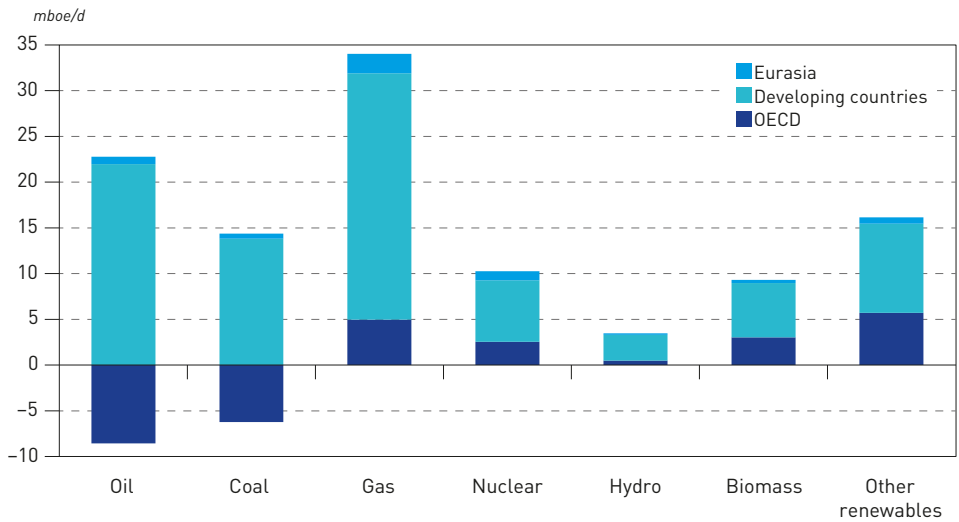
Conversely, the residential consumption of biomass in OECD countries accounts for less than 20% of the total use of biomass. In the OECD, most of it is typically consumed for heat and electricity generation, industrial use and the production of biofuels. A similar pattern can also be seen in Eurasia, though with a somewhat higher share of residential use and lower usage for biofuels production. Moreover, in both of these regions the contribution of biomass to the energy mix is relatively low, with less than 6% in the OECD and below 3% in Eurasia.

Future changes in energy demand by fuel will also likely vary across regions. This reflects variations in the current regional base demand, as well as the economic and demographic changes that will not be uniform across all regions over the forecast period. These variations are summarized in Figure 2.3, which shows total energy demand growth by fuel type for each of the three regions.

The key to understanding future energy trends relates mainly to what happens in developing countries, as several factors with counterbalancing effects will be at play there. Supporting the demand growth of all energy types is expected population growth and an expansion of economic activities, especially if combined with the United Nation's SDGs such as ending extreme poverty (Goal 1) and ensuring access to affordable, reliable and modern energy for all (Goal 7). At the same time, the need for growing energy demand should also be seen in the context of the emerging global frameworks aimed at limiting future carbon emissions levels. This will certainly have an impact on the future energy mix of developing countries. Access to modern energy sources should reduce the shares of both (traditional) biomass and coal in the energy mix in these countries. On the other hand, the shares of gas, other renewables and nuclear energy are expected to increase over the forecast period.

Indeed, as already outlined in Table 2.1, more than 90% of future energy demand growth from 2015–2040 will come from Developing countries. Figure 2.3 shows that the pattern of dominant demand increases from Developing countries holds true across all fuel types. The

Figure 2.3
Growth in energy demand by fuel type and region, 2015–2040



Box 2.1

Africa – The next frontier?

As reviewed in this Chapter, Developing Countries constitute 90% of future energy demand growth through 2040. While India and China represent the lion's share of this demand growth, Other Developing Countries, including those in the African continent, will continue to grow significantly. As the African continent continues to grow and develop, it has significant potential to emerge as the next frontier in energy demand growth – provided that critical human and economic resources are deployed carefully and strategically.

The main sources of upside potential for Africa stem from the continent's burgeoning population, increasing urbanization, natural resource deposits, infrastructure development, and technology adoption leading to leap-frogging. These themes underpin the anticipated growth of African economies, leading institutions such as the International Monetary Fund (IMF) and Oxford Economics to predict that the region will experience an annual GDP growth rate of 4.3% and 4.4% respectively between 2016 and 2020. Consequently, Africa is foreseen to become the second fastest growing region in the world, after Asia, by 2020.

By 2040, 2.1 billion people are anticipated to call Africa home, with Nigeria expected to have the highest population of 333 million people (or about 16% of the total region's population). The bulk of the region's population growth is characterized by working age population (between the ages of 15–64), which are anticipated to make up over 60% of the region's population by 2040 – compared to 56% in 2015. An increasingly youthful population provides the potential to create a thriving labour force, provided that job opportunities are created and sustained over time.

Urbanization is taking place in Africa at a rapid pace, driven by population growth. By 2040, over half of the continent's population is projected to live in urban areas, growing from over 42% in 2020, and 40% in 2015. While urbanization presents vast opportunities, significant strategies and strong political commitment are required to harness the full potential of such population growth, by way of poverty alleviation and access to affordable energy, jobs, education, and adequate healthcare.

Leap-frogging is considered a unique property of African economic development, through technological advancement and access to capital investment. While agricultural productivity and industrialization have historically fuelled other economies, in 2014, the services sector contributed to almost 60% of Africa's GDP.

Continental economic integration is a top priority for African leadership, and is a critical element of African Union's (AU) Agenda 2063. In 2016,[4] the AU proceeded with the issuance of a common passport among African citizens. Trade and infrastructure connectivity are also high on the AU agenda, with the first phase of the Continental Free Trade Area (CFTA) negotiations expected to be reached by the end of 2017.

While the opportunities for an African renaissance are boundless, challenges remain. Government leaders have the opportunity to elevate the continent's economic position through the mobilization of domestic resources, economic diversification, and achieve poverty alleviation through sustainable job creation, education and healthcare opportunities, and the provision equitable access to affordable energy resources.

largest demand growth is expected for gas which is projected to increase by 27 mboe/d between 2015 and 2040, followed by oil and coal with 22 mboe/d and 14 mboe/d, respectively. Overall, Developing countries' energy demand is expected to grow by 1.9% p.a. on average from 2015–2040, with the fastest growth rate forecast for other renewables (7.7% p.a.) and nuclear (7.1%). On the low end, biomass energy demand is estimated to grow 1% p.a. over the forecast period.

Within Developing countries, it is worth taking a more detailed look at the energy demand mix of the two largest and most populous economies, China and India. Energy demand in these two countries together constitutes more than 55% of the overall demand in Developing countries and close to 30% of the global demand.

Given China's abundance of natural resources, its primary energy demand is currently dominated by coal with a share of 64% of the total energy mix (see Table 2.6). Because of this high base demand, it is inevitable that coal will remain a dominant source of energy in China for the foreseeable future, despite the fact that its share is set to decline significantly, to below 50% by 2040. Despite this decline, coal is still anticipated to be by far the most important fuel in China's energy mix by 2040.

In the Reference Case, coal demand in China is projected to lose almost 16 percentage points of its share in the period through 2040, although, in absolute terms, its demand will decline to around 1 mboe/d over the forecast period. To a large extent, this is the result of the significant growth in other energy sources (led by gas, oil, nuclear and renewable energy), but also due to the changing pattern of coal demand over time. After a period of rather sluggish growth

Table 2.6
China primary energy demand by fuel type

	Levels *mboe/d*				Growth *% p.a.*	Fuel shares *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
Oil	11.0	12.5	14.7	16.5	1.6	17.5	18.2	18.5	19.4
Coal	40.3	41.6	43.3	41.3	0.1	64.3	60.3	54.3	48.6
Gas	3.3	4.5	7.1	9.0	4.1	5.3	6.5	8.9	10.6
Nuclear	0.8	1.8	4.1	5.8	8.3	1.3	2.6	5.2	6.8
Hydro	1.9	2.0	2.4	2.7	1.5	3.0	3.0	3.0	3.2
Biomass	4.5	4.7	5.1	5.3	0.7	7.2	6.8	6.3	6.3
Other renewables	0.9	1.8	3.0	4.3	6.3	1.5	2.6	3.8	5.0
Total	**62.7**	**69.0**	**79.7**	**84.9**	**1.2**	**100**	**100**	**100**	**100**

until around 2025, coal demand in China is anticipated to peak sometime around 2030 before declining during the last decade of the forecast period.

There are several reasons for this. The first one relates to the structural changes in the Chinese economy, which is experiencing a shift from energy intensive industries to services and light industry. Part of this transition is also a technology driven shift to higher energy efficiency across a wide range of sectors. Moreover, a significant deceleration of coal demand growth is also a result of policy driven efforts to reduce the country's emissions. Coal offers China many cost-effective options to achieve such a goal. As part of the efforts, in January 2017, China's National Energy Administration (NEA) cancelled more than 100 projects for planned coal-fired power plants, including some (a total of 15) that were already under construction. In addition, the upgrading of existing equipment with low-emissions technology and increased efficiency is taking place in a number of coal power plants.

As mentioned earlier, while shifting away from coal, the growing energy needs of China will primarily be provided by gas, oil, nuclear and renewable energy. Oil will be mainly used as an energy source in the transportation and petrochemical sectors. The other three sources will compete more directly with coal in the electricity sector. Nuclear energy in China, in particular, is set for impressive growth, in terms of both additional energy provided (+5 mboe/d) and average growth rates (8% p.a. on average). Other renewables are also expected to post strong growth of 5.9% p.a. from 2015–2040, contributing more than 3 mboe/d to the future energy mix of China.

Similar to China, India's energy mix is also dominated by coal, which has a 45% share of the energy mix followed by oil with 24% (Table 2.7). Compared to China, however, energy demand in India is set to grow much faster, at an overall average rate almost three times that of China. The main reason for this is that India is at a different stage of development with a very low base demand, especially if measured on a per capita basis. According to the IMF, the percentage of the population living below the national poverty line in India was close to 30% in 2013. Moreover, energy poverty in India is one of the critical issues that needs to be addressed with around 100 million people living with no access to electricity. It is important to note that the country's high energy demand growth is accompanied – and, to a large extent, driven – by high population growth. As a result, even by 2040, energy consumption per capita in India is still expected to be much lower (by a factor of almost three) than in China despite impressive average growth rates.

In terms of the energy mix, demand for coal and oil in India is each projected to grow at 3.8% p.a. on average. This is above the average growth for total energy in the country. Hence, the share of coal is estimated to increase to 48% by 2040. Similarly, gas and renewable energy are also anticipated to see an increase in their share by around 3 percentage points. The fastest growing energy sources in India are forecast to be other renewables and nuclear energy, which are projected to increase an average of 11.1% p.a. and 7.4%, respectively. On the other hand, biomass demand growth is expected to be subdued, registering 0.4% p.a., while the share of biomass is forecast to fall from 23% in 2015 to 11% in 2040. This would likely be the result of a combination of factors such as a limited resource base for biomass, the intentions of Indian policymakers to contribute to emissions abatement by increasing forestation and by shifting away from traditional biomass (used primarily in rural areas for cooking) towards other fuel sources (such as LPG and kerosene).

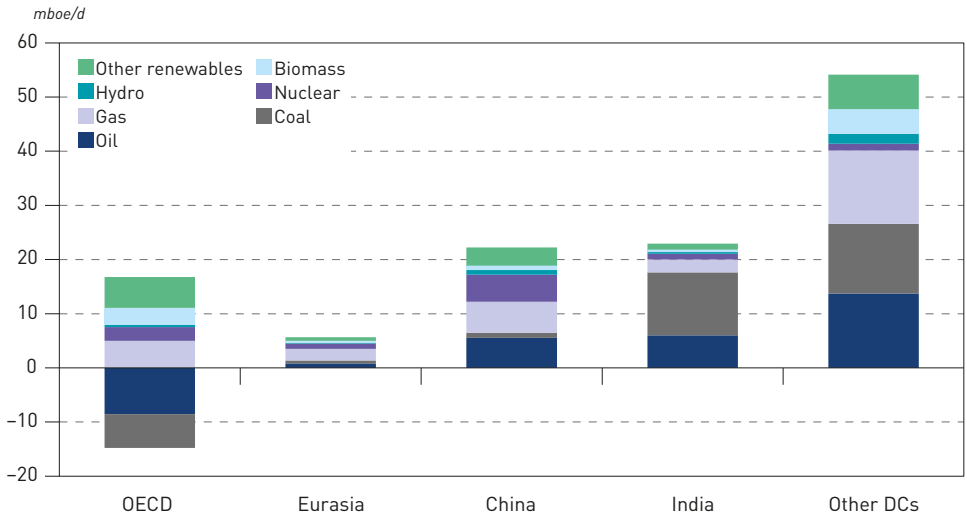
Table 2.7
India primary energy demand by fuel type

	Levels *mboe/d*				Growth *% p.a.*	Fuel shares *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
Oil	3.9	4.9	7.5	9.9	3.8	23.5	24.0	24.6	25.0
Coal	7.5	9.6	14.6	19.1	3.8	44.8	46.3	48.0	48.2
Gas	0.9	1.2	2.1	3.3	5.2	5.5	5.6	6.8	8.3
Nuclear	0.2	0.4	0.8	1.3	7.4	1.3	1.8	2.5	3.1
Hydro	0.2	0.3	0.4	0.6	3.6	1.4	1.5	1.5	1.4
Biomass	3.9	4.1	4.3	4.3	0.4	23.0	19.8	14.3	10.9
Other renewables	0.1	0.2	0.7	1.2	11.1	0.5	1.1	2.3	3.0
Total	**16.8**	**20.6**	**30.4**	**39.7**	**3.5**	**100**	**100**	**100**	**100**

Energy demand increases in the two other major regions – OECD and Eurasia – are significantly lower than those in Developing countries. This is well illustrated in Figure 2.4. Nevertheless, they will also experience important changes in the composition of the energy mix over the forecast period. In the OECD, while total energy demand is expectd to stay in a fairly narrow range, the greatest shifts in the energy mix are forecast to occur from a lower reliance on oil (–8.6 mboe/d) and coal (–6.2 mboe/d) and a shift towards other renewables (+5.7 mboe/d) and gas (+5 mboe/d). Some additional contribution to the energy mix is also expected from nuclear energy (+2.5 mboe/d) and hydro (+0.5 mboe/d). These shifts are primarily a reflection of growing environmental concerns and related policy measures aimed at reducing global carbon emissions and minimizing local pollution. These policies not only provide direct support to the expansion of renewable energy (such as wind, solar and geothermal), but also provide incentives for fostering technology developments that result in better energy efficiency (thus, energy savings) and accelerating the substitution of current fuels with less carbon emitting energy sources.

Compared to the OECD, energy demand in Eurasia is set to grow somewhat faster, at 0.9% p.a. on average over the forecast period, leading to an overall increase of 5.7 mboe/d. Although the projected shifts in the energy mix in this region are less pronounced, they are still revealing. While all types of energy sources see positive growth between 2015 and 2040, there is estimated to be an overall decrease in the share of fossil fuels. In aggregate, their share is anticipated to decrease by more than 5 percentage points, with gas having the largest decrease of 2 percentage points followed by coal and oil, both decreasing by slightly more than 1.5 percentage points. The declining share of fossil fuels is be primarily offset by gains in other renewables (+2.4 percentage points) and nuclear (+2.1 percentage points). Some potential for

Figure 2.4
Energy demand growth by region, 2015–2040



increases in both additional energy and in terms of share is also seen in biomass, while the use of hydropower will likely remain virtually unchanged from its current levels.

2.3 Global primary energy demand

2.3.1 Oil

Oil is expected to remain the main fuel in the global energy mix during the forecast period. Between 2015 and 2040, demand is expected to grow by 14.3 mboe/d, from 86.5 mboe/d observed in 2015 to 100.7 mboe/d projected for 2040. This makes oil the third largest contributor to energy demand growth, surpassed only by other renewables and gas. It is interesting to observe that oil's share in the global energy mix is expected to decline by over 4 percentage points, falling from 31% in 2015 to 27% in 2040. Despite this decline, however, it is forecast to remain the energy source with the highest share in the energy mix over the forecast period. In fact, the average rate of oil demand growth is anticipated to be only half of that of global energy demand. At the global level only coal is expected to grow at a lower growth rate than oil during the forecast period.

As already mentioned, this year's projection indicates that oil will remain as the lead fuel in the energy mix up to 2040. In the past few WOOs (since 2014), gas was anticipated to overtake oil as the main fuel towards the second half of the 2030s. There are a number of reasons why this view has changed. To begin with, the historical baseline of oil demand has been revised upwards (for more details refer to Box 3.1). Secondly, oil demand has exhibited very healthy

growth in 2015 and 2016, and it is anticipated that this strong trend will continue in 2017 and 2018. This also shifts the long-term expectations upwards. Moreover, the lower oil price assumption adopted this year also provides some support to future oil demand. Finally, gas is facing stronger-than-expected competition from other renewables and nuclear in the power generation sector, which has contributed to a downward revision in expected gas demand growth.

While a detailed analysis of the oil demand and supply outlook is provided in Chapters 3 and 4, it is important to note that the figures shown in this Chapter are not directly comparable with those shown in Chapter 3 and 4. There are a number of reasons for this. Firstly, Chapter 2 uses energy equivalent units (mboe/d) to make the correct comparison between the different fuel types. In Chapters 3 and 4, however, oil is expressed in volumetric units (mb/d). Secondly, the definition of oil in Chapter 2 is different from that used in Chapters 3 and 4. While Chapter 2 deals with the origin of energy, the other chapters consider the liquids fuel outlook. In that sense, while in Chapter 2 biofuels is considered as biomass, coal-to-liquids (CTLs) as coal and gas-to-liquids (GTLs) as gas, in Chapters 3 and 4 they are all part of the liquids outlook.

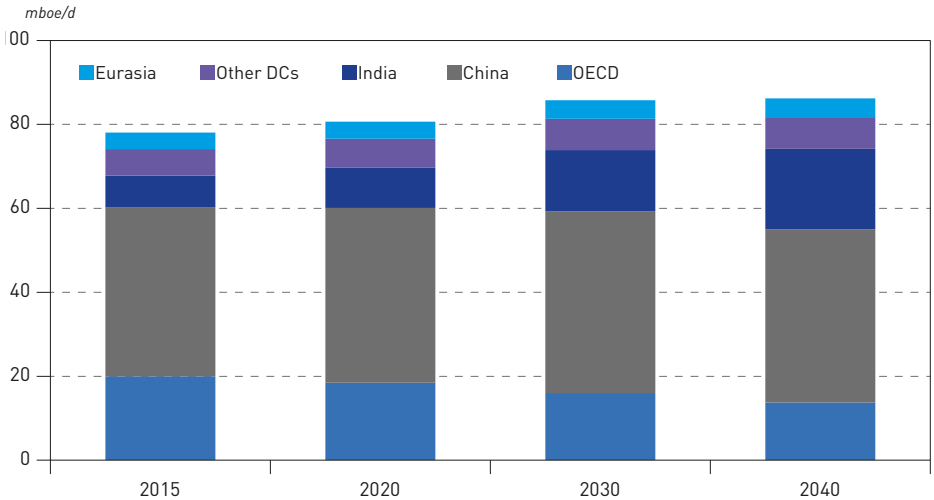
2.3.2 Coal

Long-term projections for coal are marked by two key observations mentioned earlier in this Chapter. First, it is the energy source whose share declines the most at the global level. Second, it is the only fuel for which demand is set to peak over the forecast period. This overall demand pattern for coal is a result of the counterbalancing effects of its driving factors. Supportive to its future demand are economic and population growth, both of which result in rising demand for energy and electricity, especially in developing countries. On the other hand, climate policy measures, including the expansion of renewables and energy efficiency measures, combined with concerns about pollution, the weakening competitiveness of coal against other fossil fuels and changes in economic structure all remain hurdles for coal demand in the long-term.

For most of the forecast period, until around 2030, economic and population growth will likely outweigh the effects of policies and other constraining factors with the net effect being a growing demand for coal. At the same time, however, the growth of global coal demand will significantly slow, before plateauing sometime between 2030 and 2035 and marginally declining for the rest of the period. An implication of this development is that the share of coal demand in the global energy mix is expected to decline by more than 5 percentage points to around 23% in 2040 from levels above 28% in 2015.

On a regional basis, projections for coal demand provided in Table 2.8 and Figure 2.5 show differentiated trends. While coal use in most developing countries is expected to rise, adding almost 14 mboe/d to future demand by 2040, the OECD region is estimated to show a strong decline in coal demand as the fuel is gradually phased out, primarily driven by policy measures and the substitution of cleaner alternatives, such as natural gas and renewable electricity. China and Eurasia stand somewhere in between as coal demand in these two regions/countries is projected to peak and gradually start to decline within the forecast period.

Figure 2.5
Coal demand growth by major regions, 2015–2040



Developing countries, which already contribute to the bulk of global coal demand, are expected to expand their share even further in the long-term, by almost 10 percentage points between 2015 and 2040. The key to this expansion is India while the other dominant player in the regional coal market, China, is expected to see a loss in its share of almost 4 percentage points.

India is currently ranked as the third largest electricity producer and consumer in the world after China and the US. As a fast-growing country (in terms of both GDP and population), demand for power in India has hugely increased over recent years and this trend is expected to continue during the projection period. Total generated power in India stood at 1,430 TWh in 2015 and it is expected to see an average of 4.5% annual growth until 2040. To meet this massive increase in electricity demand, India is considering all sources of power supply to be able to provide end users with sufficient electricity. A significant portion of these additional needs will be provided by coal, largely also due to the fact that the country is a large coal producer. Accordingly, its demand for coal is expected to increase by 11.6 mboe/d by 2040, compared to 2015.

This pattern of fast growth shifts, however, if China is considered. Demand for coal in China – which for years was leading world demand growth – is no longer experiencing any significant increases. Nevertheless, it is still projected to remain the largest coal market in the world within the forecast period. Coal-fired plants in China account for more than 70% of its electricity generation, which is projected to grow on average by 2% p.a. in the period to 2040. As shown earlier, the majority of additional electricity in China will be provided by other energy sources but coal will remain the dominant fuel.

Table 2.8
Coal demand by region

	Levels *mboe/d*				Growth *% p.a.*	Share of global energy demand *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
OECD America	9.3	8.5	7.4	6.4	–1.5	11.9	10.5	8.7	7.5
OECD Europe	5.7	5.2	4.2	3.4	–2.1	7.3	6.4	4.9	3.9
OECD Asia Oceania	5.0	4.8	4.4	4.0	–0.9	6.4	5.9	5.1	4.6
OECD	**20.0**	**18.5**	**16.0**	**13.7**	**–1.5**	**25.6**	**22.9**	**18.7**	**16.0**
China	40.3	41.6	43.3	41.3	0.1	51.7	51.6	50.5	47.9
India	7.5	9.6	14.6	19.1	3.8	9.6	11.8	17.0	22.2
OPEC	0.1	0.1	0.1	0.1	–0.1	0.1	0.1	0.1	0.1
Other DCs	6.2	6.9	7.4	7.5	0.7	8.0	8.5	8.6	8.7
DCs	**54.1**	**58.1**	**65.4**	**68.0**	**0.9**	**69.4**	**72.1**	**76.2**	**78.9**
Russia	2.0	2.1	2.4	2.4	0.8	2.6	2.6	2.8	2.8
Other Eurasia	1.9	1.9	2.1	2.0	0.3	2.5	2.4	2.4	2.4
Eurasia	**3.9**	**4.0**	**4.4**	**4.5**	**0.5**	**5.0**	**5.0**	**5.2**	**5.2**
Total world	**78.0**	**80.7**	**85.8**	**86.2**	**0.4**	**100**	**100**	**100**	**100**

The recent slowdown in China's coal demand due to a combination of slower economic growth and a shift away from energy-intensive industries (that is, declining energy intensity), but also environmental policies aimed at reducing air pollution and CO_2 emissions. Moreover, public opinion in China is increasingly turning against coal-fired power plants, thus creating additional hurdles for coal use in the country. This is also reflected in the recent decision of China's NEA to halt more than 100 projects for new coal-fired power plants, including some that are already under construction. Furthermore, the ongoing replacement of old coal-fired power generation units with highly efficient coal power plants is also contributing to a decrease in coal demand per unit of power produced.

Given these developments and despite current weaknesses, China's coal demand is expected to continue growing in the next 10–15 years, although at a much lower average rate compared to the recent past. As a result, coal demand in China is estimated to reach its maximum at around 43.3 mboe/d in 2030. It is then expected to decline slightly during the last decade of the forecast period to stand at 41.3 mboe/d in 2040. Compared to last year's projections, this represents a significant downward revision in China's long-term coal demand of almost 5 mboe/d.

The group of Other DCs, which includes coal-rich countries like Indonesia, South Africa, Colombia and Vietnam, shows a moderate demand increase over the forecast period, at 0.7% p.a. on average, leading to additional demand of 1.2 mboe/d. Growing economies such as Indonesia, Thailand and Vietnam show strong demand growth over the outlook period. This is, however, offset by moderate growth and declines in several other developing countries.

In Russia, coal demand is set to grow at rates comparable to those in Other DCs. This will also likely be the case of Ukraine and Kazakhstan. However, higher growth rates in these countries are partly moderated by sluggish increases and declines in other countries of the Eurasia region, so that the overall growth rate for the region is 0.5% p.a. Nevertheless, the share of coal in the total energy mix of Eurasia is expected to gradually decline to 16% in 2040, down from almost 18% in 2015. This is due to the expansion of other fuels such as nuclear and renewables.

In OECD countries, the picture for coal is gloomy with countries there set to reduce coal use in both the power generation and industrial sectors. This is driven not only by regulation (including a push for greater renewables use), which has squeezed coal out of the energy mix, but also by increasing energy efficiency and growing competition from cleaner alternative fuels such as natural gas. Population growth and changes in the structure of the economy have contributed to this trend. In absolute terms, coal demand is expected to decline from 20 mboe/d in 2015 to 13.7 mboe/d in 2040. Consequently, its share of the energy mix is estimated to decline by more than 6 percentage points. It is expected to reach 12.3% in 2040 (see also Table 2.3).

2.3.2 Natural gas

Compared to the first decade of the 21st century, global gas demand growth has been faced challenges for the past several years due to a variety of reasons. Slower economic growth combined with stronger competition from coal, as well as the growing penetration of renewables, were all major reasons behind the slowdown. In addition, warm weather in major consuming centres drove down demand for heating on occasions, thus also contributing to the overall sluggish trend. However, even though the global gas demand growth was on a slowdown, certain regions such as Japan (after the Fukushima disaster) and the US (in the midst of increasing gas supply) showed rather strong gas demand growth. Overall, the average gas demand growth rate in the period 2011–2015 was seen at levels around 1.5% p.a., down from an average level of around 3% p.a. in the period 2000–2010.

In the midst of declining gas prices, a glimmer of hope – especially in 2016 – came from the power generation sector, which is sensitive to price movements. The drop in prices resulted in a positive reaction in terms of gas demand. In the US, gas-fired power generation has been on the rise for the past several years surpassing coal on an annual basis. In addition, gas-fired generation increased strongly in Europe, especially in 2016, due to low gas prices, but also supported by increasing coal prices and supportive mechanisms such as the carbon price floor in the UK.

Looking to the future, gas consumption is likely to remain dependent on several important factors, such as the availability and affordability of gas supplies, but also competition against other fuels such as coal, especially in power generation. Regulation of the energy market in

combination with overall climate change policies (including the Paris Agreement) are also expected to play a decisive role in the future of gas demand. Other factors, such as pricing mechanisms (oil-linked versus hub-based) or developments in potential new demand sectors (such as transportation) are also expected to play an important role in the long-term.

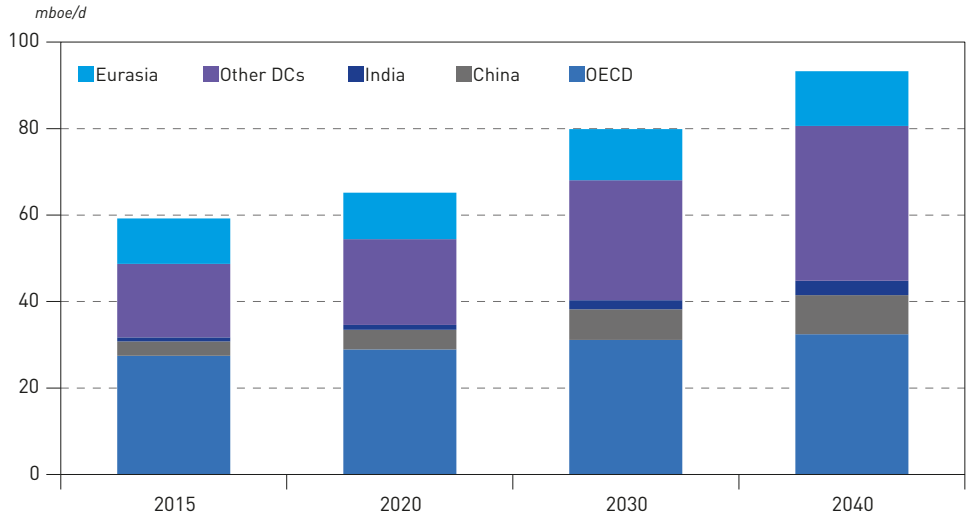
Table 2.9 and Figure 2.6 show the long-term projections for gas demand in the Reference Case between 2015 and 2040. Over this period, gas demand is estimated to increase from just below 60 mboe/d in 2015 to around 93 mboe/d in 2040, comprising an average annual growth rate of around 1.8% p.a. Compared to other fossil fuels, gas has the highest growth rate over the forecast period. Consequently, the share of gas in the overall energy mix is seen rising from around 21.5% in 2015 to more than 25% in 2040, thus overtaking coal and becoming the second most important fuel in the energy mix. The majority of the growth in the 2015–2040 period comes from non-OECD countries, with around 29 mboe/d, while the rest (some 5 mboe/d) is located in the mature markets of OECD countries.

The highest gas demand growth in the OECD region is projected in OECD America (predominantly the US). In this region, gas demand increases from 16 mboe/d in 2015 to almost 20 mboe/d in 2040. This translates into an average annual growth rate of around 0.9% throughout

Table 2.9
Gas demand by region

	Levels *mboe/d*				Growth *% p.a.*	Share of global energy demand *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
OECD America	15.8	16.8	18.6	19.7	0.9	26.7	25.7	23.3	21.1
OECD Europe	7.8	8.6	8.9	9.0	0.6	13.2	13.1	11.2	9.6
OECD Asia Oceania	3.9	3.6	3.6	3.8	–0.1	6.5	5.6	4.5	4.1
OECD	**27.5**	**28.9**	**31.1**	**32.5**	**0.7**	**46.4**	**44.4**	**39.0**	**34.8**
China	3.3	4.5	7.1	9.0	4.1	5.6	6.9	8.9	9.7
India	0.9	1.2	2.1	3.3	5.2	1.6	1.8	2.6	3.5
OPEC	8.4	9.6	13.2	16.1	2.6	14.3	14.8	16.5	17.3
Other DCs	8.6	10.2	14.6	19.7	3.4	14.4	15.6	18.2	21.1
DCs	**21.3**	**25.5**	**36.9**	**48.2**	**3.3**	**35.9**	**39.1**	**46.2**	**51.6**
Russia	7.1	7.1	7.5	7.8	0.4	12.0	10.9	9.4	8.4
Other Eurasia	3.4	3.7	4.3	4.8	1.4	5.7	5.6	5.4	5.2
Eurasia	**10.5**	**10.7**	**11.8**	**12.6**	**0.7**	**17.7**	**16.5**	**14.8**	**13.5**
Total world	**59.2**	**65.2**	**79.9**	**93.3**	**1.8**	**100**	**100**	**100**	**100**

Figure 2.6
Natural gas demand by major regions, 2015–2040



the outlook period compared to a total primary energy demand growth rate of only 0.1% in the same period. The growth is provided by the vast and cost competitive gas resources in North America (primarily shale gas). The largest potential for demand growth is seen in power generation, where cost competitive gas supplies have already replaced some of the coal-based power supplies during 2015 and 2016. However, further progress in this direction, especially in the US, will also depend on the future development of energy policies, such as the US position on the Paris Agreement and its Clean Power Plan. Furthermore, relatively low gas prices in the US, in comparison with other regions, support an increase in gas demand in countries in the industrial sector, especially in the petrochemical industry where gas is used as both feedstock and as a fuel.

In OECD Asia Oceania, gas demand is expected to decline somewhat in the medium-term. This is due to the expected gradual restart of nuclear power plants in Japan, which were shut down following the Fukushima disaster of 2011. Gas demand in this region is seen at around 3.6 mboe/d in 2020, marginally down from 2015 levels. Although the consumption of coal and oil declines significantly in the long-term, gas is not expected to fill the gap due to a significant increase in renewable energy. Therefore, only minimal growth is seen in the long-term with gas demand rising to 3.8 mboe/d in 2040. To some extent, this generally reflects low energy demand growth in OECD Asia Oceania.

In OECD Europe, gas demand is projected to pick up gradually, from around 7.8 mboe/d in 2015 to 8.8 mboe/d in 2040, or around 0.5% p.a. on average. This growth is even more pronounced when bearing in mind that overall energy demand growth in OECD Europe in the

period 2015–2040 is anticipated to decline slightly by –0.1% p.a. The support for gas demand growth comes from the heat and power generation sector where several factors contribute to the re-emergence of gas in the power generation mix.

First, there is the decommissioning of old coal power plants, which is expected to occur not only due to the age of the power plants, but also because of national and EU (e.g. Industrial Emissions Directive (IED)) regulations that require the phasing out of old, polluting coal units in the medium- to long-term. Second, earlier this year almost all major national energy utilities (except for those in Poland and Greece) committed not to invest in new coal power plants after 2020, which is seen as a contribution to the Paris Agreement, and to instead push for alternative energy sources (including gas). Third, it is expected that the intention of some countries (such as Germany, but also France) to phase out their nuclear power plants will open up a supply gap that can be filled by gas-fired power generation. Finally, in line with the implementation of the Paris Agreement, it is likely that the EU Emissions Trading System (ETS) system will regain importance with CO_2 prices increasing. This should provide additional support for the use of gas in the power generation sector.

In non-OECD countries, the majority of growth is located in the emerging economies of Asia, including China and India. Strong population growth in most of the developing countries, combined with robust economic development, leads to gas demand growth in all the relevant sectors: power generation, industry, as well as the residential and commercial sectors. The increasing availability of gas on the global market due to the expansion of LNG production is also contributing to the high growth rate for this energy source. Consequently, in the long-term, the share of gas in the overall energy demand is expected to increase in all non-OECD sub-regions except for Eurasia.

In China, natural gas consumption is projected to increase from around 3.3 mboe/d in 2015 to 9 mboe/d in 2040, comprising an average growth rate of just above 4% p.a. This is far above the average energy demand growth in China of around 1.2% p.a. Environmental concerns, especially in the large urban centres, have prompted policymakers to support environmentally friendlier gas-fired power generation over heavily polluting coal power plants. The switch to gas is expected to occur not only in the power generation sector, but also in the energy intensive industry, which is also anticipated to look for solutions that are cleaner than coal. Further gasification and the expansion of the distribution network in China are expected to boost gas consumption in the residential and commercial sector. The demand growth will only partially be covered by imports (including LNG and pipeline gas from Russia), while a large part is also expected to come from increasing domestic production.

A similar situation is observed in India and in Other Developing countries (excluding China, India and OPEC countries), where gas demand increases significantly over the outlook period. India is likely to solve the problem of its currently under-utilized gas-fired power plants (due to falling domestic production) and is likely to rely increasingly on LNG supplies. Some Indian companies (such as GAIL) have reportedly booked long-term capacities on US LNG terminals (e.g. Sabine Pass), which should help to increase the stability of gas supplies. As a result, Indian gas demand in the Reference Case is expected to rise from just below 1 mboe/d in 2015 to around 3.3 mboe/d in 2040. At the same time, in Other Developing countries, gas

consumption is seen increasing from 8.5 mboe/d in 2015 to around 19.7 mboe/d in 2040. The development of natural gas infrastructure in all these countries will play a crucial role in driving future demand growth.

Based on their vast natural gas resources, OPEC Member Countries are projected to boost gas demand in the long-term based on their dynamic population growth and ongoing economic development efforts. In addition, some OPEC Members are seeking to increase the share of gas in power generation in order to free up oil volumes for export, much of which is currently used in power generation. OPEC gas demand in the Reference Case is seen to almost double from around 8.4 mboe/d in 2015 to more than 16 mboe/d in 2040. Consequently, the share in the energy mix is seen to increase to over 50% in 2040, up from around 43% in 2015.

Finally, gas demand in Eurasia, a region with well-developed gas infrastructure and a massive gas resource base, is seen to increase from 10.5 mboe/d in 2015 to about 12.5 mboe/d in 2040. This is broadly in line with overall energy demand growth in this region. The share of gas in the overall mix is seen to decline, albeit, slightly. It is expected to still remain dominant in the energy mix above 45% in 2040.

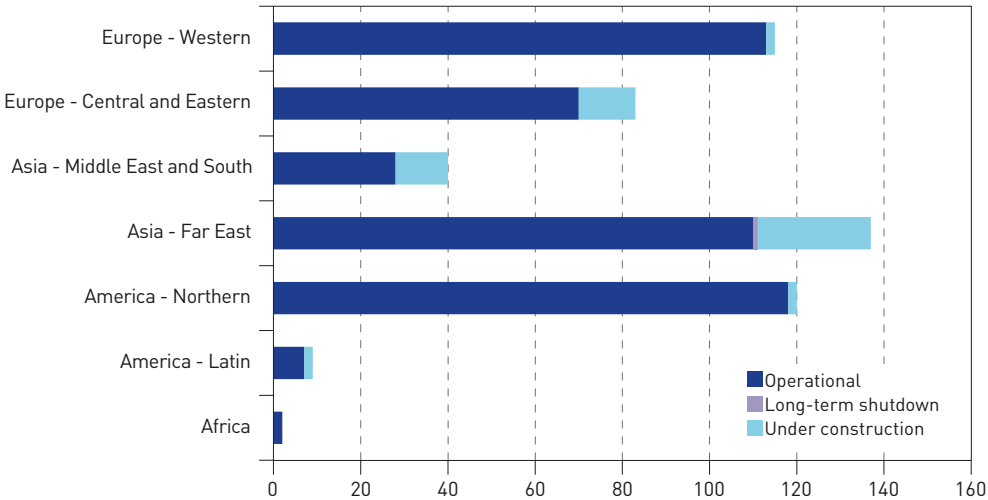
2.3.4 Nuclear

According to statistics from the International Atomic Energy Agency (IAEA), there are 446 reactors currently operational around the world with the majority installed in North America, Western Europe and Far East Asia. On top of these, more than 60 reactors are under construction, of which 20 are in China and eight in Russia. Six of these will be built in India, while the UAE and US each have four reactors under construction. Another ten countries each have 1–3 reactors under construction (Figure 2.7).

Nuclear capacity in OECD Europe, with a share of almost 24% in power generation in 2015, is projected to decline as plants that are gradually retired and phased out (such as in Germany and France) more than offset upcoming investments. A recent addition to the list of retired nuclear plants is Unit 1 of the Oskarshamn nuclear power plant in Sweden, which was permanently shut down in June 2017. Overall, nuclear power generation in OECD Europe is expected to be less than 800 terawatt hours (TWh) by 2040, down from more than 850 TWh in 2015. This represents a decline of 0.3% p.a. on average between 2015 and 2040.

In contrast to Europe, the US nuclear sector is still projected to grow, although this growth is anticipated to slow down significantly compared to the last two decades. Five nuclear plants have been closed in the US within the past several years and another few are likely to be shut down in the medium-term. This is due both to policy uncertainties, as well as competition from gas-fired power plants and renewable electricity. Moreover, investors are still uncertain about the impact of new regulations and the future of the industry. There are even doubts about when (and if) all four nuclear plants currently under construction will be needed and how many of the additionally planned reactors will finally be activated. It seems that plentiful and cheap sources of natural gas, as well as development of renewables, will restrict any significant expansion of the nuclear industry in the US. Nevertheless, some growth, especially in the longer term, is likely to take place.

Figure 2.7
Number of nuclear reactors by region, 2017



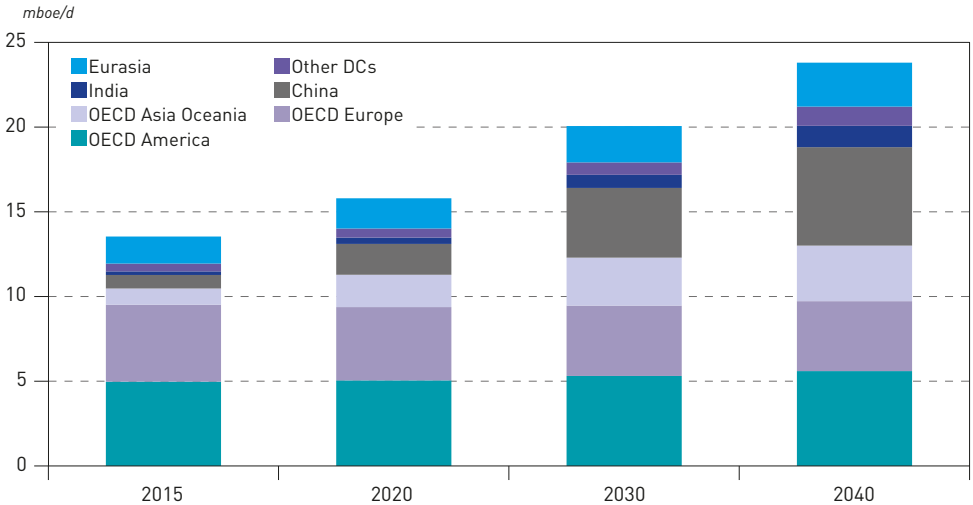
Source: *International Atomic Energy Agency (IAEA).*

In Canada, nearly 15% of electricity comes from nuclear power, with 19 reactors providing 13.5 GW of power capacity. However, the future expansion of nuclear energy is not so encouraging in Canada due to high capital costs, as well as social and political constraints. Therefore, demand for nuclear energy in OECD America is projected to grow only by 0.5% p.a. on average over the forecast period, reaching a level of 5.6 mboe/d by 2040 (Figure 2.8). This allows nuclear energy to raise its share slightly in the region's overall energy mix to 9.7% by 2040.

Nuclear power plants are expected to increase their contributions to power generation in OECD Asia Oceania from 174 TWh in 2015 to nearly 630 TWh in 2040. This represents a share of around 23% of the total electricity needed in the region at the end of the forecast period. By 2040, nuclear energy is actually at a similar level to coal and gas as key sources for power generation in the region.

Since the 2011 Fukushima disaster, 17 reactors have been permanently shut down. Currently 42 reactors remain offline, but are operable and potentially able to restart. Of these, 24 reactors are currently in the process of getting approvals to restart. Two reactors restarted in August and October 2015 and three reactors started operation in 2016. This situation is not expected to improve significantly in the next three years. The nuclear industry, however, has a chance to play a more important role in Japan's energy sector after 2020 when implementation of new regulations and the execution of the government's plan for long-term electricity generation are anticipated.

Figure 2.8
Nuclear energy demand by region, 2015–2040



Turning to Developing countries, China is leading the newly-built nuclear plants globally and pursuing an ambitious plan to add much more electricity from nuclear power plants in the medium- and long-term. Nuclear energy is now considered an important element in China's changing energy pattern. China currently has 37 operational reactors with more than 32 GW of capacity and another 20 reactors under construction. Accordingly, nuclear energy in China is projected to grow even faster than solar and wind, at 8.3% p.a. on average until 2040. China's rapid nuclear expansion plan is expected to produce around seven times more nuclear energy by 2040, compared to 2015, rising from 0.8 mboe/d in 2015 to 5.8 mboe/d by 2040. Within China's electricity sector, nuclear power is expected to have a share of nearly 12%.

India is also expected to be one of the fastest expanding countries in utilizing nuclear energy in the medium- and long-term. More than 20 reactors are operational in India and six are under construction. India's expanding nuclear industry is expected to generate around 240 TWh by 2040, which would then represent 6% of total electric power in India. This will be six times more than the production of 40 TWh recorded in 2015. This represents growth of more than 7% p.a. on average over the forecast period, which will be achieved through the operation of new projects and an increase in the efficiency of current plants.

Growth in nuclear energy in the remaining Developing countries is projected at much lower rates at 3.6% p.a. on average. Nevertheless, combining these three regions together, nuclear energy in the group of Developing countries grow at an impressive rate of 7.1% p.a. on average

in the period 2015–2040. In terms of energy, it increases by 6.7 mboe/d, rising to 8.2 mboe/d by 2040 from 1.5 mboe/d in 2015.

Demand for nuclear power in Russia, which has 35 operational and seven reactors under construction, is expected to increase from 1 mboe/d in 2015 to 1.5 mboe/d in 2040. This would increase the share of nuclear energy in Russia's energy mix from 6.5% to 8.4% over the forecast period. A similar pattern is also projected for Other Eurasia. Thus, nuclear energy in Eurasia is anticipated to increase by 1 mboe/d between 2015 and 2040.

At the global level, nuclear-powered electricity generation is projected to increase from around 2,650 TWh in 2016 to more than 4,500 TWh in 2040. In terms of its contribution to the global energy mix, nuclear energy is projected to grow on average by 2.3% p.a. and increase from 13.5 mboe/d in 2015 to 23.8 mboe/d in 2040. This will add 1.5% to the share of nuclear energy in global energy demand by 2040. It is expected to reach a level of 6.4% by 2040. As clearly demonstrated, growth in nuclear power generation is expected to come primarily from Developing countries. However, because of the high installed capacity in the OECD, electricity production from nuclear energy in Developing countries in 2040 will be still less than production from the OECD region in 2015.

2.3.5 Hydropower

Despite the fact that hydropower constituted just 2.6% of the global primary energy demand in 2015, because of its high conversion efficiency, it contributed more than 16% to the global electricity generated during this year. Obviously, this percentage is much higher in countries and regions with abundant water resources such as Norway, Canada, Venezuela, Brazil and Austria. At the same time, the availability of water is also the key limitation for future expansion of this energy source, which is restricted to countries and regions where a steady supply of flowing water exists. Moreover, technologies used for hydropower generation have matured significantly with the best units reaching an impressive 98% conversion. Thus further improvements in efficiency or production capacity will be rather limited to upgrading older plants.

Besides providing a significant portion of electricity needs, hydropower also fulfils an important role in stabilizing power systems in countries and regions that have an installed capacity that is sufficient to balance out variations in constantly changing power demand and supply levels. However, one drawback is that hydropower itself is subject to weather risks (such as a shortage of rainfall), which can lead to unstable production volumes and extreme variations in production over time, as experienced, for example, in South America during an extreme drought in 2016.

In addition to playing the balancing role, many countries consider an expansion of hydropower as a way to reduce future emissions. However, the construction of large dams and the associated blockage of natural water flows may particularly have a severe impact on the environment. An effect which has been neglected in the past is the production of methane mainly through the decay of organic material in the reservoir's water. While on land, soil microorganisms convert such biomass into useful nutrients for plants without the emission

Table 2.10
Hydropower demand by region

	Levels *mboe/d*				Growth *% p.a.*	Share of global energy demand *%*			
	2015	2020	2030	2040	2015–2040	2015	2020	2030	2040
OECD America	1.2	1.3	1.4	1.5	0.9	18.1	17.2	16.0	14.9
OECD Europe	1.0	1.0	1.1	1.2	0.6	14.5	13.9	12.5	11.2
OECD Asia Oceania	0.2	0.2	0.2	0.3	0.6	3.2	3.1	2.8	2.5
OECD	**2.5**	**2.6**	**2.8**	**3.0**	**0.7**	**35.9**	**34.2**	**31.2**	**28.6**
China	1.9	2.0	2.4	2.7	1.5	27.1	27.1	26.8	26.0
India	0.2	0.3	0.4	0.6	3.6	3.5	4.0	5.0	5.6
OPEC	0.2	0.2	0.3	0.4	2.0	3.3	3.3	3.4	3.6
Other DCs	1.6	1.8	2.4	3.1	2.7	22.9	24.3	27.0	29.8
DCs	**3.9**	**4.4**	**5.6**	**6.7**	**2.2**	**56.7**	**58.6**	**62.1**	**64.9**
Russia	0.3	0.3	0.4	0.4	1.1	4.5	4.3	4.1	3.9
Other Eurasia	0.2	0.2	0.2	0.3	1.0	3.0	2.8	2.6	2.5
Eurasia	**0.5**	**0.5**	**0.6**	**0.7**	**1.0**	**7.5**	**7.2**	**6.7**	**6.4**
Total world	**6.8**	**7.5**	**9.0**	**10.3**	**1.7**	**100**	**100**	**100**	**100**

of methane, the largely anaerobe fermentation in a lake produces a substantial amount of methane – GHG with high warming potential. In extreme cases, the effect of the produced methane may even surpass the benefit of the CO_2-free power generation of the corresponding hydropower plant.

Reflecting all mentioned factors, the key projections for hydropower demand are presented in Table 2.10. In OECD regions, the growth of hydropower is mostly constrained, providing around 0.5 mboe/d of additional energy by 2040, compared to the base year of 2015. While growth in large-scale projects may be limited in the region, because of concerns over environmental impacts, some upside potential exists not only from small-scale hydropower (run-of-river), but also from the refurbishment of older plants.

Most of the additions within OECD countries will likely come from the US and Canada where some undeveloped resources exist. However, these additions are only in the range of 0.3 mboe/d from 2015 levels of 1.2 mboe/d. An even lower additional contribution of hydropower is projected in OECD Europe. Some countries in this region, such as Turkey, are still investing in large-scale hydropower projects, while other countries, such as Austria

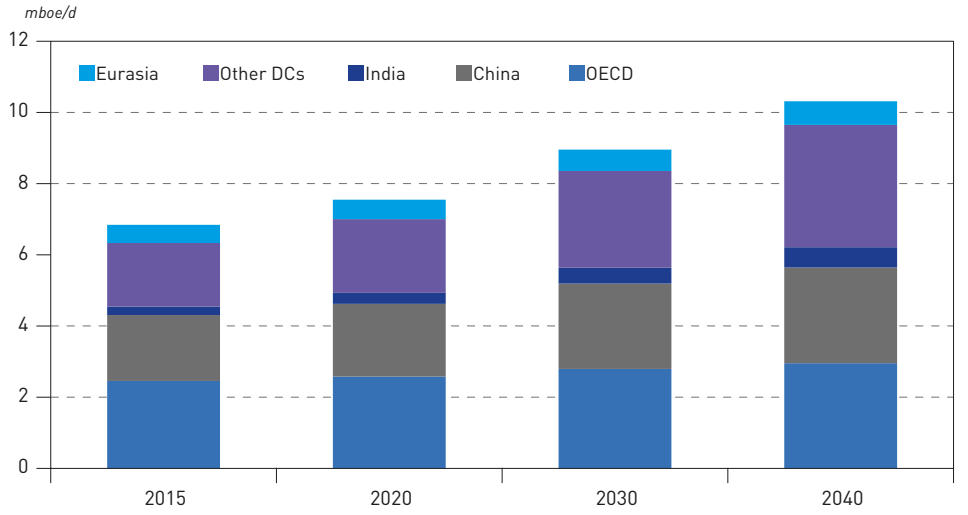
and Norway, are likely to add mostly smaller units that are also supported by governmental subsidies for renewable energy. In OECD Asia Oceania, no major changes are expected with hydropower levels expected to remain stable at round 0.3 mboe/d throughout the forecast period.

The rate of expansion of hydropower in the OECD is not dissimilar to that of Eurasia. The Reference Case for this region sees only slight growth over the forecast period, increasing by 0.2 mboe/d to 0.7 mboe/d in 2040. This represents an average growth of 1% p.a. The development of hydropower in Eurasia remains subdued despite its great potential given the resource base. The main reasons for this outlook are a lack of infrastructure, the remoteness of potential projects and the strong, continuing focus on fossil fuels in the region.

Contrary to the other two major regions, a much greater potential exists for the expansion of hydropower in Developing countries, especially in the Asian region (Figure 2.9). This is where water resources meet population growth and economic activity – hence the need for more electricity in the future. The highest increase in hydropower is expected in China, where it is expected to grow from around 1.6 mboe/d in 2015 to 2.7 mboe/d in 2040. These projections reflect the existence of relatively large water resources across the country and government efforts to reduce air pollution and CO_2 emissions, as part of the country's commitment to the Paris Agreement.

A similar trend is also expected in several other countries in non-OECD Asia, such as India, Thailand, Vietnam, Philippines and Indonesia, driven by expanding electricity demand in these countries, as their economies grow and more people have access to electricity. Elsewhere, the

Figure 2.9
Hydropower demand by major regions, 2015–2040



potential exists in several Latin American countries, such as Brazil, Venezuela and Peru, as well as in sub-Saharan Africa. As a result, hydropower in Developing countries is projected to increase from 3.9 mboe/d in 2015 to 6.7 mboe/d in 2040.

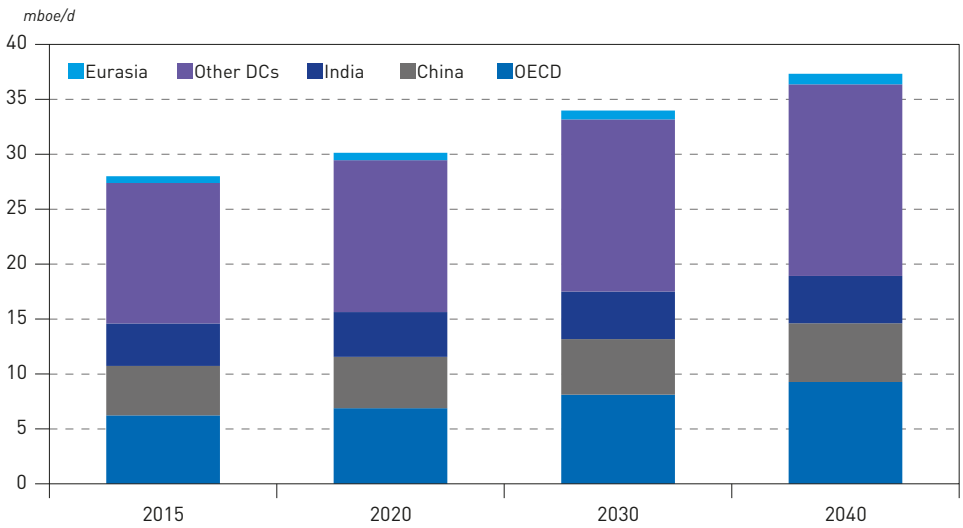
At the global level, hydropower is projected to grow at an annual average rate of 1.6% p.a. over the forecast period, increasing from 6.8 mboe/d in 2015 to 10.3 mboe/d in 2040.

2.3.6 Biomass

Primary energy demand for biomass includes feedstocks for liquid biofuels, traditional (essentially domestic) use (heating, cooking etc.) and the commercial use of biomass, mainly for power generation. Total consumption of biomass is projected to rise by an average of 1.2% p.a. from 2015–2040, or from 28 mboe/d in 2015 to 37.3 mboe/d in absolute terms (Figure 2.10). As in previous assessments, total biomass use remains the fourth-largest source of energy, albeit well behind the three fossil fuels.

In terms of regional breakdown, the highest growth rates are expected in Eurasia, at 1.7% p.a. over the forecast period – albeit from a low base. By comparison, OECD countries' total biomass use is projected to increase at 1.6% p.a., while consumption in Developing Countries is estimated to grow at 1% p.a. In absolute terms though, the lion's share of global use is in Developing Countries, at around 75% throughout the forecast period. The same is true of overall growth, with total Developing Countries' biomass consumption increasing by 5.9 mboe/d, or two-thirds of the global growth in the period 2015–2040.

Figure 2.10
Outlook for biomass demand by region, 2015–2040



While increasing biomass use in OECD countries tends to be in the form of feedstock for liquid biofuels, the traditional use of biomass is overwhelmingly concentrated in Developing Countries. Biomass use for power generation is spread globally. However, contrary to the global level, where the share of biomass in total primary energy demand remains quite stable (at around 10% throughout the forecast period), there is expected to be a decline in the share of biomass within the energy mix of Developing Countries over the long-term. Standing at 14.7% in 2015, the share of biomass in these countries falls to 11.7% in 2040. This drop comes on the back of improving living standards in these countries. As a result, it is anticipated to reduce the consumption of solid biomass like waste and residues relative to other energy sources.

2.3.7 Other renewables

Recent statistics by International Renewable Energy Agency (IRENA)[5] confirm the ongoing rapid expansion of renewable energy worldwide. An important part of this expansion is also growth in 'other renewables' which include mainly wind, PV, solar thermal and geothermal. Solar energy, in particular, saw a record addition of 71 GW of capacity during 2016, followed by wind energy with an additional installed capacity of 51 GW. This rapid growth in other renewables is part of the transition to energy sources with lower emissions that is enabled by technological advances and the support of specific policies by governments around the world.

Significantly, a rapid reduction in production costs for all major renewable energy sources, especially for solar PV and wind, is also increasingly a major factor in expanding their use. This has been possible due to technology advances and economies of scale, which in turn have encouraged the spread of renewables, thus creating a virtuous circle. As a result, solar and wind electricity are in many parts of the world now increasingly competitive with power generation based upon gas or coal. Most obviously, this is true for offshore wind, where particularly large turbines and complexes can be deployed.

However, a supportive policy environment remains a key element in the growth of other renewables. Most major energy consumers, including the US, China, India and the EU, have so far kept these in place, in various forms and with multiple motivations. The former include everything from fiscal incentives, to subsidies and even simple mandates in certain areas. Incentives to encourage the greater deployment of other renewables capacity include energy security (diversification of sources, as well as reduced import dependency), but also environmental concerns and in many cases an increasing desire to support a buoyant technology industry. It is worth emphasising that political and fiscal support for other renewables use remains focused on electricity generation, in contrast with thermal power.

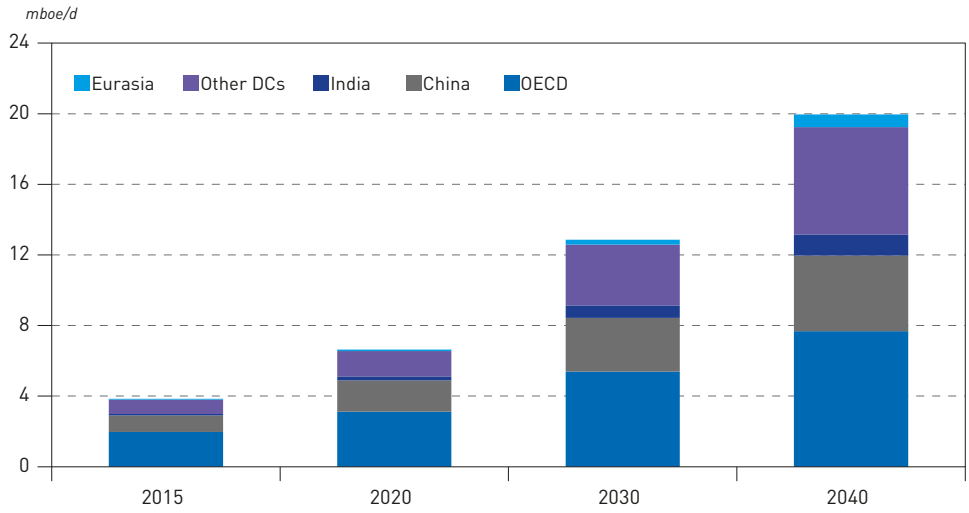
Still, despite the strongest growth rates of all major energy sources, other renewables continue to represent only a small share of total energy demand, at around 1.4% in 2015. Besides fiscal and political support, the main challenge is the integration of intermittent renewables (mainly solar PV and wind energy) into highly fluctuating (and seasonal) end-user electricity consumption patterns. Besides maintaining a certain degree of baseload power generation capacity from non-intermittent/non-renewable sources, other possible solutions to this challenge include demand-side management (such as smart grids, smart meters etc.), but also innovative storage technologies and systems.

On the basis that such challenges can gradually be addressed, the Reference Case projects strong growth in other renewables, amounting to 6.8% p.a. on a global level, or from 3.8 mboe/d in 2015 to 20 mboe/d in 2040 (Figure 2.11). However, this masks significant regional variations. While in the past, OECD countries showed somewhat higher volumes of other renewables compared to non-OECD countries, this is expected to reverse around 2020. In total, demand for other renewables in the OECD region is expected to increase from 2 mboe/d in 2015 to 7.7 mboe/d in 2040, or a growth rate of 5.6% p.a. Consequently, the share of other renewables in the total energy mix of OECD countries is forecast to be 6.8% by 2040, up from 1.8% in 2015.

Meanwhile, consumption of other renewables in Developing countries will grow at a higher rate of 7.7% p.a. It is set to thus increase from 1.8 mboe/d in 2015 to 11.6 mboe/d by 2040 in absolute terms. As in so many respects, China is the largest volumetric contributor to growth, with other renewables is estimated to rise from 0.9 mboe/d in 2015 to 4.3 mboe/d by 2040, or to a share of around 21% of global other renewables consumption. Besides continued government support, China benefits from its emergence as a world leader in solar panel and wind turbine technology. India meanwhile is actually projected to experience even stronger growth, at 11.1% p.a., albeit starting from a much lower base of only 0.1 mboe/d in 2015. It is estimated to rise to 1.2 mboe/d in 2040. Other DCs are also forecast to see healthy growth, with total use of other renewables rising to 6.1 mboe/d by 2040, thus making up 30% of global other renewables use by the end of the forecast period.

Lastly, some of the strongest relative growth rates are expected in Eurasia, where other renewables use is expected to rise by 12.3% p.a. Again, this is from minimal current use. It rises to only a modest 0.7 mboe/d by 2040.

Figure 2.11
Global expansion of other renewables, 2015–2040



Globally, at the end of the forecast period, the share of other renewables in the global energy mix is projected to be at 5.4%.

2.4 Energy related CO_2 emissions

As mentioned earlier in this Chapter, global energy demand is set to grow by 35% between 2015 and 2040, reaching 372 mboe/d by 2040. Despite the rapid rise of non-fossil fuels, fossil fuels will remain the primary energy source. Furthermore, high levels of industrialization, urbanization, population growth and income growth in developing countries will promote faster growth in energy demand in the countries than in the OECD region. These trends have clear implications for CO_2 emissions.

Total annual energy-related CO_2 emissions are set to increase from 33.3 billion tonnes (bt) in 2015 to around 40.6 bt by 2040. This reflects the projections for regional energy demand levels and the energy mix. It also represents an emissions increase of around 22% by the end of the forecast period, significantly lower than the overall increase in energy demand. On an annual basis, as shown in Figure 2.12, emissions of Non-Annex I[6] countries exceeded those of Annex I[7] countries for the first time sometime around 2007. Driven by growing energy needs of those countries, their energy-related emissions are set to increase.

At the same time, however, there is a significant gap in per capita emissions between the United Nations Framework Convention on Climate Changes (UNFCCC) Annex I and Non-Annex I countries. This is well illustrated in Figure 2.13. In 1990, the per capita emissions of Annex I

Figure 2.12
Annual CO_2 emissions from the combustion of fossil fuels, 1990–2040

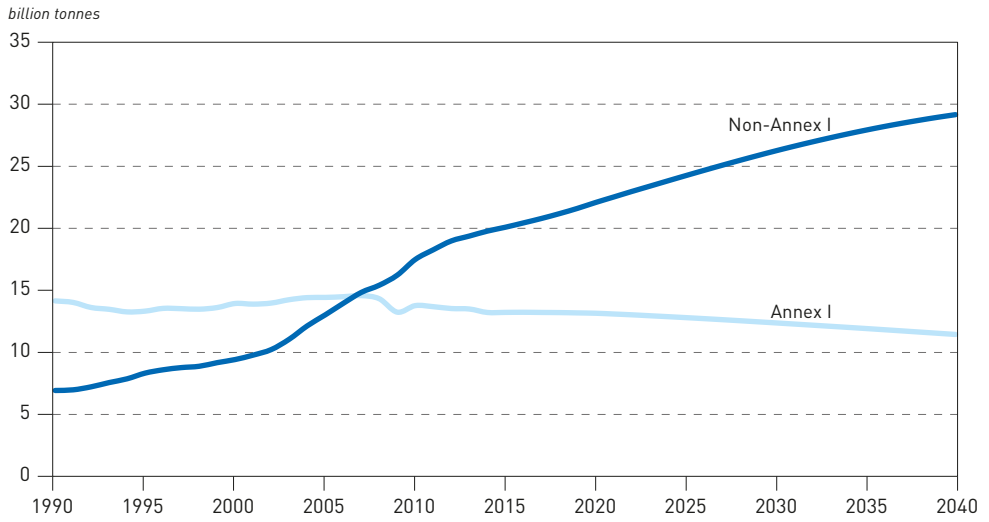
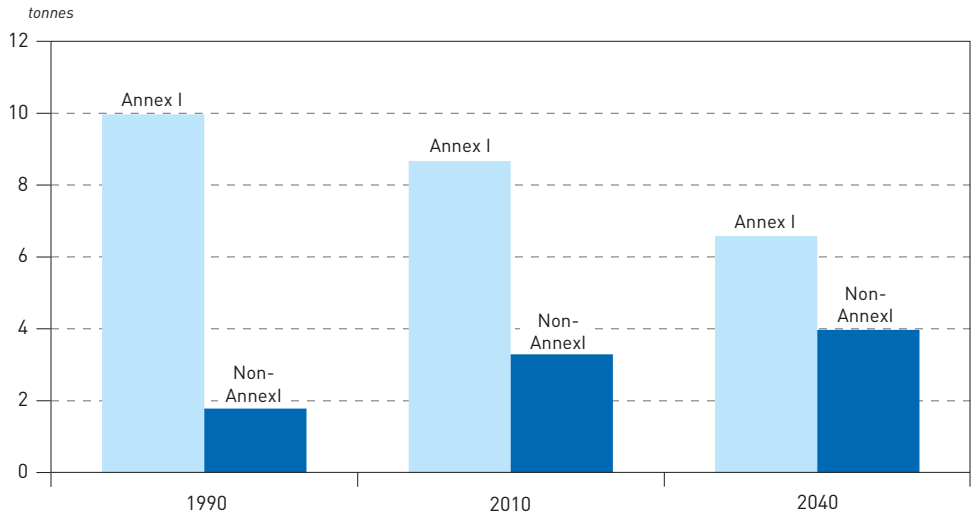


Figure 2.13
Per capita CO_2 emissions in the Reference Case, 1990–2040



countries were around six times larger those of Non-Annex I countries. This gap is gradually being narrowed over time. But even by 2040, under the Reference Case, per capita emissions from Annex I countries are projected to be almost twice those of Non-Annex I countries. This difference is also reflected in the historical cumulative emissions.

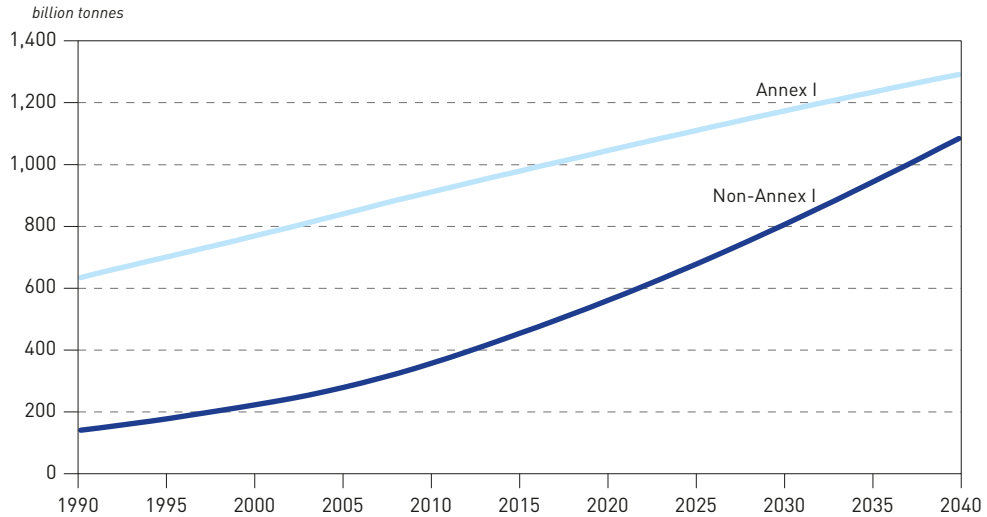
Estimates of cumulative CO_2 emissions, as presented in Figure 2.14, show a significant gap in cumulative emissions between Annex I and Non-Annex I countries. This has developed throughout the past century. Moreover, despite growing energy demand in Developing countries, this gap is expected to remain in place throughout the projection period in the Reference Case. Even by 2040, historical cumulative emissions by Non-Annex I countries will be more than 200 billion tonnes of CO_2 lower than those generated by Annex I countries since 1990.

2.5 Energy intensity and consumption per capita

Energy intensity, a measure of energy consumed per unit of GDP, shows how much energy is needed to generate all the goods and services that an economy produces. In a broad sense, therefore, it could be considered as an indirect measure of energy efficiency and energy productivity.

Driven by technological progress, a tightening of energy policies and changes in economic structure, the world has continuously become more energy efficient. At a global level, in 1970 a total of 104 mboe/d of energy was consumed to produce $23 trillion (PPP 2011) of GDP. That meant that, on average, the world needed 1.7 boe of energy for every $1,000 (PPP 2011) of

Figure 2.14
Cumulative CO_2 emissions from 1900, 1990–2040

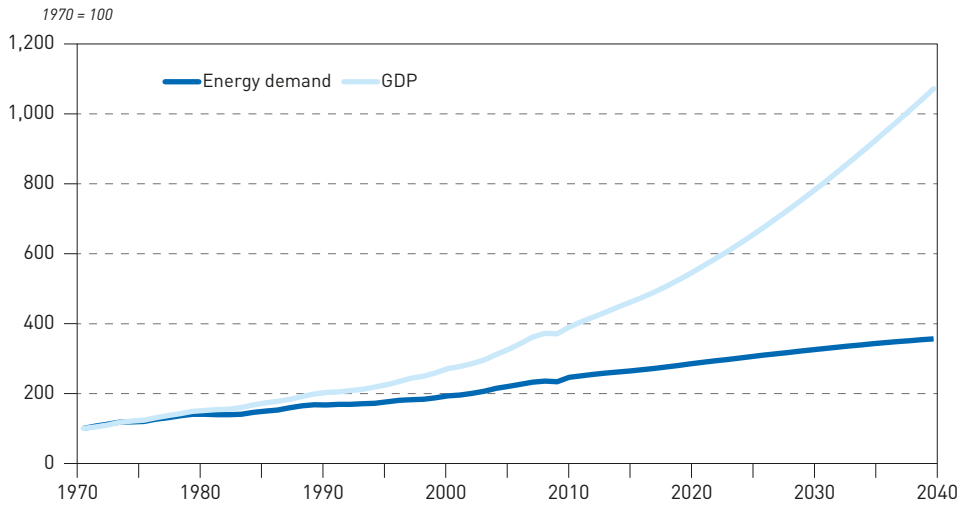


production. By 1995, the world used less energy to produce the same value of products and services, around 1.3 boe for every $1,000 (PPP 2011). Currently, the world needs slightly less than 1 boe to produce $1,000 (PPP 2011). In fact, as shown in Figure 2.15, the global economy in 2015 was 4.6 times that in 1970. However, energy efficiency improvements meant that energy demand in 2015 was only 2.6 times that in 1970.

Looking to the future, technological progress, energy policies promoting energy efficiency and a continuous shift towards a more service-oriented global economy is expected to keep reducing energy intensity. Figure 2.15 also shows that global GDP is estimated to increase at healthy growth rates during the forecast period. In particular, it is expected that the global economy will expand at 3.5% p.a. on average. However, the anticipated demand for energy will increase by only 1.2% p.a., a clear sign that the decoupling of economic growth and energy demand is set to continue. In a sense, the 'economic pie' in 2040 will be 2.3 times bigger than in 2015, but the 'ingredients' needed in 2040 are only 1.3 times more than in 2015.

It is noteworthy that increasing energy efficiency over the last few decades has been an achievement of both the developed world (OECD regions) and also of the developing world (non-OECD regions). As shown in Figure 2.16, energy intensity decreased in the OECD between 1980 and 1995, on average by 1.5% every year, as the economy grew at 2.8% p.a. and energy demand increased by 1.2% p.a. In the following 15 years, a similar pattern was observed as energy intensity continued decreasing at an average rate of 1.5% p.a. In the case of the non-OECD region, between 1980 and 1995 efficiency improvements were limited and energy intensity dropped at lower rates than those in the OECD, on average by 0.7% p.a.

Figure 2.15
Global energy demand and real GDP, 1970–2040

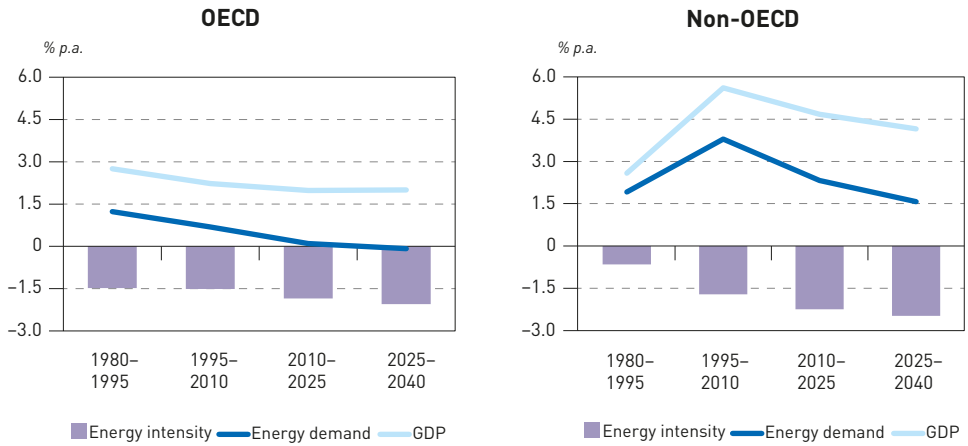


However, between 1995 and 2010, efficiency improvements in the non-OECD region accelerated. Despite the fact that the regional economy boomed, growing by 5.6% p.a., energy demand increased by only 3.8% p.a. implying that energy intensity dropped on average by 1.7% p.a. In specific countries, such as China and Russia, the declines in energy intensity were even higher (energy intensity dropped by around 3% p.a. though declines in Russia also reflected changes in the structure of the economy).

Figure 2.16 also emphasizes that energy efficiency improvements are anticipated to continue in both the OECD and non-OECD regions. Moreover, improvements will likely accelerate. Between 2010 and 2025 energy intensity is anticipated to decline by 1.8% p.a. in the OECD region and by 2.2% p.a. in the non-OECD region. As technology further develops and policies are further tightened in the last 15 years of the forecast period, energy intensity is estimated to drop by 2% p.a. and 2.5% p.a., respectively.

Another important trend in the energy landscape is that the world has increasingly become less energy poor. In 1970 the gap between energy consumption per capita in the OECD region and in the Developing countries was rather wide. While in the OECD region the average energy consumption was almost 27 boe per capita, in the Developing countries it was only 3 boe per capita. In some specific countries such as China and India, the average consumption was even below 1.5 boe per capita. By 1990, the gap had not narrowed significantly and average consumption in the OECD region was still more than six times higher than in the Developing countries. However, since then, rapid economic expansion in the developing world, particularly in developing Asia, lifted millions of people out of poverty and enlarged the middle class base, prompting an

Figure 2.16
Real GDP, energy demand and energy intensity growth



increase in access to energy. In 2015, the average energy consumption in the Developing countries had almost tripled with respect to 1970 and the gap with the OECD had clearly narrowed.

Nevertheless, the gap not only remains wide, but also energy poverty remains an critical issue. In specific regions, such as India and Africa, energy consumption per capita is still very low, underscoring the serious problem of energy poverty. Strong political commitment and the resolute support of the global community is needed to ensure that energy is made universally accessible and affordable.

In regards to energy poverty, billions of people around the world still do not have access to electricity or clean fuels and technologies for cooking. Based on the latest available data, about 85% of the world population had access to electricity in 2014.[8] An increase of 0.4 percentage points has been observed since 2012, implying that annually 86 million people gained access to electricity for the first time. However, 1.1 billion people still function without electricity, and half of those people live in Sub-Saharan Africa.

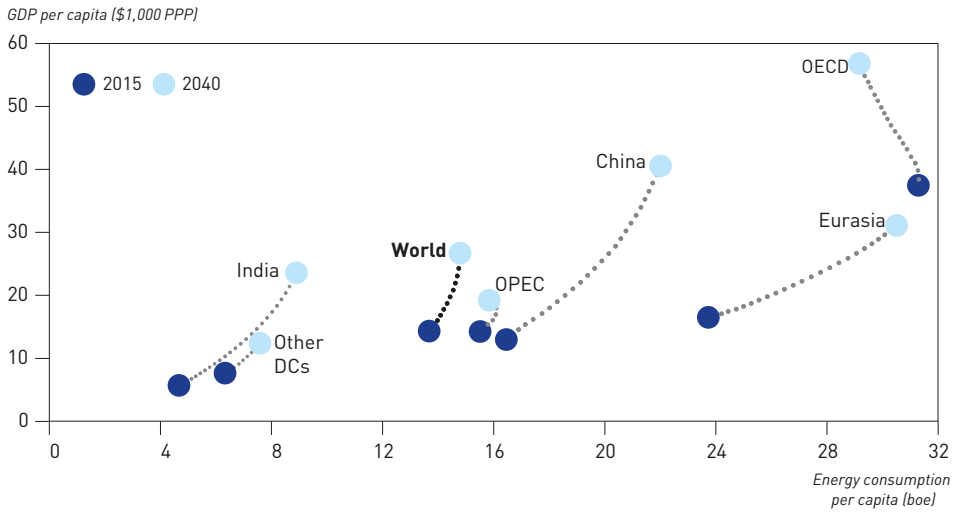
In general, electrification has outpaced population growth in most regions, and countries in South Asia have increased their electrification by 22.8 percentage points in the course of the 2000–2014 period. Nevertheless, more than 20 African countries still have electricity access rates of 30% or less, accounting for the access deficit. Even within these countries, significant differences are observed between urban and rural areas. At a global level, 27% of people living in rural areas did not have access to electricity in the year 2014. This rate increases to 28% in South Asian countries, and further to 82% in Sub-Saharan Africa. These figures, therefore, underscore the need for enhanced action with the objective to close the reported gap and ensure energy access for all in the coming decades.

At the same time, approximately 3 billion people, the majority of them living in Sub-Saharan Africa and Asia, are still cooking without clean fuels and efficient technologies. In 2000, the global average for electrification was 77.6% of world population and for clean cooking it was 50.4%. In 2014, the share of population with access to electricity reached the level of 85.3%, while the respective figure for clean cooking was only 57.4%. As a result, the absolute number of people relying on solid fuels for cooking has increased. In urban areas, 78% of the world population has access to clean cooking, but this falls to only 22% of those living in rural areas. Overall, some countries – including those of Indonesia, Peru, Azerbaijan and South Africa – have made rapid progress in clean cooking, but for others there is more room for improvement (such as Madagascar, Rwanda, Tanzania, Uganda, Mali and Ethiopia).

It should be highlighted that even those regions and countries that report (almost) universal electrification and access to clean cooking, there may also be a need to address energy access challenges. These relate mainly to remote, off-grid locations, on-grid access with limited or intermittent supply due to poor infrastructure or fuel supply problems, and affordability issues. The indicators highlighted above to measure energy access may be at (or close to) 100% in terms of physical access; however, the energy services considered may not be accessible to the energy poor, if they cannot afford their cost. In addition, ageing infrastructure, a lack of supply diversity, and interruptions or shortages in supply restrict access to energy in particular regions and populations – therefore, leading to energy poverty.

Moreover, the problem of energy poverty should not be seen in isolation as poverty and energy poverty go hand in hand. Indeed, Figure 2.17 shows that differences in average

Figure 2.17
Energy consumption per capita versus GDP at PPP per capita, 2015–2040



energy consumption can be linked to differences in the level of development and, therefore, in average income levels. This Outlook anticipates that energy consumption in the non-OECD region will increase driven by rapid economic growth. This will bring increasing electrification, rising income levels, increasing urbanization and a growing middle class. This is clearly seen in two cases: China and India. In the former, average energy consumption is set to increase significantly from 16 boe in 2015 to 22 boe in 2040. In the latter, average consumption is anticipated to double, reaching 9 boe at the end of the forecast period. Contrary to these cases, a diverging trend is foreseen in the OECD region. Despite anticipated modest economic growth, energy consumption per capita is set to continue to decline, a tendency that started in 2004. This is a result of technology and policy driven energy efficiency gains.

Oil demand

Key takeaways

- The oil demand outlook for the medium-term period 2016–2022 shows an increase of 6.9 mb/d, rising from 95.4 mb/d to 102.3 mb/d. Overall, oil demand has been revised upwards by 2.24 mb/d in 2022 compared to the WOO 2016. This revision includes the upward shift to the baseline (+1.17 mb/d) in 2016.
- The IMO regulations are anticipated to impact the demand growth pattern in the medium-term. In particular, oil demand growth in 2020 is expected to be higher because of these regulations (almost 1.4 mb/d), primarily due to the likely surplus of high-sulphur fuel oil volumes priced at a discount assumed to be absorbed by the power generation sector and volumetric processing gains from switching from fuel oil to diesel.
- Long-term oil demand is expected to increase by 15.8 mb/d, rising from 95.4 mb/d in 2016 to 111.1 mb/d in 2040. Demand in the OECD region is anticipated to decline by 8.9 mb/d during the forecast period. Driven by an expanding middle class, high population growth rates and stronger economic growth, oil demand in Developing countries is expected to increase by almost 24 mb/d.
- Global oil demand growth is forecast to decelerate steadily to a level of only 0.3 mb/d every year between 2035 and 2040. This is a result of decelerating population and GDP growth, the structural shift of the global economy, further efficiency improvements driven by a tightening of energy policies and/or technological improvements and fuel switching, particularly in the road transportation sector.
- In the long-term, more than half of the oil demand growth is expected to be satisfied by light products. The demand for middle distillates is anticipated to increase by 6.8 mb/d during the forecast period, while that for heavy products increases only marginally by 0.5 mb/d. Jet/kerosene is the fastest growing fuel in the Outlook.
- Demand in the road transportation sector is anticipated to increase by 5.4 mb/d between 2016 and 2040. A clear differentiation exists between the OECD and Developing countries. In the former, sectoral oil demand is expected to decline by 7 mb/d, while in the latter it is estimated to increase by 12.1 mb/d.
- The vehicle stock is expected to increase significantly during the forecast period. The number of passenger cars and commercial vehicles is anticipated to almost double. Most of this growth comes from Developing countries fuelled by increasing economic activity and income levels.
- The passenger car fleet is anticipated to change smoothly over the forecast period. The fleet share of alternative fuel vehicles (electric, natural gas and fuel cell vehicles) is estimated to rise from around 2% in 2016 to nearly 16% in 2040 with EVs alone rising from 0.1% in 2016 to approximately 12% in 2040. In the commercial vehicle segment electrification is expected to play a minor role.

This Chapter examines in detail the future oil demand prospect. A dedicated regional analysis for the medium-term outlook (up to 2022) is initially presented where special attention is placed on the impact of the IMO MARPOL Annex VI Global Sulphur Cap regulations adopted in October 2016. Then, the Chapter presents the long-term demand outlook where particular emphasis is put on the product demand prospects up to 2040. Finally, an extended analysis of the sectoral demand is presented. Given the importance in terms of oil demand and the significant structural shifts occurring in the road transportation sector, aviation, marine bunkers and petrochemicals, a more detailed analysis on these specific sectors is shown.

3.1 Medium-term oil demand

The oil demand outlook for the medium-term period 2016–2022 shows an increase of 6.9 mb/d, rising from 95.4 mb/d to 102.3 mb/d (Table 3.1). This corresponds to an average annual increase of almost 1.2 mb/d. However, it should be noted that global annual demand growth decelerates from 1.45 mb/d in 2017 to 0.81 mb/d in 2022, as expected higher oil prices, efficiency improvements, lower population growth rates in the OECD and China, and the further penetration of alternative fuel vehicles limit growth potential.

Table 3.1
Medium-term oil demand in the Reference Case

mb/d

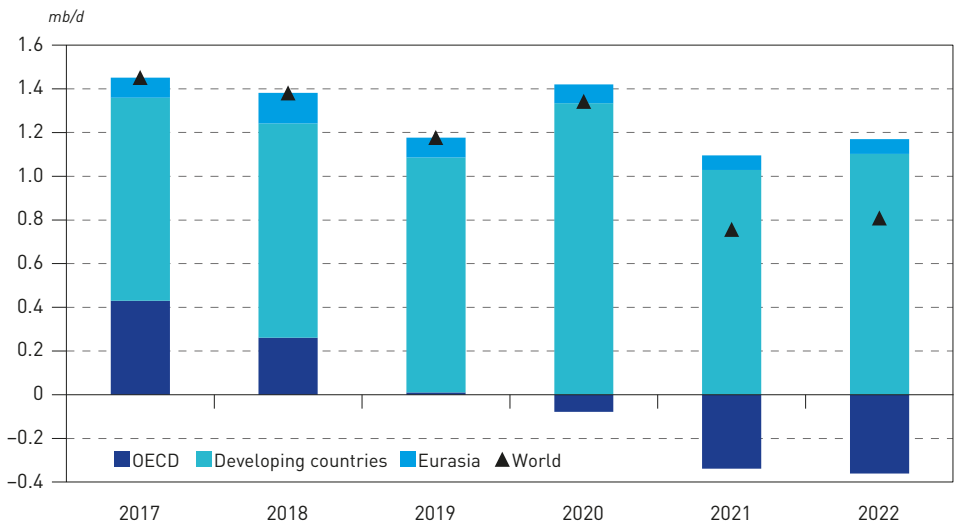
	2016	2017	2018	2019	2020	2021	2022	Growth 2016–2022
OECD America	24.7	24.9	25.1	25.2	25.2	25.0	24.9	0.2
OECD Europe	14.0	14.2	14.3	14.3	14.3	14.2	14.0	0.0
OECD Asia Oceania	8.1	8.1	8.1	8.1	8.0	7.9	7.9	–0.3
OECD	**46.8**	**47.3**	**47.5**	**47.5**	**47.5**	**47.1**	**46.8**	**–0.1**
Latin America	5.7	5.7	5.8	5.9	6.0	6.1	6.1	0.5
Middle East & Africa	3.8	3.9	3.9	4.0	4.1	4.2	4.3	0.5
India	4.4	4.5	4.6	4.8	5.1	5.3	5.6	1.2
China	11.8	12.2	12.6	12.9	13.2	13.4	13.7	1.9
Other Asia	8.5	8.7	8.8	9.0	9.4	9.5	9.8	1.3
OPEC	9.1	9.2	9.3	9.5	9.8	9.9	10.1	1.1
Developing countries	**43.2**	**44.1**	**45.1**	**46.2**	**47.5**	**48.5**	**49.6**	**6.5**
Russia	3.4	3.5	3.5	3.6	3.6	3.6	3.7	0.2
Other Eurasia	1.9	1.9	2.0	2.1	2.1	2.2	2.2	0.3
Eurasia	**5.3**	**5.4**	**5.6**	**5.6**	**5.7**	**5.8**	**5.9**	**0.5**
World	**95.4**	**96.8**	**98.2**	**99.4**	**100.7**	**101.5**	**102.3**	**6.9**

This year's demand analysis places special emphasis on the impact of the implementation of the new IMO regulations starting in January 2020 (further details can be found in the marine bunkers section in this Chapter). As shown in Figure 3.1, in the Reference Case, oil demand is expected to decelerate from almost 1.5 mb/d in 2017 to around 1.2 mb/d in 2019. However, oil demand in 2020 is expected to grow by almost 1.4 mb/d, before dropping away again to around 0.8 mb/d in 2021 and 2022. If the IMO regulations had been put in place after the medium-term, as was assumed in the WOO 2016, then the oil demand growth pattern would be much smoother with a gentle deceleration.

The expected increase in oil demand growth in 2020 due to the IMO regulations is a combination of two factors. The primary reason is the need for additional refinery runs to provide required fuels that lead to a surplus of high-sulphur fuel oil volumes priced at a discount. It is assumed that these will mainly be absorbed by the power generation sector. Furthermore, higher demand growth is also a direct consequence of volumetric processing gains from switching from fuel oil to diesel. Most of the resulting additional demand will be located in regions with the main bunkering ports, such as Other Asia, OPEC, OECD America and OECD Europe.

Similar to previous estimates (WOO 2016), demand in the OECD region (Figure 3.2) is expected to decrease during the forecast period, particularly during the second half of the medium-term. However, the pattern is slightly different in this year's WOO. This year, OECD regional oil demand is expected to grow until 2019, before reversing this trend. In the WOO 2016, OECD demand grew only until 2017.

Figure 3.1
Global oil demand growth in the medium-term in the Reference Case



This pattern is partly explained by OECD America. The WOO 2017 sees more optimism for economic growth in 2018, coupled with increasing SUVs sales and an expected increase in drilling activity. This results in a more optimistic oil demand outlook for OECD America in 2018 and 2019. Overall, demand in this region rises from 24.7 mb/d in 2016 to 25.2 mb/d in 2020, before declining thereafter to 24.9 mb/d in 2022. In OECD Europe, the surprising strong demand growth witnessed in 2015 and 2016 (+0.29 mb/d and +0.22, respectively) is expected to continue, to a lesser extent this year and in 2018. However, with potentially higher oil prices, continued efficiency improvements and a greater penetration of alternative fuel vehicles, the region is expected to revert to its long-term trend of declining demand. By 2022, oil demand is estimated to decline to 14.0 mb/d, comparable to the level of a decade earlier. In OECD Asia Oceania, oil demand is foreseen to decline by 0.3 mb/d during the forecast period to reach 7.9 mb/d in 2022. This is on the back of a sluggish economic outlook, coupled with further efficiency gains and lower population growth.

In the medium-term, oil demand in the Developing countries (Figure 3.3) is expected to be strong, increasing from 43.2 mb/d in 2016 to 49.6 mb/d in 2022. This corresponds to an average growth of 1.1 mb/d p.a. This follows a somewhat disappointing 2016 where demand grew by only 0.89 mb/d, as a result of a sluggish economic situation in major commodity-exporting regions such as Latin America and OPEC. In Latin America, improving economic conditions, particularly in Brazil and Argentina, is anticipated to support demand growth that reaches 6.1 mb/d at the end of the medium-term. Supported by improving geopolitical conditions and a strong demographic outlook, demand in the Middle East & Africa is expected to increase by 0.5 mb/d to reach 4.3 mb/d by 2022.

The outlook for India shows accelerated demand growth. While in 2017, oil demand is expected to only grow by 0.1 mb/d, impacted by the demonetization of the economy, growth is set to rebound, so that by 2022, demand is expected to be growing at 0.25 mb/d. Overall, India's demand is estimated to increase from 4.4 mb/d in 2016 to 5.6 mb/d in 2022.

On the back of decelerating economic growth and a profound restructuring of its economy, China's oil demand is expected to increase by an annual 0.32 mb/d on average in the medium-term to a level of 13.7 mb/d. This average yearly growth is significantly lower than that observed over the last few years (0.5 mb/d between 2002 and 2006, 0.44 mb/d between 2007 and 2011 and 0.42 mb/d between 2012 and 2016).

The demand outlook for Other Asia shows strong growth of an additional 1.3 mb/d over the medium-term, to total 9.8 mb/d by 2022, supported by high economic growth. For OPEC, the demand outlook is closely linked to the oil price through its contribution to economic growth. In fact, in 2016, demand dropped for the first time since 1999, by 0.2 mb/d. Looking ahead, potentially rising oil prices are expected to have a positive impact on the economy, which will, in turn, support oil demand. By 2022, demand in OPEC is anticipated to reach 10.1 mb/d, an increase of 1.1 mb/d from 2016.

In Eurasia, demand is estimated to increase steadily from 5.3 mb/d in 2016 to 5.9 mb/d in 2022, as a result of improving economic conditions and better geopolitical circumstances. However, growth decelerates from 1.7% p.a. in 2017 to 1.2% p.a. in 2022, due to an unfavourable

Figure 3.2
Annual oil demand growth in the OECD (2017–2022)

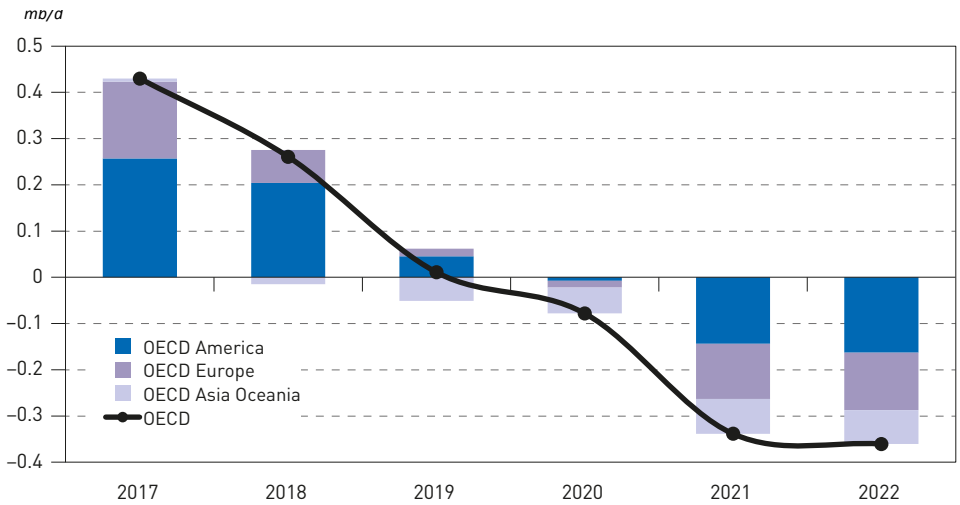
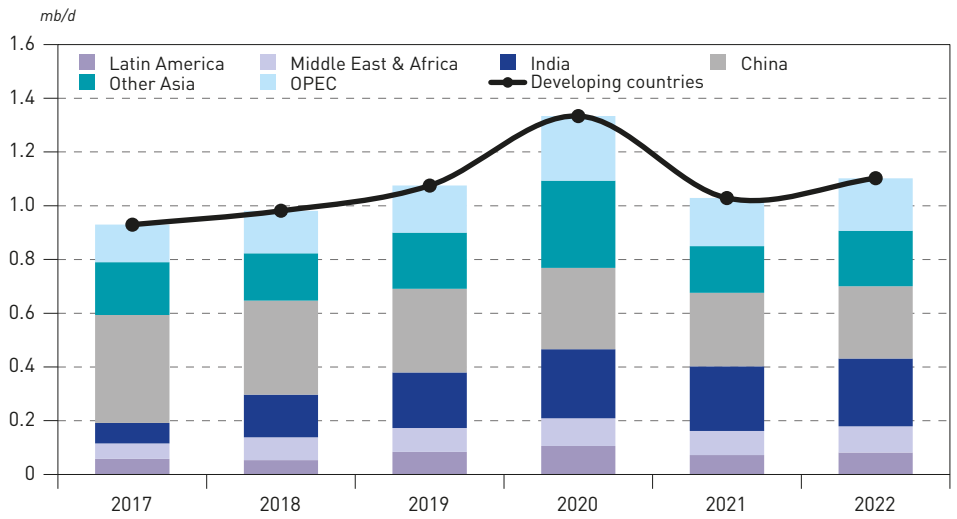


Figure 3.3
Annual oil demand growth in the Developing countries (2017–2022)

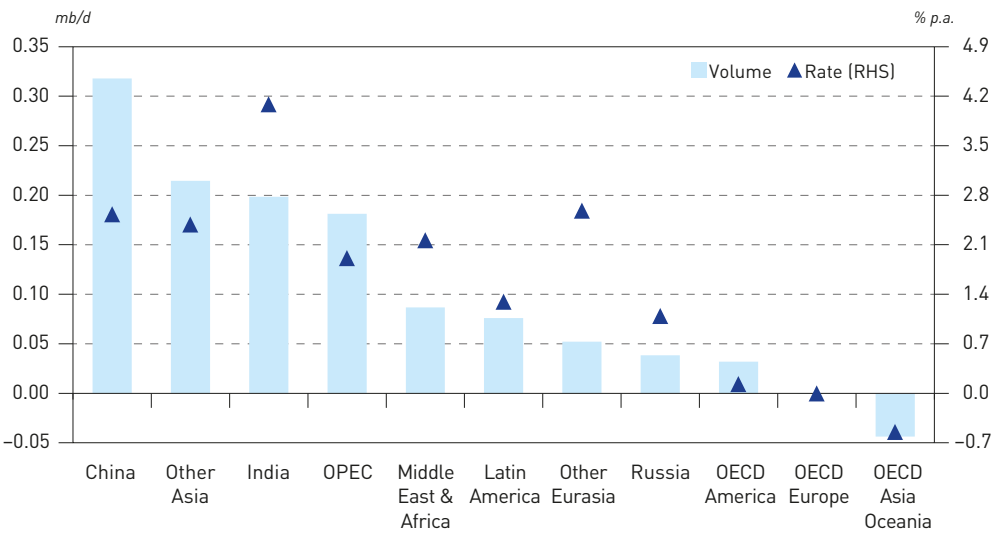


demographic outlook. Russian demand is expected to increase by 0.2 mb/d to reach 3.7 mb/d by 2022. In the case of Other Eurasia, a stronger demand growth is foreseen, rising from 1.9 mb/d in 2016 to 2.2 mb/d at the end of the medium-term.

As mentioned earlier, between 2016 and 2022 oil demand is expected to grow on average by almost 1.2 mb/d p.a. Figure 3.4 shows how growth is distributed between regions together with the corresponding demand growth rate (both on an average annual basis). Most of the growth is concentrated in the non-OECD Asian region with an additional 0.73 mb/d every year. On average, China's demand is anticipated to rise by more than 0.3 mb/d p.a. over the forecast period. Growth in Other Asia and India is estimated to be 0.21 mb/d and 0.20 mb/d, respectively, with the latter being the region where demand is growing at the fastest pace (4.1% p.a.). On the other hand, as already noted, demand in the OECD region is expected to decline, with OECD Asia Oceania the region showing the highest and fastest average annual decline.

When comparing oil demand numbers with those of last year, some important observations should be noted. To begin with, the historical baseline is different (see Box 3.1 for further details). Global oil demand in 2016 is 1.17 mb/d higher than last year. Most of the regions have been revised upwards, especially China (+0.69 mb/d), OECD Europe (+0.31 mb/d) and OECD Asia Oceania (+0.12 mb/d). In addition, the economic growth assumptions have been updated and show, in general, a marginally more optimistic picture. Furthermore, as already mentioned, last year it was assumed that the implementation date for new IMO regulations would be after the medium-term period. However, the implementation date has now been set for

Figure 3.4
Average annual oil demand growth between 2016 and 2022



Box 3.1

Historical oil demand baseline update

The quantification of historical oil demand often requires retroactive adjustments. These adjustments are largely a consequence of lags in data collection and reporting by primary and secondary sources, which necessitate the estimation of data points not available at the time of demand assessment, and apply to all aspects of flows and petroleum product categories.

One of the main data challenges underlying the assessment of historical oil demand is associated with the coverage of reported data in international marine bunkers. The current lag in reporting time, even under the well-established data collection procedures in place within OECD countries, is two years at best. Data reporting time lags for the non-OECD region are substantially wider, as data collecting and reporting agencies in this region are even rarer.

The direct use of oil relates solely to two sectors: liquid hydrocarbons for electricity generation and feedstock for the petrochemical industry. The direct use of oil for electricity generation takes place only in a few countries worldwide, with present data availability and data quality at satisfactory levels. However, substantial difficulties are encountered when collecting accurate data for oil used as feedstock for the petrochemical industry. The data reporting of many petrochemical entities is not centralized and, in some cases, national-level petroleum ministries might not necessarily include these volumes under reported oil demand. Moreover, a smaller, but significant amount of oil used as petrochemical feedstock returns to the oil pool as backflows to refineries and would have to be accounted for accordingly.

Modifications to the oil demand assessment are also found in petroleum product categories. This occurs for different reasons. Firstly, the inclusion of petroleum product volumes originating from non-oil sources – such as natural gas, coal and renewables – influences demand in each main petroleum category. Natural gas would largely have more weight on the high and middle parts of the barrel, while renewables are blended with gasoline, diesel and jet kerosene. Secondly, since the interaction of several primary energy commodities is substantial, ensuring the availability of data for the calculation of an overall energy balance is crucial. Such calculations, however, rely heavily on applied conversion factors that convert mass to volume and/or energy equivalents. Revisions to these applied conversion factors may occur and may even be the source of petroleum product demand adjustments. Thirdly, data collection of both actual volumes, as well as accurate conversion factors pose challenges for the so-called 'other products'. Prominent examples of such 'other products' are bitumen and petroleum coke and lubes.

The historical baseline for 2016 global oil demand has been modified upwards by 1.17 mb/d as compared to the WOO 2016. Upward revisions in Other Asia, India and China relate to the petrochemical and transportation sectors. In OECD America, changes are mainly attributed to higher gasoline demand than previously anticipated, while the bulk of OECD Europe's oil demand corrections are for middle distillates in the road transportation sector.

Some downward revisions have also occurred in the Middle East and Africa, primarily reflecting lower actual demand for the heavier part of the barrel, as well as volumes for direct use, as a result of its substitution with other commodities.

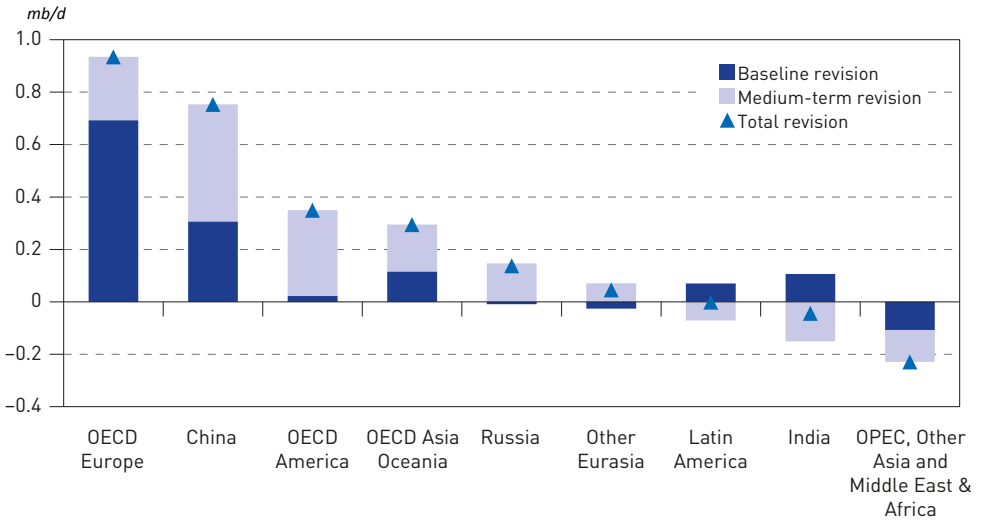
January 2020, before the end of this period. Finally, another factor is evolving energy policies that continue to push for greater energy efficiency.

Globally, oil demand has been revised upwards by 2.24 mb/d in 2022. This revision includes the upward shift to the baseline (+1.17 mb/d) in 2016. Figure 3.5 shows the oil demand revision by region in 2022, compared to the WOO 2016 figures. The total demand revision in 2022 is split by baseline revision in 2016 and the medium-term (2017–2022) revision.

On the positive side, Chinese demand was revised upwards by 0.93 mb/d in 2022. However, almost 75% of this revision is due to a higher baseline. Demand in OECD Europe has been lifted by 0.75 mb/d in 2022. Of this, around 0.45 mb/d corresponds to the medium-term (2017–2022) revision on the back of a more optimistic economic outlook. In the case of OECD America and the OECD Asia Oceania, the brighter economic outlook has increased the demand forecast in 2022 by 0.35 mb/d and 0.29 mb/d, respectively. On the other hand, oil demand in India by 2022 remains practically unchanged. However, this is a result of the counterbalancing of a higher historical baseline and a downward revision of the medium-term expectations, mainly as a result of the demonetization process.

Oil demand in OPEC together with Other Asia and Middle East & Africa was revised downwards by 0.23 mb/d in 2022, both as a result of the change to the historical baseline, but also given lower medium-term expectations. It should be mentioned that the updated OPEC Membership is reflected in Figure 3.5. Thus, Indonesia, which was part of 'OPEC' in the WOO 2016, is now included in 'Other Asia'. Moreover, Equatorial Guinea, which was part of 'Middle East & Africa' in

Figure 3.5
Oil demand revision (with respect to the WOO 2016) in 2022



the WOO 2016, is now part of 'OPEC'. That is why, for comparability reasons, Figure 3.5 shows the demand revision for the sum of the three regions.

3.2 Long-term oil demand by region

Long-term oil demand is expected to increase by 15.8 mb/d, rising from 95.4 mb/d in 2016 to 111.1 mb/d in 2040. As shown in Table 3.2, demand in the OECD region is anticipated to show a significant decline of 8.9 mb/d during the forecast period. This is in line with the historical declining trend that began in 2005, before it was broken in 2015 after the oil price decline. As already noted, this positive growth is scheduled to continue to 2019 only. The overall declining oil demand forecast in the OECD region is a result of a number of factors. To start with, population growth in the OECD is expected to be rather low in the future, with a rise of only 0.3% p.a. on average for the period 2016–2040. Similarly, average economic growth in the region is estimated at only 2% p.a. for the same period. Furthermore, in the OECD a stronger tightening of energy policies targeting energy efficiency is anticipated. Finally, the Reference Case also sees a significant penetration of alternative fuel vehicles in this region.

Table 3.2
Long-term oil demand in the Reference Case

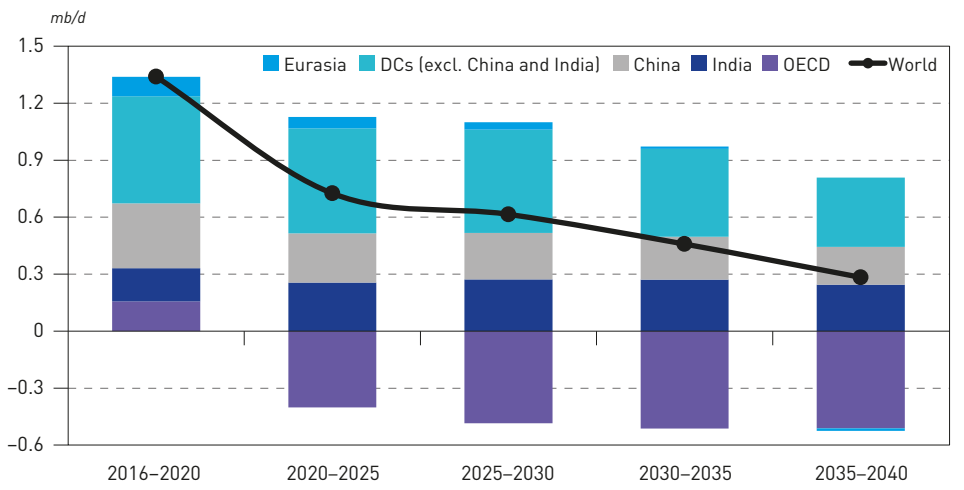
mb/d

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	24.7	25.2	24.2	23.0	21.6	20.2	–4.4
OECD Europe	14.0	14.3	13.6	12.9	12.2	11.5	–2.6
OECD Asia Oceania	8.1	8.0	7.6	7.1	6.7	6.2	–1.9
OECD	**46.8**	**47.5**	**45.5**	**43.0**	**40.5**	**37.9**	**–8.9**
Latin America	5.7	6.0	6.4	6.8	7.0	7.3	1.6
Middle East & Africa	3.8	4.1	4.6	5.2	5.8	6.4	2.6
India	4.4	5.1	6.4	7.7	9.1	10.3	5.9
China	11.8	13.2	14.5	15.7	16.8	17.8	6.0
Other Asia	8.5	9.4	10.3	11.3	12.2	12.8	4.4
OPEC	9.1	9.8	10.7	11.5	12.0	12.4	3.3
Developing countries	**43.2**	**47.5**	**52.8**	**58.2**	**63.0**	**67.0**	**23.8**
Russia	3.4	3.6	3.7	3.8	3.8	3.7	0.3
Other Eurasia	1.9	2.1	2.3	2.5	2.5	2.5	0.7
Eurasia	**5.3**	**5.7**	**6.0**	**6.2**	**6.3**	**6.2**	**0.9**
World	**95.4**	**100.7**	**104.3**	**107.4**	**109.7**	**111.1**	**15.8**

The Reference Case envisages substantial oil demand growth in Developing countries. Driven by an expanding middle class, high population growth rates and stronger economic growth potential, the region's oil demand is expected to increase by almost 24 mb/d. It rises from 43.2 mb/d in 2016 to 67 mb/d in 2040. Within the Developing countries, China is expected to continue to be the largest consumer of oil during the forecast period, adding 6 mb/d to reach 17.8 mb/d by 2040. India will be the region with the second largest overall demand growth, adding 5.9 mb/d between 2016 and 2040. Indian demand growth sees the fastest annual average growth rate of 3.6% p.a. Fast growth is also expected in the Middle East & Africa (2.2% p.a.) while growth potential in Latin America is more limited (1% p.a.). In Eurasia, oil demand is forecast to increase by less than 1 mb/d to reach 6.2 mb/d in 2040. In fact, demand is anticipated to plateau around 2035 at 6.3 mb/d. Most of the growth is expected to come from Other Eurasia, which adds 0.7 mb/d during the forecast period.

Figure 3.6 clearly highlights the importance of Developing countries as a long-term oil demand growth driver. Over the forecast period, oil demand in the region is expected to increase, on average, by 1 mb/d p.a., with China and India combined accounting for half of that growth. However, the picture is rather different at the end of the forecast period, compared to the beginning, as oil demand growth decelerates and the regional demand growth gravity centre shifts from China to India. Between 2016 and 2020, regional oil demand is expected to increase at an annual average of 1.1 mb/d, with China representing almost two out of every six additional regional barrels and India one out of every six. During the last five years of the forecast period, however, oil demand growth decelerates significantly, to an annual average of just 0.8 mb/d as developing economies mature and see lower GDP growth figures. China will add one out of every four regional barrels, while India will add almost one out of three regional barrels by 2040.

Figure 3.6
Average annual oil demand growth in the Reference Case



In the OECD region, overall oil demand marginally increases between 2016 and 2020 driven by strong demand in OECD America and OECD Europe to a lesser extent. Thereafter, a continuous and accelerated decline is expected. In the last years of the forecast period, oil demand will decline, on average, by 0.5 mb/d p.a. Most of the decline will come from the road transportation sector as the regional car fleet becomes increasingly more efficient and the prevalence of EVs, which include PHEVs and BEVs, expands. In Eurasia, improving economic conditions and geopolitical stability will incentivize oil demand in the medium-term. However, in the long-term, oil demand growth is expected to be constrained by low economic growth and a declining population.

Figure 3.6 also shows another important demand trend. Global oil demand growth is forecast to decelerate steadily going from over 1.3 mb/d every year during the period 2016–2020 to only 0.3 mb/d every year between 2035 and 2040. The relatively strong oil demand growth up to 2020 is a result of the lower oil price environment, accelerating economic growth and the impact of the IMO regulations on oil demand in 2020. Looking to the long-term, the outlook assumes that oil prices will gradually rise and that the global economy will decelerate as a result of lower employment growth coupled with lower labour productivity growth. These assumptions will certainty curtail demand growth. However, three further structural factors that can be expected to limit growth potential are of particular interest.

Firstly, the economy, particularly that of developing countries, is anticipated to increasingly shift away from heavy industry, which tends to be more oil intensive, to a more service-oriented structure. A good example of this is China, where the weight of the service sector in the national economy has increased steadily over the past decade. According to the World Bank, in 2006 it represented 42% of the economy, while in 2015 its share had increased to 50%. Over the same timeframe, the weight of the industry sector dropped from 48% to 41%.

Secondly, further efficiency improvements will likely curb future oil demand growth. Whether it comes from a tightening of energy efficiency policies, technological improvements, or both, the use of energy (and oil) is expected to become ever more efficient. For example, cars will consume less fuel per kilometre, airplanes will burn less fuel per passenger kilometre and less energy will be needed to heat the same house in the future.

Finally, oil demand will likely continue to be limited by fuel switching. This is particularly true in the road transportation sector, where increasingly more EVs are estimated to penetrate the market, thus, displacing barrels of oil. In the marine bunkers sector the use of LNG could also displace some barrels of oil in the long-term. Similarly, in the residential/commercial/agriculture sector a certain degree of substitution by gas can be expected to limit oil's sectoral demand growth.

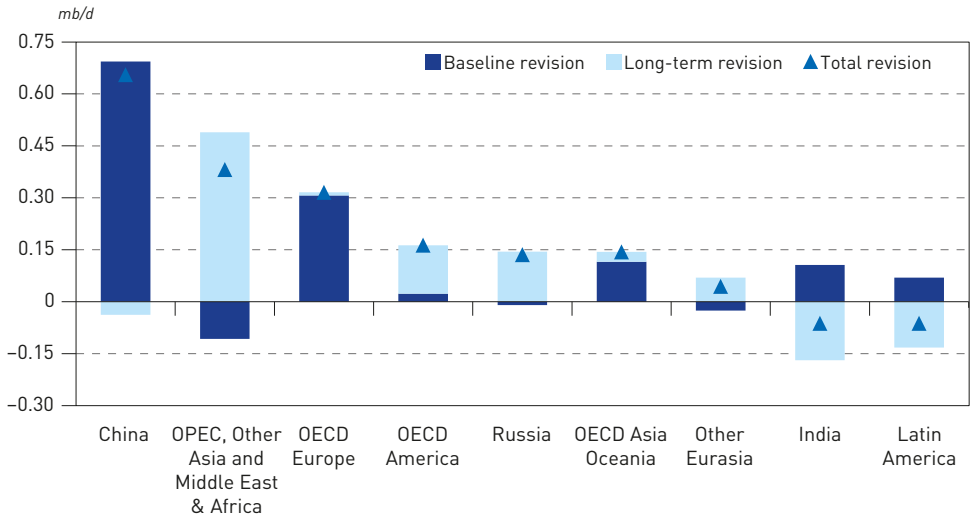
It is interesting to observe, though, that oil demand growth will decelerate steadily in every region except two: India and the Middle East & Africa. These two regions share common features. Both of them have a young and dynamic population. And it is expected that future economic development will lift millions out of poverty and help alleviate the challenge of energy poverty. Moreover, infrastructure development will be able to unlock great economic growth potential. In India, oil demand growth will exhibit only a very marginal deceleration towards the end of the forecast period. In the case of the Middle East & Africa, accelerating demand growth is forecast all the way up to 2040.

The long-term oil demand figures in this year's WOO report are somewhat different compared to those in the WOO 2016. To start with, global oil demand in 2040 in this year's WOO (111.1 mb/d) is higher than in the WOO 2016 (109.4 mb/d). However, as it noted the 2016 baseline has been updated and in the WOO 2017 (95.4 mb/d) already is higher than last year (94.2 mb/d). Nonetheless, this year there is a more optimistic view in terms of total oil demand growth over the forecast period (15.8 mb/d compared to 15.2 mb/d last year).

As can be observed in Figure 3.7, the revision to oil demand by 2040 – including both baseline and the long-term revision – is significant for many regions. On the positive side this is particularly apparent for China, OPEC, Other Asia and Middle East & Africa, as well as for OECD Europe, and on the negative side for India and Latin America. However, an important part of the revision is due to the baseline. Focusing on just the long-term revisions (not the baseline changes), it can be observed that the WOO 2017 is particularly more optimistic for OPEC, Other Asia, Middle East & Africa and Russia. In the case of the Middle East & Africa and Russia, the upward revision is on the back of a more optimistic economic growth outlook, as mentioned in Chapter 1. For OPEC & Other Asia, the revision is the result of a brighter outlook for the petrochemicals industry.

This year's Outlook also shows a gloomier long-term demand picture for India and Latin America due to a marginally less optimistic economic growth outlook, particularly in the 2030s.

Figure 3.7
Oil demand revision (with respect to WOO 2016) in 2040



3.3 Long-term oil demand by product category

The Outlook also provides a detailed analysis by refined product category as shown in Table 3.3. Light products are grouped into three categories: ethane/LPG, naphtha and gasoline (including ethanol). Middle distillates are grouped into two categories: jet/kerosene (including jet kerosene and domestic kerosene) and diesel/gasoil (including biodiesel). Finally, residual fuel oil (including refinery fuel oil) and 'other products' (including bitumen, lubricants, waxes, still gas, coke, sulphur, direct use of crude oil) account for the heavy part of the refined barrel.

Ethane/LPG demand in 2016 accounted for 10.7 mb/d, which represents 11% of total oil demand. Demand growth for this product is forecast to average 1% p.a. In terms of volume, this represents 2.9 mb/d of additional demand between 2016 and 2040. Most of the long-term demand growth is expected to be focused on ethane use in the petrochemicals sector, particularly in OPEC Member Countries. Significant LPG growth is also expected in India as a fuel in the residential sector and as energy poverty alleviation measures are taken. The use of LPG in the road transportation sector will remain marginal and concentrated in OECD Europe and OECD Asia Oceania.

Naphtha is used almost exclusively as a petrochemical feedstock. When cracked, it produces not only ethylene, but also propylene and butadiene. It is anticipated to be the fastest growing light product and the second fastest growing product over the forecast period, driven primarily by strong demand for petrochemical products in China and Other Asia. The average naphtha demand growth rate is forecast to be 1.3% p.a. In terms of volume, this represents 2.3 mb/d of additional demand by the end of the forecast period when total demand reaches 8.4 mb/d.
Gasoline is the second most important product category. In 2016, more than 25 mb/d of gasoline was consumed, with OECD America accounting for more than 40%. Looking ahead, gasoline demand is forecast to reach 28.4 mb/d in 2040. However, growth decelerates sharply over the forecast period and during the last ten years gasoline demand increases only marginally (0.1% p.a. on average). This is a result of the overall trends in road transportation demand, such as the increasing penetration of EVs and improving fuel efficiency. Regionally, demand growth will be driven by the Developing countries. In the OECD, the current lower oil price is anticipated to support a temporary demand increment. However, in the long-term, demand is expected to decline so that, by 2040, gasoline demand in the OECD is around three-quarters of that in 2016.

Jet/kerosene is the fastest growing fuel in the Outlook, averaging 1.4% p.a. between 2016 and 2040. This is significantly above the average growth rate for all products. In volume terms, this represents some 2.7 mb/d of additional demand by 2040. This product category consists of two similar products – jet kerosene for the aviation sector and domestic kerosene used mostly for lighting, heating and cooking. While strong growth is expected in the aviation sector, and therefore in the use of jet kerosene, the demand for domestic kerosene is forecast to decline due to a switch to alternative fuels in most regions.

In Table 3.3 it can also be observed that gasoil/diesel is the category with the highest demand, accounting for almost 30% in 2016. In the long-term, the demand for this product category is expected to increase by 4.1 mb/d to reach 32.6 mb/d in 2040. The growth

Table 3.3
Long-term oil demand by product category in the Reference Case *mb/d*

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
Ethane/LPG	10.7	11.3	12.1	12.6	13.2	13.6	2.9
Naphtha	6.1	6.5	7.0	7.4	8.0	8.4	2.3
Gasoline	25.1	27.0	27.8	28.1	28.3	28.4	3.3
Light products	**41.9**	**44.9**	**46.8**	**48.2**	**49.5**	**50.4**	**8.5**
Jet/kero	7.0	7.5	8.1	8.7	9.3	9.7	2.7
Gasoil/diesel	28.5	30.2	31.0	31.8	32.3	32.6	4.1
Middle distillates	**35.5**	**37.7**	**39.1**	**40.5**	**41.6**	**42.3**	**6.8**
Residual fuel	7.0	6.9	7.0	7.0	6.9	6.9	–0.2
Other products	10.9	11.3	11.5	11.7	11.7	11.6	0.7
Heavy products	**18.0**	**18.2**	**18.5**	**18.7**	**18.6**	**18.4**	**0.5**
World	**95.4**	**100.7**	**104.3**	**107.4**	**109.7**	**111.1**	**15.8**

expectation is driven by a number of factors. Firstly, increasing demand from the road transportation sector in the Developing countries due to an expanding fleet of trucks and buses, as well as diesel-driven light-duty vehicles. Secondly, gasoil/diesel growth will be further supported by the expected partial shift from fuel oil to diesel in the marine bunker sector as a consequence of the IMO's regulations. In fact, the use of diesel in this sector is expected to more than double, increasing from 0.8 mb/d in 2016 to 1.7 mb/d in 2040. However, growth is partially offset by the expected demand reduction in the road transportation sector in the OECD region as a result of limited scope for further fleet expansion and the increasing tightening of efficiency measures. Moreover, the continued declining use of oil in the electricity generation sector is also anticipated to curtail the use of gasoil/diesel in this sector.

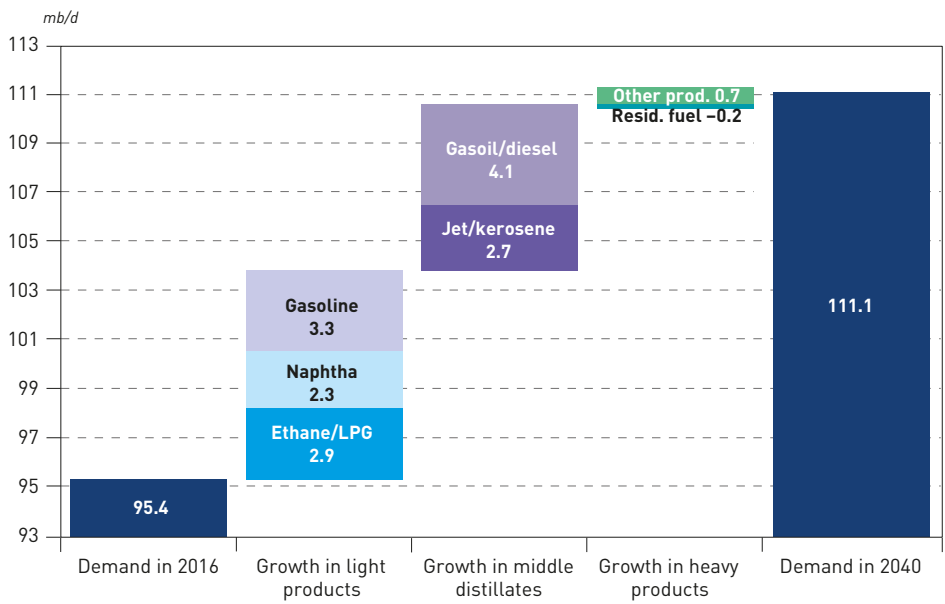
Residual fuel is the only fuel category where demand is anticipated to decline during the forecast period. Between 2016 and 2040, product demand is estimated to decline by 0.2 mb/d. However, its behaviour is expected to be rather uneven. A sharp drop is expected in 2020. Thereafter, a smooth recovery is foreseen until the early 2030s when demand is expected to start falling again. This behaviour is a result of a number of market driven forces. Firstly, the IMO regulations beginning in 2020 will likely provoke a switch away from residual fuel to diesel. As the shipping industry adapts to the new regulations and as scrubbers are increasingly installed, the use of residual fuel in the marine bunkers sector is then anticipated to recover smoothly (further details on the marine bunkers sector and the impact of the IMO regulations can be found later in this Chapter). Secondly, the use of residual fuel in other sectors, such as

electricity generation and rail and domestic waterways, is expected to decline smoothly over the whole forecast period as the overall sectoral demand declines (in the case of the former) and residual fuel is substituted by diesel (in the case of the latter).

In 2016, demand for 'other products' totalled 10.9 mb/d, with most of the demand concentrated in the industry sector, particularly bitumen/asphalt for road construction. The product outlook shows that demand for 'other products' is anticipated to increase at modest rates in the next few years before plateauing in the early 2030s, to finally exhibit a marginal decline at the end of the forecast period. This behaviour is a result of two factors. On the one hand, demand for bitumen is set to increase, driven mainly by the expansion of road transport infrastructure in Developing countries, particularly in China and India. This will more than offset demand declines in the OECD region, which has a more developed road network. However, in the long-term, total capacity expansion is likely to decelerate. On the other demand for 'other products' in the electricity generation and petrochemical sectors is expected to drop steadily over the forecast period. In the former, this is a result of the overall declining trend for the sector, and in the latter, it is due to a switch to light products, particularly ethane.

Figure 3.8 shows the demand growth outlook by product category. It can be observed that more than half of the oil demand growth will be satisfied by light products, which account for 8.5 mb/d out of the total demand growth of 15.8 mb/d. The demand for middle distillates is expected to increase by 6.8 mb/d during the forecast period, while that for heavy products increases

Figure 3.8
Demand growth by product category in the long-term

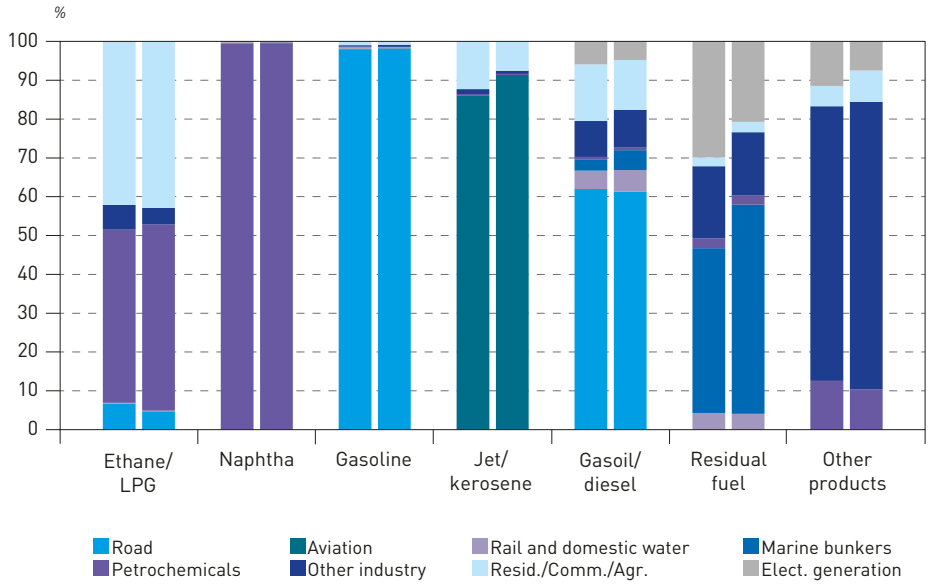


only marginally by 0.5 mb/d. In last year's edition of the WOO, the demand for heavy products was expected to decline due to a more pessimist view on the use of residual fuel in the marine bunkers sector. This year, with further clarity on the IMO regulations, the expectation is that less residual fuel will be substituted by diesel than previously forecast.

It is worth highlighting that only a few years ago (WOO 2014 and 2015) it was expected that middle distillates would account for more than half of the oil demand growth. That view has somewhat changed. In this year's WOO, the contribution of middle distillates to long-term growth is only slightly above 40%. The reason is mainly due to the fact that diesel/gasoil demand growth in the long-term has been revised downwards. This downward revision is on the back of three main factors. The first factor relates to the IMO regulations. As mentioned earlier, with the certainty of the implementation date being January 2020, this year the expectation is that less residual fuel will be substituted with diesel than previously forecast. The second factor relates to the road transportation sector. The so-called 'diesel scandal' and its scars, together with the higher than previously expected penetration of EVs, has resulted in a further downward revision of diesel/gasoil demand. Finally, a further factor relates to the faster than expected oil demand decline in sectors such as residential/commercial/agriculture and electricity generation where diesel plays an important role.

Figure 3.9 shows the share of the different sectors in demand by product in 2016 and in 2040. A few important aspects are worth highlighting. Ethane/LPG is mainly used in the petrochemi-

Figure 3.9
Share of the different sectors in demand by product, 2016 and 2040



cals and residential/commercial/agriculture sectors. This is expected to remain the case in the long-term. The weight of the road transportation sector and 'other industry' is estimated to drop. In the jet/kerosene product category the demand for domestic kerosene – used mainly in the residential/commercial/ agriculture sector – is anticipated to decline, while demand for jet kerosene grows steadily. That is why the weight of the aviation sector in this product's demand increases from 86% in 2016 to 91% in 2040.

In the gasoil/diesel product category the share of the different sectors is not expected to change significantly. The road transportation is set to continue to account for around 61% of product demand. However, it is worth noting that the weight of the marine bunkers sector is estimated to increase from 3% to 5% as a result of the IMO regulations. For residual fuel, the weight of the electricity generation sector is forecast to reduce from 30% to 20% as the overall sectoral demand drops. At the same time, marine bunkers gain weight in demand for residual fuel as scrubbers allow for high sulphur fuel oil (HSFO) consumption and low sulphur fuel oil (LSFO) is increasingly used. For 'other products', the weight of the 'other industry' sector is anticipated to increase from 71% to 74% as the expansion of road transport infrastructure in developing countries supports the use of bitumen. Simultaneously, the demand for 'other products' in the electricity generation and petrochemical sectors is set to drop steadily.

3.4 Long-term oil demand by sector

This section presents the sectoral oil demand breakdown in the Reference Case and an overview of long-term sectoral demand trends. The analysis covers the transportation sector, which includes road transportation, aviation, rail and domestic and marine bunkers; the industry sector, which comprises petrochemicals and 'other industry'; and other uses of oil such as the residential/commercial/agriculture sector; and the electricity generation sector. Given the particular importance of the road transportation, aviation, marine bunkers and petrochemicals sectors, in terms of oil demand and the significant structural shifts occurring, a more detailed analysis of these is also presented.

As shown in Table 3.4 and Figure 3.10, most of the demand for oil in the Reference Case is used for transportation. This is the sector where oil faces less strong competition from alternative fuels. Between 2016 and 2040, the transportation sector is expected to account for two out of every three additional barrels consumed. Nevertheless, demand growth is foreseen to decelerate on the back of efficiency improvements driven by technological developments, the tightening of energy policies and the somewhat marginal (but increasing) penetration of natural gas and electricity fuelled means of transportation.

Oil use for industrial purposes is also expected to increase, though at a slower pace than in the transportation sector. Growth is driven mainly by the petrochemicals sector, while oil demand in the rest of the industry sector will continue to face strong competition from alternative fuels. Oil consumed for other uses is forecast to grow marginally, particularly because demand in electricity generation is projected to decline. However, measures to alleviate energy poverty, coupled with rising income and urbanization levels, will continue to foster a switch away from traditional fuels to oil.

Table 3.4
Sectoral oil demand in the Reference Case

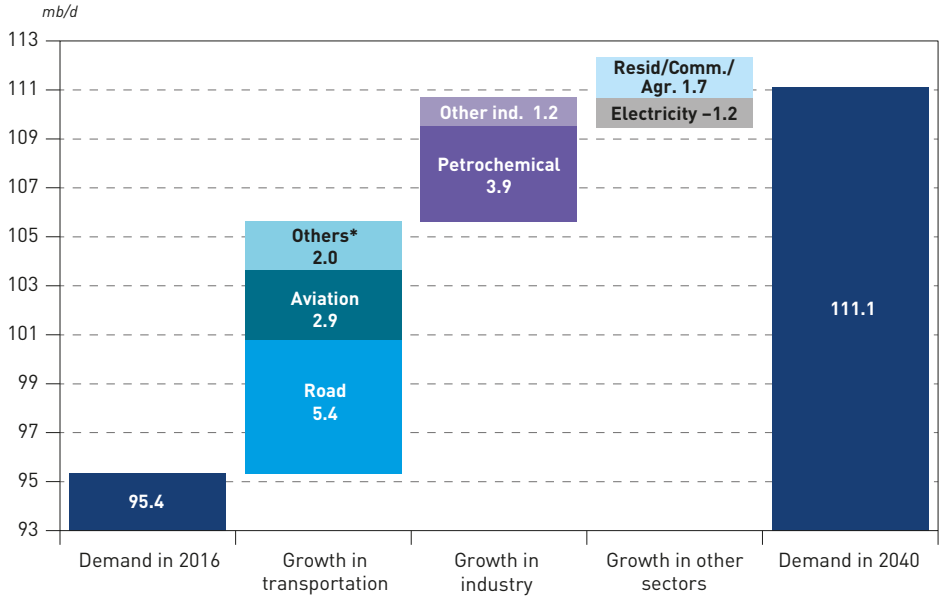
mb/d

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
Road	43.0	45.4	46.8	47.7	48.2	48.4	5.4
Aviation	6.0	6.6	7.2	7.8	8.4	8.9	2.9
Rail & dom. waterways	1.8	1.9	2.0	2.1	2.1	2.2	0.4
Marine Bunkers	3.8	4.2	4.7	5.0	5.2	5.4	1.5
Transportation	**54.6**	**58.1**	**60.6**	**62.5**	**63.9**	**64.9**	**10.3**
Petrochemicals	12.6	13.4	14.3	15.0	15.9	16.5	3.9
Other Industry	12.5	13.0	13.3	13.6	13.7	13.7	1.2
Industry	**25.2**	**26.4**	**27.6**	**28.6**	**29.6**	**30.2**	**5.1**
Resid./Comm./Agr.	10.5	10.9	11.4	11.7	12.0	12.1	1.7
Electricity generation	5.1	5.3	4.8	4.6	4.2	3.9	–1.2
Other uses	**15.6**	**16.2**	**16.1**	**16.3**	**16.2**	**16.0**	**0.4**
World	**95.4**	**100.7**	**104.3**	**107.4**	**109.7**	**111.1**	**15.8**

The road transportation sector is currently the biggest contributor to oil demand. In 2016, this sector represented 45% of global demand with 43 mb/d. Significant growth is expected in the long-term with an additional 5.4 mb/d up to 2040 to reach 48.4 mb/d. In fact, demand for one out of every three new barrels between 2016 and 2040 is estimated to come from the road transportation sector. Noteworthy growth is also expected for the petrochemicals sector where demand is anticipated to increase by 3.9 mb/d during the forecast period. Interestingly, sectoral demand is seen to grow at a much faster rate (1.1% p.a.) than overall demand (0.6% p.a.), so that the share of the petrochemicals sector is forecast to increase from 13% in 2016 to 15% in 2040.

The 'other industry' sector – comprising primarily iron and steel, glass and cement production, construction and mining – is the third biggest sector in terms of demand, with a total of 12.5 mb/d in 2016. At a global level, sectoral demand is anticipated to increase by 1.2 mb/d up to 2040. However, growth is expected to decelerate as global GDP moves from an industry-oriented structure towards a more service-oriented one. In fact, sectoral oil demand will exhibit almost negligible growth in the last few years of the forecast period. The use of oil in the residential/commercial/agriculture sector totalled 10.5 mb/d in 2016. Demand is expected to grow by 1.7 mb/d between 2016 and 2040, corresponding to an average growth rate of 0.6% p.a. Growth is partially curtailed because of the substitution away from oil to natural gas and renewables.

Figure 3.10
Sectoral oil demand growth in the Reference Case



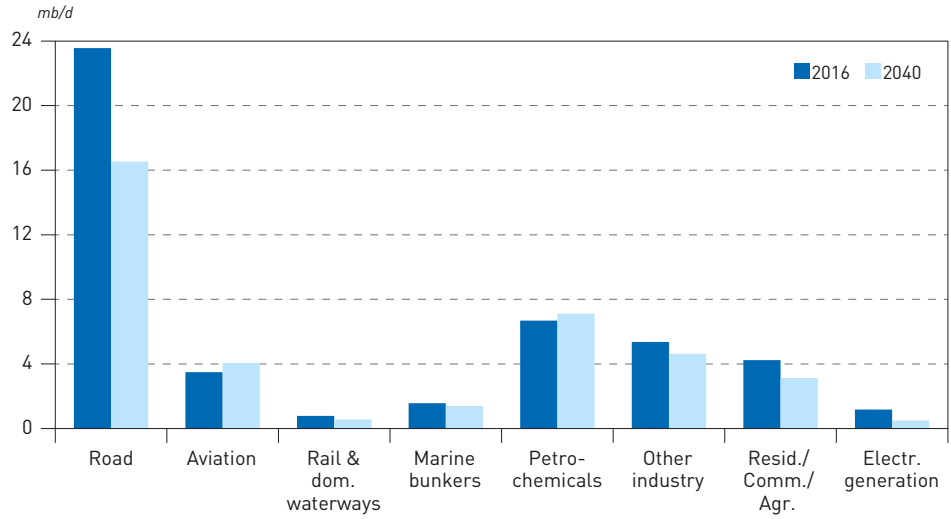
* *Others include marine bunkers and rail and domestic waterways.*

Aviation is the fastest growing sector driven by a rapidly growing middle class, particularly in developing countries and an increasing penetration of low-cost carriers (LCC). It is foreseen that oil demand will increase at an average rate of 1.4% p.a. between 2016 and 2040. In volumetric terms, demand is estimated to increase by 2.9 mb/d, rising from 6 mb/d in 2016 to 8.9 mb/d in 2040. Electricity generation is the only sector where declining demand is forecast at a global level. This is a result of increasing competition from coal and gas, as well as from renewables.

Oil use in the marine bunkers sector is anticipated to grow at a healthy rate (1.4% p.a. on average) up to 2040. The additional 1.5 mb/d of oil demand is a result of the increasing global economic and trade activity. Finally, the rail and domestic waterways sector is the smallest in terms of oil demand. It accounts for only 2% of global demand. However, expanding infrastructure and trade activity, together with rising urbanization levels, is expected to foster demand growth in the long-term. Demand is expected to reach 2.2 mb/d in 2040.

An interesting observation is that sectoral demand growth is not evenly distributed among regions. As shown in Figure 3.11, in the case of the OECD region, sectoral demand growth between 2016 and 2040 is expected only in the aviation sector (+0.6 mb/d), partially because of increasing traffic from developing countries, and the petrochemicals sector (+0.4 mb/d). For the rest of the sectors, declining demand is anticipated, particularly in the road transportation sector (–7 mb/d) and the residential/commercial/agriculture sector (–1.1 mb/d).

Figure 3.11
Sectoral oil demand in the OECD, 2016 and 2040



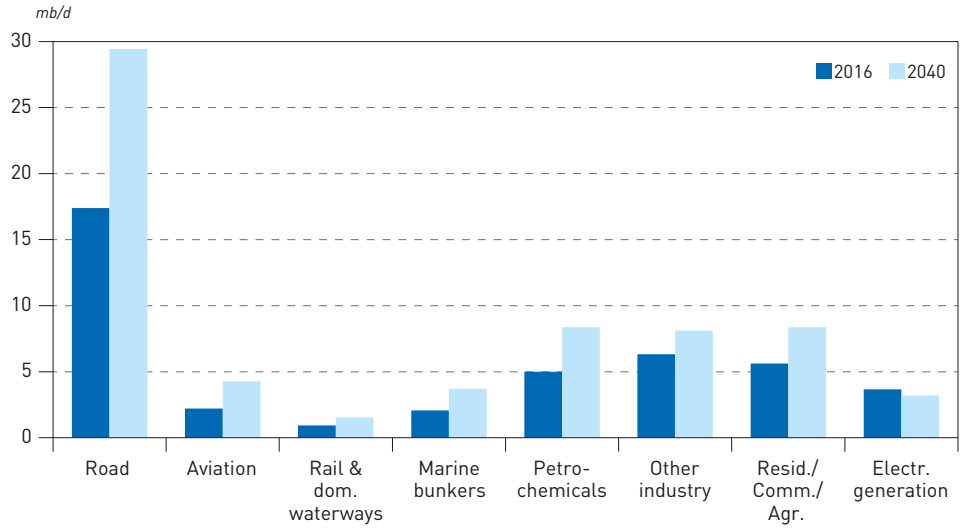
In the Developing countries, the picture is rather different. Figure 3.12 shows sectoral demand between 2016 and 2040. Driven by healthy economic growth rates, rapidly growing population and an ever expanding middle class, a demand increase is expected in every sector except electricity generation. Growth is particularly strong in the road transportation sector where demand is anticipated to increase by 12.1 mb/d driven by a massive expansion of the car fleet. Oil demand in the aviation sector is estimated to double as rising income levels foster demand for air travel services.

In Eurasia, oil demand growth is also expected in every sector except electricity generation. However, growth will be somewhat limited by lower GDP and population growth rates. The road transportation and the aviation sectors are seen as the main sectoral sources of demand increases, adding 0.4 mb/d and 0.2 mb/d, respectively, between 2016 and 2040.

3.4.1 Road transportation sector

As already mentioned, most of the oil consumed today is in the road transportation sector. In 2016, a total of 43 mb/d was used in this sector with the OECD accounting for around 55% and Developing countries for 40%. Regionally, demand is concentrated in OECD America, where one out of every three barrels is consumed, and to a lesser extent in OECD Europe and China. Since 2000, demand growth has been concentrated in Developing countries, particularly China and India. In 2000, China accounted for only 4% of the total sectoral demand, but in 2016 it represented over 11%. India's share has also increased during that same period from 2% to 4%.

Figure 3.12
Sectoral oil demand in Developing countries, 2016 and 2040



Historically, global oil demand growth in the road transportation sector has exhibited a rather marginal deceleration, from around 2.6% p.a. in the 1990s to 2.4% in the early 2000s, before sharply decelerating in 2008 and 2009 as a result of the Global Financial Crisis. In fact, sectoral demand did not show any growth in 2009 for the first time since 1979. However, regional growth dynamics have been markedly different. For the OECD region, demand growth since the early 1990s, when it showed an increase of around 2.4% p.a., has witnessed a pattern of steady deceleration. In the years before the Global Financial Crisis, this growth was reduced even further to 1.3% p.a., and even declined in 2008 and 2009. In the last couple of years, sectoral demand growth has partially recovered, fuelled by the lower oil prices of 2015 and 2016. In the case of Developing countries, sectoral demand growth has actually accelerated from 4% p.a. in the late 1990s to around 6% p.a. in the late 2000s. Only recently has demand growth shown signs of a slight move towards deceleration.

Looking ahead, sectoral demand projections have benefitted from OPEC's Road Transport Model (ORTM). The model is designed to replicate how oil is consumed in the road transport sector region by region, and for passenger cars and commercial vehicles separately. Demand projections are based on two main factors: first, the development of the global vehicle fleet, both in terms of total number of vehicles and its composition, taking into account the penetration of alternative fuels; second, changes in the oil use per vehicle (OPV) on the back of changes in average vehicle miles travelled (VMT) and overall improvements in fuel efficiency. These changes in the vehicle fleet and average OPV are closely linked to other developments in the road transportation sector, such as energy policies and technological issues.

Policy developments

As highlighted in Chapter 1, the Reference Case policy assumptions are driven strongly by the global trends of climate change mitigation, energy efficiency and energy security, as well as efforts across several regions to eradicate poverty and increase access to energy. As the largest source of oil demand, the transportation sector is one of the primary targets for policymakers who want to pursue these priorities.

Among the most visible long-term global transportation policy trends are the increasing penetration of EVs, the tightening of fuel emissions standards, desulphurization in the road transportation and marine sectors, and decarbonization in the aviation sector. Various governments are utilizing both financial and non-financial mechanisms to shift policies in the direction of meeting related goals. For example, diesel-fuelled vehicles are increasingly facing bans in various cities across the globe, and sulphur limits are tightening in the automotive transportation sector, as well as in the maritime sector worldwide. The impetus of such actions has increased pressure on the refining sector to adapt to the changes imposed on refined products, since diesel demand in particular will be facing slower growth than previously anticipated.

To promote its energy priorities, the new US Administration has taken advantage of the Congressional Review Act, which enables newly elected presidents to review the policies enacted by their predecessors at the end of the latter's presidential term. President Trump has thus ordered a series of changes to energy-related policies, including a review of the 2022–2025 fuel economy standards for passenger vehicles and the RFS on transportation fuels.

Uncertainty prevails in the sentiments for the US energy outlook. But what seems possible is higher petrol taxes, coupled with a phasing out of EV incentives, in order to raise funds for infrastructure investments. State tax incentives for electric and hybrid vehicles are also under pressure as only 16 US states currently offer financial support for EV buyers, as opposed to 25 previously. Other states, including Georgia, are not only revising their financial incentives for EVs or allowing them to expire, but are also establishing annual registration fees of between $150 and $300 for each EV. The motivation for allowing incentives to expire and introducing registration fees is mainly to allow individual states to generate income for infrastructure projects, including highway maintenance.

Meanwhile, heavy- and medium-duty vehicles' fuel economy standards, which were set in place by the previous US Administration in August 2016, are also under scrutiny by the current Administration. The emissions policy mandates that HDVs must achieve a 9% reduction in CO_2 emissions by 2027 compared to 2005 levels, and must become 2.5% more efficient on an annual basis between 2021 and 2027. Regulators will require other vehicles, such as tractor-trailers, delivery trucks and school buses, to have 25% lower carbon emissions and fuel consumption compared to existing standards, as well as tighter diesel engine emissions standards (with a reduction of fuel consumption by up to 5% for tractor engines and 4% for vocational engines). While the US is undergoing an examination of its fuel efficiency and emissions standards, the EU, China and India are moving forward with fuel efficiency plans.

The EC intends to introduce proposed legislation effective post-2020 on HDV emissions, which would require CO_2 emissions from new HDVs to be certified, reported and monitored. Following

the legislation's enforcement, the EC is also considering the introduction of additional mandatory limits on average CO_2 emissions from newly-registered HDVs, as is already done being for passenger vehicles. It is also considering the development of modern infrastructure supporting alternative fuels for HDVs, smarter pricing on infrastructure usage, and the effective and coherent use of vehicle taxation by EU members.

China is also moving forward with clean fuel plans in order to achieve its overall goal of achieving cleaner air by way of launching several policies. China's State Council, in its 13th Five-Year Plan released in early 2017, announced plans to stimulate the transition to cleaner fuels. The plan also includes reducing SO_2 emissions by 15% by 2020, compared with 2015 levels, and increasing the share of public transportation to 30% of total traffic in all major cities by 2020.

Consequently, the country is increasing road fuel standards and promoting EV penetration. In April 2017, China announced that by 2025 it aims for EVs to represent at least one-fifth of its projected 35 million annual vehicle sales. Furthermore, China aims for sales of EVs to reach two million by 2020. These announcements come one year after China's main traffic management authority, the Traffic Management Bureau, implemented new special license plates for EVs in order to help traffic police apply preferential policies to EVs compared to conventional vehicles. For example, while EVs are allowed unlimited access to central Beijing, conventional vehicles are denied access for one day of the week.

Additionally, China will tighten standards on conventional vehicles by requiring all light vehicles to adhere to more stringent emission levels under the new China VI standards by mid-2020, limiting sulphur to 10 ppm, and lowering the cetane number to 51. Consequently, the government expects 300,000 obsolete vehicles to be removed from roads in Beijing this year alone, according to the city's mayor. Twenty-eight cities are expected to expedite the application of the China VI fuel specification standards starting in September 2017, pressuring 'teapot refineries' to also begin meeting demand for the tighter fuel specifications in addition to the China V standard that is currently applied in rural areas.

Similarly, India is seen advancing with its clean fuel policy drive in both the road transportation and bunkering sectors. The government implemented a nationwide mandatory Mass Emission Standard for Bharat Stage-IV (Euro 4) fuel standards on 1 April 2017. The plans reflect India's push for the goal of 'leap-frogging' to the application of the Bharat Stage VI (Euro 6) standards nationwide by 2020. The fuel standard reform puts further downward pressure on diesel demand following the Indian Supreme Court's ban in July 2016 on all diesel cars over 10 years old in New Delhi.

In working toward meeting its 'climate action plan' to reduce emission intensity by 33–35% by 2030, over 2005 levels, India plans to have new vehicle sales consisting solely of EVs by 2030, and aims to build infrastructure for charging stations and battery-swapping programmes. This ambitious goal would have important implications. However, in the absence of a detailed plan, the exact manner in which they are to be achieved remains to be seen. Given the limited capacity of Indian automakers, as well as international vehicle manufacturers to meet the amount of demand that such policies would generate, it is foreseen that their anticipated contributions to the achievement of the stated goals will take time to fully develop.

In a similar vein, several cities across the world have decided to ban diesel vehicles by 2025, using such a policy as a tool to address both air quality and traffic congestion. The mayors of the cities of Paris, Mexico City, Madrid and Athens announced this commitment at the C40 Meeting of Urban Leaders in Mexico City in November 2016.

In a move towards achieving this goal, Paris enacted a ban in July 2016 on diesel vehicles built between 1997 and 2000, affecting nearly 6% of all cars in Paris. Restrictions are expected to tighten until 2020, when the only private vehicles that will be permitted to access central Paris will be those that are registered after 2011 (and only motorcycles registered after July 2015). Similarly, Madrid plans to ban cars from 500 acres of its city centre by 2020 through transforming 24 of the city's busiest streets into pedestrian zones. London is establishing Ultra-Low Emission Zones (ULEZ) in the city centre in April 2019, and introducing penalty fees of £12.50 for polluting vehicles that enter the ULEZ. From September 2020, all vehicles entering the ULEZ would be charged a daily fee (£130 for light-duty vehicles and £1,000 for heavy-duty vehicles.)

Similarly, several European countries, including Norway, Sweden, Belgium and the Netherlands, also plan for EVs to replace diesel and gasoline vehicles in the next decades. In particular, France and the UK have recently announced their intention to achieve 100% of new car sales to be electric by 2040.

Tightening road transportation fuel specifications are also a trend in Africa. The African Refiners Association (ARA) supported a measure in March 2017 to implement the AFRI-4 specification on lower sulphur limits in gasoline and diesel by 2020, and the AFRI-5 specification by 2030. The AFRI-4 specification limits sulphur levels in gasoline to 150 ppm, which is half of the current AFRI-3 standard, and reduces the sulphur limit in diesel to 50 ppm (compared to the current level of 600 ppm). The ARA is currently in talks with the 54-nation African Union to pave the way for broad implementation of the new specifications. Previous attempts to tighten fuel standards in Africa, such as efforts to remove lead from gasoline, have been successful, but took more than a decade to implement.

Technology developments

Over the past few decades, the road transportation sector has been characterized in part by the largely continuous development and improvement of underlying technology. For example, the fuel efficiency of the commonly used ICEs and especially gasoline engines has increased steadily. It is expected to further increase in the coming decades at a moderate, albeit continuous, pace of between 0.5% and 1.5% p.a. On the other hand, the associated cost increase of this generally economic engine technology helps electric mobility close the cost gap imposed by high upfront battery investments. When low fuel consumption is the main focus, diesel will remain the best choice ICE for passenger cars in the future. However, it is an open question as to what extent diesel technology may co-exist with optimized gasoline engines in view of their higher costs as soon as the latter come close in terms of grammes of fuel per kWh.

Recent headlines concerning diesel vehicles have attracted public attention in respect to emission pollutants, mainly nitrogen oxides (NO_x). Moreover particulate may soon be important in

the case of modern direct injection (DI) gasoline engines. However, further developing exhaust gas after-treatment in the future will allow engine manufacturers to comply with strict regulations in view of gaseous, as well as particulate emissions. Besides these emission aspects that have gained substantial importance in the case of urban areas, technical advances in terms of renewable energy have given rise to electric mobility. It is important to note that the sharp increase of installed wind and solar power can be used for transport purposes only through the electrification of vehicles.

The 1997 commissioning of Toyota's first fully hybrid electric vehicle (HEV) marked a milestone in powertrain electrification. The original intention behind this was to allow the main gasoline engine to run as far as possible at its point of optimum efficiency – either while cruising or recharging the battery – and to stop the engine when idle or at low load. However, modern diesel engines still provide better efficiency and the ICE passenger car is substantially cheaper.

A leap towards full electric mobility was taken through the introduction of Tesla's Model S in 2012. It should not be forgotten that such BEVs may weigh up to 500 kilogrammes (kg) more than a comparable gasoline or diesel car with accordingly increased energy consumption at the wheel to move the vehicle. BEVs will remain costly even at battery prices as low as the $100/kWh now expected for the mid-2020s. The cost of other required components are not anticipated to drop in price in the same way, and average battery capacity will inevitably increase to guarantee a satisfying range.

The required density of charging points for BEVs will likely be achieved in urban areas only because a large number of car owners do not own a garage with a dedicated connection. In view of the technical challenges, and more importantly the investments required, the build-up of the necessary charging infrastructure will be a substantial challenge in urban areas. It should also be noted that most of today's distribution infrastructure is largely under-dimensioned to meet future demand and needs a complete upgrade – not only of the backbone, but especially of the so-called 'last mile'.

In light of the Paris Agreement on climate change, electric mobility is regularly presented as the 'silver bullet' to reduce GHG emissions. However, as widely acknowledged, it is important to recognize that actual CO_2 emissions for a BEV largely depend on how the power is generated. While that fact that currently only a small percentage of power generation comes from renewables has already entered the public consciousness, the production of batteries and the related GHGs has only attracted minor attention. Recent studies reveal that the overall manufacturing chain may produce a further substantial amount of GHG emissions. The overall ecologic advantage is, therefore, questionable, as long as power generation is not largely based on renewables. Another uncertainty refers to the secondary market for used BEVs. As long as no stable market for used BEVs exists, consumers may tend to delay their decision to purchase electric vehicles.

While HEVs and BEVs each rely on one single energy source – namely, fuel and electric power, respectively – so-called PHEVs can use both. Today HEVs offer a satisfactory range due to their ICE, but they cannot use renewable power; PHEVs seem to be the natural advance in this context. Their modestly sized battery may increase substantially in the future when battery costs

fall further. Therefore, the most probable scenario until 2040 is a coexistence of partially (HEV, PHEV) or fully (BEV) electrified vehicles with passenger cars based on conventional gasoline and diesel engines.

Natural gas vehicles (NGVs) are also the cause of some diversification in the transportation fuel market. In the case of passenger cars, Compressed Natural Gas (CNG) is the first choice as it does not require thermal insulation and can be produced from the gas grid by simple compression. Natural gas has traditionally been mentioned in view of the substantially lower CO_2 emissions (approximately 195 gCO_2/kWh of natural gas) compared to gasoline and diesel fuel (approximately 270–280 g CO_2/kWh of fuel). However, this advantage has been counterbalanced by the substantially lower efficiency of gas engines (25–30%) compared to diesel engines (35–40%) in city traffic.

An earlier advantage, not only for CNG, but also for LPG, has been its far cleaner combustion when compared to the earlier standard gasoline or diesel engine. This has supported the use of LPG in passenger vehicles over many years, but it has been limited to only a few countries (South Korea, Russia, Turkey and Italy, among others). Therefore, this year's WOO expects that on a global scale LPG will remain a marginal fuel in the future for both passenger and commercial vehicles.

Fuel Cell Vehicles (FCVs) have a similar base structure as HEVs, but with the decisive difference that the electric power generating component is a fuel cell instead of a combustion engine. The conversion efficiency of a hydrogen-based fuel cell – which is currently the most efficient – is often over-estimated. Still, the level is approaching 60% or at least a value within the scope of future ICEs. It is imperative to generate hydrogen from a renewable source or another CO_2-free energy source such as nuclear.

Besides the fuel efficiency and pollution aspects, the comfort and security of a passenger car plays an important, if not decisive role, in a customer's purchasing decision. Given that fuel or power consumption at the vehicle's wheel is directly related to the vehicle's weight, the additional weight has significantly counteracted the manufacturers' desire to improve fuel efficiency. For such a purpose, the vehicle weight in most developed countries has begun to decline in recent years. However, it should be noted that strong economic growth in developing and emerging countries will not only increase the number of vehicles, but may also shift their demand from small and lightweight vehicles to more comfortable and safe – and, hence, heavier – ones.

The desire to save fuel is even more important for commercial vehicles. This has already led to the fact that heavy-duty diesel engines for large trucks are among the most efficient piston engines with specific fuel consumption as low as 195g/kWh. Given this high level of already achieved fuel efficiency there is a far lower future improvement potential compared to passenger vehicles. Even introducing exigent concepts, such as waste heat recovery, may only decrease specific fuel consumption at a comparably low rate of 0.5% p.a. at the global level.

The recent development of large gas reserves and the attractive pricing of natural gas in several regions, notably the US, alongside its lower carbon content have also fostered its use for commercial vehicles. However, in most countries neither LNG nor CNG has been able gain a

decisive market share. An unattractive price spread between diesel and natural gas in recent years has stalled the large-scale adoption of LNG in the case of commercial vehicles.

It is logical to examine whether commercial vehicles may also be electrified. Several manufacturers have announced the development of pure electric medium-duty delivery trucks with a range up to 200 kilometres (km). These are expected to be on the road by the early 2020s.

The issue of road infrastructure is not only a challenge in industrialized countries where it is often full or at over-capacity, but also in developing and emerging nations that need for the first time to provide a connected road system that can cope with expanding vehicle usage. Additionally, the quality of the roads must be satisfactory in view of traffic and load capacity. It should be noted that poor or insufficient road infrastructure increases fuel consumption due to frequent accelerate/decelerate events and large detours.

The IT and electronic revolution in vehicles commenced decades ago with the first fully-electronic engine management and security systems, such as anti-lock brake systems. Today passenger cars incorporate a large number of electronic components. Recent and future innovations comprise the integration of networked applications, both in the vehicle itself and in the management of the car fleet. The latter includes real-time traffic guidance, as well as Internet services leading to shared mobility (further analysis on this topic can be found later in this Chapter).

It can be concluded that the velocity of technical advances has accelerated substantially with the introduction of BEVs, which are now considered a serious alternative to traditional gasoline and diesel passenger cars. However, it should be noted that technological developments have occurred not only in this segment of the market. There has also been a strong push for improvements in conventional ICEs. It is expected that gasoline engines will retain their economic advantage for the build-up of new fleets in developing countries, while diesel will remain the main mover for commercial vehicles. In general, the market will see a far broader diversification of powertrain technologies than in the past, giving rise to a coexistence of various concepts according to customer needs and personal preferences. Alternative fuels are expected to retain or increase their market share, although this may rely strongly on government support related to taxation and/or infrastructure subsidies. The continuous advancement in IT will also continue, particularly as vehicles become more networked in the coming years.

Vehicle stock

As mentioned earlier, the first of the two components of oil demand in the road transportation sector is vehicle stock. Fuelled by increasing economic activity and income levels, as well as a growing middle class, the global numbers of passenger cars and commercial vehicles have increased steadily in the last few decades.

In the case of **passenger cars**, in 1970 there were only 218 million cars on the roads. By 1990, that number had grown to 491 million. In 2016, the global passenger car fleet totalled 1,076 million. Historically, the majority of the cars have been driven in the OECD region, a result of the region's higher income levels. However, the relative weight of the OECD in terms of the

global car fleet has been in constant decline as saturation effects limit the potential for additional cars in the region and income levels in the Developing countries increase. Currently the OECD accounts for 12 out of every 20 cars in the world. In 1970, it represented 19 out of every 20.

Looking to the future, the global number of passenger cars is expected to grow steadily at an average rate of 2.7% p.a. up to 2040. In volume terms, the passenger car fleet is forecast to increase by 954 million during the forecast period, to reach 2,030 million in 2040. The vast majority of new passenger cars are expected to be seen in the Developing countries on the back of higher population and economic growth rates, rising income levels and increasing urbanization. The regional fleet is forecast to more than triple between 2016 and 2040. Within the Developing countries, China is estimated to add over 300 million passenger cars and India, the region with the fastest car fleet growth (9% p.a.), will add almost 160 million cars.

The passenger car fleet in the OECD region is expected to increase only marginally as a result of already high levels of car ownership, as well as public policies targeting the use of public transportation. Most of the regional growth in the OECD will come from OECD America where

Table 3.5
Projection of number of passenger cars

millions

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	278	290	305	318	329	339	61
OECD Europe	253	258	263	267	271	273	20
OECD Asia Oceania	93	94	95	96	96	96	3
OECD	**624**	**642**	**663**	**681**	**696**	**708**	**84**
Latin America	75	83	93	103	113	123	48
Middle East & Africa	30	38	48	61	74	90	59
India	23	34	56	87	129	179	157
China	137	189	263	336	398	443	306
Other Asia	59	78	107	142	182	225	166
OPEC	48	60	78	98	118	139	91
Developing countries	**373**	**482**	**644**	**826**	**1,014**	**1,200**	**827**
Russia	34	38	43	48	53	58	23
Other Eurasia	45	51	56	60	63	65	20
Eurasia	**80**	**89**	**100**	**109**	**116**	**123**	**43**
World	**1,076**	**1,213**	**1,407**	**1,615**	**1,826**	**2,030**	**954**

saturation effects are less of a constraint to additional cars. In Eurasia, the number of cars is forecast to increase by 50% by 2040 to total 123 million. Growth seems to be partially constrained by lower population growth expectations.

The passenger car fleet forecast in this year's WOO is slightly different from the one included in the WOO 2016. Specifically, the total number of cars in the long-term is marginally lower this year by around 80 million. This downward revision comes mainly from OECD America, OECD Europe, India and China, and is a result of the more optimistic view on the penetration of shared mobility services in these regions. As these services are increasingly adopted by consumers, the likely impact would be that the appetite for car ownership would be somewhat reduced. It should also be mentioned that the car fleet forecast for the Middle East & Africa has been revised upwards compared to the WOO 2016 on the back of upwardly revised expectations for long-term GDP growth.

The number of **commercial vehicles** is expected to more than double between 2016 and 2040, rising from 224 million to 463 million. In contrast to the case of passenger vehicles, in which car ownership is driven by GDP per capita and where saturation plays a very important role (at

Table 3.6
Projection of number of commercial vehicles

millions

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	38	41	45	49	54	58	20
OECD Europe	39	43	47	52	58	64	24
OECD Asia Oceania	26	26	26	26	27	27	1
OECD	**103**	**109**	**118**	**128**	**138**	**149**	**46**
Latin America	19	22	26	31	36	42	23
Middle East & Africa	14	16	20	25	32	39	25
India	14	18	25	34	46	59	46
China	24	30	37	45	55	66	41
Other Asia	25	29	36	44	52	60	36
OPEC	15	17	20	24	28	32	18
Developing countries	**110**	**132**	**165**	**204**	**248**	**299**	**188**
Russia	6	6	6	6	7	7	1
Other Eurasia	4	5	6	7	8	9	4
Eurasia	**10**	**11**	**12**	**13**	**14**	**15**	**5**
World	**224**	**253**	**296**	**345**	**400**	**463**	**239**

least at higher income levels), the increase in the commercial vehicle fleet is related more to trade and economic growth. For this reason, significant growth is foreseen in the OECD region where the fleet is forecast to increase by almost 50%. In the Developing countries, the number of commercial vehicles is expected to continue growing at healthy growth rates in the forecast period. In particular, in developing Asia the commercial fleet is anticipated to triple with India growing at the fastest rate (6.3% p.a.). By the late 2030s, China is forecast to overcome OECD Europe as the region with the biggest commercial fleet.

Vehicle fleet composition

In the past, both vehicle sales and fleet composition were quite stable over long periods of time, with few changes from year to year. The shift in Europe's passenger car fleet towards diesel was an exception. Nevertheless, the dominating role of ICEs has remained untouched and, apart from some minor market share of NGVs, the entire passenger and commercial fleet still relies mainly on oil-based fuel.

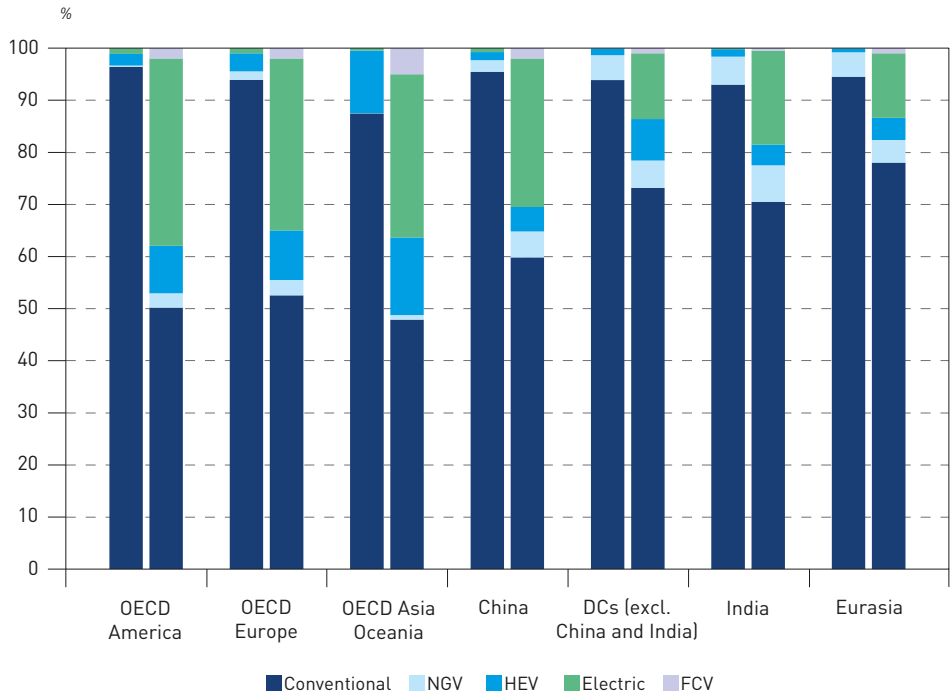
Today, the transport business is witnessing the appearance of a new energy source to propel vehicles: electric power. Substantial advances in technology and manufacturing have increased the storage capacity of batteries and decreased the costs per kWh of battery capacity. Additionally, the increasing bid for so-called 'clean' mobility has provided electrified vehicles with increasing market share. Since electric motors are best-suited for fast and wide fluctuations in the required power, it is not surprising that the passenger car market is influenced far more than the commercial vehicles market by powertrain electrification.

Passenger cars

Governments around the globe have started creating incentives to promote electric mobility, especially in urban areas. Nevertheless, since EVs are still far more expensive than comparable ICE-based cars and in view of the poorly developed charging infrastructure, the sales share of EVs remained low for 2016. This may change substantially in the future (until 2040) in several regions. Figure 3.13 shows the expected passenger car sales according to technology for such fast adopting regions (OECD America, OECD Europe, OECD Asia Oceania and China) and in slower adopting regions (Eurasia, India and Developing countries excluding China and India).

The WOO expects sales shares of EVs – comprising both BEVs and PHEVs – to be as high as around 35% in OECD America by 2040. This is closely followed by OECD Europe and OECD Asia Oceania with 33% and 31%, respectively. In China it reaches nearly 29%. It is apparent that wealthy regions with access to advanced capital markets are among the fast adopting ones. Other regions are electrifying passenger transport far less quickly. India, which is the country with the most aggressive electrification programme of any region, may reach 18% of market share for EVs in 2040. In both Developing countries (excluding China and India) and Eurasia, the share is expected to be around 12% each by 2020. Apart from the additional costs for BEVs and PHEVs, which must be shouldered by the individual car owner, the large investments required in power generation and charging infrastructure also limit the market share of EVs.

Figure 3.13
Composition of new passenger car sales according to technology, 2016 and 2040



Power train electrification started with HEVs as an alternative technology to diesel when it came to improving fuel efficiency. In the future, HEVs may multiply their market share in all regions with the exception of OECD Asia Oceania where only a minor increase occurs. The latter region already has an HEV share of around 12% because it is where this technology originated and it may eventually reach nearly 15%. HEVs are anticipated to remain strong (with shares between 8% and 9%) in OECD America, OECD Europe and Developing countries. In Developing countries (excluding China and India), HEVs provide a cheaper technology for the achievement of improved fuel efficiency without having to use the potentially more polluting diesel technology or far more expensive EVs.

A slight to moderate increase of NGVs is foreseen in all regions. India may have the highest share by 2040 at around 7%, while in the other slowly adopting regions the NGV share may grow only marginally from 4.8% to 5.3% (in Developing countries excluding China and India) or even decline a little from 4.7% to 4.3% (in Eurasia). In the fast adopting regions, the NGV share rises considerably, although from a very low level. The strong relative increase from 0.2% in 2016 to 2.7% in 2040 in OECD America or from 2.2% to 4.9% in China again indicates that these markets are looking to diversify transport technology. FCVs may occupy a share of 5% in OECD

Asia Oceania, but not more than 2% in any other region. Again, the other fast adopting regions show higher FCV shares than the slowly adopting regions which have a maximum of 1%.

Although the rise of electric, hybrid, natural gas and fuel cell vehicles will inevitably be at the expense of conventional vehicles – gasoline, diesel and LPG – these conventional vehicles are still forecast to occupy the largest or even a major share of passenger car sales in 2040. In fast adopting regions, their share is expected to decline significantly from above 96% to around 50%, as is the case for OECD America. In OECD Asia Oceania their share is anticipated to decrease from approximately 87% to around 48% .

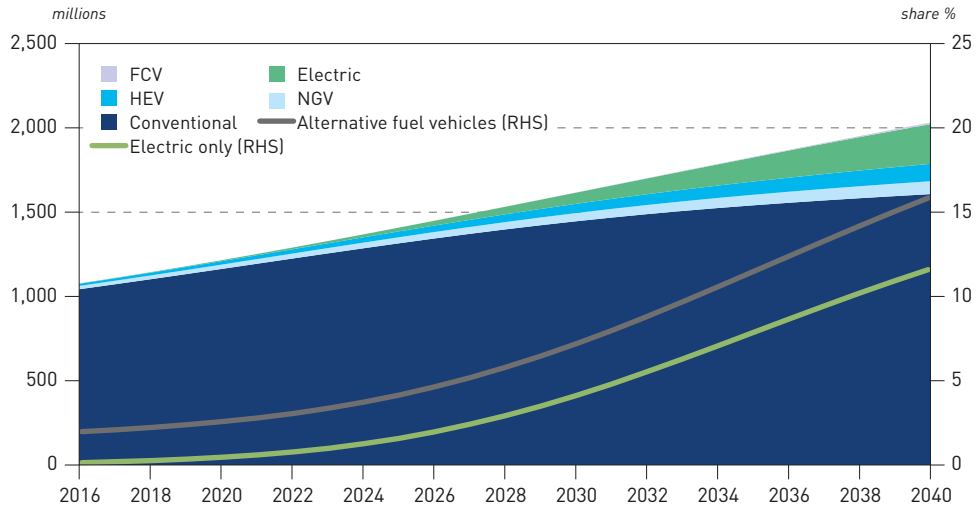
Although China is pursuing an energetic policy towards electric and, in general, alternative fuel vehicles, conventional cars are still expected to represent close to 60% of all passenger vehicle sales in 2040, compared to more than 95% in 2016. The country still needs to build up a large fleet in many areas and customers may prefer to look for inexpensive technology. Since gasoline engines with substantially improved fuel efficiency will become available at a reasonable cost in the future, they may end up representing the best value-for-money choice for many customers.

This aspect is even more important in the group of slowly adopting regions given their current economic development conditions. In all of these regions a substantial decline is expected in the share of conventional passenger cars, which is currently more than 93%. India's aggressive electrification strategy already cited is estimated to reduce the share of conventional vehicles down to a value as low as approximately 70%. Eurasia is expected to remain substantially higher at 78%, given that most of the countries in that region have climatic conditions that are especially averse to electric mobility. The remaining Developing countries (excluding China and India) are expected to be somewhere in the middle at around 73%.

The fast adopting regions represent today more than two-thirds of all global passenger car sales. It may, therefore, appear that the fleet composition to 2040 will also change substantially towards electrified powertrains. However, the global sales share of fast adopting OECD America and OECD Europe drops, while the global sales share of the more slowly adopting Developing countries (excluding China and India) are expected to rise significantly. Together with the fact that passenger cars bought earlier will remain in service and, therefore, form part of the car fleet long after the actual sale, the effect of having the fleet adopt new technologies is far less pronounced than is the case for sales. Figure 3.14 shows the corresponding passenger car fleet composition from 2016–2040.

The overall number of conventional passenger cars is forecast to further increase from around 1,040 million units in 2016 to more than 1,600 million units in 2040, although the relative rise decreases constantly. HEVs, with 103 million units by 2040, are estimated to occupy a notable share in the future car fleet. Alternative fuel vehicles including electric, natural gas and fuel cell vehicles will increasingly penetrate the global fleet. With approximately 235 million units (126 million being BEVs and 109 million PHEVs) by 2040 EVs will represent the major fleet share of alternative fuel vehicles. NGVs with nearly 77 million units are anticipated to occupy a notable, but not decisive share over the forecast period. Finally, 9.6 million units of FCVs are not expected to play a significant role for the global fleet, though they may occupy a notable niche in OECD Asia Oceania.

Figure 3.14
Passenger car fleet composition, 2016–2040



Overall, the fleet share of all alternative fuel vehicles is estimated to rise from around 2% in 2016 to nearly 16% in 2040 with EVs rising from 0.1% in 2016 to approximately 11.6% in 2040. In fact, electric vehicles contribute to the majority of the increase of all alternative fuel passenger cars.

Commercial vehicles

The challenge for passenger car manufacturers and, hence, the manufacturers of passenger car engines, is the frequent power demand change caused by acceleration and deceleration, as well as by substantially varying speeds. Engine power development for a mainstream vehicle may vary between 10 kilowatts (kW) and 100 kW or more in the case of large sports utility vehicles (SUVs) or limousines. One reason is that in terms of engine power, passenger vehicles are typically over-equipped to provide the car owner with a convenient driving experience. On the other hand, it is preferable to run the engines as stationary engines, at constant power development, in order to achieve higher fuel efficiency. Hybridization has been a logical strategy to achieve this behaviour: if the vehicle demands only a little power, then the engine also drives the generator to charge the battery. As a consequence, the combustion engine closely preserves the characteristic of a highly efficient stationary engine.

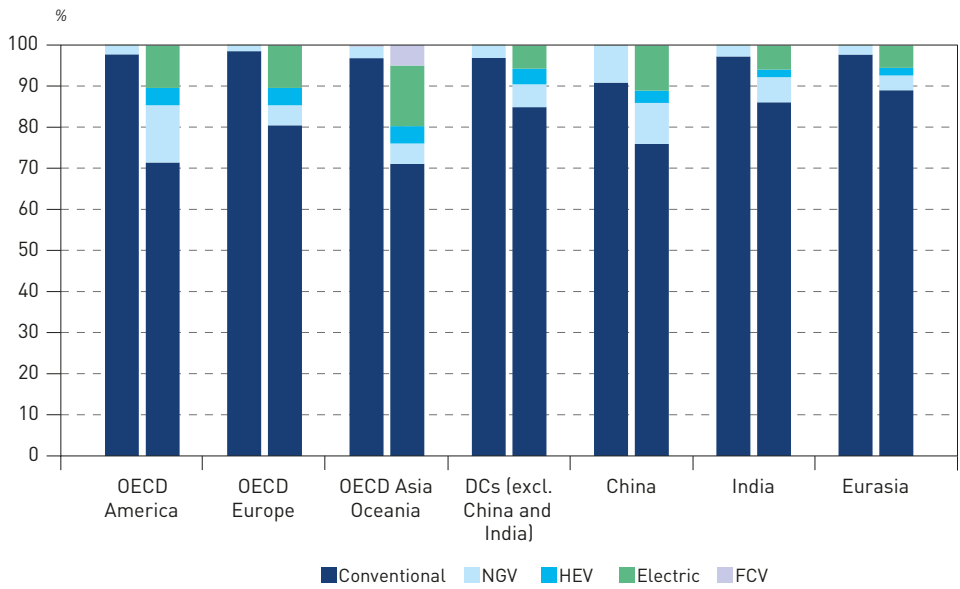
However, driving experience is not a criterion in the case of commercial vehicles. The fleet manager is simply obliged to buy the appropriately equipped truck or van. As a consequence, especially large commercial vehicles, such as long distance trucks, run their accordingly dimensioned engine in a more or less constant manner at a stable power development. The

variation is typically around a factor of two (i.e. peak/dip power development is not higher/lower than twice/half the average power development). This is comparable to a stationary combustion engine. It is, therefore, easier to optimize the fuel efficiency of most commercial vehicles. Exceptions cover frequent stop/start applications such as,urban buses or delivery vans. This has made heavy-duty diesel engines for commercial vehicles the most efficient ones in the road transport sector. As a consequence, fleet managers will mainly look for cheaper, alternative fuels instead of new technology. Natural gas may be the preferred choice.

Conventional powertrains will, therefore, occupy the predominant sales share in 2040 as Figure 3.15 shows. In 2016, only in China is there a substantial share – around 9% – of new commercial vehicles sold as NGVs. In all other regions, the share of non-conventional powertrains is expected to be 3% at most.

Figure 3.15 also shows that in the future – until 2040 – the share of commercial vehicle sales are forecast to likely undergo a notable change towards a far more versatile pattern. Natural gas vehicles will occupy an increasing share, with around 14% in OECD America and around 5–6% in OECD Europe, OECD Asia Oceania, Developing countries (excluding China and India) and India. China may increase the share of commercial NGVs from around 9.1% to 10%. Hybrid electric commercial vehicles are only of relatively minor importance even in 2040, comple-

Figure 3.15
Composition of new commercial vehicle sales according to technology, 2016 and 2040

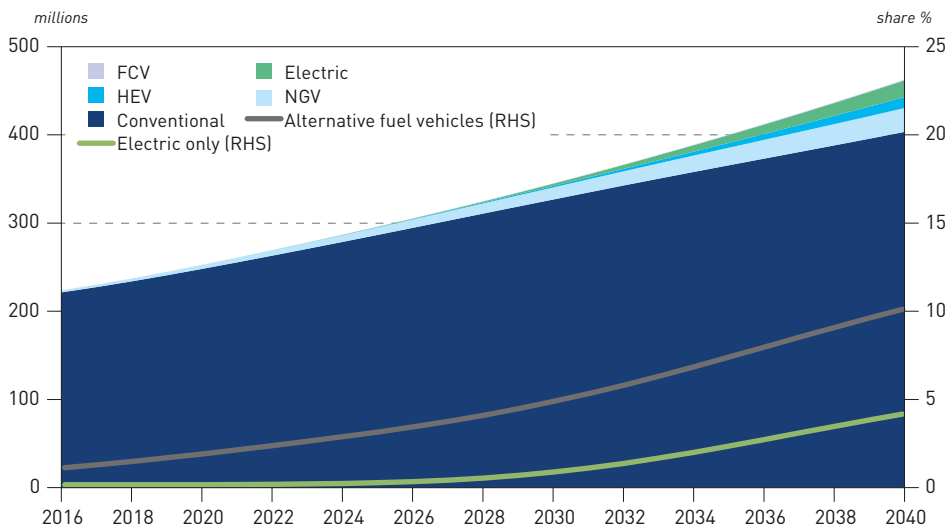


menting mainly gasoline commercial vehicles to improve their fuel efficiency, and to recuperate brake power in the case of urban and delivery vehicles.

Electrified commercial vehicles – which comprise battery electric and plug-in hybrid electric commercial vehicles – are forecast to represent a notable sales share in 2040, mainly in OECD America and OECD Europe at approximately 10% each, as well as China at around 11%. The deepest penetration is expected in OECD Asia Oceania with nearly 15%. Electric commercial vehicles are mainly short distance and urban vehicles which, apart from improved fuel efficiency, may also take advantage of zero emissions and nearly silent operation – an important asset in densely populated areas. As is the case for passenger cars, fuel cell commercial vehicles may play a significant role only in OECD Asia Oceania with an expected sales share of around 5%, while in the remaining regions their share is limited to 0.1%.

Because commercial vehicle sales are not anticipated to undergo diversification on the same scale as passenger vehicles, and since the more slowly adopting Developing countries (excluding China and India) will contribute more than one-third to global commercial vehicle sales, the overall fleet composition will change far less in the period to 2040 than in the case of passenger cars. Figure 3.16 indicates the corresponding commercial vehicle fleet composition from 2016–2040.

Figure 3.16
Commercial vehicle fleet composition, 2016–2040



The figure clearly shows that by far the largest fleet share is composed of conventional vehicles with more than 220 million units in 2016 and more than 400 million units in 2040. Hardly any deceleration in the fleet build-up is visible until 2040. Electric and HEVs are estimated to start to contribute a notable share only after 2030, and may reach approximately 31 million units in 2040, while FCVs are nearly invisible on a global scale with less than 1 million units. Only natural gas commercial vehicles occupy a significant and growing share beyond 2025, and may reach around 27 million units by 2040. Altogether, all alternative fuel vehicles have a minor 1% fleet share in 2016, which is forecast to rise to around 10% in 2040. However, only around 4% of them are expected to be electric.

Overall fleet compositions

In summary, it can be stated that powertrain electrification will change the composition of passenger car sales significantly until 2040, mainly in the four regions of OECD America, OECD Europe, OECD Asia Oceania and China. In the remaining regions, led by India, adoption of these new powertrains will be slow.

The only region where FCVs are anticipated to succeed in occupying a notable sales share of around 5% is in OECD Asia Oceania. Together with an optimistic view on EVs it is expected that conventional sales may be as low as around 48% in this region by 2040. In all other regions conventional powertrains will maintain a majority share of between 50% and 78%. The impact on fleet composition is notable, but less visible until the late 2030s. While all alternative fuel passenger vehicles rise to almost 16%, electric passenger cars are limited to a nearly 12% share in the case of the global passenger fleet. The fast growing sales numbers and fleet in Developing countries (excluding China and India) and their slower adoption of alternative fuel vehicles keeps the global alternative fuel fleet significantly below the level expected for fast adopting regions such as, for example, OECD America, OECD Europe and China.

In the case of commercial vehicles, conventional powertrains will dominate both sales and fleet composition. Electrification will play an increasing, but still minor role with the exception of short-distance and urban vehicles. Natural gas is expected to occupy a significant share mainly in OECD America and China. In general, the penetration of alternative fuel vehicles in the case of commercial vehicles is forecast to be far below the level of passenger cars.

Sectoral demand in road transportation

Oil demand in the road transportation sector is forecast to increase by 5.4 mb/d between 2016 and 2040, from 43 mb/d to 48.4 mb/d. A clear differentiation exists between the OECD and the non-OECD region. In the former, sectoral oil demand is expected to decline by 7 mb/d. Furthermore, the demand trend will revert rapidly going from a marginal growth of 0.2% p.a. between 2016 and 2020 to a strong decline of 2.2% p.a., on average, in the last five years of the forecast period. This is a result of a deceleration of the growth in the car fleet and an acceleration of the penetration of EVs. In OECD America, sectoral demand is expected to hold up to 2020, galvanized by lower oil prices and policy unwinding, particularly with regards to fuel efficiency standards. Thereafter, a smooth decline is anticipated. However, it is in the other OECD regions (Europe and the Asia-Pacific) where a strong sectoral demand

Table 3.7
Oil demand in the road transportation sector by region

mb/d

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	14.1	14.3	13.5	12.4	11.3	10.3	–3.9
OECD Europe	6.6	6.7	6.3	5.8	5.2	4.6	–2.0
OECD Asia Oceania	2.8	2.8	2.6	2.4	2.0	1.6	–1.2
OECD	**23.6**	**23.7**	**22.4**	**20.5**	**18.6**	**16.5**	**–7.0**
Latin America	2.7	2.9	3.1	3.2	3.3	3.3	0.6
Middle East & Africa	1.7	1.9	2.1	2.4	2.8	3.1	1.4
India	1.7	2.0	2.7	3.5	4.4	5.3	3.7
China	4.9	5.6	6.2	6.8	7.2	7.6	2.7
Other Asia	3.2	3.6	4.0	4.5	5.0	5.4	2.2
OPEC	3.2	3.5	3.9	4.3	4.5	4.7	1.5
Developing countries	**17.4**	**19.4**	**22.1**	**24.7**	**27.1**	**29.4**	**12.1**
Russia	1.1	1.2	1.2	1.2	1.2	1.1	0.1
Other Eurasia	0.9	1.0	1.2	1.2	1.3	1.3	0.4
Eurasia	**2.0**	**2.2**	**2.4**	**2.4**	**2.5**	**2.4**	**0.4**
World	**43.0**	**45.4**	**46.8**	**47.7**	**48.2**	**48.4**	**5.4**

is foreseen. In these regions, car fleet saturation plays a more limiting effect than in OECD America.

In the Developing countries region, demand is foreseen to increase rapidly, increasing from 17.4 mb/d to 29.4 mb/d, growth almost 70%. Demand growth is driven by a massive increase in the car fleet that more than compensates for the efficiency gains and penetration of EVs. Similar to the OECD case, sectoral demand growth in the future is also expected to decelerate. Nevertheless, towards the end of the forecast period demand is still expected to increase at healthy rates (1.6% p.a.).

As mentioned earlier, there is a clear differentiation between the expected sectoral demand pattern in the OECD region and in the non-OECD region, particularly in Developing countries. This is shown in Figures 3.17 and 3.18. In the OECD, sectoral demand is anticipated to decline from 23.6 mb/d to 16.5 mb/d between 2016 and 2040. This is driven by the decline in the OPV, due to increasing the fuel economy of internal combustion engines, declining average VMT and the increasing penetration of alternative fuel vehicles that outbalance the increase in the car fleet.

Figure 3.17
Demand in road transportation in the OECD, 2016 and 2040

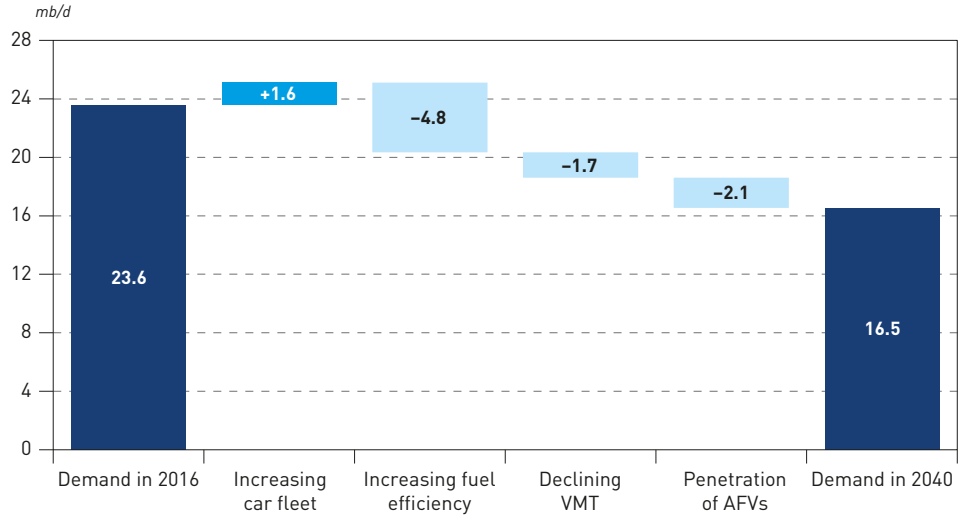
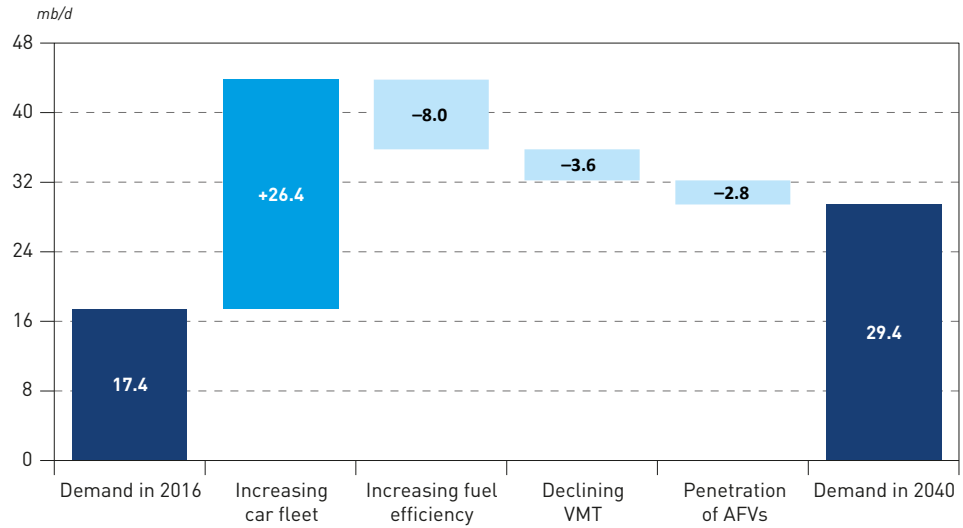


Figure 3.18
Demand in road transportation in Developing countries, 2016 and 2040



In particular, in the OECD region the moderate increase in the car fleet would, other things being equal, add only 1.6 mb/d to sectoral demand. However, improvements in efficiency as a result of a further tightening of emission reduction policies and technological developments will have a significant effect on demand. It is estimated that it will reduce demand by 4.8 mb/d between 2016 and 2040. Driving behaviour will also limit curb sectoral demand. The expected decline in the average VMT will further reduce demand by 1.7 mb/d during the forecast period. Finally, the penetration of alternative fuel vehicles, particularly EVs (including PHEVs and BEVs) and, to a lesser extent, natural gas and fuel cells, is anticipated to shrink sectoral demand by 2.1 mb/d.

In Developing countries, the picture is rather different. The massive increase in the car fleet by far outbalances the decline in the OPV so that sectoral demand increases from 17.4 mb/d in 2016 to 29.4 mb/d in 2040. In particular, the increase in the number of passenger cars (827 million) and commercial vehicles (188 million) would, other things being equal, increase sectoral demand by 26.4 mb/d during the forecast period. The fact that this expanding car fleet will increasingly become more efficient is forecast to translate into a reduction in demand of 8 mb/d. Furthermore, increasing income levels and, thus, increasing car ownership, will affect the average VMT so that demand is expected to be further reduced by 3.6 mb/d. Finally, the penetration of alternative fuel vehicles, particularly EVs in China and India, is estimated to shrink sectoral demand by 2.8 mb/d during the forecast period.

Table 3.8 shows sectoral oil demand by vehicle segment. It can be observed that commercial vehicles account for two-thirds of demand growth. Out of a total growth of 5.4 mb/d between 2016 and 2040, commercial vehicles' demand increases by 3.5 mb/d. This is a result of a number of factors. To start with, in the OECD region the commercial vehicle fleet increases significantly more than the passenger car fleet during the forecast period (45% and 13%, respectively), particularly because saturation levels affect mainly passenger cars. Moreover, in

Table 3.8
Oil demand in the road transportation sector by segment

mb/d

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
Passenger cars	**24.4**	**26.1**	**26.7**	**26.7**	**26.6**	**26.4**	**2.0**
OECD	14.8	15.1	14.1	12.7	11.3	10.0	–4.8
Developing countries	8.3	9.5	11.0	12.4	13.7	14.7	6.5
Eurasia	1.4	1.5	1.6	1.7	1.7	1.6	0.3
Commercial vehicles	**18.6**	**19.3**	**20.1**	**20.9**	**21.6**	**22.1**	**3.5**
OECD	8.8	8.6	8.3	7.9	7.3	6.5	–2.3
Developing countries	9.1	10.0	11.1	12.3	13.5	14.7	5.6
Eurasia	0.7	0.7	0.7	0.8	0.8	0.8	0.1

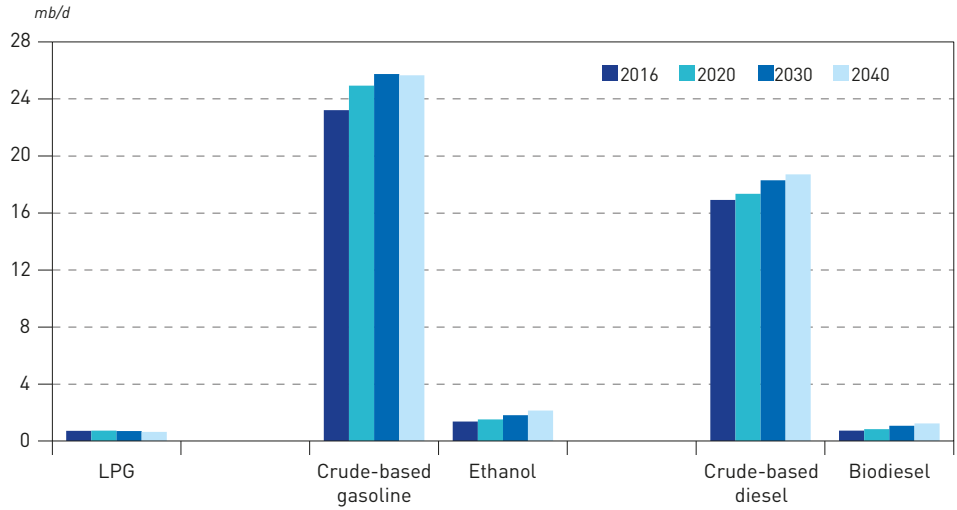
the commercial vehicles' segment the penetration of alternative fuel vehicles is much lower than in the passenger cars' segment. Finally, the potential for further efficiency gains in ICEs for commercial vehicles is more limited.

In the passenger cars' segment, the massive expansion in the car fleet in Developing countries, coupled with the higher penetration of EVs in the OECD region, means that the passenger cars' demand growth gravity centre increasingly shifts towards Developing countries. In 2016, they accounted for one out of every three barrels consumed. In 2040, more than one of every two barrels used to fuel passenger cars forecast to come from there.

From the point of view of product demand, as shown in Figure 3.19, gasoline (both crude-based and ethanol) is expected to remain the most important fuel. Its demand is expected to increase from 24.65 mb/d in 2016 to 27.8 mb/d in 2040. However, a different trend is anticipated for crude-based gasoline and ethanol. In the case of the latter, a smooth growth pattern is forecast with demand increasing at an average rate of 2% p.a. until the end of the next decade and averaging 1.6% p.a. in the last decade of the forecast period. For crude-based gasoline, a strong growth deceleration is foreseen on the back of the increasing efficiency of passenger cars and the penetration of alternative fuel passenger cars, mainly EVs. In fact, demand is anticipated to plateau around 25.8 mb/d in the mid-2030s and then start a marginal decline.

The demand outlook for diesel (including both crude-based and biodiesel) shows an increase of 2.3 mb/d, from 17.7 mb/d in 2016 to 20 mb/d in 2040. Most of the growth comes from crude-

Figure 3.19
Oil demand in the road transportation sector by product



based diesel with an additional 1.8 mb/d to reach 18.6 mb/d in 2040. This corresponds to a marginal downward revision compared to last year's estimate. This is the result of the repercussions of the recent emissions related diesel scandal among some automakers, together with a higher than previously expected penetration of EVs. Finally, LPG use in the road transportation sector is anticipated to remain marginal.

Shared mobility

Drive, ride or share? This is the question that people are increasingly asking themselves when considering urban travel. In big cities around the world, issues like pollution and congestion, and public policies towards urbanism and environmental concerns, are progressively changing societal travel preferences.

For many decades, owning and driving a personal car was seen as a status symbol and owners have not been worried about excess capacity (passenger cars tend to be used less than 5% of the time). However, things are changing. As cars seem to have become less expensive, the barrier to own one has been lowered – and so has the status associated with it. Additionally, increasing urbanization and the associated congestion makes car ownership a less desirable option.

Shared mobility has emerged as part of a new transportation landscape offering travellers a flexible and on-demand alternative to 'conventional' mobility – one without car ownership. It is not a completely new concept as such. However, what has empowered this new trend is technology that allows customers to quickly make and respond to requests for mobility services. More importantly, technology has reduced transaction costs, making sharing mobility cheaper and easier than ever before.

Shared mobility is developing under different schemes that could be grouped into three main categories: car sharing, carpooling and ride hailing.

Car sharing offers its members access to an unoccupied parked vehicle. Through a dedicated 'app', members find the nearest available car and pay for the time that the car is driven. Additionally, shared cars tend to benefit from highly accessible on-street parking. Car sharing schemes are increasingly gaining popularity. For example, Car2go started in 2008 and currently operates in European and North American cities, and has 2.2 million members. Zipcar has more than one million members throughout Austria, Canada, France, Spain, Belgium, UK and the US. Drivenow, the car sharing service from BMW, counts with 800,000 members and operates in Germany, Austria, the UK, Denmark, Sweden, Belgium, Italy and Finland.

App-based **ride hailing** allows travellers access to immediate, on-demand mobility services that are provided by a transportation network company. These companies use an online-enabled platform to connect passengers with privately-owned vehicles. Didi Chuxing, China's top ride-hailing app is the largest in the world, booking 14 million rides a day in 400 cities across the country. Uber, currently available in more than 500 cities in 73 countries, operates over 1.5 million rides every day, with the US being its largest market. Its rival in the US, Lyft, booked 163 million rides in 2016. Ola, the ride hailing service in India served almost 1 million rides in 2016.

Carpooling allows travellers to share a ride and split the cost of the trip with other travellers. While this scheme became popular in the US in the 1970s, its popularity decreased significantly in the following decades. In 1970, it accounted for 20% of commuter rides, but by 2011 this had dropped to less than 10%. In recent years, however, technological development plus on-demand flexibility has sparked renewed interest. Interestingly, over 20% of the Uber rides correspond to UberPool, the company's short-distance carpooling service that is increasingly popular. Contrary to other shared mobility services, carpooling is not limited to urban areas. Blablacar, the world's largest long-distance carpooling service that pairs people travelling between cities with drivers who have empty seats in their car is present in 22 countries. Every month it is estimated that four million people use its service.

These new mobility options could influence personal travel demand and, therefore, oil demand. However, their effects are currently not fully understood. Furthermore, the ride-sharing market, its adoption by clients, and its acceptance by policymakers and society is still clouded by a significant degree of uncertainty.

The Reference Case assumes a moderate adoption of car sharing, carpooling and ride hailing services on a global scale. Constraints such as the lack of legislative frameworks, union pressures, the inertia of established car ownership schemes and policy support towards public transportation, among others, will tend to limit the adoption of shared mobility services in the passenger sector. In a sense, the Reference Case assumes that shared mobility will more likely be a complement to, rather than competition for, existing private and mass transit.

However, things could develop in a different way. Policymakers may opt to accommodate and even promote these services into the regulatory framework. This might be done as part of broader efforts to fight city pollution and congestion, for example. Additionally, the cost of these shared mobility services might become more affordable in the future as a result of increasing competition from other similar operators, but also from other sources of transport such as taxis and even public means. At the same time, this might encourage a larger customer base and an expanded network that might promote economies of scale.

Furthermore, consumer habits could change rapidly so that they might be more open to the use of shared mobility services. A good example of changing consumer preferences can be viewed in mobile and branch banking. According to the report, 'The Way We Bank Now, by the UK's British Bankers' Association, in 2010 branch banking carried out 502 million transactions while only 85 million were made through a mobile phone. In 2015, the number of branch transactions dropped to 427 million while those made with a mobile phone increased ten-fold to reach almost 900 million. By 2020, it is expected that the number of mobile transactions will be ten times higher than branch transactions.
In order to explore the possible implications of a faster and wider adoption of shared mobility services, a Mobility as a Service (MaaS) case is presented. In this case, vehicles move more consumers as a service, without travellers needing to own vehicles themselves. At a certain stage, the focus moves from ownership to usership.

This MaaS case analysis only focuses on OECD America and China because it is in these regions where there is the highest potential for the penetration of mobility services. According to

a recent McKinsey article ('How shared mobility will change the automotive industry'), China and the US are currently the two largest markets for shared mobility, representing $24 billion and $23 billion, respectively. Europe only accounts for $6 billion. Moreover, both OECD America and China are technology leaders with very high digitalization levels, and a rather urban and dynamic population.

It could be argued that the potential for mass adoption of shared mobility schemes in other regions such as OECD Europe, OECD Asia Oceania and India is more limited. This could be a result of, for example, regulatory pressure (OECD Europe), car ownership as a status symbol due to low car ownership levels (India), strong competition from public transportation (OECD Europe and OECD Asia Oceania) and even lower cost incentives (India). However, potential growth in these regions is not to be dismissed.

The MaaS case works under the assumption that there will be a certain degree of substitution from personal car use to shared mobility services. This would have a number of effects. First, the car fleet would be affected as some people might avoid buying a car for personal use, particularly a second or third car, and instead opt for a shared mobility scheme. Some studies estimate that the car fleet could be reduced by 9–13 vehicles for each shared vehicle in North America (see Martin and Shaheen, 2016). Secondly, the utilization of the car fleet would increase as a result of higher travel demand services with a smaller car fleet.

At the same time, this would prompt a more rapid turnover of the car fleet, therefore, increasing average fuel efficiency. Finally, the penetration of EVs could also increase as it could be argued that this type of vehicle is more suitable to satisfy mobility demand if fast re-charging facilities were widely available. This is due to the lower running cost, but is also a result of the higher vehicle turnover that could accelerate the penetration of new technologies.

In the MaaS case it is assumed that the increasing use of shared mobility schemes in OECD America and China will limit growth in the passenger car fleet, compared to the Reference Case. In particular, the MaaS assumes that the average annual growth rate of car ownership is marginally slower than in the Reference Case (in the range of 0.1 percentage points). Figure 3.20 shows the total passenger car fleet in OECD America and China in the Reference Case and in the MaaS case. Increasing substitution of private cars has the impact of reducing the growth of the passenger fleet. For OECD America, in the Reference Case, it is estimated that the fleet will total 339 million in 2040. In the MaaS case, it is estimated to be 2.9% lower. For China, the availability of MaaS has a higher impact on the car fleet because of a lower motorization rate and more congestion. In the MaaS case, the passenger car fleet is 4.3% lower than in the Reference Case.

Additionally, the penetration of EVs (both PHEV and BEV) will be impacted depending on the case considered. In OECD America, the number of EVs would be 12 million higher in 2040, reaching 74 million, in the MaaS case compared to the Reference Case. They would represent 22% of the fleet, four percentage points higher than in the Reference Case. In China, EVs would come close to the 100 million mark in 2040 in the MaaS case, 27 million higher than in the Reference Case, accounting for 23% of the passenger fleet.

Figure 3.20
Passenger car fleet in the Reference Case (first series) and in the MaaS case (second series)

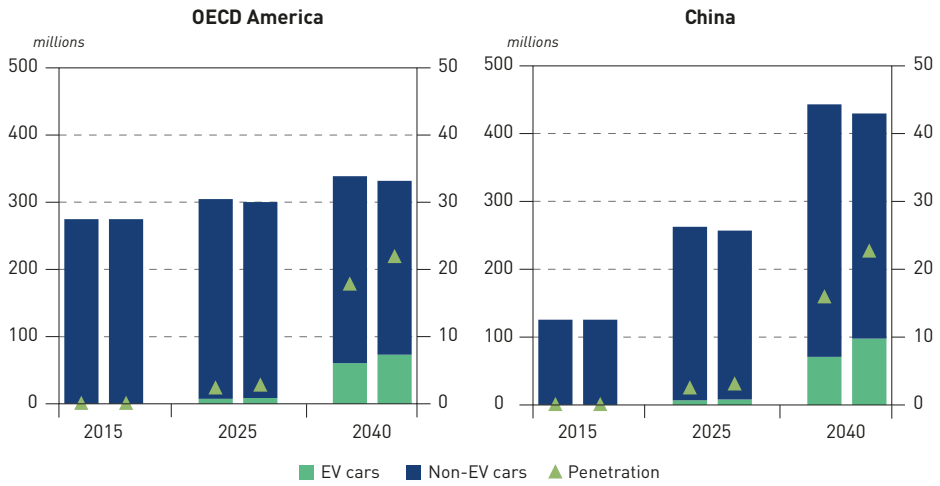
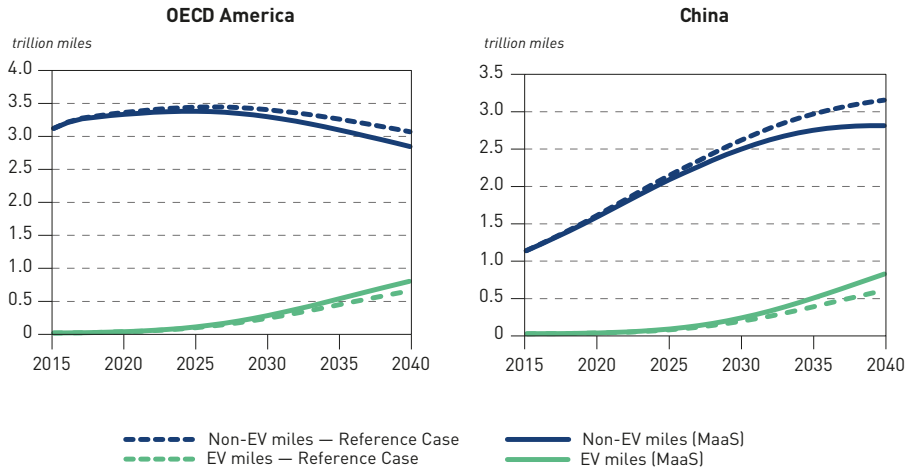


Figure 3.21
Total miles driven in the Reference Case (dotted lines) and in the MaaS case (solid lines)

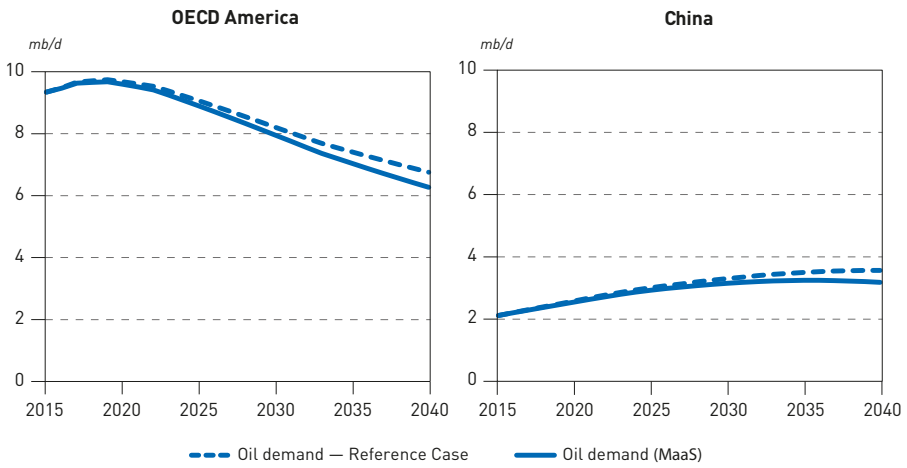


As already mentioned, the total number of miles would also be impacted. In the MaaS case, car ownership is reduced but, at the same time, the fleet is more utilized so the average VMT increases. The impact on the total miles driven could be negative as increasing carpooling and car sharing will predominantly substitute private vehicle use. Some studies estimate that car sharing reduces the total miles travelled between 6% and 16% per household (Martin and Shaheen, 2016). However, it could also be argued that widespread use of shared mobility services may prompt additional miles travelled resulting from the substitution for public transportation and biking and walking trips, but also due to additional demand for mobility services.

Additionally, the increasing penetration of EVs that would tend to be utilized more (higher average VMT) in the MaaS case would result in a clear dichotomy between the expected total miles driven by EVs and non-EV passenger cars. In OECD America the non-EV miles are reduced by over 223 billion miles in 2040 compared to the Reference Case. At the same time, EV miles reach over 0.8 trillion miles, which is 149 billion miles higher than in the Reference Case.

In China, the increased use of car sharing, carpooling and ride hailing services would result in non-EV miles almost plateauing towards the end of the forecast period at around 2.8 trillion miles instead of growing steadily to 3.2 trillion as in the Reference Case. In the case of EV miles, growth would accelerate, reaching 830 billion, 38% more than in the Reference Case.

Figure 3.22
Oil demand in the passenger car segment in the Reference Case (dotted line) and in the MaaS case (solid line)



Overall, as can be observed in Figure 3.22, oil demand in the passenger car segment could be impacted by the increasing use of car sharing, carpooling and ride hailing services. In the MaaS case, demand in OECD America would be reduced by 7% to total 6.3 mb/d by 2040. In China, the effect would be higher in relative terms because of the expected rapidly expanding car fleet that could foster a faster adoption of new technologies and services. In this case, oil demand in the passenger car segment would peak in 2035 and then marginally decline to 3.2 mb/d in 2040. This is 11% lower than in the Reference Case where no peaking demand is anticipated.

As already mentioned, it should also be noted that there remain many uncertainties on how MaaS could shape the future transportation picture – not only from the adoption point of view, but also from the perspective of how consumer habits might change. Will there be additional demand for mobility services, not only because shared mobility is cheaper, but also because it is available to non-drivers such as people that are too young or too old? Will there be a massive shift away from public transportation? Will road congestion decrease? Could MaaS actually accelerate demand for permanent car ownership by spurring interest in driving? How will the auto manufacturing industry react? How will governments react? What would be the role, if any, of Autonomous Vehicles in this new scheme?

These and other questions remain unresolved. Therefore, a close monitoring of developments in all these areas will be essential.

3.4.2 Aviation sector

Oil demand in the aviation sector has been increasing steadily in the last few decades driven by a massive increase in air traffic. According to the World Bank, the number of passengers carried has increased from 1.3 billion in 1995 to 3.5 billion in 2015. Similarly, Airbus reports that annual traffic – measured in revenue passenger kilometres (RPK) – has increased from around 2.5 trillion RPK in 1995 to 6.5 trillion RPK in 2015. At the same time, a constant feature of the market has been ongoing efficiency improvements. Despite this substantial air traffic increase, oil demand in this sector has increased 50% between 1995 and 2015. Higher load factors, better navigation equipment and, more importantly, increasing fuel economy have been the main drivers constraining demand growth.

Looking ahead, technological improvements will continue to shape sectoral demand. Besides security, fuel efficiency has always been the target of technical innovations in the aviation sector. To this end, the last decade has seen the commissioning of several airplanes considered milestones in aviation history: from the world's largest and two-decked passenger airplane, the Airbus A380, to the Boeing 'Dreamliner' B787 and the Airbus A350XWB. The latter two both replace a major part of the traditional metal structure with carbon fibre-reinforced compounds (CFCs). They all claim unsurpassed fuel efficiency around 2.5 l/100 passenger-km, although under optimum conditions.

Several innovations have contributed in the last decades to lower specific fuel consumption. The aerodynamic properties of airplane wings have been improved towards supercritical designs that provide more uplift with less thrust, as well as 'winglets' or 'sharklets' on the wing

tips for the same effect. Both concepts reduce the decelerating effects of pressure shocks, as well as turbulences and swirls around the wings and wing tips, which were previously known to increase the thrust requirement and, as a consequence, the fuel consumption of the flight gas turbines.

The extended use of CFCs, as well as new lightweight, but resistant metal alloys will also substantially reduce the weight of airplanes in the future. Lighter and smaller seats, as well as lighter galleys and other cabin equipment, have had, and will continue to have, advantageous effects on airplane mass. In addition, reliable electro-hydraulic actuators for flaps and landing gear have largely reduced the weight of these components when compared to traditional all-hydraulic means.

Lower airplane weight and aerodynamically improved wings have reduced the required thrust to overcome induced air resistance, which must be provided by the flight gas turbines. These turbines have also undergone a significant efficiency increase that allows them to provide more thrust while burning less fuel. The turbines' compression ratio has been increased and the bypass ratio of the large front fans has risen. Further advancement on this path and the introduction of so-called geared fans in the near future may reduce jet fuel consumption by 25%, when compared to the flight gas turbines commissioned just two decades ago.

Electrification is also underway in the air transport segment, although at a substantially slower pace than in the road transport sector because of security reasons. Air conditioning compressors, as well as the pressurizing system that maintains cabin pressure at an acceptable level can be driven by electric motors instead of drawing 'bleed air' from the compressor stage of the flight gas turbine directly. This improves not only the efficiency of the flight gas turbine but also provides a far more comfortable feeling of air humidity and freshness than before. In the future, electric motors integrated into the undercarriage may move the airplane while on the ground instead of using the turbine thrust, which is largely inefficient. The pilot would then start the engines just before take-off. This strategy also reduces emissions while on the ground, and minimizes noise and pollution.

In general, emissions have been, and will remain, an issue for the air transport industry. Tests with biofuels to replace ordinary kerosene have been undertaken. However, their costs are still far too high to be competitive. Additionally, they have to prove to be sufficiently secure in view of maintaining, for example, the appropriate viscosity at high and correspondingly freezing cruising altitude conditions. It is not expected that these fuels will replace a significant share of ordinary kerosene in the foreseeable future. The same applies to the concept of using LNG or even liquefied hydrogen (LH) as airplane fuel. Security issues and obvious passenger concerns will hardly allow employment of these fuels in the foreseeable future.
A more imminent area of innovation is the incorporation of connectivity and IT services akin to what we has been seen in road transport. While the use of the Internet in the sky is the most visible consequence of such connectivity, airplane operators have for years already been taking advantage of a continuous information stream covering engine and airplane conditions during the flight. This real-time data enables the ground crew at the destination to prepare for any preventive or corrective maintenance before the airplane arrives. Such connectivity may

additionally improve flight scheduling and flight guidance in the future by avoiding unnecessary waiting loops, as well as by allowing efficient point-to-point routes instead of detours through traditional beacon points. This is especially important as the most successful strategy to reduce the per-passenger fuel consumption of the past decade, namely increasing the load factor (in 2016 a level of 80% was reached), is approaching its natural saturation point.

At the same time, this sector has increasingly been impacted by energy policies targeting its decarbonization. The IATA aims for an average improvement in fuel efficiency of 1.5% p.a. from 2009–2020, a cap on net aviation CO_2 emissions (carbon-neutral growth) from 2020 and a reduction in net aviation CO_2 emissions of 50% by 2050 (compared to 2005 levels).

These plans are in line with the UN's International Civil Aviation Organization's (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) pact, agreed to be implemented by its 191 member states in October 2016. The focus is to voluntarily achieve a reduction of the aviation sector's CO_2 growth by 80% in the period 2021–2026. From 2027, the reduction is expected to become mandatory. So far, 66 countries representing over 86.5% of international aviation activity have indicated their plans to volunteer for the first phase (2021–

Table 3.9
Oil demand in the aviation sector by region

mb/d

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	1.7	1.8	1.8	1.9	1.9	1.9	0.2
OECD Europe	1.2	1.3	1.3	1.4	1.4	1.5	0.2
OECD Asia Oceania	0.5	0.6	0.6	0.6	0.6	0.7	0.2
OECD	**3.5**	**3.7**	**3.7**	**3.9**	**4.0**	**4.1**	**0.6**
Latin America	0.3	0.3	0.4	0.4	0.4	0.5	0.2
Middle East & Africa	0.2	0.2	0.3	0.3	0.3	0.4	0.2
India	0.1	0.2	0.3	0.4	0.5	0.5	0.4
China	0.5	0.6	0.7	0.8	0.9	1.0	0.5
Other Asia	0.7	0.8	0.9	1.0	1.1	1.2	0.5
OPEC	0.3	0.4	0.5	0.6	0.6	0.7	0.4
Developing countries	**2.2**	**2.5**	**3.0**	**3.5**	**3.9**	**4.3**	**2.1**
Russia	0.3	0.3	0.3	0.4	0.4	0.5	0.2
Other Eurasia	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Eurasia	**0.3**	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.2**
World	**6.0**	**6.6**	**7.2**	**7.8**	**8.4**	**8.9**	**2.9**

2023). These countries include EU member states, member states of the European Civil Aviation Conference (ECAC), the US, Canada, Japan, South Korea and Singapore.

Table 3.9 shows the oil demand levels in the aviation sector up to 2040. Driven by healthy growth in air traffic, sectoral demand is anticipated to grow by 2.9 mb/d, increasing from 6 mb/d in 2016 to 8.9 mb/d in 2040. Most of the growth is expected to come from Developing countries, as rising income levels will allow millions of people to rise out of poverty and join the middle class. It is especially relevant in the case of India where demand is forecast to increase almost four-fold by 2040. In fact, in March 2017, Prime Minister Narendra Modi launched the first flight under the Regional Connectivity Scheme, which connects 31 more airports to the nation's existing network of 76 airports. The government will cap fares for half of the seats of every flight at Rs 2,500 ($38.72 equivalent) per seat per hour of flight. In the OECD region, a mature market, growth is somewhat constrained by infrastructure capacity.

3.4.3 Marine bunkers

The marine bunker sector is currently undergoing an important structural shift as a result of the IMO MARPOL Annex VI Global Sulphur Cap regulation. In October 2016, the IMO decided to lower the maximum allowed sulphur content for marine bunkers from 3.5% to 0.5% (on a weight basis) as of 1 January 2020, for all areas outside the Emissions Control Areas (ECAs), which already have a maximum 0.1% fuel sulphur limit. As the implementation date is less than three years away, and given the overall size of the marine bunker market, this decision is set to become a major disrupting event in the oil downstream and shipping sectors over the medium-term. It also has likely implications for the oil supply sector too.

It is worth emphasizing that there are several uncertainties surrounding the potential path resulting from the current state of both the refining and the shipping industry, and from possible adjustments of these industries to the IMO decision. Shipping companies, which are the final consumers of the bunker fuel and thus obliged to comply with the regulation, have three options: switch to 0.5% fuel from 2020 onwards, in the form of LSFO or middle distillates; continue burning HSFO, combined with a scrubbing facility aboard; or switch to an alternative fuel – such as LNG – which will achieve at least the same sulphur oxide (SOx) emissions reduction.

Since it has not been significantly employed to date, LNG bunkering is expected to play only a minor role in the medium-term, but could become significant in the long-term. Some interesting policy moves to promote its use are under way there are regular new announcements about plans, often centring on LNG bunkering in a specific port or on orders for newbuild ships that will be dual-fired (LNG/petroleum). The United Arab Emirates is reportedly working on plans to install LNG storage facilities at the Port of Fujairah, which is the world's second-largest fuel oil bunkering hub. Additionally, the EU approved the EC's Trans-European Transport Network (TEN-T) proposal to fund an LNG pipeline for marine fuel use. The TEN-T fund consists of €22.1 million, a portion of which is allotted to the development of an LNG pipeline from Italy to Malta for marine transportation fuel. Finally, the potential for LNG bunkering has also gained traction globally, as an international focus group formed in 2014 to cooperate on LNG

bunkering – initially consisting of the ports of Singapore, Rotterdam, Antwerp and Zeebrugge – was expanded in October 2016 to include the Port of Jacksonville (Florida); the Norwegian Maritime Authority; the Ministry of Land, Infrastructure, Transport and Tourism (Japan); and the Ulsan Port Authority (South Korea).

Regarding scrubbing facilities, which enable shipowners to continue using cheaper high sulphur bunker fuel, there is a perceived capacity limitation of between 2,500 and 3,000 scrubber installations per year. This stems from what is currently seen as the maximum fabrication capacity of the scrubbing industry, plus limitations on moving ships into dry-dock to undertake part of the needed installation. In addition, bearing in mind that currently there is still no financial incentive to invest in scrubbers, many ship-owners are not likely to rush to retrofit existing ships or to install scrubbers on newbuilds before 2020. Therefore, a more significant uptake in the number of installed scrubbers can only be expected from 2019/2020, which should be supported by a widening price differential between HSFO and low sulphur fuels. In line with the constraint on the number of scrubbers that can be installed each year, this uptake will nevertheless be limited.

Therefore, the IMO might consider the option of issuing waivers/allowances to those vessels that are committed to installing scrubbing facilities in the years after 2020. In other words, the IMO could allow such vessels to continue using HSFO for a limited period of time after 2020, which effectively means allowing 'legal non-compliance'. Annex VI also allows for such legal non-compliance if and when ships demonstrate that they could not obtain compliant fuel. The mechanism, known as a Fuel Oil Non-Availability Request (FONAR), has already been in use in the US and would likely be applied to global fuel as well. It is important to note that the regulation does not require a ship to deviate from its route in order to seek out compliant fuel. In more general terms, this raises the question as to the level of compliance rate that could reasonably be assumed at a global scale, as it is easy to foresee a certain level of 'illegal non-compliance'. This is especially the case in the early years of implementation in parts of the world where enforcement measures are expected to be rather weak (generally away from global bunkering hubs).

Annex VI falls under the purview of the IMO Marine Environmental Protection Committee (MEPC). At the October 2016 MEPC70 meeting, an MEPC subcommittee was designated to develop a plan for ensuring efficient and even-handed implementation of the Global Sulphur Cap. The subcommittee, Pollution Prevention and Response (PPR), presented a framework at the July 2017 MEPC71 meeting, but will likely not issue a formal plan until 2019. Additionally, at MEPC71, the IMO reaffirmed its commitment to move ahead with the regulation in January 2020 and without any transitional period or phasing. It is worth noting, however, that the IMO has no enforcement authority. This lies with flag states (where vessels are registered) and port states (where they call). There is also the new concept of the 'bunker state' (where the ship bunkers) as a possible point of enforcement.

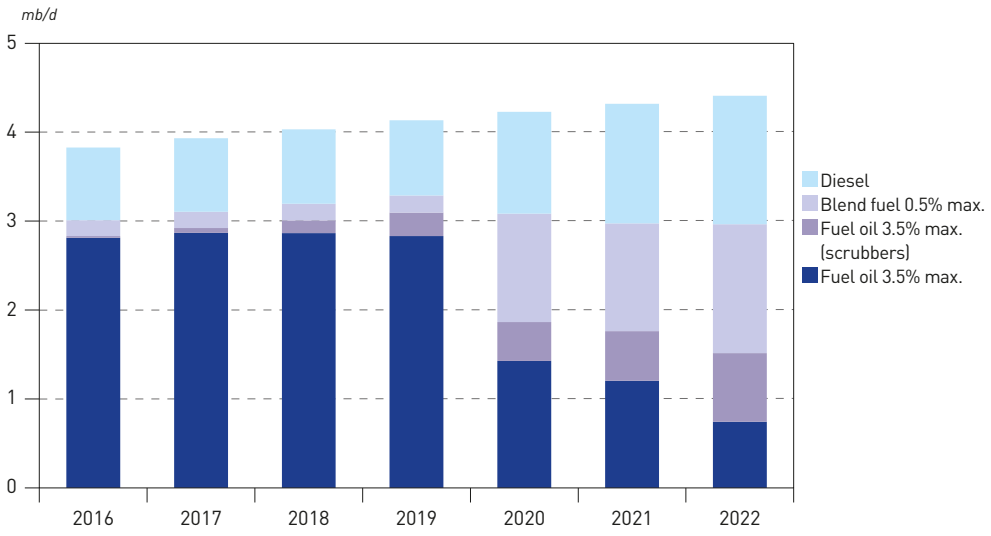
Altogether, the number of scrubbers installed, as well as the level of assumed 'legal' and 'illegal' non-compliance determines the required volume of low sulphur bunker fuel in 2020 (diesel or LSFO). Even with significant non-compliance rates in 2020, the refining industry is expected to be challenged and to adapt to new conditions only gradually. Further details on the impact of IMO regulation on the refining industry can be found in Section 2.

As already mentioned, the IMO decision specifies only the sulphur content and not explicitly the fuel type, which means that the on-spec fuel can be diesel fuel, HFO with low sulphur content or various blends of these fuels. This allows different approaches on the refining side where flexibility in terms of refining yields and/or blending can be utilized. Due to the long-term uncertainty regarding the required fuel mix (depending on the progress of the penetration of scrubbing technology and the shift to LNG as bunker fuel), the tight time schedule, as well as the uncertainty of the legal framework already describe, it is highly unlikely that the IMO decision will trigger additional refinery investments on top of the ones that are already planned. This means that little additional flexibility can be expected from the investment activities of refiners.

It is assumed that refiners will attempt to maximize their flexibility to produce diesel and LSFO without increasing overall refinery runs unless this is unavoidable – mainly through the additional use of secondary units including desulphurization. Projections indicate that the required overall volume of low sulphur material resulting from the IMO regulation is likely to put an additional call on refining. Needless to say, the most probable path for additional runs will be driven by maximizing middle distillates yields, which would be blended with fuel oil in order to produce 0.5% max blend fuel. Nevertheless, depending on the available crude slate and the likely refining yields, this could lead to an oversupply of fuel oil. In this case, the surplus fuel oil, driven by depressed prices, will be ultimately consumed in the power generation sectors.

Turning to projections, the Reference Case assumes 'compliance' of 60% in 2020 via a combination of legal non-compliance through FONAR requests, the potential use of waivers for

Figure 3.23
Marine bunker demand by fuel type in the medium-term



vessels with existing commitments to install scrubbers, plus some level of non-enforcement or illegal non-compliance. The rate of compliance increases gradually in the post-2020 period. This is primarily driven by an increasing number of ships with scrubbing facilities aboard that increase the volume of scrubbed HSFO, thus reducing the need for conversion to cleaner fuels. In 2020, around 2,500 of the largest ships are assumed to have scrubbers installed. The number of scrubbing installations increases to around 4,500 in 2022, 18,000 in 2030 and around 23,000 in 2040.

As presented in Figure 3.23, after accounting for the ontinued use of HSFO during the period 2020–2022 (either through scrubbing technology or both legal and illegal non-compliance) and increased demand for diesel, the refining industry will face a challenge of providing around 1.2 mb/d of blend fuel (0.5% max) in 2020, which is set to increase to over 1.4 mb/d by 2022. Part of this fuel will be provided in the form of LSFO, but the most significant part comes through the blending of diesel and fuel oil. However, as the ability of the refining sector to produce additional barrels of diesel via conversion processes is limited, the most viable alternative option appears to be through additional refinery runs. This need, however, is a temporary phenomenon which is set to taper off in the years thereafter, as penetration of scrubbing

Table 3.10
Oil demand in the marine bunkers sector in the Reference Case *mb/d*

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	0.5	0.5	0.5	0.5	0.5	0.5	0.0
OECD Europe	0.8	0.8	0.8	0.8	0.8	0.7	–0.1
OECD Asia Oceania	0.2	0.2	0.2	0.2	0.2	0.2	–0.1
OECD	**1.6**	**1.6**	**1.6**	**1.5**	**1.5**	**1.4**	**–0.2**
Latin America	0.3	0.3	0.4	0.4	0.5	0.5	0.2
Middle East & Africa	0.1	0.1	0.2	0.2	0.2	0.2	0.1
India	0.0	0.0	0.0	0.0	0.0	0.0	0.0
China	0.2	0.2	0.3	0.4	0.4	0.4	0.3
Other Asia	1.0	1.2	1.4	1.6	1.8	1.9	0.8
OPEC	0.4	0.5	0.5	0.6	0.6	0.7	0.2
Developing countries	**2.1**	**2.4**	**2.8**	**3.2**	**3.4**	**3.7**	**1.6**
Russia	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other Eurasia	0.1	0.1	0.1	0.1	0.2	0.2	0.1
Eurasia	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.1**
World	**3.8**	**4.2**	**4.7**	**5.0**	**5.2**	**5.4**	**1.5**

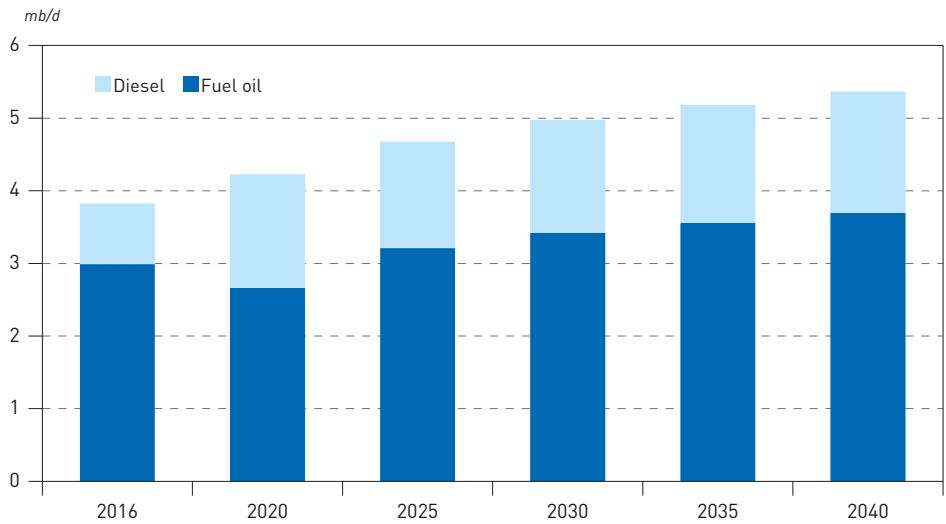
technology progresses and as refiners gain more time for investments that could increase their ability to produce higher volumes of LSFO. It is important to mention that additional crude runs are also expected to lead to an HSFO surplus of around 0.3 mb/d in 2020, which will be most likely absorbed by the power generation sector.

Table 3.10 shows oil demand in the marine bunkers sector up to 2040. It can be observed that demand is anticipated to increase by 1.5 mb/d during the forecast period, from 3.8 mb/d in 2016 to 5.4 mb/d in 2040. Interestingly, growth is forecast to decelerate in the long-term as efficiency improvements and a penetration of LNG curtails growth potential. In fact, compared to last year, sectoral demand has been revised downwards in the long-term on the back of a more optimistic, though still marginal, expectation of LNG usage.

Another important observation is that sectoral demand growth will be focused in Developing countries as the gravity centre of trade growth increasingly shifts there. In fact, oil demand in the OECD region is expected to remain flat in the next 10 years. Thereafter, a marginal decline is anticipated. Within Developing countries, sectoral demand and growth is concentrated in Other Asia where the world's largest bunkering port, Singapore, is located.

From the product point of view, and in line with the analysis already presented on the IMO implications, the use of diesel for marine fuel will increase significantly from 0.8 mb/d in 2016 to 1.7 mb/d in 2040. However, the diesel demand pattern is far from smooth. In 2020, its demand is estimated at 1.6 mb/d (1.2 mb/d of pure diesel and 0.4 mb/d used for blending purpose). As the penetration of scrubbers increases and as investments needed in the refining

Figure 3.24
Product demand in the marine bunkers sector



industry to produce LSFO are made, the use of diesel for blending is expected to be drastically reduce so that total diesel demand falls to almost 1.4 mb/d in 2025. Thereafter, a smooth growth pattern is anticipated. Similarly, the demand pattern for fuel oil is rather uneven. In 2016, demand totalled 3.0 mb/d and, in 2020, it is expected to be reduced to around 2.6 mb/d. Thereafter, and in line with the penetration of scrubbing facilities, the use of fuel oil is estimated to increase to 3.7 mb/d in 2040.

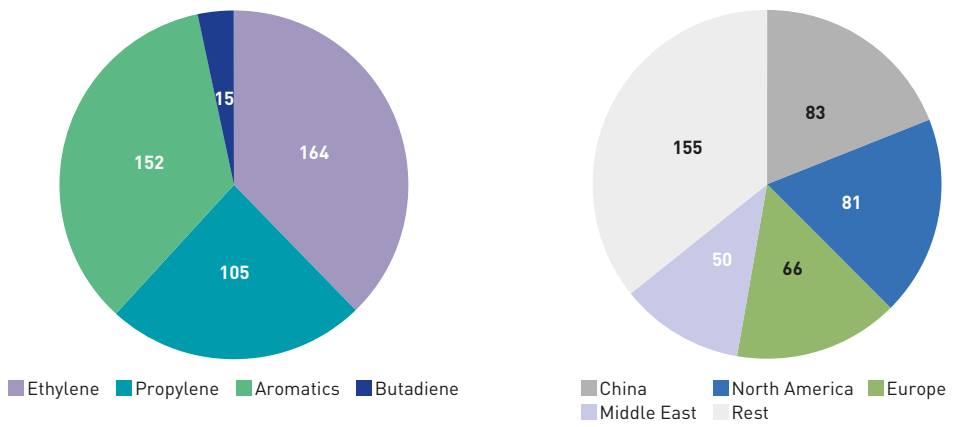
3.4.4 Petrochemicals

The petrochemical sector is an important source of oil demand. Oil is consumed mainly as feedstock, but is also used as an energy source. In 2016, a total of 12.6 mb/d were consumed in this sector with the OECD accounting for over 53%. The economics and investment decisions in the petrochemicals sector are determined, to a large extent, on feedstock availability and cost advantage, as feedstock represents the largest cost share. The main feedstocks in the petrochemical industry are ethane and naphtha. However, other feedstocks, such as methane, LPG, gasoil, and even crude oil and coal are also used.

Over 90% of petrochemical final products are derived from the three main petrochemical building blocks. These are olefins (which include ethylene, propylene and butadiene); aromatics (including benzene, toluene, xylenes); and methanol. In general, the lighter the feedstock used the more ethylene is produced. For example, to produce a tonne of ethylene, 3.2 tonnes of naphtha is required while 1.2 tonnes of ethane is required. However, ethane cracking limits production mainly to ethylene derivatives, while cracking naphtha produces a much larger spectrum of products and derivatives.

Figure 3.25
Global basic petrochemicals capacity

million tonnes



Source: *ICIS Database.*

The current status of the basic petrochemicals capacity (excluding methanol) shows that the world's current installed capacity in operation is around 434 million tonnes. As shown in Figure 3.25, 60% of the world's operating basic petrochemical capacity is olefins, with ethylene alone representing almost 40%, whereas butadiene, mainly from naphtha cracking in Europe and Asia, holds a marginal 3%. Aromatics capacity totals 152 million tonnes (35% of the global capacity). Regionally, operating basic petrochemicals capacity is concentrated in China, North America, Europe and the Middle East. These four regions attract two-thirds of global capacity.

Looking to the medium-term, and based on project review analysis, 81 million tonnes of additional capacity is anticipated to be added to the current capacity up to 2022. Most of the additional capacity will be located in China (23 million tonnes), the Middle East (18 million tonnes) and North America (14 million tonnes). The largest additions will come in the form of ethylene production capacity, with more than 50% of global additions (42 million tonnes), followed by propylene capacity (20 million tonnes).

There are several important regional trends that are shaping the petrochemical industry. The availability of new feedstocks, essentially light ones, either through the development of natural gas or gasification (coal), is creating an evolving paradigm that requires special attention. In the US, shale gas production has provided the country with cheap ethane, enhancing the competitiveness of the US petrochemical industry. In fact, in the US a surge in the construction of ethane crackers is expected in the coming years, which is expected to add more than 10 million tonnes of ethylene capacity. Another important trend has been the recent push by China to rely on coal derivatives and refinery feedstocks as the main building blocks for its petrochemicals industry. In fact, the development of alternative supply routes, such as coal-to-olefins (CTO), methanol-to-olefins (MTO) and propane dehydrogenation (PDH) projects, has allowed China to stand as the most diversified petrochemical industry from a feedstock sourcing standpoint.

Europe is one of the largest mature petrochemical markets and relies heavily on liquid hydrocarbons as the main cracker feedstock. Current basic petrochemical installed capacity stands at over 66 million tonnes p.a. Naphtha and condensates provide a large part of the feed to the European ethylene crackers. The development of mixed feed capacity in Europe is being contemplated as the availability of ethane improves.

Most of the petrochemical development in the Middle East is based on gas advantaged resources, mainly ethane and propane from associated gas that was flared in the past. During the last decade, the Middle East's share of global ethylene capacity has significantly increased, with ethane, ethane/propane and mixed feed crackers being added in Saudi Arabia and IR Iran, and ethane crackers starting up in Qatar, the UAE and Kuwait. Ethane is the preferred petrochemical feedstock in the Middle East region, although petrochemical facilities in Saudi Arabia and IR Iran use sizable volumes of LPG and naphtha as well. A large number of petrochemical projects are planned in the region. The bulk of the new basic petrochemical capacity are focused on ethylene and propylene projects, again denoting the high reliance on gaseous feedstock.

IR Iran has plans to develop mainly a gas-based competitive petrochemical industry after the lifting of international sanctions. It is set to complete almost 70 unfinished petrochemi-

Table 3.11
Oil demand in the petrochemicals sector in the Reference Case *mb/d*

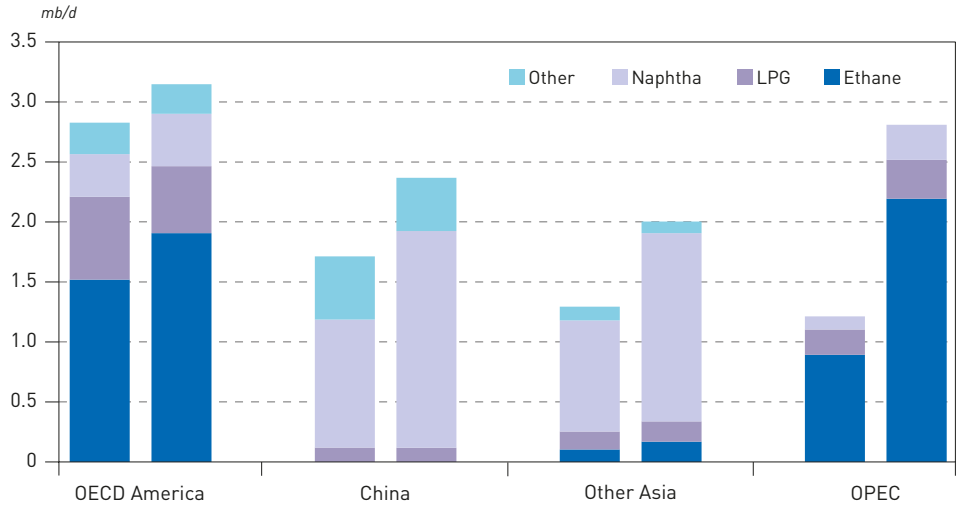
	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	2.8	3.0	3.0	3.1	3.1	3.1	0.3
OECD Europe	1.8	1.9	1.8	1.8	1.8	1.8	–0.1
OECD Asia Oceania	2.0	2.0	2.1	2.1	2.1	2.2	0.2
OECD	**6.7**	**6.8**	**6.9**	**7.0**	**7.0**	**7.1**	**0.4**
Latin America	0.3	0.3	0.3	0.3	0.3	0.3	0.0
Middle East & Africa	0.0	0.1	0.1	0.1	0.1	0.1	0.0
India	0.4	0.4	0.5	0.6	0.7	0.7	0.3
China	1.8	1.9	2.1	2.2	2.3	2.4	0.6
Other Asia	1.3	1.4	1.6	1.7	1.9	2.0	0.7
OPEC	1.2	1.4	1.8	2.1	2.5	2.8	1.6
Developing countries	**5.0**	**5.6**	**6.3**	**7.0**	**7.8**	**8.4**	**3.4**
Russia	0.9	1.0	1.0	1.0	1.0	1.0	0.1
Other Eurasia	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Eurasia	**0.9**	**1.0**	**1.0**	**1.1**	**1.1**	**1.0**	**0.1**
World	**12.6**	**13.4**	**14.3**	**15.0**	**15.9**	**16.5**	**3.9**

cal projects and plans to substantially increase its petrochemicals production. Saudi Arabia is expanding its ethylene capacity at Al Jubail by 93,000 tonnes. The expansion of the Petro-Rabigh ethane cracker is also set to serve the Kingdom's diversification programme. Kuwait is planning for Olefins III at its Al Zour refinery project, adding 1.4 million tonnes of ethylene and 500,000 tonnes from gaseous feed. Iraq also has important volumes of associated gases, and will increase the capture and utilization of associated gas for petrochemicals production, although it seems unlikely that associated gas as feedstock will be available before 2020. Notably, Aramco and Sabic of Saudi Arabia are planning to launch a large crude-oil-to-chemicals project, probably in phases, but for which the contours are not yet clearly defined.

Table 3.11 shows the oil demand forecast in the petrochemical sector. Globally, sectoral demand is anticipated to increase by 3.9 mb/d, from 12.6 mb/d in 2016 to 16.5 mb/d in 2040. In line with the anticipated capacity additions, growth will be concentrated in OPEC (mainly in Middle East Member Countries) with an additional 1.6 mb/d during the forecast period.

The regional petrochemical product demand outlook (mainly for feedstock purposes, but also for energy use) is also likely to change significantly, as shown in Figure 3.26. In OECD America,

Figure 3.26
Regional demand in the petrochemicals sector by product



all of the additional sectoral demand is anticipated to be satisfied by ethane so that it will account for around 60% of the demand in 2040, up from around 53% in 2016. Similarly, in OPEC, the relative weight of ethane is expected to increase significantly. Out of a total sectoral growth of 1.6 mb/d between 2016 and 2040, ethane is forecast to increase by 1.3 mb/d. In China, sectoral demand is anticipated to increasingly be satisfied by naphtha. In 2016 this product accounted for 62% of the demand, while in 2040 it is forecast to account for over 75%. A similar picture is expected in Other Asia where demand growth is expected to come almost exclusively from naphtha. Its demand is estimated to increase by 0.6 mb/d between 2016 and 2040.

3.4.5 Other sectors

Oil is also used in other sectors such as rail and domestic waterways, 'other industry', residential/commercial/agriculture and electricity generation.

In rail and domestic waterways, demand is highly concentrated in OECD America and China, with 0.5 mb/d and 0.6 mb/d, respectively, out of a total of 1.8 mb/d in 2016. In OECD America, the majority of sectoral demand comes from the rail subsector, particularly because of the low electrification levels of its railways. However, in China most of the demand comes from the domestic waterways subsector since the country has many inland bodies of water, and the longest navigable rivers and canals in the world. The country accounts for 110,000 km of inland waterways, which represents almost 17% of the total global length of domestic waterways. Looking ahead, the growing electrification of railways in OECD America, together with expanded pipeline infrastructure, will limit the use of oil. In contrast, expanded domestic

Table 3.12
Oil demand in rail and domestic waterways in the Reference Case *mb/d*

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	0.5	0.5	0.5	0.5	0.4	0.4	–0.1
OECD Europe	0.2	0.2	0.1	0.1	0.1	0.1	0.0
OECD Asia Oceania	0.1	0.1	0.1	0.1	0.1	0.1	0.0
OECD	**0.8**	**0.8**	**0.7**	**0.7**	**0.6**	**0.6**	**–0.2**
Latin America	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Middle East & Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
India	0.1	0.1	0.1	0.1	0.1	0.1	0.0
China	0.6	0.6	0.7	0.8	0.9	1.0	0.4
Other Asia	0.1	0.1	0.1	0.1	0.2	0.2	0.1
OPEC	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Developing countries	**0.9**	**1.0**	**1.1**	**1.2**	**1.4**	**1.5**	**0.6**
Russia	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eurasia	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.0**
World	**1.8**	**1.9**	**2.0**	**2.1**	**2.1**	**2.2**	**0.4**

waterway traffic in China, both for passenger and freight, will support oil demand growth. By 2040, total sectoral demand is forecast at 2.2 mb/d, 0.4 mb/d higher than in 2016.

Oil demand in the 'other industry' sector is closely linked to the stage of development and economic structure of a given country. Typically, countries initially tend to have a high share of agriculture in their GDP. However, as countries grow and income levels rise, the agriculture sector increasingly becomes displaced by the industrial sector. Eventually further economic growth translates into a growing weight for the services sector. It is, therefore, not surprising that sectoral demand growth will come from Developing countries, particularly India and, to a lesser extent, China. By 2040, oil demand in the 'other industry' sector is forecast to have increased by 1.2 mb/d compared to 2016 with an additional 1.8 mb/d from Developing countries. In the OECD region, sectoral demand is anticipated to be reduced by 0.7 mb/d during the same period as a result of the shrinking weight of the industry sector, as well as efficiency improvements and fuel switching towards gas, particularly in OECD America.

In the residential/commercial/agriculture sector, oil demand in 2016 totalled 10.5 mb/d. In the last several years, sectoral demand has exhibited rather moderate growth with demand

Table 3.13
Oil demand in 'other industry' in the Reference Case

mb/d

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	3.0	3.0	2.9	2.9	2.8	2.7	–0.2
OECD Europe	1.4	1.4	1.4	1.3	1.3	1.2	–0.2
OECD Asia Oceania	1.0	0.9	0.8	0.7	0.7	0.6	–0.3
OECD	**5.4**	**5.3**	**5.1**	**4.9**	**4.7**	**4.6**	**–0.7**
Latin America	0.9	0.9	0.9	1.0	1.0	1.0	0.1
Middle East & Africa	0.5	0.6	0.6	0.7	0.7	0.8	0.2
India	0.9	1.0	1.2	1.4	1.5	1.6	0.7
China	1.8	1.9	1.9	2.0	2.1	2.1	0.4
Other Asia	0.9	0.9	1.0	1.0	1.0	1.0	0.1
OPEC	1.4	1.5	1.6	1.7	1.7	1.6	0.3
Developing countries	**6.3**	**6.8**	**7.3**	**7.7**	**8.0**	**8.1**	**1.8**
Russia	0.5	0.5	0.5	0.5	0.5	0.4	0.0
Other Eurasia	0.4	0.4	0.5	0.5	0.5	0.5	0.1
Eurasia	**0.9**	**0.9**	**0.9**	**1.0**	**1.0**	**1.0**	**0.1**
World	**12.5**	**13.0**	**13.3**	**13.6**	**13.7**	**13.7**	**1.2**

increasing at an average rate of only 0.8% p.a. between 2010 and 2016. However, the picture is rather different at a regional level during the same period. Demand in the OECD region decreased steadily by 1.6% p.a., while in Developing countries it increased at 2.5% p.a.

Policies promoting energy efficiency programmes in the residential sector are gaining momentum in several parts of the world. With the EC's proposal in November 2016 for an update to the Energy Performance of Buildings Directive, the EU is targeting the residential sector to meet its energy efficiency goals. The proposal aims for all new buildings in the EU to be "nearly zero energy buildings" by the end of 2020, while new public buildings would need to meet such a standard by 2018. Additionally, under the proposed update, the Directive would require EU member states to carry out energy efficient renovations on at least 3% of all governmental buildings.

In October 2016, the Mayor of London applied a zero-carbon standard to new residential developments (of 10 or more units) in the UK capital. The policy rewards homes that achieve a reduction of at least 35% in regulated CO_2 emissions. The remaining CO_2 emissions (up to 100%) are to be offset through a cash-in-lieu contribution to the relevant London borough.

Table 3.14
Oil demand in residential/commercial/agriculture in the Reference Case *mb/d*

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	1.7	1.7	1.6	1.5	1.4	1.2	–0.4
OECD Europe	1.7	1.7	1.6	1.5	1.4	1.3	–0.4
OECD Asia Oceania	0.9	0.9	0.8	0.8	0.7	0.6	–0.3
OECD	**4.2**	**4.3**	**4.0**	**3.8**	**3.4**	**3.1**	**–1.1**
Latin America	0.7	0.7	0.7	0.8	0.9	1.0	0.3
Middle East & Africa	0.6	0.7	0.7	0.8	0.9	1.0	0.4
India	1.0	1.1	1.4	1.5	1.7	1.8	0.7
China	2.0	2.1	2.3	2.5	2.8	3.1	1.1
Other Asia	0.8	0.8	0.9	0.9	0.9	0.9	0.2
OPEC	0.6	0.6	0.6	0.6	0.6	0.6	0.0
Developing countries	**5.6**	**6.0**	**6.6**	**7.3**	**7.9**	**8.4**	**2.7**
Russia	0.3	0.3	0.3	0.3	0.3	0.3	0.0
Other Eurasia	0.3	0.3	0.4	0.4	0.4	0.4	0.1
Eurasia	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**	**0.0**
World	**10.5**	**10.9**	**11.4**	**11.7**	**12.0**	**12.1**	**1.7**

China is continuing its own push for energy efficient buildings, as demonstrated by the Ministry of Housing and Urban-Rural Development's plan issued in May 2017. The Ministry set a goal for all new urban residential and public buildings to meet energy conservation requirements by 2020, with energy efficiency levels 20% higher than 2015 levels. Furthermore, approximately 40% of all new urban construction projects should use environmentally friendly and energy-saving construction materials.

A different perspective in the residential sector is provided by the mayor of Moscow who announced in March 2017 the launch of a housing renovation programme to update 7,900 of the city's urban housing projects. The plan consists of demolishing five-storey apartment buildings built during the 1950–1960s, and replacing them with modern and more efficient structures.
Oil demand in this sector in the OECD is expected to continue to decline, driven by energy policies targeting efficiency improvements, and a switch towards natural gas and renewables. Between 2016 and 2040, oil demand is anticipated to decline by 1.1 mb/d. In Developing countries, rising incomes and increasing urbanization levels will continue to galvanize a switch away from traditional fuels for cooking and heating – such as wood, dung or crop residues – to commercial fuels. Oil demand is thus expected to increase to 8.4 mb/d in 2040

Table 3.15
Oil demand in electricity generation in the Reference Case

mb/d

	2016	2020	2025	2030	2035	2040	Growth 2016–2040
OECD America	0.3	0.4	0.3	0.3	0.2	0.1	–0.2
OECD Europe	0.3	0.3	0.2	0.2	0.2	0.2	–0.1
OECD Asia Oceania	0.5	0.5	0.4	0.3	0.2	0.2	–0.3
OECD	**1.2**	**1.2**	**0.9**	**0.8**	**0.6**	**0.5**	**–0.7**
Latin America	0.5	0.5	0.5	0.5	0.5	0.5	0.0
Middle East & Africa	0.5	0.6	0.6	0.7	0.8	0.8	0.3
India	0.2	0.2	0.2	0.2	0.3	0.2	0.1
China	0.2	0.2	0.2	0.2	0.2	0.2	0.0
Other Asia	0.5	0.5	0.4	0.4	0.4	0.3	–0.2
OPEC	1.9	1.9	1.7	1.6	1.4	1.2	–0.7
Developing countries	**3.7**	**3.8**	**3.6**	**3.6**	**3.4**	**3.2**	**–0.5**
Russia	0.2	0.2	0.2	0.2	0.1	0.1	–0.1
Other Eurasia	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Eurasia	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**–0.1**
World	**5.1**	**5.3**	**4.8**	**4.6**	**4.2**	**3.9**	**–1.2**

from 5.6 mb/d in 2016, with China, India and the Middle East & Africa as the main sources of growth.

Oil will continue to play a marginal role in electricity generation. In 2016, a total of 5.1 mb/d was consumed in the sector, heavily concentrated in OPEC Member Countries. In the future, sectoral oil demand is expected to decline by 1.2 mb/d to reach 3.9 mb/d in 2040, as a result of strong competition from alternative sources. Marginal growth is only expected in the Middle East & Africa and India on the back of energy poverty alleviation policies. As mentioned earlier, one of the side effects of IMO regulations is the likely surplus of around 0.3 mb/d of HSFO in 2020, priced at a discount. It is assumed that the surplus will be absorbed by the electricity generation sector, providing temporary support to sectoral demand.

Liquids supply

Key takeaways

- This year's non-OPEC supply projections have been revised up, largely due to the recovery and improved outlook for US tight oil production.
- Total non-OPEC liquids supply is now forecast to grow from 57 mb/d in 2016 to 62 mb/d in 2022, with the US alone making up 75% of that increase.
- Besides the US, Brazil and Canada are the most important contributors to non-OPEC supply growth in the medium-term. China and Mexico see the most pronounced decline.
- Tight oil (both crude and NGLs) makes up the bulk of rising supply in the US, rising to 11.1 mb/d by 2022. With the exception of Canada, and minimal volumes in Russia and Argentina, tight oil remains overwhelmingly a US success story.
- Of the incremental 4.9 mb/d in non-OPEC supply in the medium-term, around half is from crude (+2.4 mb/d, including tight crude), 1.2 mb/d from NGLs, 0.7 mb/d from non-conventionals (including oil sands, CTLs, GTLs) and 0.4 mb/d from biofuels.
- Demand for OPEC crude is projected to remain just over 33 mb/d until US tight oil peaks in the mid-2020s, after which demand for OPEC crude rises steadily to reach 41.4 mb/d by 2040.
- By contrast with the medium-term, with US tight oil peaking after 2025, non-OPEC supply shows a modest decline in the long-term, falling to 60.4 mb/d by 2040, from a peak of 63.8 mb/d in 2027.
- Canadian oil sands, Brazilian pre-salt barrels and Kazakhstan's giant oil fields are noteworthy sources of supply growth beyond 2020, but these are insufficient to offset declines elsewhere.
- Recent declines in global upstream investment appear to have been halted, as preliminary data indicates a modest rise in spending in 2017. This Publication calculates that some $7.9 trillion (in 2016 $), or $328 billion p.a., will be needed in the years until 2040 in order to achieve a balanced and stable oil market. The bulk of this spending is needed in the OECD and other non-OPEC countries; however, in the longer-term, OPEC's share of upstream investment grows, as the call on OPEC increases.
- In terms of crude quality, the most significant development is the expansion of light crude oil production with its share in the overall mix rising to 44% in 2025 from around 42.5% in 2015. This is in line with expanding production of tight oil in the US, but also rising light production in other regions such as Eurasia.

This Chapter describes the findings of the Reference Case outlook for liquids supply from 2016–2040. As in previous reports, the medium-term prognosis for 2016–2022 and the long-term outlook are discussed separately, due to the different methodologies employed. The medium-term view relies upon a bottom-up approach, identifying individual upstream project start-ups, their progress and the underlying decline in mature fields, while the long-term outlook is based upon an assessment of the available resource base.

It is important to note that the supply balances, tables and graphs all reflect Indonesia suspending its Membership of OPEC, while Equatorial Guinea joined the organization effective 25 May 2017. This has obviously led to some revisions to historical and forecast data, which should, however, not be confused with actual changes to the outlook.

4.1 Medium-term outlook for liquids supply

Compared to last year's WOO, the medium-term outlook for non-OPEC liquids growth has changed quite considerably. Compared to 2016, crude prices have on average-to-date been higher in 2017, which – coupled with higher upstream activity and sustained demand growth – has stimulated a recovery in non-OPEC liquids supply growth. Most strikingly, US tight oil production has exceeded previous growth expectations and is currently forecast to contribute to a rise in overall US liquids by some 0.6 mb/d in 2017 and then 0.9 mb/d in 2018. This contrasts with an annual decline in US liquids in 2016, overall non-OPEC production.

In the medium-term, total non-OPEC liquids are forecast to grow by 4.9 mb/d to 62 mb/d in 2022, of which 3.8 mb/d is incremental supply from the US alone. This means non-OPEC liquids grow by an average of 0.8 mb/d in the medium-term period, with growth slowing thereafter, before beginning to decline again from the late 2020s.

Table 4.1 shows the Reference Case outlook for total liquids supply until 2022, broken down by major producers and regions. Growth is heavily concentrated geographically, with the overwhelming majority – over 75% – coming from the US, mostly driven by a resurgence in tight oil production. Other important sources of non-OPEC liquids growth include Brazil, Canada, Russia and Kazakhstan (in descending order), as well as global refinery processing gains (Figure 4.1).

In terms of revisions to the medium-term forecast, the largest upward adjustments were made to the US, but also for Canada, Russia, Kazakhstan and Norway. Countries for which the production outlook was revised down meaningfully include China and Mexico.

Broken down into the various liquids supply components, of the total incremental non-OPEC supply of 4.9 mb/d by 2022, nearly half (2.4 mb/d) is from crude (including tight crude), while 1.2 mb/d stems from non-OPEC NGLs. Another 0.7 mb/d is contributed by non-conventional supply (essentially oil sands, CTLs, GTLs and others), while 0.4 mb/d of additional supply comes from biofuels. The remaining 0.2 mb/d increase is due to higher global refinery processing gains (Figure 4.3).

Table 4.1
Medium-term liquids supply outlook in the Reference Case

mb/d

	2016	2017	2018	2019	2020	2021	2022	Change 2016–2022
US & Canada	18.1	18.9	20.0	20.6	21.4	22.0	22.6	4.4
of which: tight crude	*4.5*	*5.1*	*5.7*	*6.4*	*7.0*	*7.5*	*7.9*	*3.3*
Mexico & Chile	2.5	2.3	2.1	2.1	2.1	2.0	2.0	–0.5
OECD Europe	3.8	3.8	3.9	3.9	3.8	3.8	3.8	0.0
OECD Asia Oceania	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.1
OECD	**24.8**	**25.5**	**26.5**	**27.0**	**27.7**	**28.4**	**28.8**	**4.0**
Latin America	5.1	5.2	5.4	5.4	5.6	5.8	6.0	0.9
Middle East & Africa	3.1	3.1	3.1	3.2	3.3	3.3	3.3	0.2
Asia	3.7	3.6	3.6	3.6	3.5	3.5	3.5	–0.2
China	4.1	4.0	3.8	3.7	3.7	3.7	3.6	–0.5
DCs, excl. OPEC	**16.0**	**16.0**	**15.9**	**16.0**	**16.1**	**16.3**	**16.5**	**0.4**
Russia	11.1	11.0	11.0	11.2	11.4	11.3	11.3	0.2
Other Eurasia	2.9	3.0	3.0	3.1	3.1	3.0	3.0	0.1
Eurasia	**14.0**	**14.1**	**14.1**	**14.3**	**14.5**	**14.4**	**14.3**	**0.3**
Processing gains	2.2	2.2	2.2	2.2	2.3	2.4	2.4	0.2
Non–OPEC	**57.0**	**57.7**	**58.6**	**59.5**	**60.7**	**61.4**	**62.0**	**4.9**
Crude	42.0	42.2	42.5	43.0	43.6	44.1	44.4	2.4
NGLs	7.7	7.9	8.2	8.5	8.7	8.9	9.0	1.2
of which: unconv. NGLs	*2.6*	*2.8*	*3.0*	*3.3*	*3.6*	*3.9*	*4.0*	*1.4*
Other liquids incl. biofuels	5.1	5.4	5.7	5.8	6.0	6.1	6.2	1.1
Total OPEC supply	**38.8**	**38.7**	**39.3**	**39.7**	**40.4**	**40.3**	**40.5**	**1.7**
OPEC NGLs	5.9	6.0	6.2	6.3	6.4	6.5	6.7	0.7
OPEC Other liquids*	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.1
OPEC crude	32.7	32.4	32.8	33.1	33.7	33.4	33.5	0.9
Stock change**	**0.5**	**-0.3**	**-0.1**	**0.2**	**0.4**	**0.2**	**0.2**	
World supply	**95.8**	**96.5**	**98.1**	**99.6**	**101.1**	**101.7**	**102.5**	**6.7**

* *This item includes other non-crude streams, such as GTLs, methyl tetra-butyl ether (MTBE) and biofuels.*

** *Stock change assumptions reflect commercial stock inventories, development of Strategic Petroleum Reserves (SPR), and the rising need for stocks as refinery capacity expands.*

Figure 4.1
Select contributors to non-OPEC total liquids change, 2016–2022

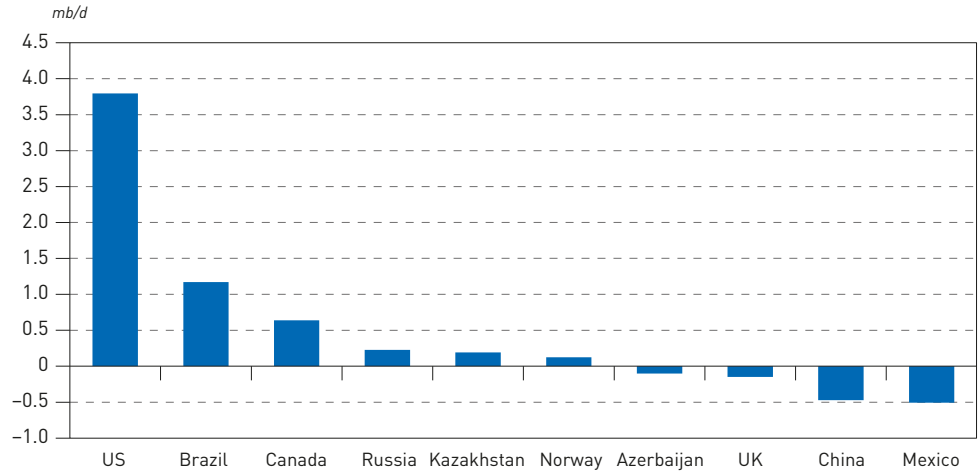


Figure 4.2
Revisions to medium-term Reference Case (vs. WOO 2016) for total liquids supply

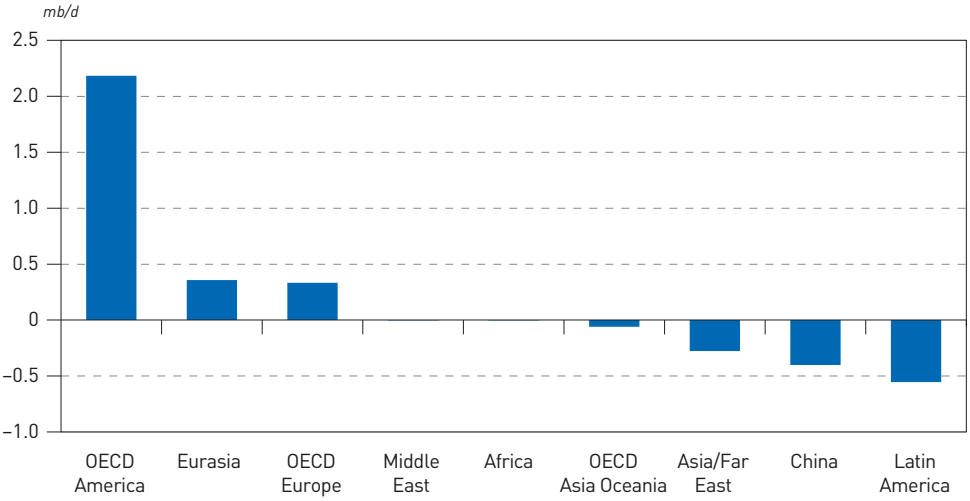
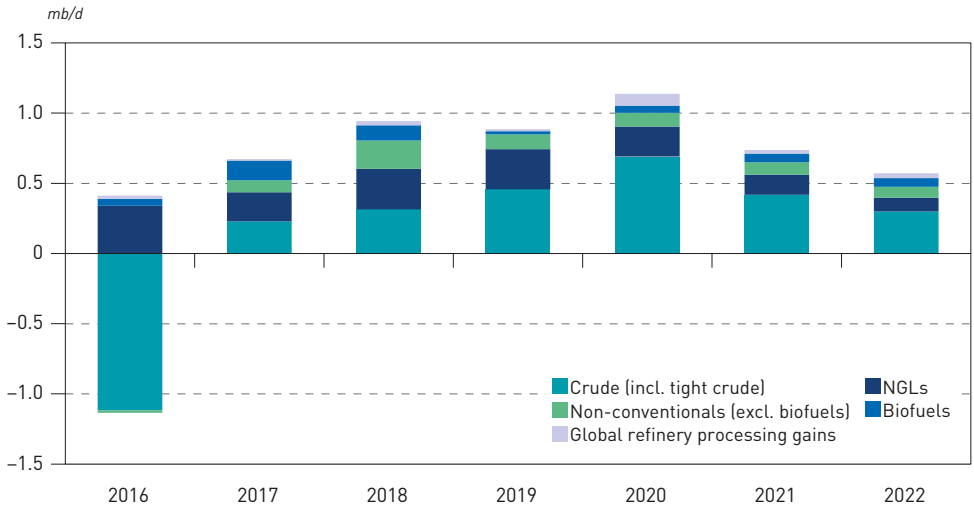


Figure 4.3
Non-OPEC liquids change by year



The most pronounced decline in medium-term liquids supply is seen in Mexico, where output is expected to shrink by 0.5 mb/d by 2022. This is essentially due to the high maturity of its oil fields and notwithstanding the assumed additional investment in its newly-opened energy sector. A similar picture is witnessed in China, where liquids production is also anticipated to decline by 0.5 mb/d over the forecast period. It should be noted that while Mexico's crude output peaked around 2004, China's only started declining in 2016 after prices tumbled in late-2014. Other sources of declining output include the UK, Oman, Egypt, Indonesia, Azerbaijan, Colombia and Malaysia.

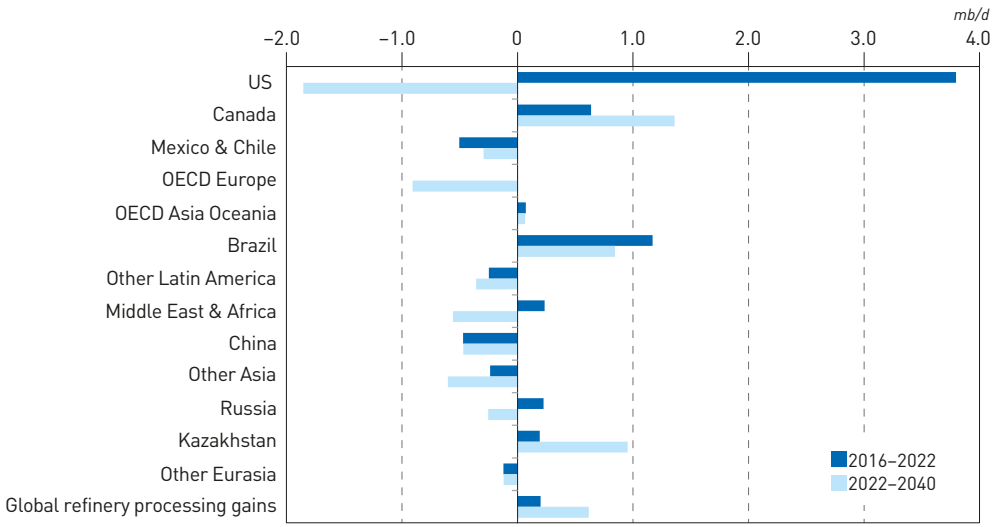
While risks to this outlook are discussed in Chapter 5 – both to the upside and downside – the premises are that:

- US tight oil production growth rates of well over 1 mb/d p.a. achieved in the 2012–2015 boom period will not be repeated sustainably (at least in the Reference Case); and
- A plethora of non-OPEC upstream projects coming online in the 2017–2022 period is the fruit of significant investment decisions in the 2010–2014 period of higher prices, but growth will slow thereafter.

4.2 Medium-term outlook for crude and NGLs

This section discusses the Reference Case outlook for non-OPEC crude and NGLs supply in the medium-term. Compared to last year's report, the medium-term outlook is moderately brighter, largely based upon the US tight oil sector's resilience and ability to bounce back. However, at the time of putting together this report, the jury remains out on how long this may last if prices were to dip from current levels. Thus, compared to the last WOO's medium-term growth forecast of 0.6 mb/d for total non-OPEC crude and NGLs for the period 2015–2021, a rise of 3.6 mb/d is now projected from 2016–2022. This is overwhelmingly driven by the US and Brazil, with growth of 3.8 mb/d and 1 mb/d, respectively. This is offset by declines elsewhere, notably in China (-0.6 mb/d), Mexico (-0.5 mb/d), the UK, Indonesia and Colombia (each -0.2 mb/d). The detailed breakdown by region and major producers can be seen in Figure 4.4 and Table 4.2.

Figure 4.4
Regional growth in non-OPEC liquids supply, 2016–2022 and 2022–2040



United States

US crude and NGLs supply growth is by far the most significant contribution to total non-OPEC liquids growth in the medium-term Reference Case. Compared to the outlook one year ago, a combination of higher-than-expected crude prices and, perhaps more importantly, expectations of prices remaining higher than previously thought, has stimulated a resurgence in upstream activity and investment. As a result, US liquids supply has already almost returned to previous peak levels seen in April 2015, before the impact of lower crude prices led to a drop-off in output. Indeed, at some point during 2018, crude output is expected to top its all-time annual record of 9.6 mb/d reached in 1970.

Table 4.2
Medium-term non-OPEC crude and NGLs supply outlook in the Reference Case *mb/d*

	2016	2017	2018	2019	2020	2021	2022	Change 2016–2022
US	12.4	13.0	13.8	14.4	15.1	15.7	16.1	3.8
of which: tight crude	*4.2*	*4.7*	*5.4*	*6.0*	*6.6*	*7.0*	*7.4*	*3.2*
Canada	2.1	2.2	2.2	2.2	2.2	2.2	2.3	0.2
Mexico	2.5	2.3	2.1	2.1	2.0	2.0	2.0	–0.5
Chile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OECD America	**16.9**	**17.4**	**18.1**	**18.7**	**19.4**	**19.9**	**20.3**	**3.5**
Norway	2.0	2.0	2.0	2.0	2.1	2.1	2.1	0.1
United Kingdom	1.0	1.0	1.1	1.0	1.0	0.9	0.9	–0.2
Other OECD Europe	0.4	0.4	0.4	0.4	0.4	0.4	0.4	–0.1
OECD Europe	**3.4**	**3.4**	**3.5**	**3.4**	**3.4**	**3.4**	**3.3**	**–0.1**
Australia	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.0
Other OECD Asia Oceania	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
OECD Asia Oceania	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.0**
OECD	**20.7**	**21.2**	**22.0**	**22.5**	**23.2**	**23.7**	**24.1**	**3.4**
Brazil	2.6	2.8	2.9	3.0	3.2	3.4	3.6	1.0
Argentina	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0
Colombia	0.9	0.8	0.8	0.7	0.7	0.7	0.7	–0.2
Other Latin America	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.0
Latin America	**4.5**	**4.6**	**4.6**	**4.7**	**4.8**	**5.0**	**5.2**	**0.8**
India	0.8	0.8	0.9	0.9	0.8	0.8	0.8	–0.1
Indonesia	0.9	0.8	0.8	0.8	0.7	0.7	0.7	–0.2
Malaysia	0.7	0.7	0.7	0.7	0.7	0.7	0.6	–0.1
Thailand	0.5	0.5	0.4	0.5	0.4	0.4	0.4	0.0
Vietnam	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0
Other Asia/Far East	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.0
Asia/Far East	**3.6**	**3.5**	**3.4**	**3.4**	**3.3**	**3.2**	**3.2**	**–0.4**
Bahrain	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0
Oman	1.0	1.0	0.9	0.9	0.9	0.9	0.9	–0.1
Syrian Arab Rep.	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Yemen	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2
Middle East	**1.3**	**1.2**	**1.2**	**1.3**	**1.3**	**1.4**	**1.4**	**0.1**
Chad	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.0
Congo	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.1
Egypt	0.7	0.6	0.6	0.6	0.6	0.6	0.6	–0.1
Sudan/South Sudan	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.0
Other Africa	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.1
Africa	**1.7**	**1.7**	**1.8**	**1.8**	**1.8**	**1.8**	**1.7**	**0.1**
China	4.0	3.9	3.7	3.6	3.5	3.5	3.4	–0.6
DCs, excl. OPEC	**15.0**	**14.8**	**14.7**	**14.7**	**14.8**	**14.9**	**15.0**	**0.0**
Russia	11.1	11.0	11.0	11.2	11.4	11.3	11.3	0.2
Kazakhstan	1.6	1.7	1.8	1.9	1.8	1.8	1.8	0.2
Azerbaijan	0.8	0.8	0.7	0.7	0.8	0.7	0.7	–0.1
Other Eurasia	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0
Eurasia	**14.0**	**14.1**	**14.0**	**14.3**	**14.4**	**14.4**	**14.3**	**0.3**
Total non-OPEC	**49.7**	**50.1**	**50.7**	**51.5**	**52.4**	**52.9**	**53.3**	**3.6**

Figure 4.5
Medium-term non-OPEC crude and NGLs supply outlook in the Reference Case

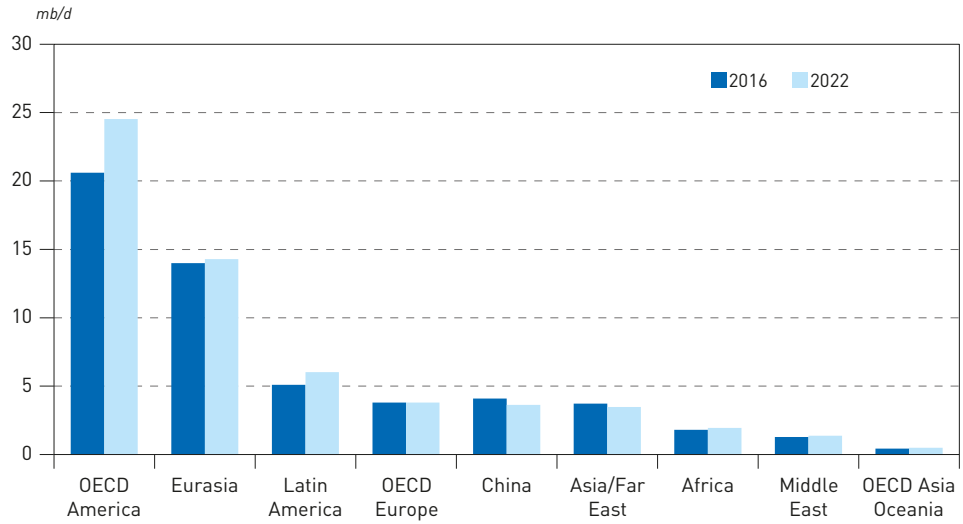
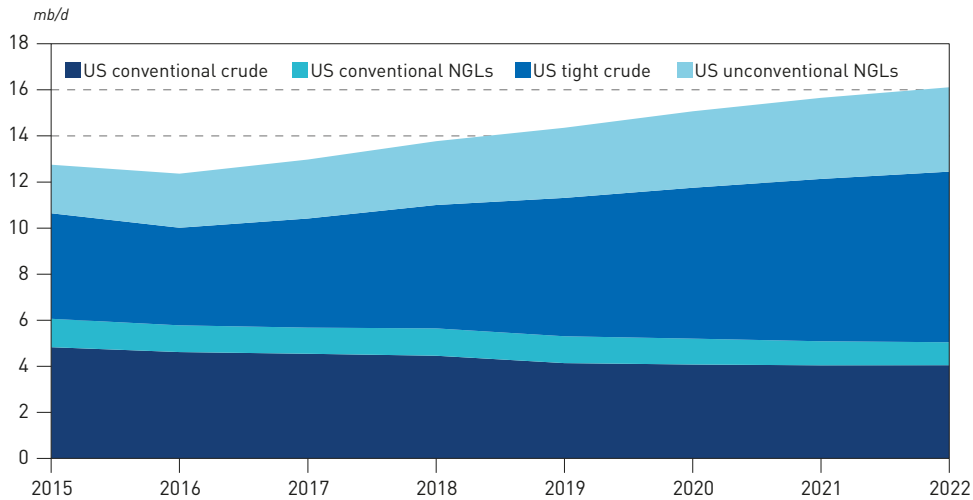


Figure 4.6
US components of crude and NGLs production over the medium-term



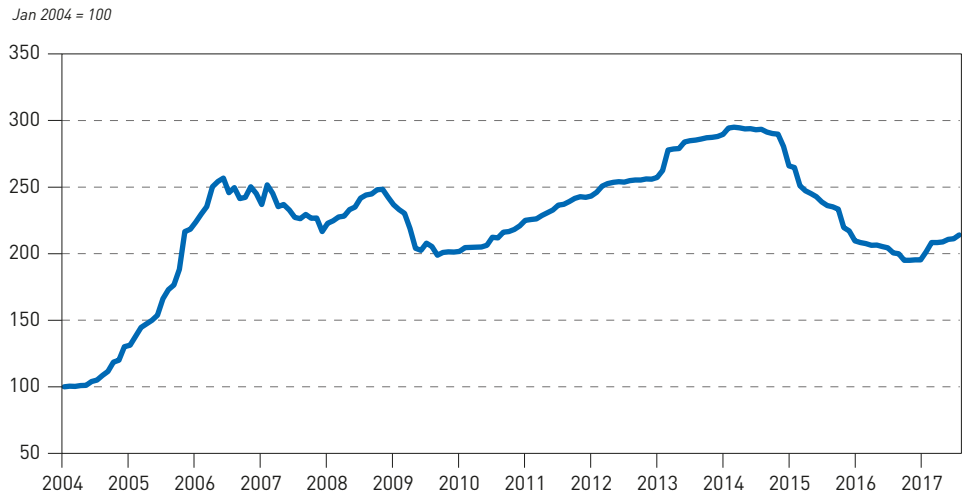
As a result, to date US crude & NGLs production in 2017 has been revised up by a sizeable 0.9 mb/d, compared to last year's WOO. Stronger-than-previously-expected growth in output sees the 2018–2022 years adjusted up by even more, namely by 2 mb/d. As a result, total US crude and NGLs production grows by 3.8 mb/d from 2016–2022 to 16.1 mb/d, or 0.6 mb/d p.a., thus making the US by far the largest producer of petroleum liquids. Of this 3.8 mb/d increment, 2.6 mb/d is from crude, while 1.2 mb/d of the increase stems from NGLs. In both cases, much of this derives from tight oil plays (see discussion on this later).

Besides US tight oil (crude and NGLs), which provides the greatest increment to US liquids production in the medium-term, other sources of US crude are also expected to remain buoyant, with some growth in the medium-term (Figure 4.6). These include Gulf of Mexico offshore crude and pockets of onshore crude in the Lower-48 states. Meanwhile, US conventional NGLs production in the medium-term is forecast to remain steady at around 1.1 mb/d.

Tight crude and unconventional NGLs supply prospects in the medium- and long-term

The US tight oil sector, which has provided the bulk of non-OPEC supply growth since its emergence in the late 2000s, continues to display a strong degree of elasticity or responsiveness to price. When crude prices declined from mid-2014, it was US tight oil production that took the greatest hit, with an annual decline observed in 2016. However, a subsequent price recovery

Figure 4.7
Cost of drilling oil and gas wells in the US



Source: *US Bureau of Labor Statistics.*

from the end of 2016 has turned sentiment around and overall US liquids supply has more or less returned to its previous peak reached in early 2015.

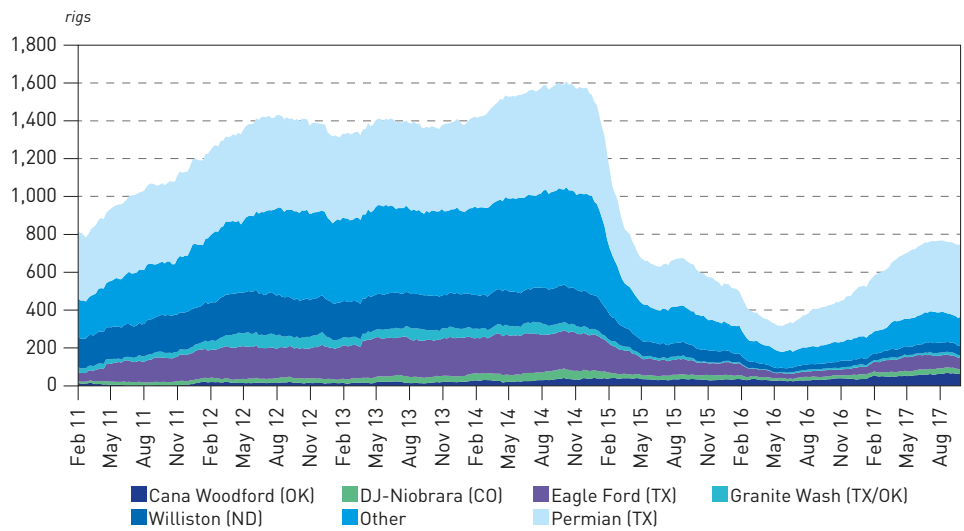
This has been possible for a number of reasons. In the main, it is evident that the US tight oil sector has proven remarkably resilient. Upstream drilling, equipment, labour and other associated costs have fallen (Figure 4.7).

Technology and techniques have advanced, providing significant efficiency gains – in other words, more wells can be drilled faster, more cheaply and with higher individual output levels. As a result, rig counts in the US have rebounded sharply, more than doubling from a low of 332 in April 2016 (Figure 4.8).

This is most obvious in the key tight oil basins, and most pronounced in the most prolific of them all, the Permian Basin.

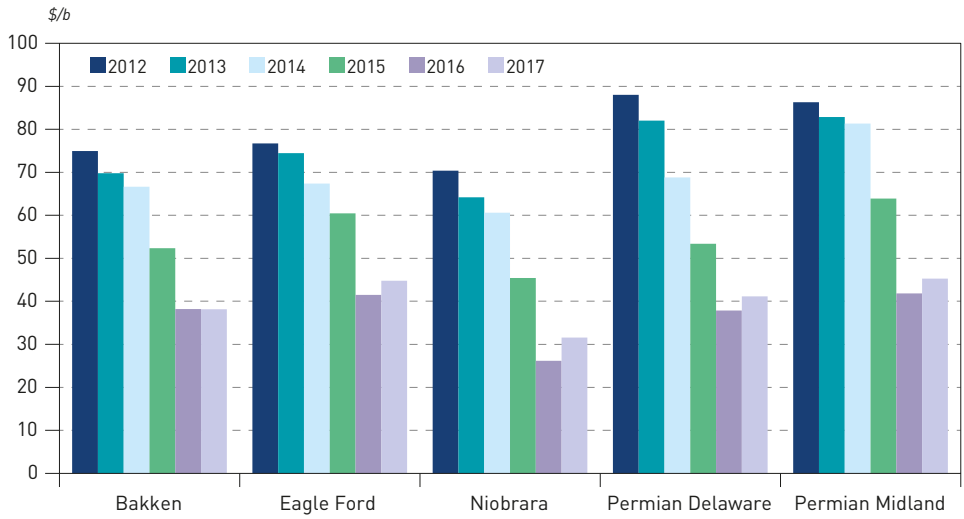
Another way of expressing this is that breakeven prices for drilling profitably in the various US tight oil plays have come down sharply (Figure 4.9), resulting in continued investment. It should be noted, however, that in 2017 the wellhead breakeven prices by play increased. At the same time, many of the previous infrastructure bottlenecks have been resolved and refineries have in many cases adapted to take in higher volumes of light tight crude produced domestically. This is despite the fact that crude exports from the US have now reached nearly 1 mb/d, with flows to most major markets.

Figure 4.8
US oil rig count by major basin



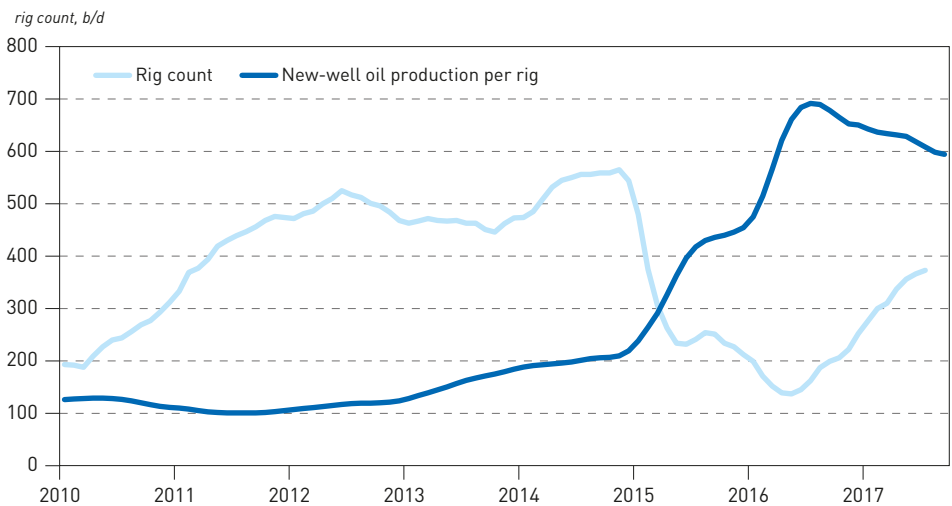
Source: *Baker Hughes: http://phx.corporate-ir.net/phoenix.zhtml?c=79687&p=irol-rigcountsoverview*

Figure 4.9
Evolution of wellhead breakeven prices by play



Source: *Rystad Energy.*

Figure 4.10
Oil rig activity in the Permian



Source: *Drilling Productivity Report, US Energy Information Administration (August 2017).*

The role of the Permian Basin is particularly important. Increasingly, it is referred to as a 'field'; indeed by this measure, it is one of the world's largest concentrations of hydrocarbons and one of the world's largest producing fields. Estimates of its resource base have been revised up, and likely will continue to be.

It should also be noted that the US tight oil story is not only about crude, but also about NGLs. While there is both a push from the upstream sector, in other words, growth in output as a result of rising crude and natural gas production, there is also increasingly a pull from the demand side, with major investments in petrochemical plants and export infrastructure.

As a result, this Outlook forecasts a growth in US total tight oil from 6.6 mb/d in 2016 to 11.1 mb/d by 2022. Thereafter, production grows at a slower pace until peaking in 2026/27, after which output is expected to decline again to 9.9 mb/d by 2040. This compares with a significantly more conservative outlook for US tight oil presented in last year's WOO, in which US tight oil was only expected to grow to 7.2 mb/d by 2022 and peak at 8.7 mb/d in the late 2020s.

By contrast with the US, there have been comparatively small revisions to the tight oil outlook elsewhere. The Reference Case still assumes steady output growth in Canada, with total tight oil output rising from 0.5 mb/d in 2016 to 0.8 mb/d by 2022, and thereafter staying relatively flat. Russia and Argentina are both assumed to have much more modest increases in their respective tight oil sectors. In the Reference Case, no tight oil production in other countries is projected, despite a significant resource base, for example, in China, Colombia or Mexico. The upside supply sensitivity analysis in Chapter 5 includes small volumes for these countries.

Figure 4.11
Global tight oil supply outlook in the Reference Case

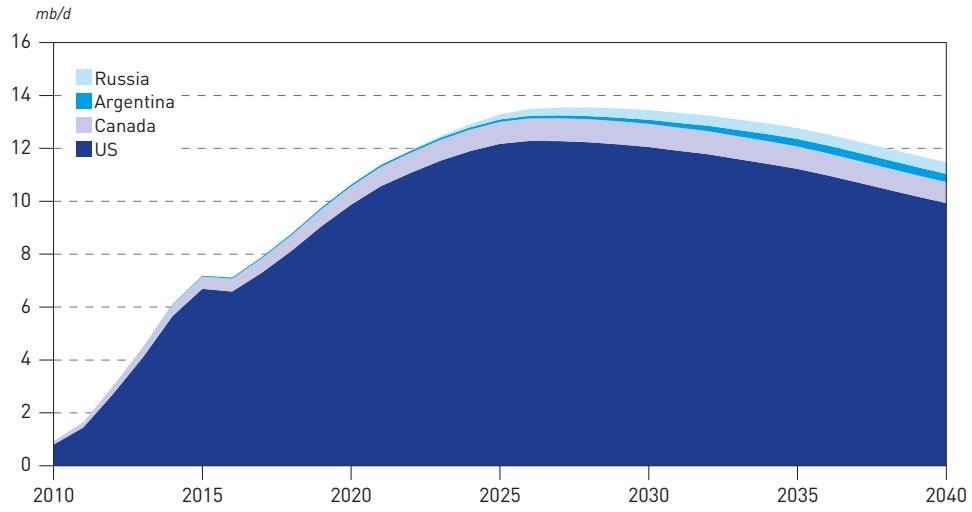


Table 4.3
Global tight crude supply outlook in the Reference Case *mb/d*

	2016	2017	2020	2025	2030	2035	2040	Change 2016–2040
US	4.24	4.74	6.55	8.25	8.26	7.75	6.81	2.57
Canada	0.29	0.32	0.40	0.49	0.52	0.51	0.48	0.20
Argentina	0.03	0.03	0.04	0.06	0.12	0.24	0.26	0.23
Russia	0.00	0.00	0.00	0.17	0.32	0.36	0.39	0.39
Total tight crude	**4.55**	**5.09**	**7.00**	**8.97**	**9.22**	**8.85**	**7.94**	**3.39**

Table 4.4
Global unconventional NGLs supply outlook in the Reference Case *mb/d*

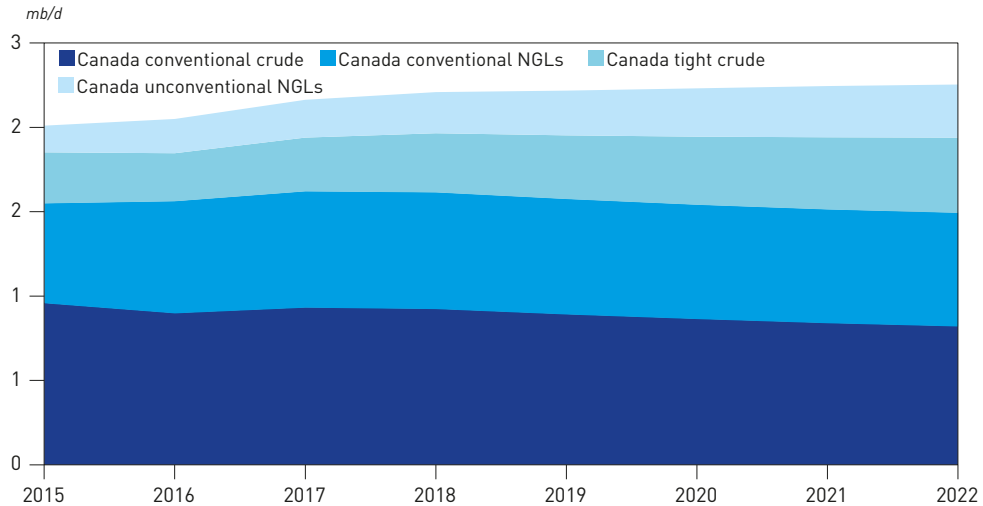
	2016	2017	2020	2025	2030	2035	2040	Change 2016–2040
US	2.35	2.56	3.32	3.92	3.79	3.48	3.12	0.77
Canada	0.20	0.22	0.29	0.34	0.36	0.34	0.31	0.11
Argentina	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.03
Russia	0.00	0.00	0.00	0.03	0.04	0.05	0.06	0.06
Unconventional NGLs	**2.57**	**2.80**	**3.63**	**4.32**	**4.23**	**3.91**	**3.54**	**0.97**

Canada

While Canadian total liquids production is another major source of growth in the medium- and long-term, with steady increases expected throughout the forecast period due to growing output from oil sands, its conventional crude and NGLs production growth in the 2016–2022 period is a more modest 0.2 mb/d. It increases marginally from 2.1 mb/d in 2016 to 2.3 mb/d in 2022.

In part, this crude and NGLs growth stems from Canadian tight oil. In the Reference Case, it is assumed that combined tight oil output in Canada will rise from 0.5 mb/d in 2016 to 0.8 mb/d in 2022, with a modestly larger share for tight crude. Meanwhile, Canada has relatively few conventional crude projects in the pipeline; notably the expected start-up of production at the 150,000 b/d Hebron field offshore Newfoundland and Labrador during the course of 2017.

Figure 4.12
Canada components of crude and NGLs production over the medium-term

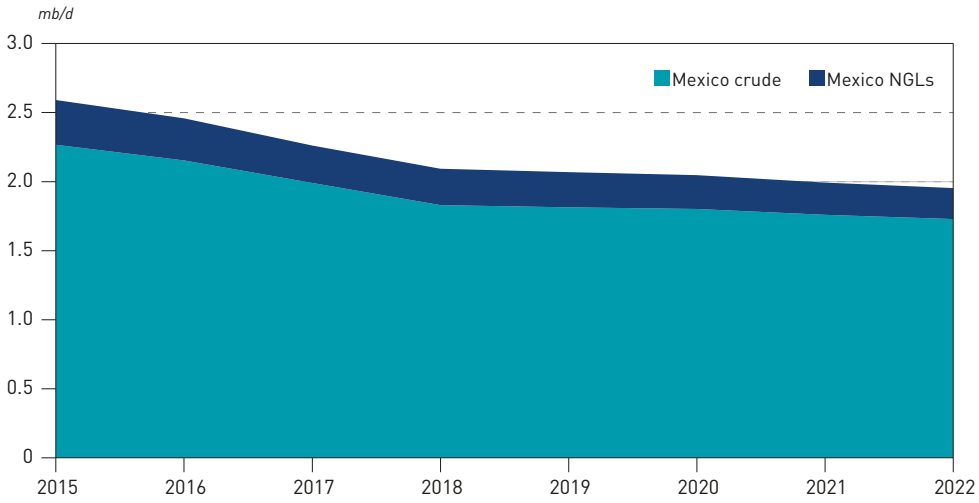


Mexico

Despite attracting considerable interest in various auction rounds for upstream blocks following its recent energy reforms, Mexico's crude and NGLs production is forecast to continue to decline steadily in the medium-term, falling by 0.5 mb/d to 2 mb/d by 2022 (Figure 4.13). This gives Mexico the distinction of being the country set to experience the second-largest output decline in the medium-term Reference Case period (behind China). As things stand, new upstream projects have yet to add any meaningful capacity, while production at mature fields, notably Cantarell, continues to decline steadily.

Having said that, assuming no changes to the new energy regime, and steady investment, particularly in the promising resource areas of non-conventional onshore and deepwater blocks, it is possible to imagine a scenario in which Mexican oil production starts to increase again. After all, the country benefits from a history of hydrocarbons production, significant infrastructure in place, strong local demand, low political risk and – especially in the deepwater areas – proximity to and experience gained in the US deepwater sector. Moreover, recent discoveries point towards a large resource base of untapped reserves. This includes for example, the discovery made by the Zama-1 exploration well offshore Tabasco, which has found an estimated 1.4–2 billion barrels of initial gross original oil in place, or the Amoca field held by Eni in the shallow waters of Campeche Bay, with an assumed 1 billion barrels of oil equivalent (boe) in place.

Figure 4.13
Mexico crude and NGLs production over the medium-term



Norway and the UK

Despite upward revisions to both Norway and the UK's crude and NGLs production outlook, the outlook for the two countries is different. Due to the expected start-up of the huge Johan Sverdrup field in late 2019, Norway's output should grow by 0.1 mb/d in the medium-term, rising to 2.1 mb/d in 2022. By contrast, and despite a pick-up in output in 2015/16 due to a string of new fields starting production, the UK's combined crude and NGLs output is anticipated to decline from 1 mb/d in 2016 to 0.9 mb/d in 2022. OECD European crude & NGLs production is expected to decline slightly in the medium-term Reference Case, due to its advanced maturity, with output falling from 3.4 mb/d to 3.3 mb/d by 2022.

Australia

Australian crude & NGLs production, which has been in steady decline since around 2000, is expected to see a modest increase in the medium-term Reference Case, as a string of huge LNG projects that produce associated condensate and NGLs start-up. As such, Australia's liquids output is anticipated to increase from 0.3 mb/d in 2016 to 0.4 mb/d in 2022. It is also expected to remain around this level for the longer term horizon. Major LNG projects starting up include Prelude, Wheatstone and Ichthys. These are set to make Australia the world's largest LNG exporter alongside Qatar in the course of 2018. Conventional crude production, meanwhile, is anticipated to continue its steady decline.

Asia/Far East

The Asia/Far East region is forecast to see a steady decline in output in the medium-term Reference Case, with crude & NGLs production falling from 3.6 mb/d in 2016 to 3.2 mb/d in 2022. Most major producers will likely see an output decline, including Indonesia, India, Malaysia, Vietnam and Thailand. The region is in a sense the most mature in the world with few prospects for major new discoveries and/or non-conventional production.

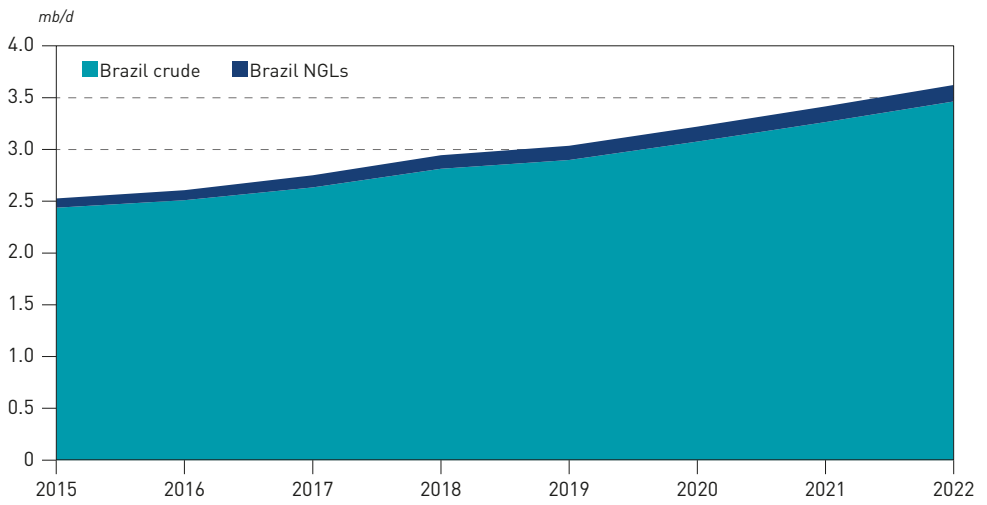
Argentina

Argentina's crude & NGLs production is expected to hold steady in the medium-term Reference Case, averaging 0.6 mb/d. Falling crude output is estimated to be offset by slightly higher NGLs volumes. Argentina is one of a handful of countries with modest growth in tight oil, as production in its Vaca Muerta formation in the Neuquén Basin slowly ramps up.

Brazil

Behind the US, Brazil is the second-largest single country contributor to non-OPEC crude & NGLs growth in the 2016–2022 period. Its medium-term production in the Reference Case is forecast to increase from 2.6 mb/d to 3.6 mb/d (Figure 4.14). The vast majority of these barrels are crude from rising deepwater production in the country's pre-salt layers in the Santos Basin, which in turn is the result of significant investments in capacity made in the

Figure 4.14
Brazil crude and NGLs production over the medium-term



latter half of the 2000s and early this decade. In the medium-term period, major start-ups include expansions of the large Lula field complex, Libra, the Buzios complex and Sepia.

This outlook compares with a recent government agency forecast (Empresa de Pesquisa Energética (EPE)), which projects that Brazil's crude and NGLs production will be around 4 mb/d by 2024, while an 'optimistic scenario' sees a higher production level of 5.2 mb/d by 2026. Brazil's current political crisis notwithstanding, recent efforts to facilitate investment in the country's upstream sector may yet help to accelerate crude production growth even further than that seen in the Reference Case.

Colombia

Colombia's crude & NGLs production is forecast to decline from 0.9 mb/d in 2016 to 0.7 mb/d in 2022 due to a lack of new field start-ups. Despite an improvement in security following the peace agreement with the FARC insurgents, which could yet make upstream activity in some underexplored parts of the country more attractive, a lack of investment and an erosion of the conventional resource base are likely to ensure a continuation of this trend. Moreover, various industry bodies have recently warned that a lack of reserves and falling investment could mean the country's production declines even more rapidly than that assumed in the Reference Case.

It should be noted, however, that Colombia does have significant non-conventional resources, though it also faces considerable scepticism among the general public regarding fracking and other techniques.

Other Latin America

The Reference Case forecast for the medium-term envisages a modest decline in crude & NGLs production in 'Other Latin America' from 0.3 mb/d to 0.2 mb/d. However, a new hydrocarbon-producing region will emerge offshore Guyana, when the ExxonMobil-operated Liza field starts up around 2020, with a first-phase capacity of up to 120,000 b/d. Its discovery in 2015 has stimulated a flurry of exploratory activity with possible further stages for the field's development, and in the coming years the neighbouring countries of Suriname and French Guiana may emerge as oil and gas producers.

Middle East

The medium-term Reference Case projects a slight rise in non-OPEC Middle Eastern crude & NGLs production, as an assumed recovery in Yemen and Syria's oil output more than offsets declines elsewhere, including in Oman and Bahrain. The region's total crude & NGLs production is thus envisaged to rise from 1.3 mb/d to 1.4 mb/d by 2022.

Africa

Crude & NGLs production in non-OPEC Africa is forecast to remain flat at around 1.7 mb/d in the medium-term period. Growth in some up and coming producing countries such as Ghana and others in West Africa is expected to offset declines in more mature producers including

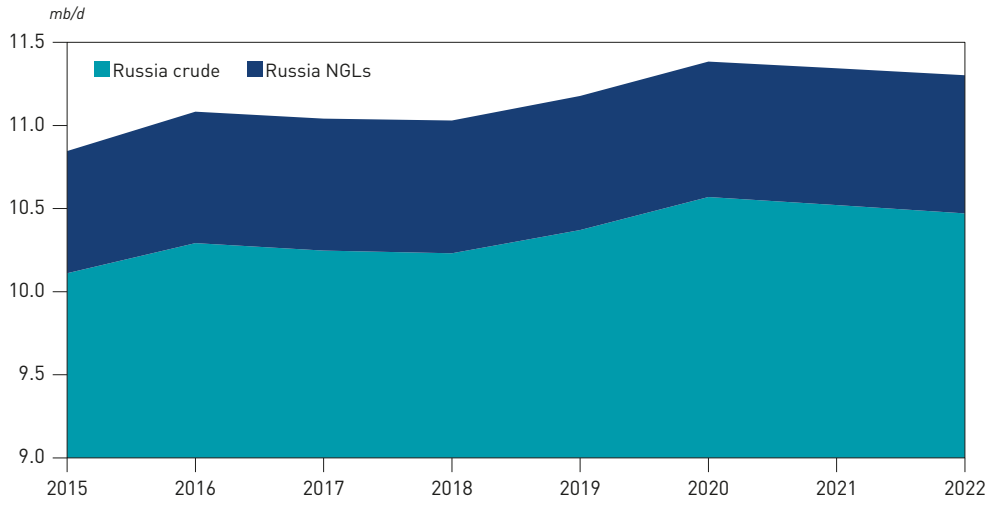
Egypt, Chad, as well as others. In the longer term, promising acreage offshore West Africa in Senegal, Liberia and Mauritania may yet see these countries become meaningful oil producers. Meanwhile, Uganda and Mozambique, among others, will see oil and gas production start-up in the coming years.

Russia

Russia's crude & NGLs production is forecast to rise from 11.1 mb/d in 2016 to 11.3 mb/d in 2022 (Figure 4.15). It is estimated to briefly touch 11.4 mb/d in 2020. Several new start-ups, including further ramp-ups at the Messoyakha, Suzunskoye and Trebs & Titov fields, and continued investment at some brownfields are likely to succeed in offsetting natural decline in the country's large mature base.

Clearly, Russia has ample reserves that could still be tapped, and it is anticipated to see the start-up of its second major LNG export terminal – Yamal LNG – in the course of the next few years. However, it is assumed that major frontier areas including the country's Arctic and non-conventional resources, largely remain prohibitively expensive and difficult to develop. The recent expansion of US sanctions on Russia has the potential to make the involvement of US energy companies, in particular, more challenging, thus theoretically curbing access to experience and technology relevant to developing the country's frontier areas.

Figure 4.15
Russia crude and NGLs production over the medium-term



Azerbaijan

Azerbaijan's crude & NGLs production is expected to continue to decline, falling from 0.8 mb/d in 2016 to 0.7 mb/d in 2022, in the absence of major new start-ups and as output at the large Azeri-Chirag-Guneshli (ACG) field complex matures. Only the Shah Deniz gas field is due to come online around 2018, adding a modest volume (65,000 b/d) of gas condensate to overall liquids production.

Kazakhstan

Kazakhstan's crude & NGLs output is expected to rise a sizeable 0.2 mb/d in the medium-term Reference Case, rising from 1.6 mb/d in 2016 to 1.8 mb/d by 2022. The super-giant Kashagan field is anticipated to continue to ramp-up first phase output in the coming years (peak capacity of this phase is expected to be 370,000 b/d), followed by the expansion of the large Tengiz field in the early 2020s (adding another 260,000 b/d). In the longer term, Kashagan could in theory expand production further, but for the time being, it is assumed no incremental capacity is added in the medium-term Reference Case, due to high costs and technical challenges continuing to put a question mark over the further development of this project.

China

China's crude and NGLs production shows the most pronounced decline in the medium-term Reference Case, falling from 4 mb/d in 2016 to 3.4 mb/d by 2022. China, more than other producing areas – barring US tight oil, which has different characteristics, and is experiencing a rise in output again – has seen a greater impact from the lower crude price environment witnessed since 2014 than anywhere else, with already-mature fields including Daqing and Shengli experiencing strong decline rates amid a lack of investment. By contrast, China is expected to see a small medium-term increase in non-conventional output due to modest growth in CTLs production.

4.3 Medium-term outlook for other liquids supply (excluding biofuels)

From 2016–2022, total other liquids output is forecast to grow by 0.7 mb/d to 3.6 mb/d (Table 4.5). The main increment stems from increased output in Canadian oil sands, which falls into the non-conventional category. Output from Canadian oil sands is forecast to increase from 2.4 mb/d in 2016 to 2.8 mb/d in 2022 and continue rising thereafter.

While Canadian oil sands projects remain attractive due to the relative absence of geological and geopolitical risk, upfront investment costs are relatively high. The Alberta Energy Regulator, in a recent report (quoted by CAPP, the Canadian Association of Petroleum Producers) estimated that developing production capacity using in-situ 'steam-assisted gravity drainage' (SAGD) techniques would require WTI-equivalent prices of $30–50/b; it also estimated that expansion of mining-based production capacity would need a relatively high $65–80/b WTI equivalent oil price. As a result, most new Canadian oil sands capacity will likely be developed using SAGD technology, and in small, modular increments, typically around 25,000+ b/d.

Table 4.5
Medium-term other liquids supply outlook in the Reference Case *mb/d*

	2016	2017	2018	2019	2020	2021	2022	Change 2016–2022
OECD America	2.6	2.7	2.8	2.9	2.9	3.0	3.0	0.4
OECD Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
OECD Asia Oceania	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0
OECD	**2.7**	**2.8**	**3.0**	**3.0**	**3.1**	**3.2**	**3.2**	**0.5**
Latin America	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Middle East & Africa	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1
Asia	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0
China	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
DCs, excl. OPEC	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**
Russia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eurasia	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Non-OPEC	**2.9**	**3.0**	**3.2**	**3.3**	**3.4**	**3.5**	**3.6**	**0.7**
Canadian oil sands	*2.4*	*2.5*	*2.6*	*2.7*	*2.7*	*2.8*	*2.8*	*0.4*
GTLs	*0.0*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.0*
CTLs	*0.2*	*0.2*	*0.2*	*0.3*	*0.3*	*0.4*	*0.4*	*0.2*
Other non-conventional liquids	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.0*

Output of other non-conventionals including GTLs and CTLs is expected to remain relatively flat in the 2016–2022 period, barring an expected modest growth of 50,000 b/d from CTLs in China.

4.4 Medium-term outlook for biofuels supply

Liquid biofuels production is forecast to grow by 0.4 mb/d in the medium-term Reference Case outlook (Table 4.6). Around one-third of this increment stems from Brazilian production of sugar cane-derived ethanol, output of which is expected to grow to 0.7 mb/d by 2022. Indonesia, India and China each see modest growth of around 50,000 b/d in this period, as does OECD Europe.

By contrast, US production of biofuels (overwhelmingly composed of corn-based ethanol) is expected to remain steady at 1.1 mb/d in this period. While in theory legislation is in place to mandate growing volumes of biofuels in US road transportation, in practice a so-called 'blend wall' or natural limit of around 10% has been reached, with automobile producers reluctant to advocate a higher share. Moreover, political support for liquid biofuels may wane or even be curtailed under the current administration. In July of this year, the US government's EPA recommended 2018 blending targets below those for 2017, and considerably below those spelled out in the 2007 RFS legislation – though in reality, most of the reduction was in so-called 'advanced' or second-generation biofuels, production of which has been minimal so far.

Table 4.6
Medium-term non-OPEC biofuels supply outlook in the Reference Case *mb/d*

	2016	2017	2018	2019	2020	2021	2022	Change 2016–2022
OECD America	1.1	1.1	1.2	1.1	1.2	1.2	1.2	0.0
of which: US fuel ethanol	*1.1*	*1.1*	*1.1*	*1.1*	*1.1*	*1.1*	*1.1*	*0.0*
OECD Europe	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1
OECD Asia Oceania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OECD	**1.4**	**1.4**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**0.1**
Latin America	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.2
of which: Brazil fuel ethanol	*0.5*	*0.6*	*0.6*	*0.6*	*0.7*	*0.7*	*0.7*	*0.2*
Middle East & Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asia	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1
China	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
DCs, excl. OPEC	**0.8**	**0.9**	**1.0**	**1.0**	**1.1**	**1.1**	**1.1**	**0.3**
Russia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eurasia	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Non-OPEC	**2.2**	**2.4**	**2.5**	**2.5**	**2.5**	**2.6**	**2.7**	**0.4**
Ethanol	*1.6*	*1.8*	*1.9*	*1.9*	*1.9*	*1.9*	*2.0*	*0.3*
Biodiesel	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.7*	*0.7*	*0.1*

Box 4.1

Higher implied decline rates to be interpreted with caution

At first glance, the medium-term annual growth rate projected for non-OPEC supply in the Reference Case does not look hugely impressive at 0.8 mb/d. For instance, despite the downturn in 2016, growth averaged 0.9 mb/d p.a. in the previous five-year period (2011–2016). Moreover, at some point after the mid-2020s, no more non-OPEC supply growth is projected in the Reference Case, largely as a result of US tight oil peaking. With medium-term non-OPEC liquids supply growth heavily focused on just a handful of countries – essentially the US, Brazil and Canada – it would be easy to think that there is little upstream activity elsewhere.

In actual fact, this picture is misleading. An analysis of non-OPEC upstream projects shows that there is still a significant backlog of greenfield and brownfield projects due to come online in the coming years. Importantly, this list includes many projects that were sanctioned in the period before mid-2014, after which crude oil prices fell sharply. WOO analysis shows there is an average of 5 mb/d of gross new non-OPEC supply capacity due to come online on a yearly basis in the period 2018–2028. In a simple exercise, deducting projected annual non-OPEC supply growth results in implied underlying decline rates – not to be confused with actual decline rates on a field-by-field basis, but a good proxy for what is happening to the non-OPEC sector overall.

This measure is not perfect, as it tends to underestimate smaller 'organic' additions to capacity at existing assets (that do not receive the same type of scrutiny compared to wholly-new investments), which in turn inflates implied decline taking place in current production. However, it does include most additional tight oil volumes, even if these typically are not labelled in the same way as other upstream projects.

Nonetheless, the WOO analysis suggests an average implied decline rate of around 4.4 mb/d in the 2018–2028 period, or 7%, of underlying non-OPEC supply. Note that this compares with previous, more in-depth, work done by the Secretariat, which indicated that underlying observed decline rates in non-OPEC were lower – on average around 5.4% – though with significant regional variations.

On the one hand, this analysis shows the challenge facing the upstream sector, with a requirement for more than 5 mb/d p.a. of new supply, if annual average demand growth of 0.9 mb/d in the Reference Case is added to the implied 4.4 mb/d 'lost' due to natural decline. On the other hand, the calculated implied decline rates and substantial new upstream volumes coming online suggest that overall upstream investment activity is perhaps higher than a quick glance at headline capex numbers would suggest (see the WOO's discussion on global upstream investment at the end of the Chapter).

Moreover, with tight oil making up a substantial and growing share of total non-OPEC supply (around 12% in 2016), and given its innate rapid decline rates after initial production, this may in a sense have accelerated the underlying decline. In other words, the system can said to be coping, with supply growth meeting demand needs at the moment. Thus any such calculations and analysis, while illuminating, must be interpreted with caution.

4.5 Long-term outlook for liquids supply

In contrast with the new medium-term outlook, the forecast for total liquids supply in the long-term has not shifted significantly. Stripping out baseline effects, the upward adjustment to the 2020–2040 period is around 1 mb/d. Upward revisions are more pronounced in the first 10–15 years, but towards the end of the forecast are considerably lower.

Despite this upward adjustment, the Reference Case total non-OPEC liquids supply outlook envisages production declining marginally from 60.7 mb/d in 2020 to 60.4 million b/d in 2040, or by 0.3 mb/d in total. Thus, looking at the forecast period in its entirety, non-OPEC liquids supply grows by a modest 3.4 mb/d from 2016–2040, all of which takes places in the first ten years, after which non-OPEC supply as a whole declines.

The breakdown of the 2020-2040 liquids supply outlook in the Reference Case can be seen in Table 4.7. Regionally, Latin America and Eurasia show modest growth of 0.9 mb/d and 0.4 mb/d, respectively, in the period 2020–2040, while refinery processing gains add another 0.7 mb/d. OECD Europe, Asia Far East and China show meaningful declines. Overall growth of 0.3 mb/d in North America masks the fact that while US and Mexican supply shrinks by 0.8 mb/d and 0.4 mb/d, respectively, Canadian liquids production grows by 1.5 mb/d.

Breaking the long-term change into individual liquids components, of the modest aggregate non-OPEC liquids decline in the 2020–2040 period, the drop is most evident in non-OPEC crude production (-3.8 mb/d, including US tight oil), and non-OPEC NGLs (-0.5 mb/d). This is partially

Figure 4.16
Long-term non-OPEC liquids supply outlook in the Reference Case

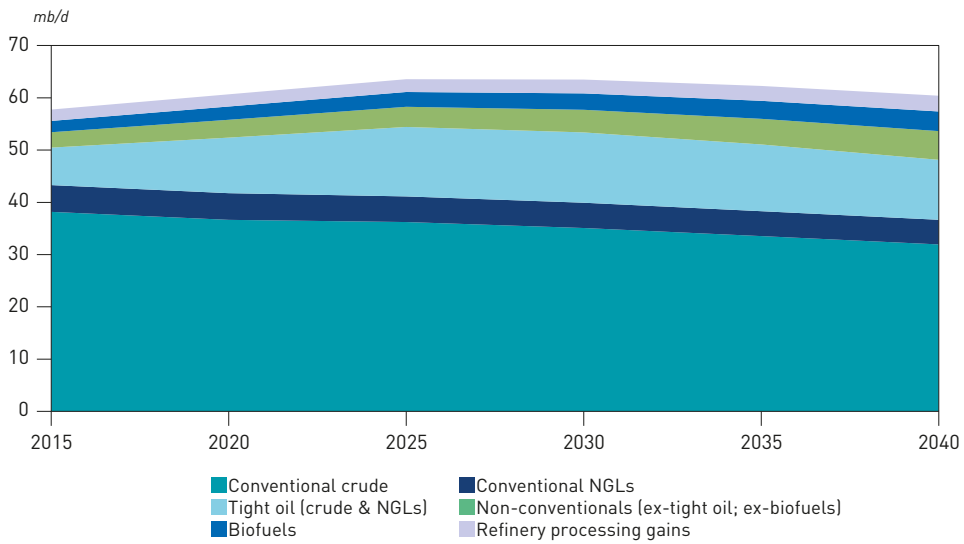


Table 4.7
Long-term liquids supply outlook in the Reference Case

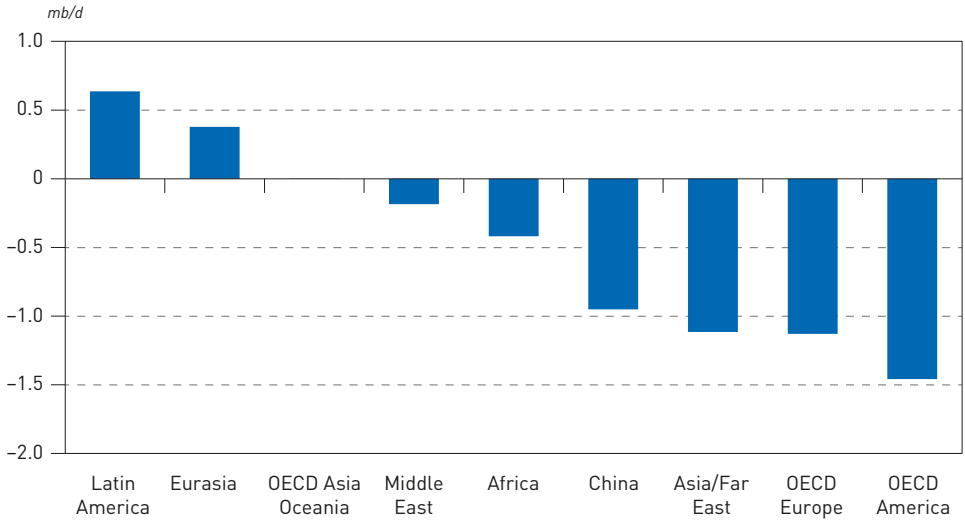
mb/d

	2016	2017	2020	2025	2030	2035	2040	Change 2020–2040
US & Canada	18.1	18.9	21.4	23.8	23.9	23.2	22.1	0.7
of which: tight crude	*4.5*	*5.1*	*5.7*	*8.7*	*8.8*	*8.3*	*7.3*	*1.6*
Mexico & Chile	2.5	2.3	2.1	1.9	1.8	1.7	1.7	–0.4
OECD Europe	3.8	3.8	3.8	3.7	3.5	3.3	2.9	–0.9
OECD Asia Oceania	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.1
OECD	**24.8**	**25.5**	**27.7**	**30.0**	**29.7**	**28.7**	**27.2**	**–0.5**
Latin America	5.1	5.2	5.6	6.3	6.4	6.5	6.5	0.9
Middle East & Africa	3.1	3.1	3.3	3.3	3.2	3.0	2.8	–0.5
Asia	3.7	3.6	3.5	3.5	3.4	3.1	2.9	–0.7
China	4.1	4.0	3.7	3.6	3.5	3.3	3.2	–0.5
DCs, excl. OPEC	**16.0**	**16.0**	**16.1**	**16.7**	**16.4**	**15.9**	**15.3**	**–0.8**
Russia	11.1	11.0	11.4	11.2	11.1	11.1	11.1	–0.3
Other Eurasia	2.9	3.0	3.1	3.2	3.5	3.7	3.8	0.7
Eurasia	**14.0**	**14.1**	**14.5**	**14.4**	**14.6**	**14.8**	**14.9**	**0.4**
Processing gains	2.2	2.2	2.3	2.4	2.6	2.8	3.0	0.7
Non-OPEC	**57.0**	**57.7**	**60.7**	**63.6**	**63.5**	**62.3**	**60.4**	**–0.3**
Crude	42.0	42.2	43.6	45.2	44.3	42.4	39.9	–3.8
NGLs	7.7	7.9	8.7	9.2	9.1	8.7	8.2	–0.5
of which: unconv. NGLs	*2.2*	*2.2*	*2.5*	*3.2*	*3.3*	*3.1*	*2.9*	*0.4*
Other liquids incl. biofuels	5.1	5.4	6.0	6.7	7.5	8.4	9.2	3.3
Total OPEC supply	**38.8**	**38.7**	**40.4**	**41.0**	**44.1**	**47.6**	**50.9**	**10.5**
OPEC NGLs	5.9	6.0	6.4	7.0	7.7	8.3	8.9	2.5
OPEC Other liquids*	0.2	0.3	0.3	0.5	0.5	0.5	0.6	0.2
OPEC crude	32.7	32.4	33.7	33.5	35.9	38.8	41.4	7.7
Stock change**	**0.5**	**-0.3**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**	
World supply	**95.8**	**96.5**	**101.1**	**104.5**	**107.6**	**109.9**	**111.3**	**10.2**

* *This item includes other non-crude streams, such as GTLs, methyl tetra-butyl ether (MTBE) and biofuels.*

** *Stock change assumptions reflect commercial stock inventories, development of Strategic Petroleum Reserves (SPR), and the rising need for stocks as refinery capacity expands.*

Figure 4.17
Regional change in non-OPEC liquids supply in the Reference Case



offset by growth from non-conventional (+2.1 mb/d, of which some 80% is Canadian oil sands), biofuels (+1.2 mb/d) and refinery processing gains (+0.7 mb/d).

The implied demand for OPEC Member Countries' barrels is expected to remain just over 33 mb/d until the mid-2020s. After that point, which is when US tight oil is expected to peak, demand for OPEC crude rises steadily to 41.4 mb/d by 2040.

4.6 Long-term outlook for crude and NGLs

By contrast with the medium-term outlook, the Reference Case non-OPEC crude and NGLs production forecast for the 2020–2040 period shows a pronounced decline, with combined output falling from 52.4 mb/d to 48.1 mb/d – a loss of 4.2 mb/d. A temporary peak is reached around 2025 which, not coincidentally, is when US tight oil is expected to reach its maximum output.

Table 4.8 shows the detail for the long-term outlook for non-OPEC crude and NGLs broken down by region and major producers. Latin America and Eurasia are the only two regions expected to experience growth, of 0.6 mb/d and 0.4 mb/d, respectively. Meanwhile, OECD America, OECD Europe, Asia/Far East and Africa are all projected to see a major decline in this period.

Broken down into individual components, the Reference Case long-term outlook is for a decline in non-OPEC crude production of 3.8 mb/d in the period 2020–2040, while NGLs fall by 0.5 mb/d.

Table 4.8
Long-term non-OPEC crude and NGLs supply outlook in the Reference Case

mb/d

	2016	2017	2020	2025	2030	2035	2040	Change 2020–2040
US	12.4	13.0	15.1	17.1	16.8	15.7	14.2	–0.9
of which: tight crude	*4.2*	*4.7*	*6.6*	*8.3*	*8.3*	*7.7*	*6.8*	*0.3*
Canada	2.1	2.2	2.2	2.3	2.2	2.1	2.0	–0.2
Mexico	2.5	2.3	2.0	1.9	1.8	1.7	1.7	–0.4
Chile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OECD America	**16.9**	**17.4**	**19.4**	**21.3**	**20.9**	**19.6**	**17.9**	**–1.5**
Norway	2.0	2.0	2.1	2.1	1.9	1.7	1.3	–0.7
United Kingdom	1.0	1.0	1.0	0.8	0.8	0.7	0.7	–0.3
Other OECD Europe	0.4	0.4	0.4	0.3	0.3	0.3	0.3	–0.1
OECD Europe	**3.4**	**3.4**	**3.4**	**3.2**	**3.0**	**2.7**	**2.3**	**–1.1**
Australia	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.0
Other OECD Asia Oceania	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
OECD Asia Oceania	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.0**
OECD	**20.7**	**21.2**	**23.2**	**24.9**	**24.3**	**22.7**	**20.6**	**–2.6**
Brazil	2.6	2.8	3.2	3.9	4.1	4.2	4.2	1.0
Argentina	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.0
Colombia	0.9	0.8	0.7	0.7	0.5	0.4	0.3	–0.4
Other Latin America	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.0
Latin America	**4.5**	**4.6**	**4.8**	**5.5**	**5.5**	**5.5**	**5.5**	**0.6**
India	0.8	0.8	0.8	0.8	0.7	0.6	0.6	–0.2
Indonesia	0.9	0.8	0.7	0.7	0.6	0.5	0.4	–0.3
Malaysia	0.7	0.7	0.7	0.6	0.6	0.5	0.4	–0.3
Thailand	0.5	0.5	0.4	0.4	0.4	0.4	0.3	–0.1
Vietnam	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.0
Other Asia/Far East	0.4	0.3	0.4	0.4	0.3	0.3	0.2	–0.2
Asia/Far East	**3.6**	**3.5**	**3.3**	**3.1**	**2.9**	**2.5**	**2.2**	**–1.1**
Bahrain	0.2	0.2	0.2	0.2	0.2	0.1	0.1	–0.1
Oman	1.0	1.0	0.9	0.8	0.8	0.8	0.7	–0.2
Syrian Arab Rep.	0.0	0.0	0.1	0.2	0.2	0.1	0.1	0.0
Yemen	0.0	0.0	0.1	0.2	0.2	0.1	0.1	0.0
Middle East	**1.3**	**1.2**	**1.3**	**1.4**	**1.3**	**1.2**	**1.2**	**–0.2**
Chad	0.1	0.1	0.2	0.2	0.1	0.1	0.1	–0.1
Congo	0.3	0.4	0.4	0.4	0.4	0.3	0.3	–0.2
Egypt	0.7	0.6	0.6	0.6	0.5	0.5	0.4	–0.1
Sudan/South Sudan	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.0
Other Africa	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.0
Africa	**1.7**	**1.7**	**1.8**	**1.7**	**1.6**	**1.5**	**1.3**	**–0.4**
China	4.0	3.9	3.5	3.3	3.1	2.8	2.6	–1.0
DCs, excl. OPEC	**15.0**	**14.8**	**14.8**	**15.1**	**14.5**	**13.6**	**12.7**	**–2.0**
Russia	11.1	11.0	11.4	11.2	11.1	11.1	11.0	–0.4
Kazakhstan	1.6	1.7	1.8	2.0	2.3	2.6	2.7	0.9
Azerbaijan	0.8	0.8	0.8	0.7	0.7	0.7	0.7	–0.1
Other Eurasia	0.5	0.5	0.5	0.5	0.4	0.4	0.4	–0.1
Eurasia	**14.0**	**14.1**	**14.4**	**14.4**	**14.6**	**14.7**	**14.8**	**0.4**
Total non-OPEC	**49.7**	**50.1**	**52.4**	**54.4**	**53.4**	**51.1**	**48.1**	**–4.2**

Major individual countries contributing to growth in the long-term are Brazil, which experiences steady increases in production and grows by 1 mb/d in the period 2020–2040 due to rising pre-salt barrels, as well as Kazakhstan, which is forecast to see combined crude and NGLs output increase by 0.9 mb/d on the back of increasing output at the large Kashagan field, among others.

4.7 Long-term outlook for other liquids supply (excluding biofuels)

Non-conventional oil production in the Reference Case (excluding biofuels) is expected to grow by 2.1 mb/d in the period 2020–2040, reaching 5.6 mb/d in 2040. Canadian oil sands make up 80% of this growth, reflecting an expansion of 1.7 mb/d in the period from 2020–2040.

Table 4.9
Long-term other liquids supply outlook in the Reference Case *mb/d*

	2016	2017	2020	2025	2030	2035	2040	Change 2020–2040
OECD America	2.6	2.7	2.9	3.2	3.6	4.1	4.6	1.7
OECD Europe	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.0
OECD Asia Oceania	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
OECD	**2.7**	**2.8**	**3.1**	**3.4**	**3.8**	**4.3**	**4.8**	**1.7**
Latin America	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Middle East & Africa	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.0
Asia	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
China	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.3
DCs, excl. OPEC	**0.2**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.4**
Russia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Eurasia	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
Eurasia	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.0**
Non-OPEC	**2.9**	**3.0**	**3.6**	**4.0**	**4.5**	**5.0**	**5.6**	**2.0**
Canadian oil sands	*2.4*	*2.5*	*2.7*	*3.0*	*3.4*	*3.9*	*4.4*	*1.7*
GTLs	*0.0*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.0*
CTLs	*0.2*	*0.2*	*0.3*	*0.4*	*0.5*	*0.6*	*0.7*	*0.4*
Other non-conventional liquids	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.2*	*–0.1*

The only other meaningful component is an anticipated rise in Chinese non-conventional production, mostly CTLs. While the profitability of CTLs is often questioned since oil prices fell in 2014, large deposits of coal in inland regions and energy security concerns have guaranteed a modicum of state support for CTLs production in China. Table 4.9 shows the breakdown of long-term non-conventionals production by region.

4.8 Long-term outlook for biofuels supply

The long-term Reference Case for liquid biofuels production projects a further increase of 1.2 mb/d in the period 2020–2040, growing from 2.5 mb/d to 3.8 mb/d. Over this timeframe, Brazilian ethanol makes up around 20% of the incremental output. The Asian countries of Indonesia and India are each expected to see growth of around 0.2 mb/d, as does OECD Europe, while production in the US and China each grows by 0.1 mb/d. Thus, in 2040, global biofuels production is anticipated to make up around 3% of the world's total oil liquids supply of 111.3

Table 4.10
Long-term non-OPEC biofuels supply outlook in the Reference Case *mb/d*

	2016	2017	2020	2025	2030	2035	2040	Change 2020–2040
OECD America	1.1	1.1	1.2	1.2	1.2	1.2	1.3	0.1
of which: US fuel ethanol	*1.1*	*1.1*	*1.1*	*1.1*	*1.1*	*1.2*	*1.2*	*0.1*
OECD Europe	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.2
OECD Asia Oceania	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
OECD	**1.4**	**1.4**	**1.5**	**1.6**	**1.7**	**1.7**	**1.8**	**0.4**
Latin America	0.6	0.7	0.8	0.8	0.9	1.0	1.0	0.3
of which: Brazil fuel ethanol	*0.5*	*0.6*	*0.7*	*0.7*	*0.8*	*0.8*	*0.9*	*0.2*
Middle East & Africa	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Asia	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.4
China	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1
DCs, excl. OPEC	**0.8**	**0.9**	**1.1**	**1.2**	**1.5**	**1.7**	**1.9**	**0.8**
Russia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eurasia	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Non-OPEC	**2.2**	**2.4**	**2.5**	**2.8**	**3.1**	**3.4**	**3.8**	**1.2**
Ethanol	*1.6*	*1.8*	*1.9*	*2.1*	*2.2*	*2.4*	*2.6*	*0.7*
Biodiesel	*0.6*	*0.6*	*0.6*	*0.8*	*0.9*	*1.0*	*1.1*	*0.5*

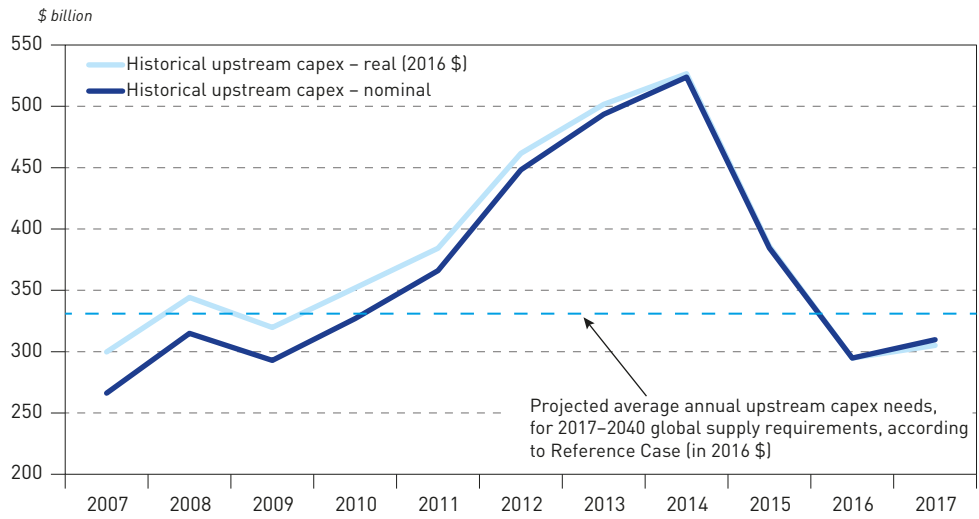
mb/d (including estimated OPEC crude production). Of the 3.8 mb/d, some 70% or 2.6 mb/d is expected to be ethanol, and the other 30% or 1.1 mb/d is anticipated to be biodiesel.

4.9 Upstream investment

Continued and sufficient upstream investment remains critical to ensuring future supply. Following sharp declines in 2015 and 2016, some have warned of a supply crunch ahead, if investment does not pick up. In actual fact, preliminary data for 2017 is promising, indicating a return to higher investment (see Figure 4.18). As crude prices have so far in 2017 averaged higher than last year, not least due to a certain degree of market stabilization following the Declaration of Cooperation between OPEC and 10 non-OPEC producing countries, the US tight oil sector in particular appears to be attracting a significant rise in upstream spending, with estimates in a range of 25–50% growth for 2017. It should be noted, however, that the recent pick-up in investments is more evident in short-cycle, rather than long-cycle projects, which are the industry's baseload.

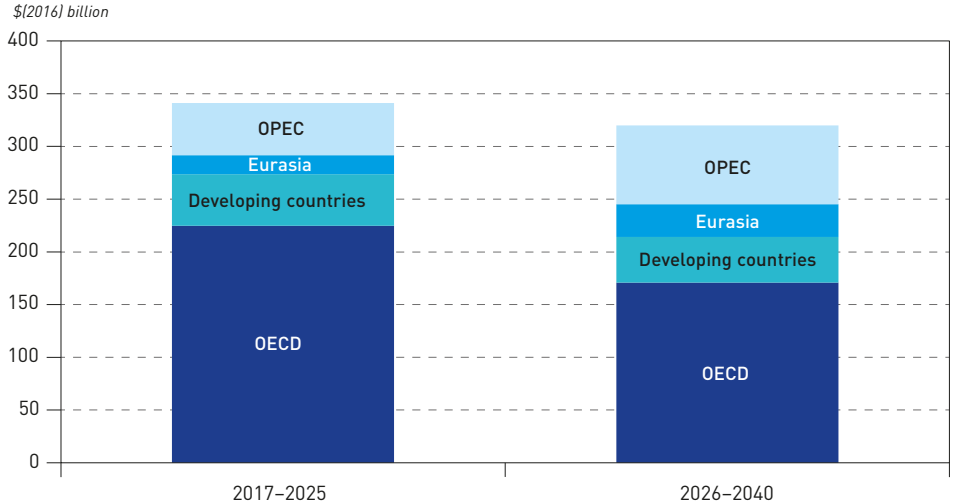
The total upstream investment needed in order to ensure a balanced and stable oil market is estimated at $7.9 trillion (all future investment figures quoted in this section are in 2016 dollars) over the period 2017–2040. This sum is estimated based on the forecasted volume of oil required to match demand out to 2040, taking into account variations in liquid stream by region, the associated costs of additional barrels and volumes that need to be replaced

Figure 4.18
Historical and projected annual upstream investment



Source: *Rystad Energy, OPEC.*

Figure 4.19
Annual upstream investment requirements for capacity additions in the Reference Case, 2017–2040



due to natural decline. On an annual basis, upstream investment is estimated at $328 billion, with OPEC adding one out of every five dollars needed. Figure 4.19 shows the annual upstream investment needed in two distinct periods. For the coming eight years until 2025, around which time US tight oil is projected to peak, an average of $341 billion p.a. will need to be invested in upstream projects. In the longer-term period from 2026–2040, this figure is reduced to $320 billion p.a., as a greater share of global supply needs is projected to be met by lower-cost OPEC barrels.
Over the entire forecast period of 2017–2040, most of the investment will need to be made in non-OPEC countries, with a required $292 billion projected for every year in the 2017–2025 period, and $245 billion in the subsequent years until 2040. The bulk of the necessary spending will be in OECD countries, as a result of higher anticipated cost per additional barrel and higher average rates of natural decline – both in some part due to the relative maturity of the region's oil fields.

Eurasia is expected to see its share of annual upstream spending requirements rise, from $18 billion p.a. in 2017–2025, to $31 billion p.a. thereafter, as high-cost barrels increasingly enter the market. Developing economies (ex-OPEC Member Countries) are estimated to see their spending share stay relatively steady, at around $45 billion throughout the entire forecast period.

Meanwhile, OPEC countries will continue to invest in order to ensure a reliable, stable and well-supplied oil market. In the 2017–2025 period, Member Countries are forecast to spend an annual average of $50 billion and than $75 billion in the longer-term, as demand for OPEC crude is projected to rise sharply after US tight oil peaks in the mid-2020s.

Can these investment needs be met? With preliminary indications for 2017 spending already more or less in line with projected requirements, the WOO 2017 remains optimistic that this goal is achievable. While future investment needs are relatively high in the historical context, they are well below the peaks reached in 2012–2014, at a time of extreme cost inflation (and much higher crude oil prices). Moreover, relatively speaking, the sector will need to target higher-cost barrels, including from deeper waters, in Canadian oil sands, and other frontier areas, as the cost of developing the marginal barrel gradually increases over time.

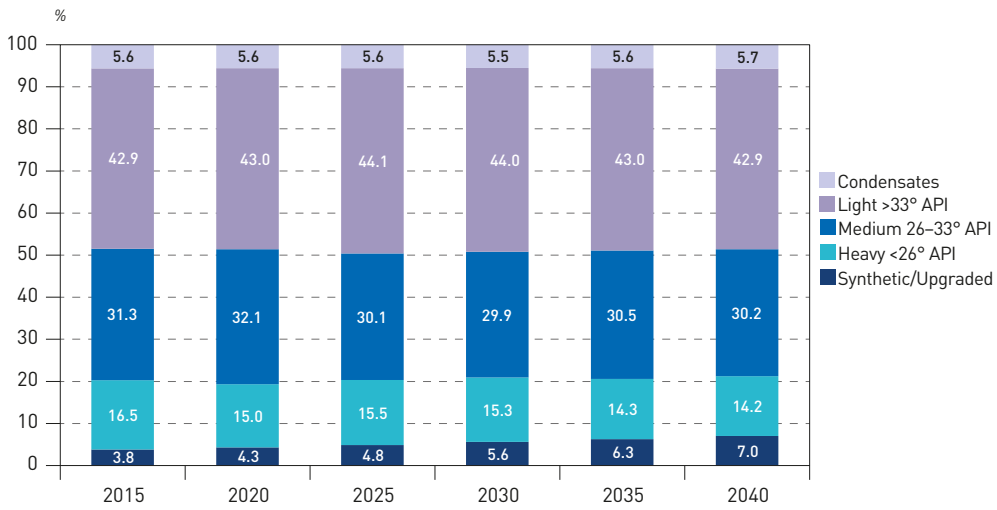
Overall, in the period up to 2040 the required global investment in the oil sector is estimated at around $10.5 trillion. This includes also the required investment in the downstream sector estimated at $1.5 trillion (see Chapter 5 for further details) and in the midstream sector at $1.1 trillion.

4.10 Crude quality developments

The quality of crude oil is of great importance for the global and regional refining systems as well as for meeting the underlying refined product demand. Changes in crude oil quality could impact global trade flows, as well as influence future refinery configurations. Therefore, it is important to understand the development of crude oil quality, which is the focus of this section.

The primary parameter of crude quality is the gravity (density), which is normally measured in degrees API and sulphur content. There are also other parameters that determine the qual-

Figure 4.20
Global crude supply by API gravity category, 2015–2040 (share)



ity of crude oil, such as acidity (TAN number), nitrogen and oxygen, as well as heavy metal content. All these parameters have an impact on the refinery setup, refinery yield, and, consequently, the pricing of the particular crude stream.

Figure 4.20 shows the relative shares of the global crude and condensate supply outlook in the Reference Case in terms of the API gravity.

The most important medium-term development is the expected expansion of light crude production, which increases its share from around 42.9% in 2015 to 44% in 2025. The major reason for this is the growth of light-sweet supplies in North America (predominantly tight oil), but also additional light-sweet volumes in other regions such as Eurasia. These increases more than offset the natural reduction of conventional light production elsewhere, such as in the North Sea and the Asia-Pacific.

However, the overall share of light grades after 2030 is expected to start declining gradually, falling back to just below 43% in 2040, as light tight oil output in North America starts to decline. At the same time, the share of medium grades is anticipated to decline gradually from around 31.5% in 2015 to just above 30.2% in 2040. This is mainly due to the increasing share of light crudes in the overall mix, but also due to the natural decline of medium streams. The share of heavy grades is expected to decline gradually in the medium- to long-term to a level around 14% in 2040, which is more than 2 percentage points lower compared to the level in 2015. Nevertheless, the share of synthetic grades (including tar sands in Canada), which are mostly heavy (API gravity in the range of 22–25° API), is projected to increase continuously over the outlook period from around 3.8% in 2015 to 7% in 2040. The share of condensates in the total slate is estimated to remain stable at levels slightly above 5.5% over the outlook period.

The outlook looks somewhat different when expressed in terms of volume (Figure 4.21). Almost all crude qualities increase over the outlook period, although at different scales. Light crude volumes increase significantly in the medium-term, rising more than 3 mb/d to reach 37.3 mb/d by 2025. This is mainly due to tight oil production growth in North America. In the period 2025–2040, the growth of light supplies slows considerably with additions of around 1 mb/d between 2025 and 2040, to reach levels of just above 38 mb/d in 2040. This is the result of two opposing movements – light tight oil production going into decline post-2030, which is then more than offset by the increase of light production in Eurasia and the Middle East.

The production of medium grades stagnates in the medium-term at around 26 mb/d. This can be explained by declining production in some regions such as the Asia-Pacific, although there is expected to be increasing volumes of medium grades in Latin America. The overall volume of medium grades is projected to increase slightly over the longer term, heading towards 27 mb/d by 2040. This is mainly due to higher output from the Middle East.

The output of heavy grades is expected to decline slightly from 13 mb/d in 2015 to around 12.5 mb/d in 2040. Despite relative stability on the global scale, there is anticipated to be heavy output decreases in some regions such as Latin America (Mexico and Colombia) and the Asia-

Figure 4.21
Global crude supply by API gravity category, 2015–2040 (volume)

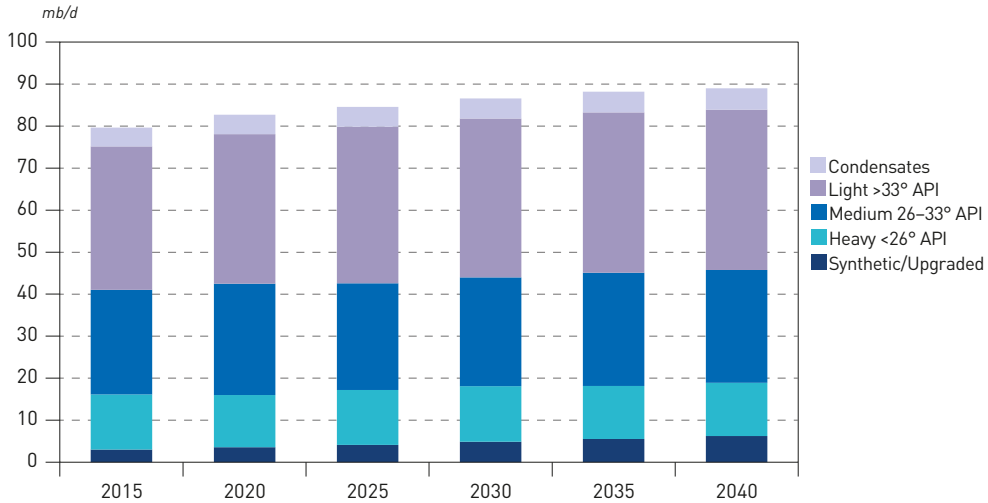
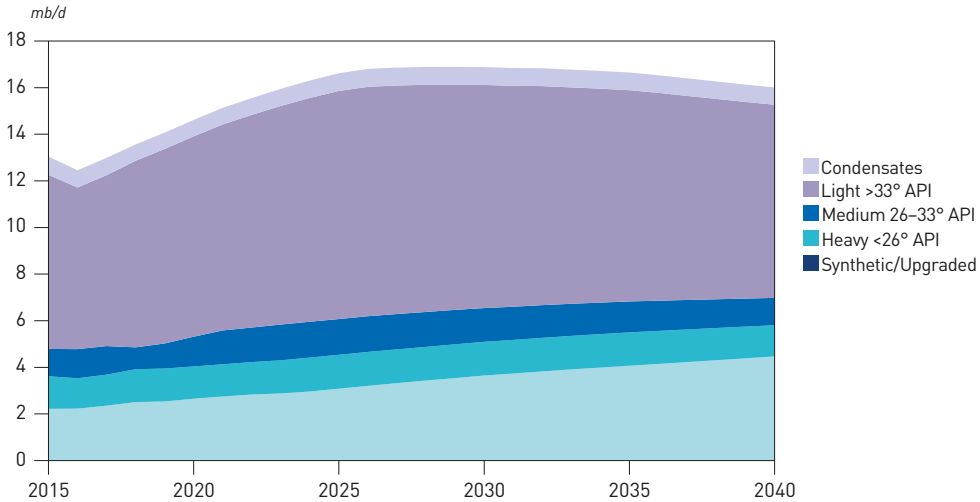


Figure 4.22
US & Canada crude supply by API gravity category, 2015–2040 (volume)



Pacific due to natural decline. This is partly offset by new heavy output in the Middle East and Brazil. Strong growth is expected in the synthetic crudes sector, which is set to more than double from around 3 mb/d in 2015 to around 6.2 mb/d by 2040, as production in Canada, as well as Venezuela expands.

Focusing on the US & Canada region, after a strong decline of light tight oil production to below 7 mb/d in 2016 due to lower oil prices, light supplies (mainly light tight oil, but also conventional production in the Gulf of Mexico) are expected to increase gradually in line with a recovering oil price. Consequently, light crude output in the US & Canada reaches levels just below 10 mb/d between 2025 and 2030, which is an increase of almost 2.5 mb/d relative to the levels seen in 2015. However, as tight oil production matures and conventional light production goes into decline, combined US & Canadian light output is seen falling to around 8.3 mb/d in 2040.

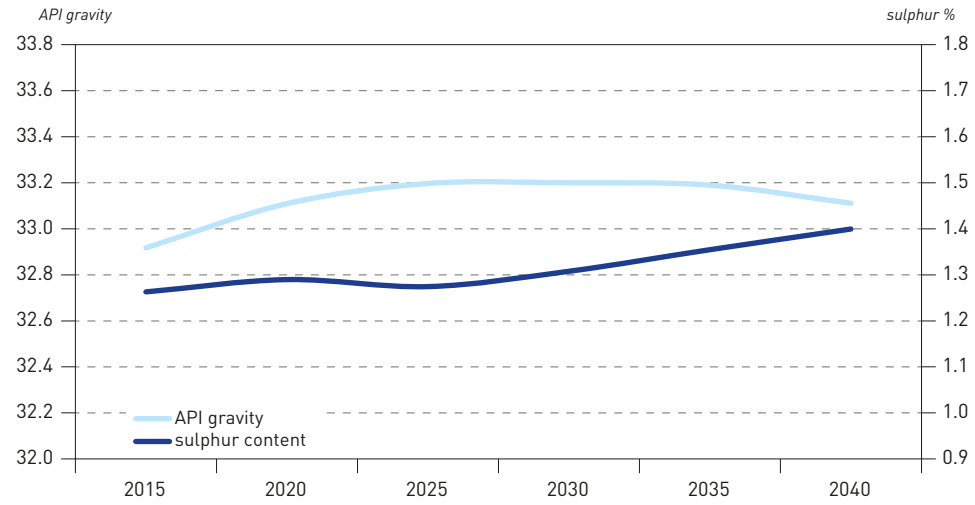
At the same time, synthetic crude output (mostly heavy material produced from Canadian oil sands) is another major contributor to overall growth. Syncrude production is expected to double from around 2.2 mb/d in 2015 to almost 4.5 mb/d by 2040. Synthetic crude output is estimated to account for around 28% of overall crude and condensate production in the US & Canada region by 2040, up from around 17% in 2015. Medium and heavy supplies in the US & Canada are expected to expand slightly in the medium-term (for instance, supported by new production in the Gulf of Mexico), but in the long-term they are seen to gradually decline due to natural depletion (especially offshore production).

Figure 4.23 shows the outlook for the development of the average API gravity and sulphur content at the global level. The average API gravity looks stable at around 33° API throughout the period, albeit with minor changes in the medium- and long-term. The API gravity increases from just below 33° API in 2015 to around 33.2° API in 2025, which is in line with the growing share of light crudes, especially in the US, but also in other regions such as Eurasia and Latin America. After 2025, the global API gravity declines marginally to a level 33.1° by 2040, as the share of light crudes declines and the share of synthetic barrels (mostly heavy) increases. Declining API gravity is also in line with expanding Middle East production, with a large share of medium and heavy grades.

The sulphur content is expected to remain stable at just below 1.3% in the medium-term. This is the result of rising light sweet production, especially in the US, which is offset by expanding sour production of OPEC grades between 2015 and 2020 and a continuous rise in heavy-sour syncrude production. Nevertheless, in the longer-term the overall sulphur content increases gradually to around 1.4% by 2040, as sweet production plateaus and the output of sour grades in the Middle East, as well as heavy-sour synthetic production, increases.

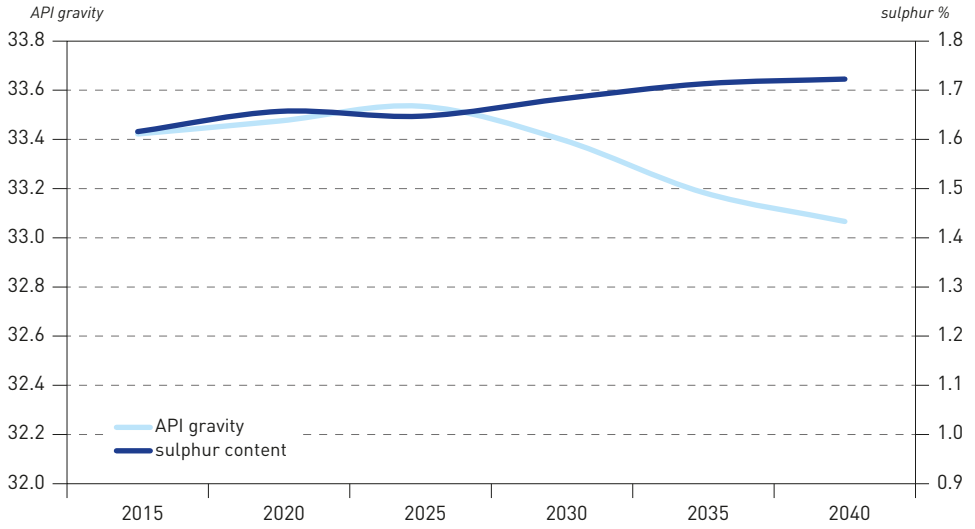
Away from the global perspective, the outlook for the average API gravity and sulphur content at the respective OPEC and non-OPEC levels displays different development paths. For OPEC crude and condensate production, the average API gravity is seen as stable at around 33.5° API in the medium-term. It is then expected to start declining after 2025 to levels around 33° API in 2040 (Figure 4.24). The decline in API gravity is in line with the rising share of heavier (and sour) crudes in the overall mix, especially in the Middle East, but also heavy synthetic barrels

Figure 4.23
Average global crude quality*



* *Includes crude from tar sands in Canada.*

Figure 4.24
Average OPEC crude quality

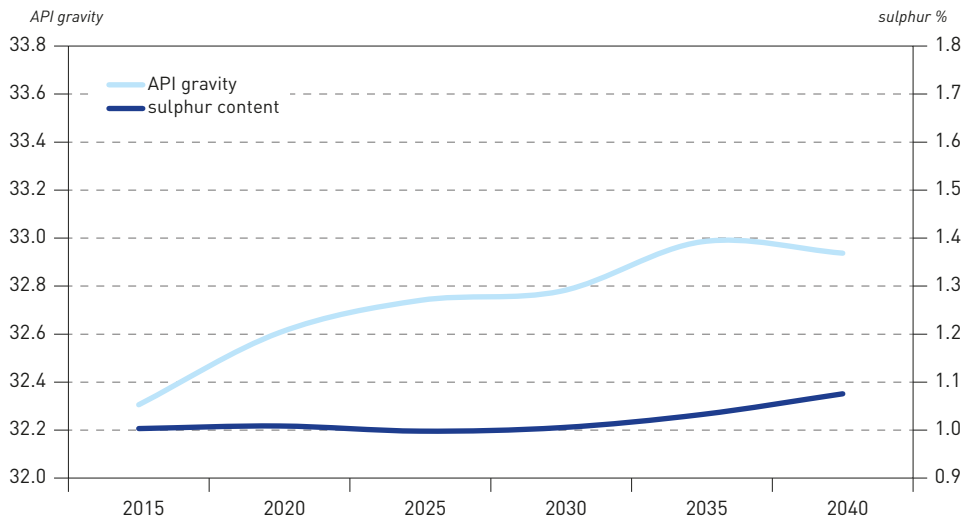


in Venezuela. In line with this, the average sulphur content of OPEC production is expected to rise gradually from around 1.6% in 2015 to above 1.7% in 2040.

Meanwhile, the average API and sulphur characteristics of non-OPEC production show a different path, with average API gravity rising throughout the assessment period. Estimated average API gravity in 2015 of around 32.3° API is likely to increase towards 32.8° API in 2030, in line with rising light tight oil production and the additions of light barrels in Eurasia. The average API gravity is anticipated to continue to rise even after sweet tight oil production in North America peaks. It is expected to reach levels just below 33° API in 2040 (Figure 4.25).

This can be explained by further expansions of light production in Eurasia, but also strong declines in non-OPEC medium and heavy production in this period, such as Mexico, Colombia, China, as well as the North Sea. In terms of sulphur content for non-OPEC, the average is expected to decline marginally until 2025 to levels below 1%, mainly supported by the increases in light sweet production. However, the average sulphur content is then seen to increase to above 1% in 2040 as sweet production plateaus and rising levels of very high sulphur production come onstream, especially synthetic crude.

Figure 4.25
Average non-OPEC crude quality*



* *Includes crude from tar sands in Canada.*

Refining outlook

Key takeaways

- Distillation capacity additions for the 2017–2022 period are estimated at around 7.6 mb/d. This is driven mostly by demand increases in developing countries.
- The majority of additions are is located in the Asia-Pacific with 3.7 mb/d (49%) and the Middle East 2 mb/d (27%), while the remaining regions combined add only around 1.8 mb/d (24%) in total.
- Potential incremental crude runs are estimated at 7.4 mb/d in the period to 2022 (not including potential closures). This is around 1.6 mb/d in excess of the 'call on refining' of around 5.75 mb/d by 2022.
- At the regional level, five regions are expected to have an excess of refined product potential compared to requirements: US & Canada, Middle East, Europe, Russia & Caspian and China, for a total of 2.4 mb/d by 2022. In contrast, the Asia-Pacific region (excluding China), Latin America and Africa exhibit a deficit of 0.8 mb/d by 2022.
- A total net closures level of 1.6 mb/d is estimated for the period 2017–2022, predominantly in developed regions led by Europe.
- Cumulative total refining distillation additions are projected to reach 19.6 mb/d by 2040, predominantly in developing regions.
- The Asia-Pacific region remains number one in terms of long-term additions with almost half of the total volume, while additions in the Middle East account for close to 20%.
- Total potential closures are estimated in the range of 6-8 mb/d from 2017–2040, mostly in developed regions.
- New distillation capacity of 7.6 mb/d in the medium-term is expected to be accompanied by an additional 3.2 mb/d of conversion units, 6.6 mb/d of desulphurization capacity and 1.7 mb/d of octane units.
- At the global level, projections indicate the need to add some 10.7 mb/d of conversion units, 22.5 mb/d of desulphurization capacity and just above 5 mb/d of octane units in the period to 2040.
- The new IMO regulations from 2020 will be a major challenge for the refining industry in the medium-term, in terms of utilization rates, required fuel mix and blending requirements, as well as the impact on price differentials and refining margins.
- The total volume of required downstream investments is estimated at around $1.5 trillion in the period 2017–2040. Of this, $285 billion is anticipated as required for the medium-term projects, $335 billion is for additions beyond known projects in the long-term, while $915 billion is for the maintenance and replacement.

Chapter 5 takes the supply and demand assumptions from the Reference Case and examines how various factors could impact the global refining sector, over the medium- and longer term. It presents the assessment of current 'base' capacity, projects, announced and further anticipated closures. Combining these three components leads to an assessment of net available capacity by year from 2017–2022, which is the period covered in the review of medium-term developments. In addition, Chapter 5 compares additions to capacity by year from 2017–2022 with the incremental 'call on refining' each year as driven by product demand growth, in order to assess the balance between incremental refining capability and the incremental refining required. This analysis also considers Reference Case assumptions on non-crude supply – that is, NGLs, GTLs/CTLs and biofuels. Balances are reviewed globally and by region.

The Chapter also presents the long-term outlook based on World Oil Refining Logistics and Demand (WORLD)[9] modelling cases from 2020–2040. Compared to the medium-term assessment, this represents a somewhat different approach. In the long-term modelling, sufficient capacity is added to accommodate changes in supply and demand (including crude and product quality), while also allowing for options to change crude and product trading patterns between regions.

Furthermore, this Chapter follows the same pattern of assessing first the medium- and then the long-term outlook for secondary capacity. The main emphasis is on conversion, desulphurization and octane units. The focus for the medium-term assessment (2017–2022) is on directly comparing secondary process unit capacity additions and potential yields by product by region with incremental demand by product by region. The long-term assessment draws from the exact same WORLD Model cases, but with the emphasis on secondary unit additions and the investments needed to meet incremental demand and product quality requirements given changes in the crude slate and non-crude supply, as well as allowing for opportunities to trade – and alter trade patterns – between regions.

This analysis serves to provide a Reference Case outlook for the global downstream and its 'strategic parameters' through 2040, as well as examining what factors could affect and alter the outlook.

As set out in Annex C, the WORLD model represents the world as 23 regions, which are aggregated into seven regions[10] for reporting purposes.

5.1 Base capacity

Overview

This Chapter provides a detailed update to base capacity assessments (distillation and secondary capacity) by refinery worldwide. It also includes new refineries that came onstream, as well as closures that occurred in 2016.

Table 5.1 compares the January 2017 base capacity of 97.4 mb/d estimated in this Outlook with assessments from other organizations – and illustrates how these have changed relative to those made in 2016. In terms of the global total, the latest assessment of base capacity is essentially identical to that of BP in its June 2017 Statistical Review. Both assessments are nearly

Table 5.1
Global refinery base capacity per different sources

mb/d

Source	Reference date	mb/d[3]
Assessments made in 2017		
OPEC WORLD Report, June 2017	Jan 2017	97.4
BP Statistical Review, June 2017	2016[2]	97.4
IEA Oil 2017, February 2017[1]	2016[2]	96.5
IHS, April 2017	Jan 2017	94.3
Assessments made in 2016		
OPEC World Oil Outlook, November 2016	Jan 2016	97.5
BP Statistical Review, June 2016	2015(2)	97.2
IEA MTOMR, February 2016	2015(2)	97.7
IHS, April 2016	Jan 2016	95.9

(1) Previously named the Medium-Term Oil Market Report.
(2) Not stated whether beginning or end of year; presumed end of year.
(3) Per calendar day.

flat versus those made a year ago, reflecting the fact that distillation capacity additions during 2016 have been almost completely offset by closures during the year.

In contrast, while the WOO 2016, BP 2016 and International Energy Agency (IEA) Medium-Term Oil Market Report (MTOMR) 2016 global assessments (for end 2015) were very close, at 97.2–97.5 mb/d, in the IEA's February 2017 Oil 2017 Report, the organization dropped its assessment of capacity by over 1 mb/d to 96.5 mb/d for the end of 2016. This was driven by an elimination of capacity no longer considered to be active. Likewise, IHS dropped its assessment to 94.3 mb/d for January 2017 from 95.9 mb/d for January 2016. It is clear that IHS has a much lower overall assessment of capacity than OPEC, BP or the IEA.

OPEC's assessment was the result of a careful refinery-by-refinery review. It is possible that part of the difference may lie with the way refineries that are struggling to operate are treated. Unless officially closed, such refineries are included in the database of 'nameplate' capacity, though their effective availability is identified as being well below nameplate level. The other fact worth noting is that no one data source can be relied upon entirely. Rigorous refinery-by-refinery research is necessary to increase the accuracy of any efforts to properly assess distillation and secondary capacity on the regional and global level. This is not always possible. Consequently, there is always an element of arriving at a 'best estimate' for base capacity, as well as for projects and closures. This point was illustrated in the WOO 2016 Box 5.1, which described extensive efforts made to deal with gaps and deficiencies in the data for three 'minor', but still important processes – namely, solvent deasphalting, and hydrogen and sulphur plant processing.

5.1.1 Capacity in 2017

This Chapter summarizes the estimated 2017 base capacity as developed and applied in the WORLD model cases (Table 5.2). At the global level, today's refineries are increasingly 'complex' with expanding secondary processing capacity per barrel of primary distillation. This trend has been supported by more stringent regulations on fuel quality, which call for higher levels of upgrading, desulphurization, octane and related supporting capacity from the outset. Thus, base levels of secondary capacity are now substantial. As a percentage of

Table 5.2
Assessed available base capacity as of January 2017

mb/d

	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	World
Distillation									
Crude oil (atmospheric)	20.3	8.0	4.1	17.1	7.1	8.9	13.9	18.0	97.4
Vacuum	9.3	3.6	1.0	6.7	2.9	2.5	5.5	5.7	37.2
Upgrading									
Coking	2.9	0.8	0.1	0.7	0.4	0.3	1.9	0.9	8.0
Visbreaking	0.2	0.4	0.2	1.6	0.5	0.6	0.2	0.5	4.1
Solvent deasphalting	0.4	0.1	0.0	0.1	0.0	0.1	0.1	0.1	1.0
Catalytic cracking	6.0	1.6	0.3	2.4	0.7	0.9	3.1	2.8	17.7
Hydrocracking	2.3	0.2	0.2	2.0	0.4	0.8	1.6	1.5	9.0
Gasoline quality									
Reforming	3.9	0.7	0.5	2.6	0.9	1.0	1.2	2.7	13.6
Isomerization	0.8	0.1	0.1	0.6	0.3	0.4	0.2	0.2	2.7
Alkylation	1.2	0.2	0.0	0.2	0.0	0.1	0.0	0.3	2.2
MTBE/ETBE	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.3
Desulphurization									
Naphtha	4.7	0.9	0.6	3.3	1.0	1.4	1.2	3.1	16.2
Gasoline	2.9	0.5	0.1	0.6	0.1	0.2	0.7	1.0	6.2
Middle distillates	6.6	2.1	0.8	5.8	1.7	2.3	3.1	5.9	28.4
Vacuum gasoil/Residual	3.1	0.4	0.0	1.8	0.2	0.5	0.4	2.7	9.2
Sulphur (short tonnes/day)	41,522	7,738	3,634	19,103	5,791	13,547	10,426	30,185	131,945
Hydrogen (million scf/d)	6,481	1,413	407	4,580	863	2,424	3,499	5,206	24,873

crude (atmospheric) distillation capacity, vacuum distillation stands at an average of 38% worldwide, upgrading at 41%, gasoline octane units at 19% and desulphurization at 62%.

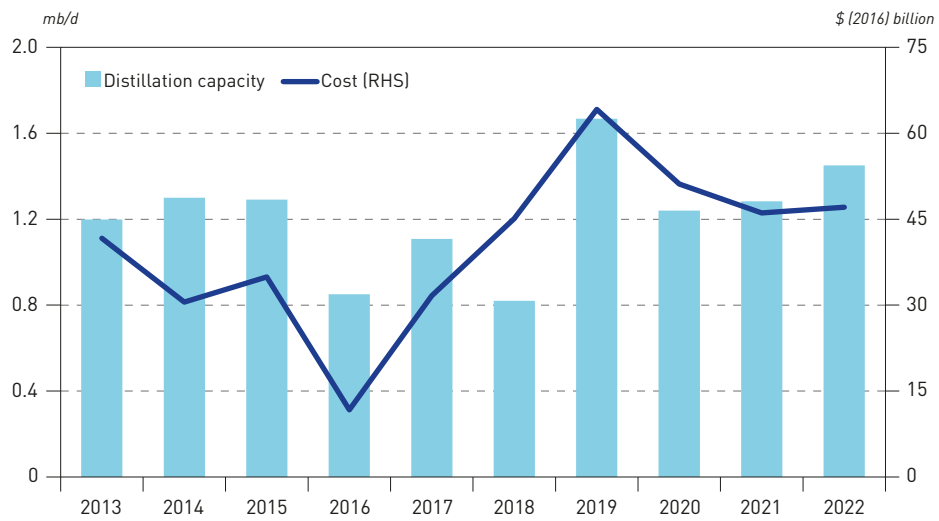
However, as Table 5.2 illustrates, regional differences are large. Global refining distillation capacity was estimated at 97.4 mb/d as of 1 January 2017. Of this, the US & Canada and Europe still comprise significant proportions, respectively at 20.3 mb/d and 17.1 mb/d of capacity, or 20.8% and 17.5% of the global total. In the US & Canada, total capacity has edged up in recent years, supported by increasing domestic oil supply, even though ongoing rationalization has reduced the total number of refineries in operation. In Europe, rationalization has entailed reductions in both the total number of active refineries and the total operating capacity. Meanwhile, the Asia-Pacific capacity has been steadily increasing to the level of the US & Canada plus Europe, supported by the region's strong oil demand growth. Capacity for the total region now stands at 31.9 mb/d (32.8%), with China accounting for 13.9 mb/d (14.3%). The increase of refining capacity in the Asia-Pacific occurred despite the fact that capacity in Japan and Australia has been declining as closures continue in those two countries. At the same time, Middle East capacity has seen a similar trend, rising from around 6.7 mb/d in 2000 to 8.9 mb/d today.

5.1.2 Refinery projects

Overview of additions and trends

The pace and the location of refinery investments continue to follow the oil demand growth. Consequently, the majority of investments are expected in developing countries, underpinned by

Figure 5.1
Annual distillation capacity additions and total projects investment



local demand. At the same time, the pace of investments in the medium-term is seen to recover from the levels seen in recent years, though they are still lower than they were three to four years ago. The reviews of existing projects carried out in 2013 and 2014 indicated that more than 8 mb/d of new distillation capacity would be added globally in the periods 2013–2018 and 2014–2019. This was followed by a number of deferrals caused mainly by the crude oil price drop. The WOO 2015 estimated additions of around 7.1 mb/d for the period 2015–2020. Last year, the pace of additions indicated a modest recovery with 7.3 mb/d in firm projects expected from 2016–2021. This year, the modest upward trend continues with 7.6 mb/d expected from 2017–2022.

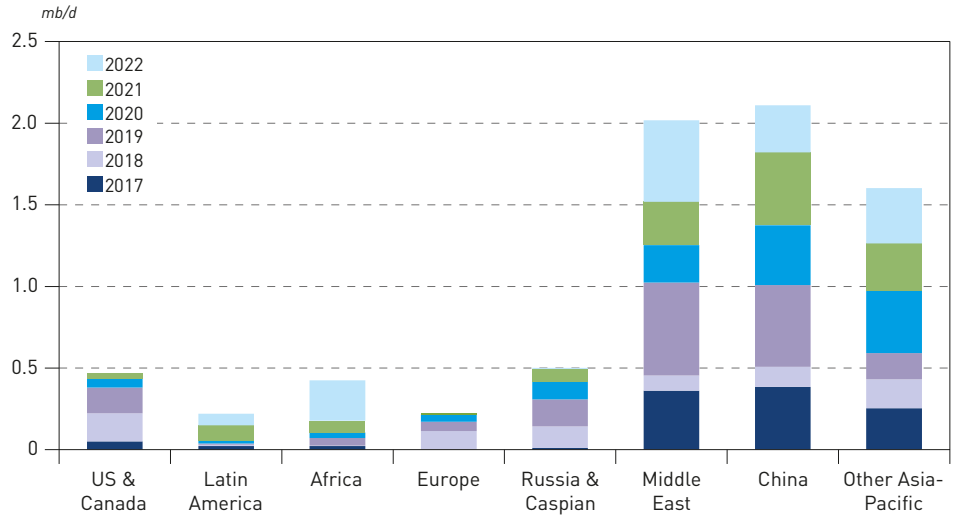
Figure 5.1 shows the recent history of capacity additions and associated total project investments, plus the projection for these between 2017 and 2022. It highlights the impact of the recent crude oil price drop and the recovery in additions now in evidence. From 2013–2015, additions were relatively stable at 1.2–1.3 mb/d p.a. In 2016, additions and investments dropped sharply to 0.85 mb/d as companies reacted to the price drop, with following expectations and reduced cash flow, and a cut in investments. The forecast for 2017 through 2019 indicates limited additions in the first two years, followed by an expected 'bump' of 1.7 mb/d from delayed projects in 2019. Thereafter, the Outlook sees a return to the typical recent level of around 1.3 mb/d with an upward trend. It is worth noting that the average rate of additions from 2017–2022 of just over 1.25 mb/d is essentially identical to that of the 2013–2015 period, indicating a tendency for the industry to maintain or revert to a 'typical' rate of around 1.2–1.3 mb/d. This is occurring despite significant year-to-year variations, and despite changes in the crude price between 2015 and 2016.

A detailed breakdown of the capacity additions projected for 2017–2022 is presented in Table 5.3 and Figure 5.2. These do not account for potential capacity closures or for the additional capacity achieved through minor 'creep' debottlenecking, which are taken into account and discussed separately.

Table 5.3
Distillation capacity additions from existing projects, by region *mb/d*

	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	World
2017	0.1	0.0	0.0	0.0	0.0	0.4	0.4	0.3	1.1
2018	0.2	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.8
2019	0.2	0.0	0.0	0.1	0.2	0.6	0.5	0.2	1.7
2020	0.1	0.0	0.0	0.0	0.1	0.2	0.4	0.4	1.2
2021	0.0	0.1	0.1	0.0	0.1	0.3	0.4	0.3	1.3
2022	0.0	0.1	0.2	0.0	0.0	0.5	0.3	0.3	1.5
2017–2022	**0.5**	**0.2**	**0.4**	**0.2**	**0.5**	**2.0**	**2.1**	**1.6**	**7.6**

Figure 5.2
Distillation capacity additions from existing projects, 2017–2022



A degree of circumspection is always required when elaborating the outlook for capacity additions from projects. The tendency is for refinery projects to 'slip', which is why the project evaluation process undertaken annually entails a 'risking' of both the probability of and the timeframe for completion. A number of high profile projects have continued to slip with some now slated for completion beyond the medium-term period. What started this year as a list comprised of projects representing 22 mb/d has been reduced to 7.6 mb/d, i.e. 33% of these are considered 'firm' within the 2017–2022 timeframe.

With regard to the circumstances specifically surrounding the 2017–2022 period, it is possible that additional project cancellations or delays (to beyond 2022) could still be forthcoming, depending on developments in the oil price and demand levels. Conversely, a surge in prices would not necessarily lead to an acceleration in major investments since refining companies are likely to want to see such a price increase confirmed over an extended period of time before making any final decisions to go ahead with projects (certainly with large projects of, say, more than $1 billion in magnitude). Another factor that now looms large in the medium-term outlook is the decision by the IMO last October to proceed with the MARPOL Annex VI Global Sulphur Rule in January 2020. While it is too late for this or any other regulation to have much of an impact on new capacity that could be brought online by 2020, this regulation could materially impact the situation in the 2021–2022 period and beyond.

One further caveat to this projection, which was also raised in previous Outlooks, remains in place – namely that only 45% of the 7.6 mb/d of projects assessed as 'firm' through 2022 are currently under construction (1.4 mb/d) or nearing the construction stage (2 mb/d). The remaining 4.2 mb/d comprises projects that are not yet near construction but which are

considered far enough advanced in terms of engineering, financing, and overall firmness of support to be accorded a high probability of going ahead and coming onstream by 2022. Since there is little time remaining to build major projects that would be up and running during the medium-term (that is, through year-end 2022), and which would thus be able to add meaningfully to available capacity, there is some potential for reductions in projected capacity because of delays and cancellations due to various reasons.

The projects, as assessed, continue to show a pattern seen in previous Outlooks with most of them concentrated in developing regions, predominantly the Asia-Pacific and the Middle East. As shown in Table 5.3 and Figure 5.2, 84% of the distillation capacity projects assessed as viable for the period 2017–2022 are located in developing regions, which is also where the biggest share of demand growth is expected. Of the remaining 16%, a little over 6% is accounted for by projects in the US & Canada. These are mainly condensate splitters needed to handle increased volumes of light tight oil. Around 3% of additions are expected to occur in Europe and around 7% in the Russia & Caspian region.

The Asia-Pacific region accounts for almost half of new global capacity or over 3.7 mb/d through 2022. This represents a continuation of a trend seen in previous WOO in which new capacity is increasingly concentrated in the Asia-Pacific. It has grown from 40% between 2015 and 2020, as seen in the 2015 Outlook, to 45% in last year's Publication to 49% this year. A recovery in the rates of additions in China is a factor, as is a steady increase in projected medium-term additions in Other Asia-Pacific. The resurgence of projects in China has led to the country accounting for 2.1 mb/d of the 3.7 mb/d of total additions in the Asia-Pacific region. Across the Asia-Pacific, the primary driver of refining projects is continuing demand growth. As can be seen today, capacity surges – such as those in China – also tend to mark the beginning of periods when product exports could increase.

Estimated medium-term expansions continue to be substantial in the Middle East which has 2 mb/d of new projects in the period 2017–2022. This comes on top of significant new recent refinery capacity in the region. Such sustained additions are being driven by a combination of growing local demand and policies in several countries that are designed to capture the value added through refining. At slightly below 1 mb/d, the region's demand increase over the period justifies half of the investments taking place. Part of the new capacity is expected to be used to reduce product imports, but the net effect of additions should still be an appreciable increase in the region's potential to market products (as well as crude oil) internationally in the near future. These and future expansion projects should materially alter the region's long-term crude versus product export balance, substantially cutting the former while boosting the latter – and producing the inverse effect in importing countries.

Latin America's medium-term crude distillation capacity additions have been in steady decline in recent years. From over 1 mb/d for the medium-term periods as projected in the 2013 and 2014 WOOs, the level in this year's Outlook for 2017–2022 is only 0.2 mb/d. This situation reflects a combination of factors across the region including less optimistic assumptions regarding economic growth in some Latin American countries and adverse impacts on cash flow – and hence the ability to finance projects in regional crude exporting countries. Even with reduced medium-term economic growth – and, thus, reduced oil demand growth – the

projected capacity additions are well below projected demand growth of 0.5 mb/d. This implies yet further increases in net product imports into the region in the medium-term.

In the US & Canada region, additions projected for the medium-term have dropped back to 0.5 mb/d from around 0.75 mb/d as estimated in the previous Outlook. This mainly reflects developments surrounding new condensate splitters, which are designed to handle the increase in US production of light tight oil and condensates. Several splitters were already built in 2015–2016, while most others have since been delayed or cancelled, courtesy of the recent pull-back in US light tight oil production in 2016 and the elimination of the US crude export ban, which had been in effect until December 2015.

Africa continues to see something of the order of 40 refining projects. If all these were built, they would add some 4 mb/d of new refining capacity to the continent. However, those projects that look firm for 2017–2022 total only slightly above 0.4 mb/d, which is below the projected demand increase of 0.6 mb/d for the same period. On this basis, the outlook continues to be for further increases in regional net product imports. Furthermore, those projects considered relatively firm are slated for start-up late in the medium-term period.

The Russia & Caspian region is expected to add around 0.5 mb/d of new capacity in the medium-term, which is higher than the projected demand growth of 0.3 mb/d. This should allow net product exports to moderately increase over the medium-term. More significant is the extensive rearrangement of crude oil, as well as of product export and excise duties, in Russia, in combination with tightening domestic transport fuel standards. This is encouraging refiners to make investments geared to overhauling and upgrading their refineries. One intended impact of this is to cut residual fuel production, which is becoming economically unattractive under new tax regulations, while boosting production of higher grade fuels, which meet the required standards for the European export market. Recent reports point to a 21% reduction in heavy fuel production by Russian refineries in 2016 versus 2015 and a 26% drop in fuel sales at Russian seaports. These statistics indicate that recent tax changes are having an effect. Medium-term additions in the Caspian are primarily centred on a handful of smaller projects, which together add less than 0.1 mb/d of distillation capacity, plus a range of secondary process additions.

In Europe, a number of projects are underway, but these are predominantly small- to mid-scale upgrading and quality improvement additions primarily emphasizing diesel. This is not surprising given the environment of declining demand and high costs faced by European refiners, which has led to a string of closures over the past few years. The only significant addition of distillation capacity is projected in Turkey, which will add close to 0.2 mb/d of capacity.

As previously noted, the overall trend is for a continuing shift of new refining capacity to new demand centres in developing countries, particularly in the Asia-Pacific region. This, in turn, is leading to shifts in the patterns of international crude and products trade.

5.1.3 Medium-term outlook

As previously described, global incremental distillation capacity resulting from existing projects was assessed at 7.6 mb/d for the six-year period from 2017–2022. This represents a

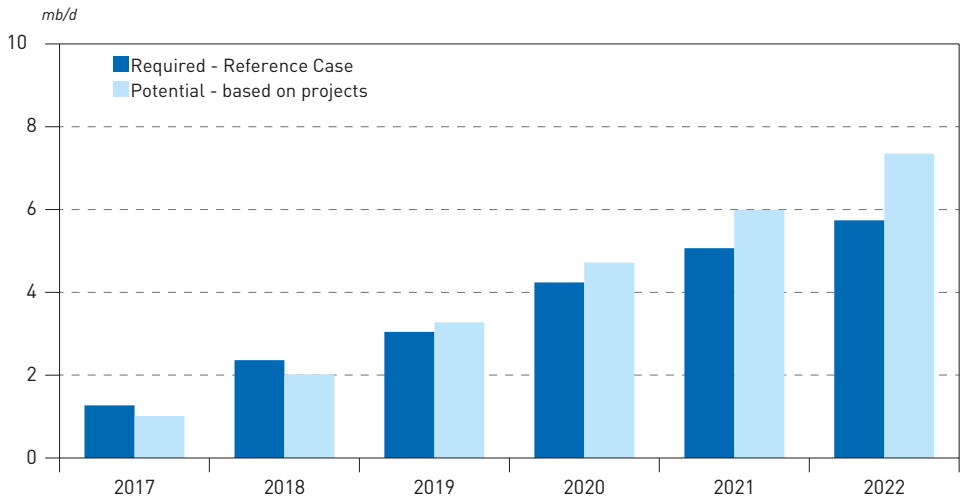
gradual recovery in the pace of additions relative to last year's projection of 7.3 mb/d for 2016–2021 and the 7 mb/d assessed two years ago for 2015–2020. As noted in the two previous Outlooks, the low level of medium-term additions assessed in the 2015 WOO stemmed from the large crude price drop that occurred in 2014/2015. Adding in an allowance for some limited additions to be achieved through 'capacity creep',[11] the total medium-term increment to crude distillation units is projected to be around 8.4 mb/d for 2017–2022.

These additions, broken down by year, are used to project potential annual incremental crude runs and associated refinery yields. These are then compared to projections for incremental refined-product demand in order to establish incremental refining supply versus demand balances, globally and by region. This Chapter addresses balances looking solely at distillation capacity, crude runs and total demand.

Figure 5.3 provides a summary assessment of the cumulative medium-term potential for additional crude runs based on assessed refinery projects – including an allowance for 'capacity creep' – compared to the required incremental product supply from refineries based on global product demand growth. The potential crude runs also take into account the maximum annual utilizations that new projects could be expected to sustain.[12] In this analysis, refinery closures are not taken into consideration.

On this basis, potential incremental crude runs average approximately 1.2 mb/d annually (similar to last year's Outlook), leading to cumulative potential incremental runs of 7.4 mb/d in

Figure 5.3
Additional cumulative refinery crude runs, required* and potential**



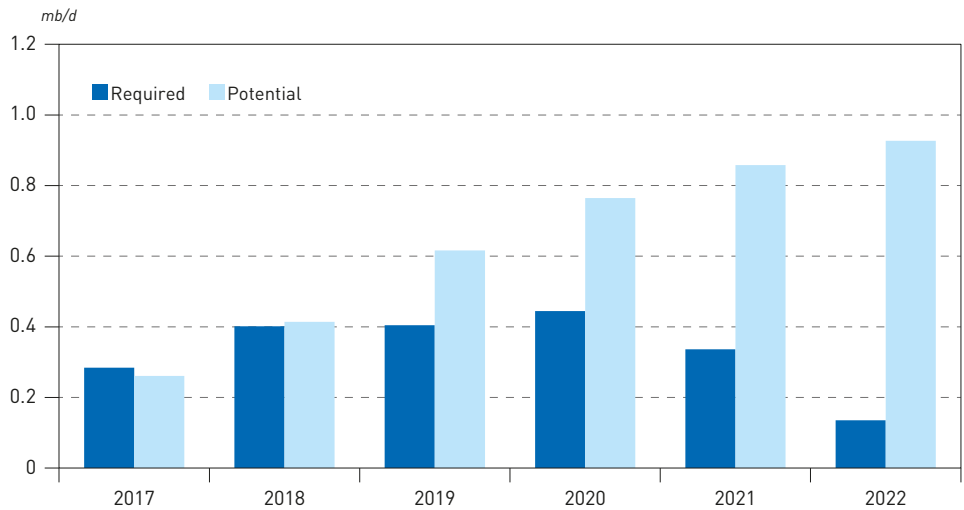
* *Required: based on projected demand increases.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

the period to 2022. The assessed potential crude runs are based on the assumption that only high probability projects will come onstream by 2022, as described. Therefore, it is earlier possible that some additional moderate-scale projects could arise over the next couple of years that may add to the capacity coming onstream versus the capacity indicated in the outlook. Conversely, it is also possible that delays could push back some high probability projects, thus reducing available capacity. The assessed 7.4 mb/d of cumulative potential through 2022 is considered a balanced outlook.

Compared to the potential from refining, annual global demand growth in the six years from 2017–2022 is projected to average 1.1 mb/d. However, close to 15% of the growth is covered by incremental supplies from biofuels, NGLs and other non-crude streams. This leaves a little under 85%, or around 0.95 mb/d annually on average, to come from crude-based products, which translates into additional requirement for crude runs. The net result is for an outlook where incremental refinery output potential and incremental refinery product demand are projected to be closely in balance through 2018 ,but thereafter, a gap progressively opens up, starting with exceptionally high additions in 2019. Consequently, the cumulative 7.4 mb/d refinery production potential is 1.6 mb/d in excess of the 5.75 mb/d that refineries are projected as being required to produce by 2022.

This cumulative overhang is lower compared to the 2.2 mb/d overhang by 2021 in the WOO 2016, and the 2 mb/d by 2020 projected two years ago. However, even a somewhat lower

Figure 5.4
Additional cumulative refinery crude runs, US & Canada, required* and potential**



* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

overhang points to a period of rising international competition in the product markets, as well as the need to continue refinery closures. In other words, if projected closures of 1.6 mb/d between 2017 and 2022 materialize, the danger of accumulating overcapacity should be averted.

At the regional level, the contrasts in the refining supply/demand balance remain stark. Figures 5.4–5.7 present a comparison of data drawn from 2017–2022 of four major world regions, namely: the US & Canada, Europe, China and the Asia-Pacific (excluding China).

Firstly, Figure 5.4 shows a widening gulf between added refinery production potential in the US & Canada and incremental requirements. Through a number of limited capacity expansions, new capacity potential expands steadily to exceed 0.8 mb/d by 2022. Against this, incremental requirements peak in 2020 at close to 0.45 mb/d, but then taper off almost towards 0.1 mb/d by 2022 as regional demand shifts from growth to decline. A primary factor in the demand trend is an expected further increase in regional gasoline demand from 10.4 mb/d in 2016 to a peak of around 11 mb/d in 2020, followed by a gradual decline thereafter. Regional gasoil/diesel demand follows a similar pattern, though less marked. Again, this projection is based on the current US CAFE vehicle efficiency standards remaining in place but also recognizes that current US Light Duty Vehicle sales have been shifting rapidly to less efficient vehicles since the drop in the crude oil price.

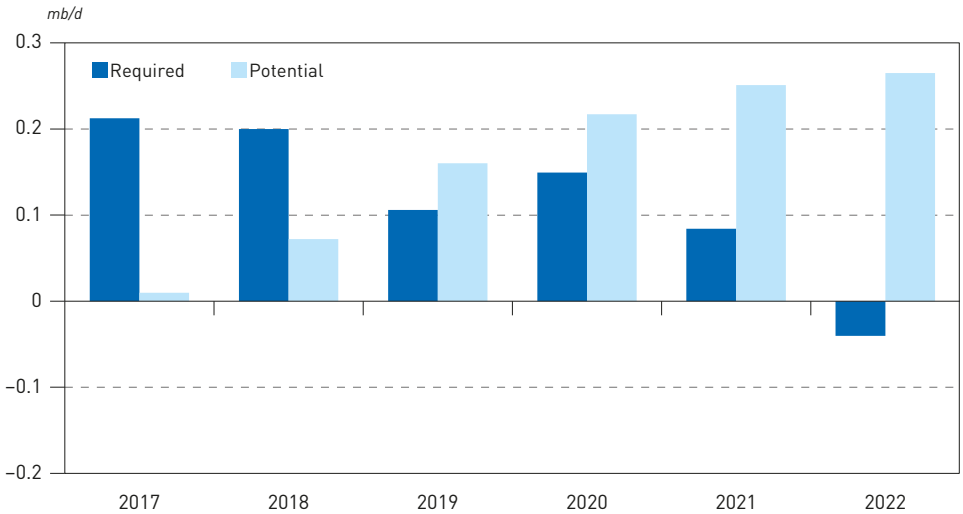
This widening gap is achieved with only minor gains to US & Canada biofuels supply which, when combined with additions to processing gains, total around 0.1 mb/d over the medium-term period. The potential-versus-required gap of 0.8 mb/d by 2022 implies either reductions – and potential closures – in US/Canadian refinery utilization and/or further increases in product exports as the time horizon moves from 2017 to 2022.

In Europe, a similar growing disparity is evident between incremental refinery potential and demand (Figure 5.5) in the medium-term, though on a smaller scale. Increases in refinery potential remain minimal at under 0.3 mb/d over the medium-term. However, this year's Outlook, like the WOO 2016, embodies small demand increases at least through 2020. As a result, disparities between incremental refinery potential and incremental requirements remain around 0.1 mb/d to 2020 before exceeding 0.3 mb/d by 2022. A projected increase in biofuels supply contributes to the disparity by 2022, but the biofuels increment expected is well under 0.1 mb/d in this period. As in previous years, this projection continues to signify a need for additional refinery closures in Europe.

Figures 5.6–5.7 show the corresponding outlooks for the Asia-Pacific region – first, China alone, then Asia-Pacific (excluding China). At a scale of well over a cumulative 3 mb/d by 2022, the increases in both incremental refinery potential and required refinery crude runs based on regional demand stand in marked contrast to the flat to declining outlook in Europe and to the 'short-term only' requirements increase in the US & Canada.

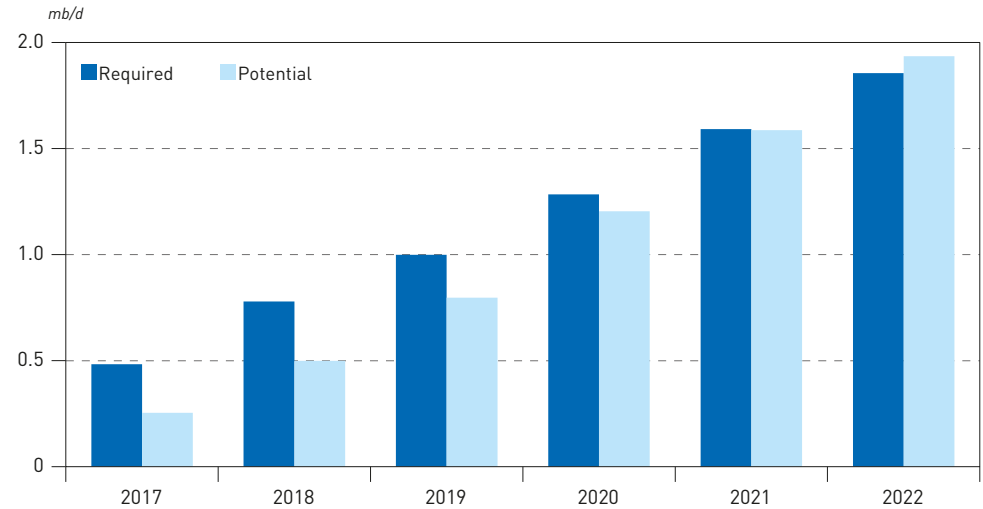
A disparity between China and other Asia-Pacific is evident in this year's Outlook. China, recovering from a recent slight slowdown in economic growth, exhibits steady refined product demand growth over the period, with incremental refining potential in line with incremental demand in the first half of the period and then only slightly in excess in the second half. Incremental required

Figure 5.5
Additional cumulative refinery crude runs, Europe, required* and potential**



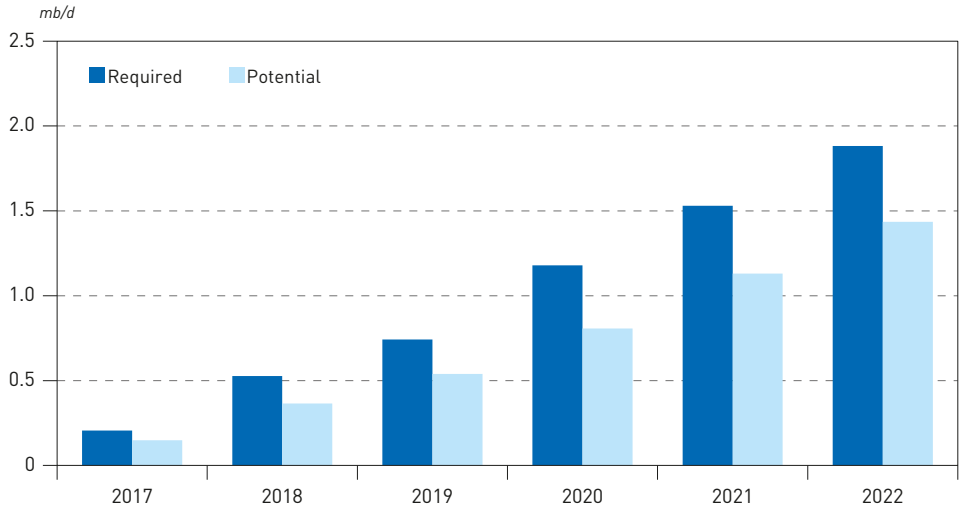
* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

Figure 5.6
Additional cumulative refinery crude runs, China, required* and potential**



* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

Figure 5.7
Additional cumulative refinery crude runs, Asia-Pacific excl. China, required* and potential**



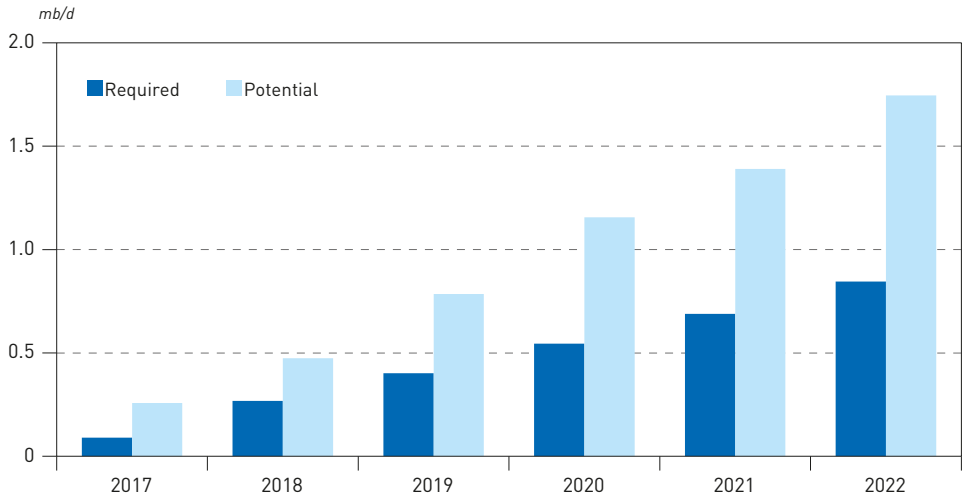
* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

refined product reaches somewhat over 1.8 mb/d by 2022 and incremental refinery potential is at 1.9 mb/d. This is a turnaround from the situation projected a year ago in which potential from new capacity was expected to lag incremental requirements through 2019, before essentially catching up to cumulative demand growth in the period 2020–2021. A key factor here is a higher rate of capacity additions for 2017–2022 than were projected for 2016–2021 in the WOO 2016.

As Figure 5.7 shows, in the Asia-Pacific (excluding China) growth in potential refinery output reaches 1.4 mb/d by the end of the medium-term period. The demand outlook for the Asia-Pacific (excluding China) has again been raised in part because of stronger projected growth in India. Thus, this year's Outlook has cumulative incremental requirements that approach 2 mb/d by 2022, which is similar to what was projected a year ago for 2016–2021. As a result, the region is projected to be in deficit throughout the medium-term, with a limited incremental-demand-versus-potential gap at close to 0.15 mb/d in 2017, which then grows steadily to nearly 0.5 mb/d by 2022. A clear implication is that the Asia-Pacific region (excluding China) will continue to need, and take in, rising levels of product imports over the period, some of which could come from China from 2020 and thereafter.

Figure 5.8 presents the outlook for the Middle East. The picture is the same as that from recent Outlooks – namely, that potential output from sustained refinery capacity additions run well ahead of incremental requirements. In other words, the region exhibits a growing potential for

Figure 5.8
Additional cumulative refinery crude runs, Middle East, required* and potential**

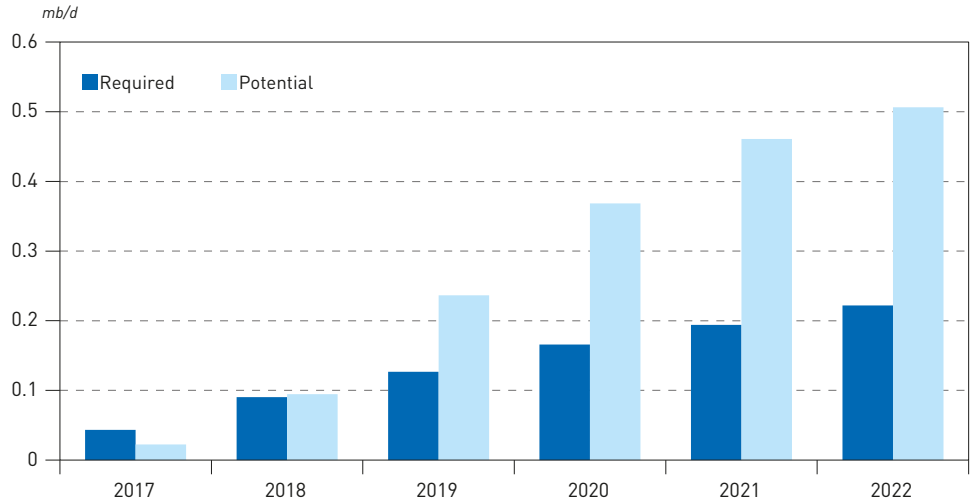


* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

not only for coping with domestic demand growth, but also for exporting increasing volumes of refined product (in place of crude oil). Excess incremental refinery output potential over and above incremental requirements grows from around 0.1 mb/d in 2017 to 0.9 mb/d by 2022. As stated, this clearly has implications for changes in product export flows to deficit regions, notably the Asia-Pacific (excluding China), but also Africa as discussed later.

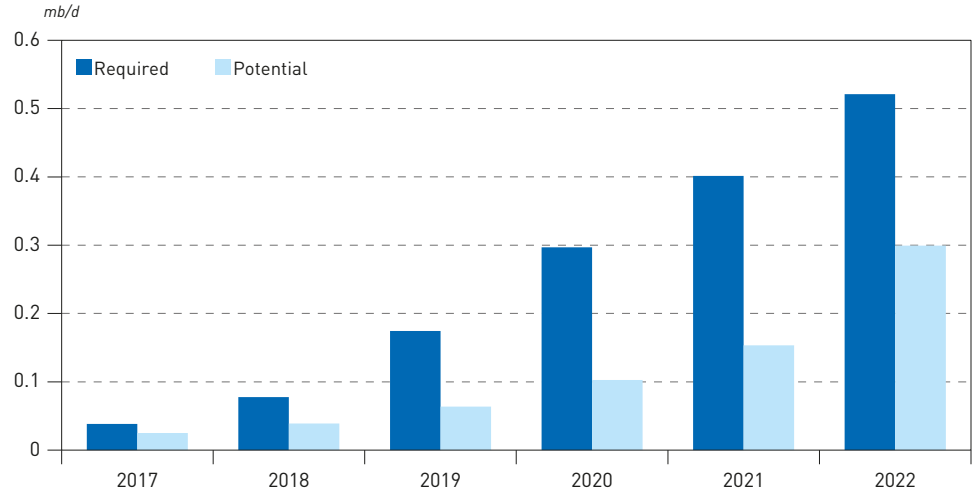
Figures 5.9, 5.10 and 5.11 present the outlooks for the Russia & Caspian, Africa and Latin America regions, respectively. In the Russia sub-region (excluding the Caspian), the outlook continues to be that a combination of flat demand with appreciable refinery investments, prodded by recent tax and duty changes, is leading to a situation where incremental refinery output exceeds incremental requirements. The scale of the excess is, however, limited: essentially nil in 2017 and 2018, before rising to somewhat under 0.3 mb/d by 2021/2022. This change is achieved with growth in required refined product output of over 0.2 mb/d over the period. Since projected capacity additions in Russia over the medium-term are focused more on upgrading and quality improvement – and since the tax changes encourage production of clean products at the expense of residual fuel – Russia should be in an improving position to export clean and Ultra Low Sulphur (ULS) products over the period. These are products that will most likely move to Europe, increasing the struggles that refiners face in that region. In line with this, there is already evidence of a shift away from heavy fuel oil exports.

Figure 5.9
Additional cumulative refinery crude runs, Russia & Caspian, required* and potential**



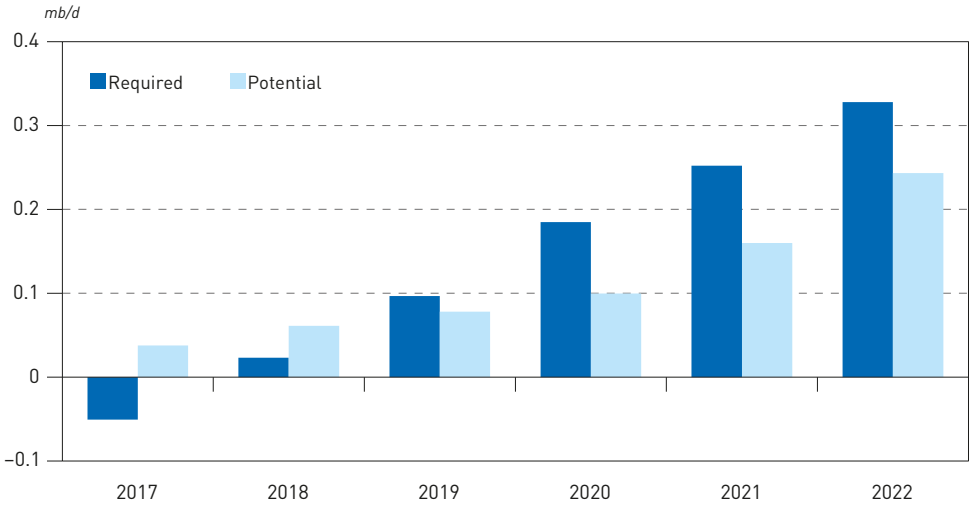
* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

Figure 5.10
Additional cumulative refinery crude runs, Africa, required* and potential**



* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

Figure 5.11
Additional cumulative refinery crude runs, Latin America, required* and potential**



* *Required: based on projected demand increases assuming no change in refined products trade pattern.*
** *Potential: based on expected distillation capacity expansion; assuming no closures.*

This situation, however, applies only to Russia and not to the Caspian. In the latter subregion, the few projects that are considered likely to go ahead will only add limited additional capacity and refinery output potential. Set against moderate demand growth, Caspian incremental refinery potential is likely to be roughly in line with incremental requirements.

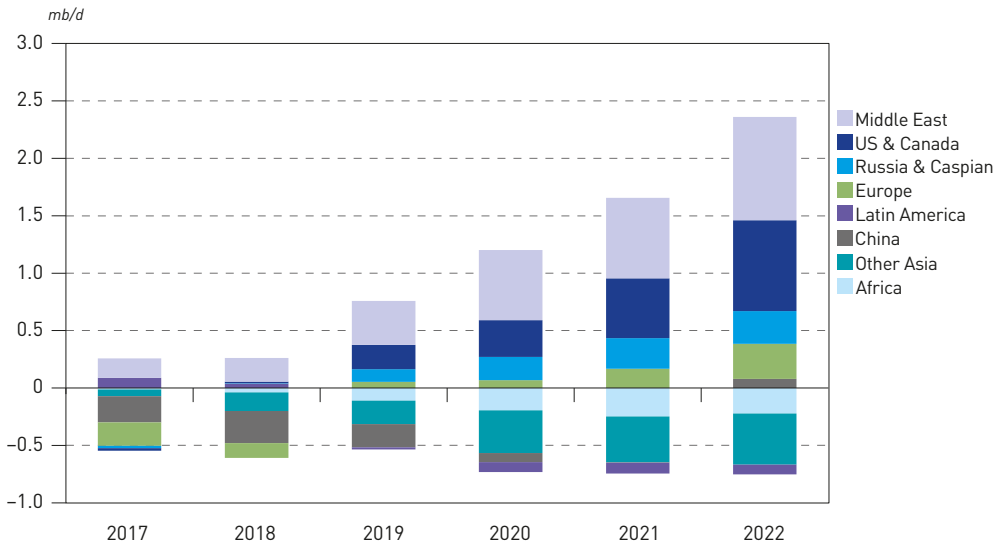
Despite the fact that Africa is a major crude oil producing and exporting region, the outlook there continues to show refining potential well below incremental requirements in the medium-term, although new projects could improve the situation somewhat toward the end of the period. Incremental requirements are projected to run at almost 0.1 mb/d per year, exceeding 0.5 mb/d by 2022. Conversely, incremental potential refinery output is projected to substantially lag incremental refined demand throughout the period, averaging over 0.2 mb/d in the second half. Thus, the outlook for Africa is that it will continue to need – and will thus provide a market for – growing product imports.

Latin America presents a picture akin to that of Africa, but on a smaller scale. Previous outlooks for Latin America had significant levels of both incremental refinery potential from projects and incremental required refined products. For example, the WOO 2014 had a six-year (2014–2019) incremental potential of 1.1 mb/d and an incremental refined product demand of 0.7 mb/d. Both parameters have since changed quite substantially. Difficulties in the

region have led to a major reduction in the pace of new projects and refining potential. The current outlook is for six-year growth in refining potential of less than 0.3 mb/d. Equally significant is a now pessimistic outlook for demand changes as a result of economic problems and slowing economic growth rates in several countries in the region. Incremental requirements for refined products are expected to be initially negative – that is, a demand reduction is projected for 2017, followed by a gradual return to limited growth, leading to a cumulative 0.35 mb/d by 2022. The result is a small deficit of incremental refining potential relative to requirements that opens up in 2019 and averages around 0.1 mb/d from 2020–2022. This should keep net regional product imports flat initially, but then create a small increase later in the period.

Bringing these regional outlooks together, five regions have an excess of refined product potential compared to requirements: US & Canada (0.8 mb/d by 2022), Middle East (0.9 mb/d), Europe (0.3 mb/d), Russia & Caspian (0.3 mb/d) and China (0.1 mb/d), for a total of 2.4 mb/d by 2022. In contrast, the Asia-Pacific region (excluding China) exhibits a deficit of 0.5 mb/d by 2022, while Africa and Latin America exhibit deficits of 0.2 mb/d and 0.1 mb/d, respectively. Figure 5.12 summarizes this outlook. It highlights how net refining potential surpluses and deficits grow rapidly, especially from 2020 onward. The net global outlook is for incremental refined product potential based on projects to exceed incremental refined product requirements by some 1.6 mb/d by 2022. Given this, the implication is for increasing excess refining capacity – and thus competition for product markets – as the market moves three to six years out, leading to reduced refinery utilizations and/or more closures. Again, careful monitoring

Figure 5.12
Net cumulative regional refining potential surplus/deficit versus requirements



of refinery projects versus demand growth is called for to gauge whether this growing excess will 'evaporate' as the time draws nearer (via project slippage, further demand growth or plant closures) or whether it will in fact remain.

5.1.4 Long-term outlook

Capacity additions

Based on the assumptions already described, the Reference Case projections for distillation capacity additions from modelling results are summarized in Table 5.4. Figure 5.13 presents the corresponding projections by region and period. 'Assessed projects' in Table 5.4 refers to those refining projects that are considered firm – that is, constructed and onstream by the stated year. In this Outlook, this means 4.8 mb/d by 2020 and 7.6 mb/d by 2022. 'New units' represent the further additions – that is, major new units plus debottlenecking – that are projected to be required over and above assessed projects. The addition of new units is developed through optimization modelling that balances the refining system for each time horizon.

Over and above the 4.8 mb/d of assessed projects by 2020, the 2020 model case indicates a further 0.4 mb/d will be required (essentially representing assumed minor 'capacity creep') for total distillation capacity additions to 2020 of 5.2 mb/d. The 2025, 2030, 2035 and 2040 cases add an additional 3.3 mb/d, 3.4 mb/d, 2.8 mb/d and 2.2 mb/d, respectively, over and above the previous case (year) totals. When combined, the cumulative total additions – that is, assessed projects plus total model additions – are projected to reach 19.6 mb/d by 2040.

Table 5.4 confirms once again the pattern evident in previous Outlooks – namely, that there is a steady reduction in the annual pace of refinery capacity additions required over time. The projections for refinery additions from 2025 onward are based on those computed in the model cases as necessary to balance demand growth, recognizing the growing role of NGLs, biofuels, CTLs, GTLs and petrochemical returns as non-crude supply streams. As Table 5.4 shows, the pace of demand growth is projected to drop steadily over time, from 5.4 mb/d (1.3 mb/d annually) in the period 2016–2020 to an annual average of somewhat over 0.6 mb/d in the period 2025–2030 and only 0.3 mb/d in the period 2035–2040. It is, therefore, not surprising that the projected refinery capacity additions drop from an annualized 1.3 mb/d from 2017–2020 to 1.2 mb/d for 2020–2025, then to the 0.7 mb/d range by 2030 and to the 0.4 mb/d level by the late 2030s. The 1.4 mb/d higher projection for total global demand in 2040 helps to sustain a rate of capacity additions slightly above that of last year's Outlook.

The values shown in Table 5.4 are nameplate capacity additions, even though refineries invariably achieve long-run utilization rates that are well below 100%. If the new capacity was to achieve an average utilization rate of around 81% from 2017 through 2040, the incremental crude runs achieved would closely match incremental product demand, both by period and overall.[14] However, as stated, incremental product demand is expected to be met in part by increases in the supply of non-crudes (NGLs, biofuels, CTLs/GTLs and other supply streams) plus processing gains. Between 2016 and 2040, these sources of supply are projected to by around 6 mb/d. This growth in non-crudes supply, plus processing gains equates to almost

Table 5.4
Global demand growth and refinery distillation capacity additions by period in the Reference Case

mb/d

	Global demand growth	Distillation capacity additions starting 2017			
		Assessed projects*	New units	Total	Annualized
2016–2020	5.4	4.8	0.4	5.2	1.3
2020–2025	3.6	2.7	3.3	6.0	1.2
2025–2030	3.1	0.0	3.4	3.4	0.7
2030–2035	2.3	0.0	2.8	2.8	0.6
2035–2040	1.4	0.0	2.2	2.2	0.4

	Global demand growth	Cumulative distillation capacity additions			
		Assessed projects*	New units	Total	Annualized
2016–2020	5.4	4.8	0.4	5.2	1.3
2016–2025	9.0	7.6	3.6	11.2	1.2
2016–2030	12.1	7.6	7.0	14.6	1.0
2016–2035	14.3	7.6	9.8	17.4	0.9
2016–2040	15.8	7.6	12.0	19.6	0.8

* *Firm projects exclude additions resulting from capacity creep. Assessed projects are split between 2017–2020 and 2020–2025.*

40% of the liquids demand growth in the 2016–2040 period. Viewed at the global level, it thus eats heavily into the need for incremental refined products.

The reason, of course, why rational increases in needed refining capacity are well in excess of requirements when viewed purely at the global level is that demand growth is in regions where new capacity is warranted. These new refineries, overwhelmingly in developing regions (Asia-Pacific and the Middle East, but also Latin America and Africa), will compete with existing facilities in the US & Canada, Europe and Russia & Caspian as demand in those regions is becoming flat and starts to decline. The model results indicate that utilizations are expected to decline in those two regions with implications for continued closures (see projected refinery closures later). As a result, the long-term potential for incremental product exports from the US & Canada and Europe is projected as limited (around an additional 1 mb/d by 2040, above 2016 levels). This is a relatively minor amount compared to around 16 mb/d of demand growth in developing Asia between 2016 and 2040, and also the 1.9 mb/d in Latin America and 2.8 mb/d in Africa.

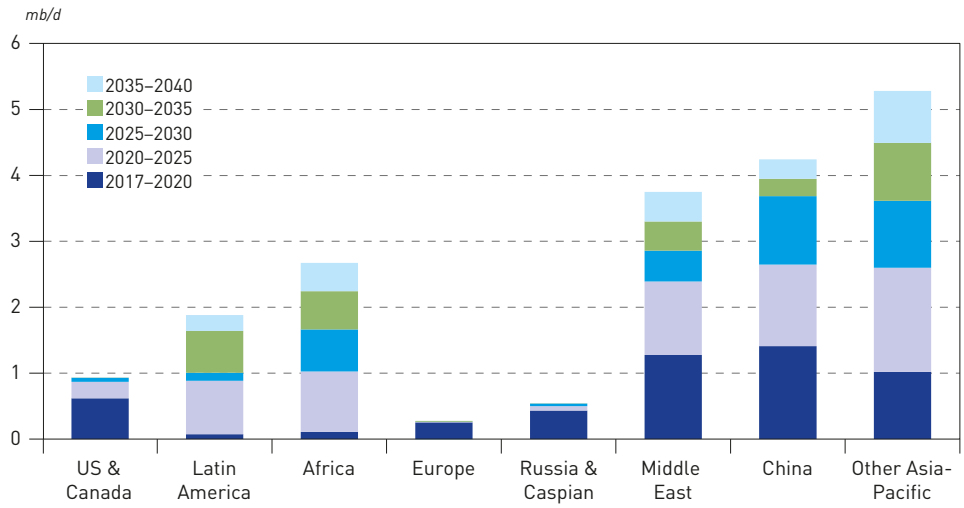
In short, while continued competition for product export markets can be expected and could put pressure on utilizations and margins, this does not look set to dominate where refineries are built over the long-term. Furthermore, the evident slowing in the pace of necessary refinery capacity additions in the long-term means that whoever invests first in new capacity may be in a better competitive position. This is because it will be increasingly difficult to justify significant new capacity as the pace of total requirements slows – and given that there will be extensive competition from existing modern, complex units (especially in the US) that have already partially depreciated.

As illustrated in Figure 5.13, 47% of 2017–2020 capacity additions are projected for the Asia-Pacific region, nearly 25% for the Middle East, and around 2% each for Latin America and Africa. The US & Canada contributes 12%, but the majority of those additions are condensate splitters. The Russia & Caspian and Europe contribute 8% and 5%, respectively.

For additions in the period 2020–2040, the share taken by the Asia-Pacific rises further to 49%, driven by regional demand growth. The Middle East, Africa and Latin America have respective shares of 17%, 18% and 13% in this period, with domestic regional growth again an important factor. Combined, the US & Canada, Europe and the Russia & Caspian account for only 3%.

Thus, the wave of major projects in the Middle East raises its share of the total in the shorter term before settling back to around 17% over the longer term. The surge in the percentage share in Africa is driven by a combination of a dearth of firm projects in the short-term,

Figure 5.13
Crude distillation capacity additions in the Reference Case, 2017–2040



followed by the expectation that significant capacity additions will be realized in the longer term to support sustained demand. The same outlook applies to Latin America, where there is a lack of firm projects today but significant longer term demand growth driving appreciable additions. In contrast, the share for the Russia & Caspian region is projected to be the inverse: an appreciable share of shorter term additions, driven by the effects of recent tax changes, followed by a decline in share as the result of flat to declining regional demand. For the US & Canada region, the pattern is similar: a shorter term share at 12%, driven mainly by condensate splitter additions, fades essentially to nil post-2030, due to a steady regional demand decline. For the same reason, no capacity additions are projected for Europe post-2020 – or for Japan and Australasia. Rather, continuing closures can be anticipated over and above those assumed by 2025.

These projections for capacity additions maintain the view from prior Outlooks. In the longer term, local demand growth (in developing regions) will be the primary driver of new projects, rather than opportunities to export products. Secondly, the pace at which new refining capacity needs to be added is expected to drop steadily. Post-2025, the rate of required new additions needed is expected to drop to the equivalent of one or two large new refineries per year worldwide. In practice, this is likely to mean that almost no new refineries will be built. However, as has been evident for some time from the situation in the US, Europe, Japan and Australia, expansions (such as they are) will come from debottlenecking and the expansion of existing facilities. These will be partially offset by the retirement of older, less efficient units or even whole refineries.

As already mentioned, the 7.6 mb/d of assessed (firm) projects in the medium-term was taken from a total 'inventory' of announced refinery distillation additions that exceeds 22 mb/d. This inventory is up 1.5 mb/d from last year's 20.5 mb/d 'inventory' and up 5 mb/d from that of 2015, shortly after crude oil prices dropped. This recovery indicates a degree of resilience or optimism in the refining sector. It is also worth noting that the 22 mb/d of current listed projects exceeds the 19.6 mb/d of total new capacity that has been assessed as required in the whole period from 2017–2040. Thus, either many of the projects currently listed will need to be modified, deferred or cancelled, or the risk of over-building will remain.

It is also important to recognize that the long-term additions projected as needed are being driven more by the shift in global demand from industrialized regions to developing regions (mostly in the Asia-Pacific) than by outright global demand growth itself. For this reason, global capacity additions continue to match and indeed exceed global demand growth in the longer term even though non-crude supplies continue to increase. In effect, as demand declines in Europe, Japan and some other regions, existing refineries are increasingly in the 'wrong' place, which means that their utilization rates could come under pressure. Consequently, a number of closures can be expected in the medium- and long-term.

Another factor that will affect required capacity additions and their location is the state of the tanker market and its evolution, which could impact project economics. Dirty freight rates have recovered moderately in 2017, but continue to be at relatively low levels by historical standards. Clean freight rates on major routes have been essentially flat since 2009. The assumption in the modelling analysis was that freight rates for crude and product tanker movements will move upwards, at least in the medium-term, driven by the effects of the

MARPOL Annex VI global sulphur rule. Higher freight rates can impact trade patterns, and higher dollar per tonne differentials between crude and product movements tend to support curbing transport activity and raising refinery investments in the demand-growth centres.

Over the longer term, a high uptake of scrubbers on vessels – several analysts see this as likely and this has formed the basis of the underlying demand outlook in this report – would keep the cost of inter-regional movements at relatively low levels. How freight rates play out will thus affect the ability of refineries in regions and countries such as Europe, the US and even Japan to compete for expanding markets in developing regions. In turn, this could either reduce or raise the level of capacity additions needed in developing regions versus those contained in the current analysis. Lower freight rates would also help to keep more refineries in industrialized regions open.

As already stated, the majority of future refining capacity expansions to 2040 are projected to be required in the Asia-Pacific region – 9.5 mb/d out of a global total of 19.6 mb/d. Expansions here continue to be dominated by China and India. Regional expansions are well below the 14.5 mb/d increase expected in Asia-Pacific demand to 2040. This figure itself is made up of a demand decline in Japan and Australasia of 1.7 mb/d, plus an increase in Asia's growth regions of 16.2 mb/d. This means that the difference between the required capacity additions and overall demand growth is covered by higher imports of refined products and other non-crude based streams.

The second largest capacity additions are projected for the Middle East with some 3.75 mb/d of total additions from 2017–2040. This is nearly 1 mb/d ahead of a projected regional demand increase of 2.8 mb/d. Driven by a series of major projects expected to come onstream by 2022, capacity additions in the Middle East are 'front-loaded' with 1.3 mb/d by 2020 and a further 1.1 mb/d by 2025, followed by increments of around 0.45 mb/d for each period 2025–2030, 2030–2035 and 2035–2040. While the longer term additions are more in line with regional product demand growth, one implication is that Middle East product exports can be expected to increase between now and 2025, and any product imports decline. Moreover, substantial refining capacity increases could lead to product exports partially displacing crude exports from the region.

In Latin America, projected capacity additions of 1.9 mb/d over the forecast period are very closely in line with the outlook for a somewhat reduced demand increase, also of 1.9 mb/d. However, 0.4 mb/d of future demand is estimated to be covered by a growing supply of biofuels. Nevertheless, regional crude throughputs are projected to rise by more than 2.0 mb/d from 2016–2040. This reflects a projected gradual increase in utilizations over the period. In addition, net imports are projected to drop slightly between 2016 and 2040, partially offsetting the growth in biofuels supply and leading to growth in refinery crude runs essentially matching demand growth in demand at 1.9 mb/d.

Total refinery distillation capacity in Africa is projected to rise 2.7 mb/d by 2040 compared to the base capacity at the end of 2016. These additions comprise 0.1 mb/d of new capacity in the period to 2020 and a further 0.9 mb/d by 2025. Compared to the cumulative capacity additions of 2.7 mb/d by 2040, demand is projected to rise by 2.8 mb/d over the same period. Even with these capacity expansions and rising utilization rates, increases in regional refinery throughputs are not seen as fully keeping up with demand growth. The region's current

significant net product imports are thus expected to further increase over the long-term, with dependency around 2.2 mb/d by 2040. The situation for Africa is especially challenging since the region is starting from very low overall refinery utilization levels. This is consistent with the fact that many of its refineries face the challenge of being old and small-scale, with relatively low complexity and low energy efficiency.

5.1.5 Refinery closures

This section reviews the recent history of refinery closures at a regional level, as well as the prospects for additional firm closures based on announcements and refinery capacity considered at risk of closure by virtue of a recent sale or other announcements. This leads to an updated assessment for total refinery closures from 2017–2022 and onward to 2025. The year 2025 was selected as the 'end date' for actively estimating closures since anything beyond that time horizon is considered too speculative.

Table 5.5 and Figure 5.14 summarize recent closures since 2012, and projected closures through 2022 and 2025. A total closures level of 1.6 mb/d is shown for 2017–2022. This also includes an assumed restart in 2020 of the 235,000 b/d Aruba refinery. It means that gross closures for the medium-term period to 2022 equate to some 1.8 mb/d. This level is lower than the 2.6 mb/d assumed for the period 2016–2021 in the 2016 Outlook. There are two reasons for this. The first, as is evident in Table 5.5 and Figure 5.14, is that 2016 saw the closure of over 1 mb/d of capacity, predominantly in Japan. The second reason is that this year's Outlook sees both 2020 and 2025 global liquids demand appreciably above the levels projected in the WOO 2016 – specifically, 100.7 mb/d versus 98.3 mb/d for 2020 and 104.3 mb/d versus 102.3 mb/d for 2025. These higher outlooks are based on both upward adjustments to recent historical demand levels and on recognition of the continued effects that the recent crude price drop has had on moving demand upward.

In recognition of these factors, an average pace of closures over the next few years is projected to be around 0.3 mb/d, well below the 1 mb/d annual rate that applied from 2012–2016. Some 5 mb/d of capacity was closed in the period 2012–2016 and a cumulative 7.5 mb/d since 2008. It is clear that the high level of actual closures achieved, leads to a lower level of closures needed in the immediate future.

This lower expected closure rate over the medium-term should not, however, be interpreted as a sign nor an assumption that the era of refinery closures is over. As further discussed later, a continuing long-term need for closures is projected, especially post-2025, as demand declines in industrialized regions and as smaller, less efficient, often ageing refineries in developed and developing regions struggle to compete with the larger, highly sophisticated, efficient refineries that are increasingly coming onstream, especially in the Middle East and Asia. In addition, the state of refinery sales acts as an indicator of refineries 'at risk' and thus for possible future closures. Today, this scene is quite active. Recently completed sales include two by Chevron – the company's small Burnaby Vancouver refinery to Parkland Fuel Corporation and its Cape Town facility to Sinopec. In addition, Petrobras is reportedly looking for partners for its refineries, as is Pemex. This sales activity, in addition to concerns over the unprofitable PetroTrin Pointe-á-Pierre refinery, mean that the majority of current activity regarding refinery restructuring is taking place in Latin America.

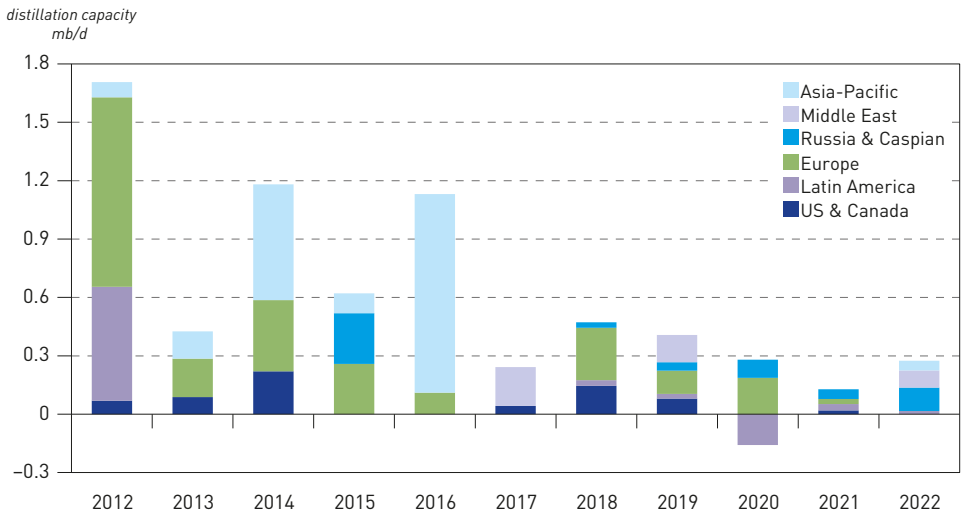
Table 5.5
Net refinery closures, recent and projected, by region

mb/d

	Total 2012–2016	2017	2018	2019	2020	2021	2022	Total 2017–2022	Total 2017–2025
US & Canada	0.4	0.0	0.1	0.1	–	0.0	–	0.3	0.5
Latin America	0.6	–	0.0	0.0	(0.2)	0.0	0.0	–0.1	0.0
Europe	1.9	–	0.3	0.1	0.2	0.0	–	0.6	1.0
Russia & Caspian	0.3	–	0.0	0.0	0.1	0.0	0.1	0.3	0.3
Africa	–	–	–	–	–	–	–	–	–
Middle East	–	0.2	–	0.1	–	–	0.1	0.4	0.4
Asia-Pacific	1.9	–	–	–	–	–	0.1	0.1	0.2
Total	**5.1**	**0.2**	**0.5**	**0.4**	**0.1**	**0.1**	**0.3**	**1.6**	**2.5**

* *Note: 2020 closures include the restart of the 235,000 b/d Aruba refinery, i.e. 'negative' closure. Thus gross closures 2017–2022 sum to just under 2 mb/d.*

Figure 5.14
Net refinery closures, recent and projected, by region*



* *No closures are expected in Africa.*

Of the 5.1 mb/d of refinery closures worldwide from 2012–2016, 1.9 mb/d have occurred in Europe and the Asia-Pacific each. In the Asia-Pacific, these have been predominantly closures in Japan, following the country's requirement that refineries increase their ratio of residue upgrading to atmospheric distillation. Since demand in Japan is flat to declining, Japanese refiners have been responding by closing existing crude distillation units rather than adding new upgrading units. These latest closures have been part of a sustained pattern in the country.

In recent years, Europe has been at the centre of closure activity, with 1.9 mb/d of capacity reductions from 2012–2016. This pace is expected to drop – though not entirely – with some 0.6 mb/d of additional closures projected for 2017–2022. Lower oil and, thus natural gas prices, have reduced (but not eliminated) the degree of competitive disadvantage European refiners have been experiencing compared to refineries in the US and the Middle East. However, regional refiners still face growing carbon costs and declining demand.

Limited closures are also projected for the US & Canada, particularly as a recent demand boost is expected to reverse toward the end of the medium-term period and into the 2023–2025 timeframe. Similarly, this holds for the Russia & Caspian region, which continues to be driven by flat demand and the Russian 'tax manoeuvre', which is designed to force refineries in the country to rationalize and upgrade their facilities. The projected closures in the Middle East are very specific. Kuwait National Petroleum Company (KNPC) completed the planned closure of its 200,000 b/d Shuaiba refinery on schedule in March of this year, converting the facility to a storage terminal. At the time, the related Clean Fuels Project was reportedly already 84% complete and is due for start-up in 2019. The Clean Fuels Project aims to transform two Kuwaiti refineries, located 10 miles apart, into a single integrated merchant refining complex. As part of this integration project, the Mina al-Ahmadi refinery will shed 140,000 b/d and the Mina al-Abdulla refinery will add 184,000 b/d. This will result in a net gain of 44,000 b/d with an eventual total of 800,000 b/d refining capacity at the new integrated complex.

The WORLD Model results provide a cross-check on whether the assumed level of closures by 2022 is appropriate or whether there is a need to indicate more (or fewer). As further discussed, the 2025 Reference Case projects global average utilizations at 81.6%. There are appreciable variations from region-to-region, with Europe looking especially vulnerable. However, the overall level tends to support the idea that the projected pace of closures leads to 1.8 mb/d of gross closures for 2017–2022 and 2.5 mb/d for 2017–2025 appearing reasonable.

Refinery closures of 1.2 mb/d assumed for 2017–2020 and a total of 2.5 mb/d by 2025 are considered in the modelling cases. The outlook for long-term regional refinery utilizations already discussed clearly demonstrates a need for continuing refinery closures, beyond those built in to the modelling, especially in the industrialized regions where demand is projected to further decline. The WORLD model can 'back-calculate' the implied closures needed within a region to reach a user-input level of utilization. This parameter is currently set to 80%, representing the lowest utilization level considered viable. Thus, any region with a utilization level below 80% from the model results will have some level of implied needed closures in the long-term.

Several regions indicate a need for potential additional closures by 2040 in order to achieve an 80% utilization level. As discussed elsewhere, US & Canada refineries are projected to be relatively resilient with overall regional utilizations still above 80% by 2040 supported by increasing product exports to international markets and despite a regional demand decline. However, specific sub-regions are vulnerable such as the US East Coast (PADD1), isolated Rocky Mountain region and on the US West Coast where a number of refineries narrowly averted closures some three-to-four years ago. They continue to face demand declines or are challenged by regulation. In the US Gulf Coast, (PADD3), overall utilizations are projected to remain above 80%, but within the region, smaller sweet crude refineries look vulnerable, especially as US tight oil production declines longer term. The US Midwest (PADD2) would appear to be the most secure US region from a refining perspective, with utilizations remaining in the high 80% range.

In Western Canada, the inland Alberta refineries, several of which are closely linked to production operations, are generally considered safe. However, Chevron has recently sold its 55,000 b/d refinery at Burnaby, which is a coastal suburb of Vancouver, British Columbia. The future of Western Canadian refining may hinge in part on whether the Trans Mountain pipeline expansion (from 300,000 b/d now to 890,000 b/d) goes ahead and whether such an expanded system would carry more products. If that were to happen, it would open up coastal and Asian product markets to refineries in the Edmonton area and increase competition on the US West Coast. Recognizing that the US and Canadian refining sectors are dynamic, and that unprofitable refineries are likely to be shut down, long-term closures could be as high as 1 mb/d.

In Europe, modelling results point to a need for a relatively high requirement for additional closures over the long-term at around 2.7 mb/d, which is over and above the nearly 2 mb/d of closures that have taken place since 2012, plus an additional 1 mb/d projected for 2017–2025 that has already been built into the modelling. The total projected closures of around 3.7 mb/d compares with a 2.4 mb/d reduction in demand projected for the period 2020–2040.

The other region that is an obvious candidate for continuing closures, Japan plus Australasia, shows a rather different picture. Recent closures through 2016 have totalled nearly 2 mb/d. These have occurred mainly in Japan as a result of the government mandate to raise the ratio of conversion capacity to distillation. Since Japanese refiners tend to have high costs and a declining domestic market, the primary effect has been closures of crude oil distillation trains rather than the addition of any new upgrading capacity to existing refineries. These, together with closures in Australia, have brought the region's base capacity down to some 3.7 mb/d, a quite substantial percentage reduction. The remaining refineries are more complex. Product imports are expected to continue to exceed exports, even though the latter may grow, leading to a situation where modelling results indicate 2040 utilization rates moderately below 80%. Associated required closures are approximately 0.2 mb/d.

In Latin America, refineries in several countries are currently struggling with their owners seeking new investors. Pemex has been looking for partners to buy in to its Salina Cruz and Tula refineries, but with no takers to date. In Trinidad & Tobago, the government considered, but then decided against attempting to sell its Pointe-á-Pierre refinery. In Brazil, Petrobras is formulating plans to offer refineries for sale as part of a massive programme to reduce debt.

All these developments are occurring on top of a period when significant capacity has closed in the region, most notably the Hovensa refinery on St. Croix. Overall, the potential for some 0.5 mb/d of long-term closures is projected for Latin America (in addition to over 0.15 mb/d assumed by 2025).

For Africa to achieve an overall average utilization of 80% by 2040, given the region's very low overall utilization levels today, it would require at least 1 mb/d of capacity closures according to the modelling. Such a level of closure is primarily an indication of the old and inefficient capacity in the region that needs to be replaced with modern, efficient and generally larger facilities. Again, refinery sales point to areas possibly at risk. Refineries across the continent are facing the challenges of meeting increasingly stringent 'AFRI' standards for gasoline and diesel. Again, the age and relative inefficiency of a number of refineries in the region could make it difficult to justify the needed investments.

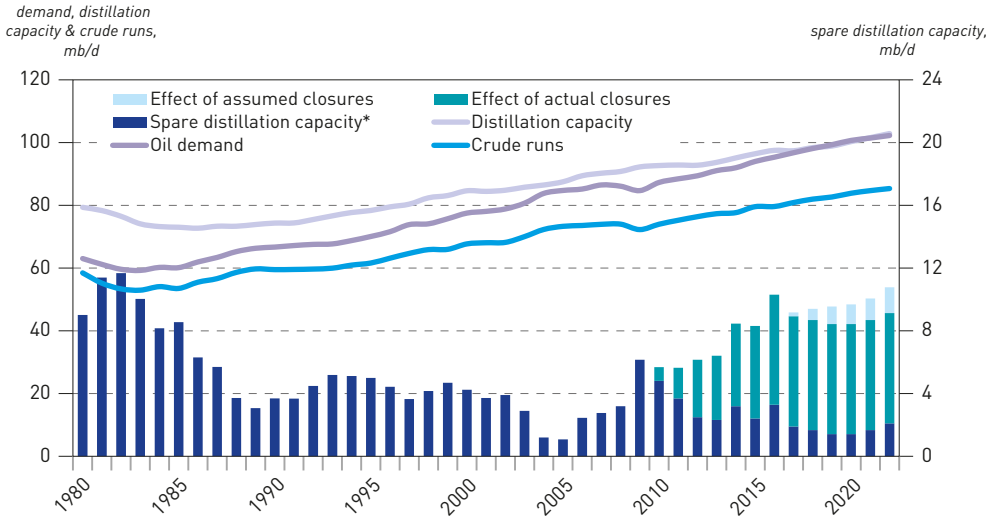
In the Russia & Caspian region, some 0.35 mb/d of closures from 2017–2025 were built into the modelling analysis. As a result, little by way of additional closures is indicated as required except potentially in the Caspian where, again, the need is to replace ageing, inefficient refineries.

In summary, closure needs across the world's regions indicates a potential requirement to close some 4–5 mb/d of capacity over the long-term. This has to be added to the 2.5 mb/d already built into the modelling base capacity for 2017–2025, indicating that total closures somewhere in the range of 6–8 mb/d are needed from 2017–2040. This equates to an annual average rate of 0.25–0.35 mb/d for 2017–2040, a level that in line with the 0.3 mb/d average included for 2017–2025. While continued closures in the industrialized regions can be expected to be a major requirement, it is also clear that significant closures are needed in other regions if efficient levels of refinery operations are to be reached and maintained.

Figure 5.15 illustrates both the history of distillation capacity, oil demand and crude runs since 1980 and estimates effective spare refining capacity, assuming an 85% utilization rate. As large surpluses of capacity have gradually been pulled down since the 1980s, the levels of total liquid demand and nameplate refinery capacity have almost converged, such that installed capacity sits minimally above global liquids demand. For 2017, for example, an installed base of 97.4 mb/d compares with global demand of 96.8 mb/d. However, refineries on average run well below their nameplate capacity and so crude runs in 2020 are projected at around 80.4 mb/d, with the gap between runs and demand met by a combination of non-crudes supply and processing gains.

The right-hand axis in Figure 5.15 illustrates the effect of refinery closures. Some 7 mb/d of closures have occurred between 2010 and 2016. To this, an estimated 1.6 mb/d of additional closures by 2022 has been added for an aggregate total of 8.6 mb/d. The chart brings home the dramatic effect closures have had on containing surplus refining capacity. If none of the recent closures hat occurred, current spare capacity (assuming 85% utilization) would be in the order of 9 mb/d, a level not seen since the large excesses of the early 1980s. Instead the actual level is in the 2–3 mb/d range. The estimated additional closures (1.6 mb/d) through 2022 have the effect of sustaining this range – assuming they or an equivalent go ahead – rather than having it creep back up to the 4 mb/d level. By way of comparison, the long-term average spare capacity from 2000–2015 was 3.2 mb/d, which took place during a period that encompassed

Figure 5.15
Global oil demand, refining capacity and crude runs, 1980–2022



* *Effective 'spare' capacity estimated based on assumed 85% utilization rate; accounted for already closed capacity.*

the 'golden age' of refining tightness, the recent major global economic recession and wide variations in oil prices.

It is clear that substantial recent closures have been effective in reducing overall global average spare capacity to a limited level that should be supportive of decent refining margins, recognizing that significant regional differences 'buried' within the global trend must be accounted for. Figure 5.15 also points to the importance of continuing with closures in order to avoid a reversion back to higher excess levels that have the potential to force abrupt closures by lowering refining margins to unsustainable levels.

5.1.6 Crude runs and refinery utilizations

The projected global and regional long-term refinery crude throughputs and related utilization rates are presented in Table 5.6. At the global level, throughputs rise from 79.6 mb/d in 2016 to 83.9 mb/d in 2020 and then to 90.5 mb/d in 2040. As emphasized elsewhere, the rate of the annual increase in refinery crude runs is projected to steadily decline due to the combined effect of a gradual slowing in the annual demand growth rate and steady increases in non-crude supplies. The annual rate of increase through to 2020 is around 1 mb/d. This rate of increase slows to somewhat below 0.5 mb/d during the period 2021–2030 and then drops to nearly 0.2 mb/d from 2031–2040. The reason for this is that the bulk of the demand growth in the outlook for the period to 2030 is 12.2 mb/d out of a total of 15.8 mb/d during 2016–2040, which leaves only 3.7 mb/d of demand growth for the

period from 2031–2040. This changing growth profile reinforces how much lower future refinery additions will need to be in the longer term versus where they are currently.

The corresponding outlook for global refinery utilizations is for a noticeable increase at the global level by 2020, driven in part by a spike in demand and refinery processing related to the January 2020 MARPOL Annex VI Global Sulphur Rule. Thereafter, however, there is a gradual decline through to 2040. It should be noted that how utilizations in fact evolve will depend on the actual realization of both potential additions and closures. Regarding long-term capacity additions over and above assessed projects, it is important to bear in mind that those generated in the modelling correspond to additions that are considered necessary to balance demand – but no more. This allows for realistic utilizations that tend to differ from region-to-region and over time. Secondly, the outlook has presumed no further closures after 2025, as any estimation beyond this timeframe was deemed too speculative.

Overall, slightly lower utilizations are projected globally compared to last year. As was the case in last year's Outlook, a key reason is that detailed research by refinery has again identified small gaps in base refinery capacity and thus a higher assessed (end-2016) base capacity.

Table 5.6 highlights the variation in outlooks between major regions. Consistent with recent projections, crude throughputs in the US & Canada are projected to rise in the medium-term to 2020 as the region benefits from capacity additions (mainly condensate splitters), growth in domestic crude supplies and slightly rising regional demand. Declining domestic demand results in a long gradual decline in crude throughputs, which becomes marked after 2025 and accelerates post-2030. From 18.6 mb/d in 2020, throughputs drop to 17.5 mb/d in 2030 and to 16.8 mb/d by 2040. Nonetheless, utilizations remain well above 80% until after 2035, indicating a limited risk of closures in the region for a significant period to come. A key aspect of this projection is that while demand in the US & Canada is projected to decline by almost 5 mb/d from 2020–2040, the region's crude runs are projected to drop by less than 2 mb/d over the same period. In other words, the competitive advantages of US refiners will enable them to partially compensate for domestic demand reductions with product export increases. As a result, net US product exports could be well above 4 mb/d in 2040.

Declining demand in Europe exacts a toll of sustained reductions in crude runs, from 13.1 mb/d in 2020 to 11 mb/d by 2040. This represents a net decline of more than 2 mb/d. Over the same period, demand declines from 15.6 mb/d to 13.1 mb/d, which is more than 2 mb/d. Since the projected reduction in runs is modestly below the reduction in demand, the implication is that net imports to Europe will moderately decline. Nonetheless, the sustained decline in domestic demand, as well as high energy costs and higher refinery costs under EU carbon initiatives, combined with the impacts from declining regional crude production, are all seen as contributing to reductions in runs and utilizations in the region.

Between 2012 and 2016, some 1.9 mb/d of capacity had already closed in Europe. On top of this, a further 0.6 mb/d of closures was projected by 2022. As a result, utilizations in that year move up to 78% (higher in northwestern Europe and lower in other parts of the continent). A further 0.45 mb/d of closures was assumed for the period 2023–2025. Even so, utilizations steadily decline post-2020 and, assuming no further closures, reach a meagre 67% by 2040.

Table 5.6
Crude unit throughputs and utilizations

	Total crude unit throughputs *mb/d*								
	World	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific
2016	79.6	17.9	5.1	2.2	12.5	6.5	7.2	11.3	17.0
2020	83.9	18.6	5.6	2.5	13.1	6.3	8.1	12.6	17.0
2025	86.7	18.0	6.6	3.2	12.4	6.0	8.9	13.9	17.7
2030	88.5	17.5	6.8	3.6	12.0	6.0	9.3	14.8	18.3
2035	89.7	17.0	7.4	4.2	11.7	6.0	9.7	14.9	18.8
2040	90.5	16.8	7.6	4.7	11.0	5.9	10.1	15.2	19.3

	Crude unit utilizations *% of calendar day capacity*								
	World	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific
2016	81.6	88.1	64.2	53.4	72.9	91.4	79.1	80.9	94.4
2020	82.6	90.0	68.5	60.1	78.0	86.2	80.8	81.9	89.6
2025	81.6	86.7	75.1	61.4	76.0	83.3	80.3	84.6	86.3
2030	80.7	84.4	76.2	62.9	73.6	82.7	80.8	84.9	85.2
2035	79.8	81.7	77.1	66.0	71.6	82.0	81.1	84.4	84.1
2040	79.0	80.8	77.4	68.7	67.1	81.5	81.4	84.3	83.1

The implication is, of course, that substantial additional closures (in the region of 2.5 mb/d) are potentially necessary for Europe by 2040, over and above the assumed 1 mb/d to 2025, as the region's refineries continue to lose throughput.

The primary driver of throughput reduction in both the US & Canada and Europe continues to be the expectation of progressively declining transport fuel consumption – and, to a much smaller degree, rising supplies of biofuels and the use of alternative vehicles. Refiners in both regions continue to face a push toward higher transport fuel efficiency standards. In the US, the updated CAFE standards should achieve marked improvements. However, the recent surge in sales of larger vehicles, especially SUVs, may undermine this goal. Conversely, the US EPA has announced initiatives targeted at tightening emissions standards and fuel efficiency for

both jet aircraft and trucks.[15] For the US & Canada region, this year's outlook has combined gasoline, jet/kerosene and gasoil/diesel demand shrinking from more than 16.5 mb/d in 2016 to somewhere above 13 mb/d in 2040, a drop of 3.5 mb/d. The decline projected for European demand for the corresponding fuels is also significant, from more than 10 mb/d in 2016 to just above 9 mb/d in 2040. This is primarily driven by an assumption of the faster penetration of alternative vehicles, such as plug-in hybrids and BEVs. This combined reduction of close to 5 mb/d contrasts with the almost 10 mb/d demand increase in Asia for the same products in 2016–2040.

In the US, the picture regarding the RFS-2 (Renewable Fuel Standard) mandate remains unchanged: that is, it is not expected to reach its original ambitious targets – most notably, 2.35 mb/d of domestic biofuels supply by 2022. This year's Outlook has US and Canadian ethanol supply rising by only a little over 0.1 mb/d between 2016 and 2040 – and much of that occurs after 2025. One factor that could influence both demand and supply in the US is, of course, the potential for the new US Administration to adopt new policies. Already in 2017, the EPA has put forward requirements for 2018 biofuels use that are essentially unchanged versus 2017 – and has initiated a review of the RFS standard, opening up the possibility it may be reduced or eliminated.

In the EU, ethanol by volume today constitutes 3.2% of regional gasoline consumption and biodiesel 5% of diesel consumption. The EC has presented initiatives that would markedly increase these percentages, at least over the long-term, although there is still debate over what is achievable. This year's outlook does allow for an increase in total European biofuels supply from below 0.3 mb/d in 2016 to almost 0.5 mb/d in 2040. Globally, biofuels supply is projected to grow from around 2.2 mb/d in 2016 to 3.75 mb/d in 2040, shaving some 1.5 mb/d from demand for refinery products.

Japan and Australasia are also expected to experience continued demand contraction, in the form of a relatively severe 32% drop from 5.3 mb/d in 2016 to 3.6 mb/d in 2040. In the tables and figures in this Outlook, the region and its demand is masked by its inclusion within the Other Asia-Pacific region. Within that region, there is also a disparity between the growth projected for the Pacific High Growth sub-region – which contains countries such as South Korea, Taiwan, Thailand, Indonesia and Vietnam – and much higher growth in the Rest of Asia sub-region, which is dominated by India. In the former, demand grows by 2.6 mb/d from 2016–2040, a 26% increase. In contrast, in the Rest of Asia sub-region, demand of 5.5 mb/d in 2016 transforms into almost 13.0 mb/d by 2040, a 137% increase. All these significant differences between sub-regions within Other Asia-Pacific, as well as their impacts on refinery throughputs and capacity additions, are captured in the model.

In the Russia & Caspian region, refinery crude runs are projected as essentially flat throughout the period to 2040. Demand increases modestly, from 4.1 mb/d in 2016 to around 4.6 mb/d in 2025, but thereafter it is almost flat, rising only to 4.6 mb/d by 2040. The 'tax manoeuvre', with its impacts on export duties, is having the effect of increasing the attractiveness of exporting crude versus running incremental crude to export mainly heavy fuel oil. Thus, there is now pressure for Russian refiners to avoid/eliminate skimming type runs where the products would go for export. The effects are evident in the high proportion of upgrading and quality improvement projects in Russia with little by the way of distillation

capacity expansions. Adding to the close to 0.3 mb/d of closures in 2015, over 0.15 mb/d of additional closures were assumed by 2020, plus a further 0.2 mb/d by 2025. This reflects expected continued pressure to rationalize capacity. Noting the absence of any assumed closures longer term, Russia & Caspian utilizations are projected to slowly decline, but from a high initial level, at least in Russia.

It is the developing regions where significant demand increases are expected to occur that have all the considerable gains in refinery throughputs from 2016–2040; Latin America with 2.5 mb/d, Africa 2.5 mb/d, the Middle East 2.9 mb/d, China 3.9 mb/d and Other Asia 2.3 mb/d (this includes a mix of declines in Japan and Australasia, but increases elsewhere in the region). Overall, these gains total around 14 mb/d and far exceed the combined almost 3 mb/d of crude run declines in the US & Canada and Europe. Associated with the throughput gains, utilizations in developing regions are projected to gradually increase.[16]

5.1.7 Industry implications

Several trends and implications for the industry are evident when various factors reviewed in the preceding sections are brought together. First, the industry continues to exhibit a pattern of investing more in capacity at the global level over the medium-term than incremental demand requirements would indicate as necessary. The medium-term capacity 'overhang' has dropped in the past few years but for now appears to have levelled out at above 1.5 mb/d when focusing on the end of the medium-term period (that is, 5–6 years out). Second, at the regional level, stark contrasts emerge as capacity excesses build in the US & Canada and Europe, while capacity/product deficits are experienced in the Asia-Pacific region, with its sustained demand growth, as well as in Africa. A further evident trend is that Latin America is slipping more toward being a region with a potential deficit as the scale of new projects there has declined. In contrast, the Middle East maintains its position one of the leading demand growth regions, but where capacity additions are moving at a much higher pace, adding substantially to product export potential.

These factors and trends carry over into the long-term. Two major drivers are evident: a steady slowdown in the rate of liquids demand growth – and with that, the net new capacity needed annually – and the relocation of capacity from industrialized to developing regions, as more closures are needed in the former and more new capacity in the latter.

A total of some 4–5 mb/d of closures are indicated as needed over the long-term, in addition to 2.5 mb/d projected for 2017–2025, in order to establish and maintain efficient utilization levels in all regions. A key question is whether and when these will occur. There is often resistance to closures because of a desire to preserve local employment and maintain the production of refined products. Both the medium- and long-term projections highlight the dangers to worldwide refining margins if all projects are implemented and substantial closures are not made in the coming years. Yet recent pressures on margins have led to significant closures in industrialized countries, so the same could – or should – continue to happen in the future. As noted, future closures will be required in developing, as well as in industrialized regions. The question is whether the same discipline regarding closures seen recently in the industrialized countries will be applied.

A potential related issue is whether the associated need to move to smaller numbers of larger refineries can readily occur. This has been the long-term trend in, for instance, the huge US market. But can it be repeated elsewhere – in countries and regions with far smaller consumption levels? In many developing countries, existing refineries are relatively small and can be isolated. Moreover, many are run by state oil companies that can be more constrained in their options than their private sector counterparts. Replacing these over time with large, modern facilities would imply a potentially significant degree of centralization. This could result in either the elimination of refineries in certain areas of a given country or in smaller countries, ending up with no refineries and relying entirely on products imported from large regional or global facilities. In addition, significant new in-country – and potentially cross-border – product distribution infrastructure (such as pipelines, terminals and marine bunkers) would need to be developed. There are many national and regional considerations associated with the achievement of such shifts, which leaves open the question as the degree to which they will be realized.

What appears certain is that the steady slowdown in capacity additions – from around 1.2 mb/d p.a. to 2025 to around 0.4 mb/d p.a. post-2035 – will require adjusting to a low growth refining sector, reinforcing the emphasis on competitiveness and efficiency. At the global level, corresponding growth rates in refinery crude runs drop from 0.9 mb/d annually to 2020, to almost a low of 0.2 mb/d post-2030. (The rate of capacity additions is higher than the net global rate of crude run growth because the latter combines declines in some regions and growth in others that need new capacity.) This steady drop-off in the rate of required additions points to the need for caution in considering any major expansion. Ironically, though, it creates an incentive for having capacity in place early on so as to deter competitors, by making it more difficult for them to justify adding new capacity when competing against existing facilities that have already incurred 'sunk costs'. It is worth noting that the projected need for long-term annual capacity additions gradually declines to a level which, at 0.4 mb/d post-2035, nearly converges with the 0.3 mb/d long-term annual average closure rate indicated as needed. This points to the arrival of a post-2030 era when there could be no net increase in global refining capacity, but rather a net shrinkage.

5.2 Secondary capacity

5.2.1 Medium-term capacity additions

Substantial amounts of new secondary units are accompanying new distillation capacity in wholly new refineries or major expansions. In addition, secondary capacity can be installed in order to upgrade existing refineries, often with limited or no added distillation capacity. Broadly, all upgrades and essentially all the new grassroots refineries evident today are geared to achieving a high degree of conversion, desulphurization and other quality improvements through the inclusion of significant proportions of secondary capacity. With few exceptions, the aim is to produce predominantly light, clean products to advanced standards.

Table 5.7 shows that the 7.6 mb/d of new distillation capacity from assessed projects by 2022 is expected to be accompanied by an additional 3.2 mb/d of conversion units, 6.6 mb/d of desulphurization capacity and 1.7 mb/d of octane units.

Table 5.7
Estimation of secondary process additions from existing projects, 2017–2022 *mb/d*

	By year		
	Conversion	**Desulphurization***	**Octane units**
2017	0.6	1.1	0.2
2018	0.5	1.2	0.3
2019	0.8	1.5	0.4
2020	0.5	0.8	0.3
2021	0.4	0.7	0.2
2022	0.4	1.3	0.3

	By region		
	Conversion	**Desulphurization***	**Octane units**
US & Canada	0.0	0.3	0.0
Latin America	0.1	0.5	0.1
Africa	0.2	0.4	0.2
Europe	0.3	0.1	0.0
Russia & Caspian	0.5	0.7	0.1
Middle East	0.6	2.4	0.6
China	0.9	1.1	0.4
Other Asia	0.5	1.0	0.2
Total world	**3.2**	**6.6**	**1.7**

* *Desulphurization capacity in this table includes naphtha desulphurization.*

As of early 2017, the total conversion capacity in place equated to around 41% of global crude distillation capacity, desulphurization to about 62% and octane units to 19%. With respect to conversion, the make-up of current firm projects is similar at 42% of new distillation capacity and octane units at 22%. For desulphurization, there is a distinct surge evident with new units equating to 87% of new distillation capacity. This is matched by rates of projected additions for hydrogen and sulphur recovery plant that are also well above their historical ratios relative to crude capacity.

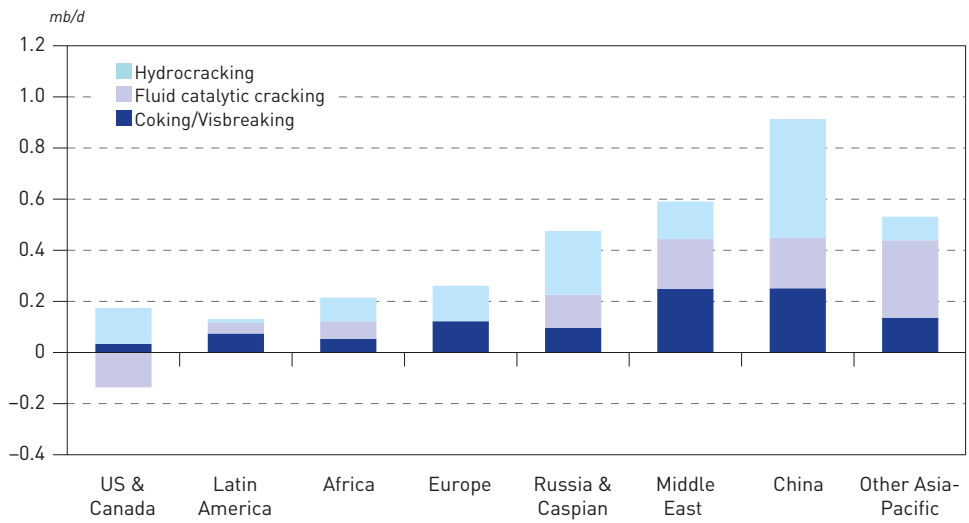
Conversion units

Figure 5.16 highlights the geographic distribution of the conversion capacity additions by major unit category. The 3.2 mb/d of additions to global conversion units for the period 2017–2022 include substantial contributions from each of the three main unit categories. These are led by

hydrocracking at over 1.3 mb/d (42%), followed then by coking/visbreaking (essentially all coking) at just over 1.0 mb/d (32%) and fluid catalytic cracking (FCC)/ residue fluid catalytic cracking (RFCC) capacity at 0.8 mb/d (25%). Recognizing that a single large project can affect the mix of conversion project additions, the outlook is very similar to that of last year. As such, the outlook sees hydrocracking as the leading source of additions. This fits – whether fortuitously or by design – with an expected increase in medium-term total distillates demand. The 2016 Outlook projected 2022 total distillate demand at below 37.0 mb/d (gasoil/diesel plus jet/kero). By way of comparison, this year's Outlook is at around 37.5 mb/d for 2022. This shift stems in part from a reappraisal of the marine fuels outlook given that the implementation date for the MARPOL Annex VI Global Sulphur Rule has been set for 1 January 2020. However, it also reflects the shift to an expectation of higher total liquids demand by 2022, 102.3 mb/d in the current Outlook, versus 100 mb/d projected a year ago for 2022.

As shown in Figure 5.16, additions in each of the three conversion unit categories are expected in all regions except Europe, where there are no projected FCC additions, and the US & Canada, where FCC additions are net negative because of announced FCC unit closures in US refineries as components of project revamps. The FCC closures (at 0.14 mb/d) offset hydrocracker additions at the same level. These developments are occurring despite a short-term surge that has pushed US gasoline demand to record levels. Over the medium- to long-term, however, the region's gasoline demand is expected to decline. In addition, the growth in light tight oil production has added to supplies of naphtha. These have provided a growing source of potential gasoline blendstock that has resulted in more emphasis being placed on catalytic reforming and isomerization to improve naphtha octane, than on incremental FCC capacity to supply gasoline

Figure 5.16
Conversion projects by region, 2017–2022



volume. In Europe, the substantial regional gasoline surplus provides little incentive to add to gasoline supply. In both regions, the emphasis continues to remain on raising distillate yields. Overall, four regions display only limited conversion additions over the medium-term period: the US & Canada, where net additions are minimal, then Latin America, Africa and Europe, where additions lie in the 0.15–0.25 mb/d range. Significant conversion additions are projected for Russia, the Middle East, China and Other Asia-Pacific. The additions in Russia (0.5 mb/d) are driven both by the recent 'tax manoeuvre' that encourages the production of clean fuel for export and discourages fuel oil production, as well as by the prospects for raising diesel/gasoil exports to Europe, which is – and is expected to remain – short of this product. In the Middle East, the conversion additions (0.6 mb/d) are geared towards adding value and, in doing so, meeting growing regional demand and supplying clean products for export. In China (0.9 mb/d) and Other Asia-Pacific (0.5 mb/d), the additions are geared more towards satisfying domestic demand. The geographical distinctions are marked. At 0.65 mb/d, total Atlantic Basin additions – as represented by US & Canada, Latin America, Europe and Africa – are not far above the 0.5 mb/d for Russia alone, but far below the additional 2 mb/d expected for the Pacific Basin (Middle East and Asia combined). Thus, the concentrations of conversion additions reflect the very specific programme under way in Russia and the fact that the preponderance of medium-term clean product growth is projected to take place in the Middle East and Asia (outside of Japan and Australasia).

In terms of coking unit additions, all regions are expected to see some level of additions, with the Middle East and China leading the way, followed by Other Asia-Pacific, Russia & Caspian and Europe. As part of the region's general decline in investment activity, Latin America has fallen back in terms of the rate of coking additions with less than 0.1 mb/d expected over the medium-term period. It will be interesting to see how these additions play out during this period in terms of coker utilization levels. The current lightening of the global crude slate would, by itself, reduce coker throughputs. However, one change expected to raise and even strain the throughput of cokers (and desulphurization units) is the introduction of the global marine fuel standard for 0.5% sulphur fuel in 2020. Given the expectation that on-board scrubber penetration will still be limited by 2020, and assuming shippers will try to achieve full compliance with the Annex VI standard, the shift could result in a scramble to dispose of excess high sulphur intermediate fuel oil (IFO) marine fuels, which are mainly residual based. This would necessarily be achieved by additional upgrading and desulphurization, with cokers' ability to process low quality residua arguably a key aspect.

Desulphurization units

Medium-term desulphurization unit additions equate to 87% of new distillation capacity. Of these additions, 1.7 mb/d is for naphtha processing, somewhat under 0.9 mb/d for gasoline, 3.1 mb/d for distillates and 0.9 mb/d for heavy streams (vacuum gasoil and resid). The naphtha desulphurization additions stem mainly from the 1.2 mb/d of new global catalytic reforming capacity, but also new condensate processing capacity in the Middle East. The gasoline additions relate primarily to the processing of FCC naphtha to ultra-low sulphur (ULS) standards. The distillate additions – nearly 47% of the total – reflect the current drive, in developing regions especially, to implement low and ultra-low standards for diesel. The vacuum gasoil/resid additions reflect mainly a mixture of FCC and RFCC pre-treatment, and resid desulphurization in the Middle East, plus limited lubes oils processing.

It appears unlikely that much of the high level of new desulphurization capacity can be attributed to the MARPOL Annex VI Global Sulphur Rule now set for 2020. The IMO did not confirm until October 2016 that the Rule would be implemented in 2020. It would appear that a few refiners may have already taken strategic decisions to move ahead with desulphurization (and conversion) projects, which were justified in part by the perceived impacts of the Rule. However, the fact that it was not clear until October 2016 whether implementation would be in 2020 or five years later in 2025 suggests that many refiners may have held back from investments specifically because of the uncertainty of the Rule's timing. The prospect that scrubbers could be adopted in large numbers from 2020 on has also acted to deter refiners from investing. Thus, the primary reason for the significant desulphurization additions, and the increase from 5.1 mb/d from a year ago, would appear to be the number of low sulphur and ULS gasoline and diesel programmes that are now moving ahead.

OECD countries have largely completed implementing ULS standards for gasoline and on-road diesel, and are now moving towards such standards for off-road diesel, as well as heating oil. This means that the continuing shift of the developing countries towards Euro 3/4/5/6 standards is the main force driving global hydro-treating capacity expansion.

Additions in the US & Canada and Europe total only around 0.4 mb/d over the medium-term period. In contrast, the Middle East is at 2.4 mb/d and Asia at 2.2 mb/d as an array of new refinery projects and upgrades come online. Additions in the Russia & Caspian region are at 0.7 mb/d and are driven, as with conversion additions, by the effects of the new tax regime, as well as regulations to achieve ULS gasoline and diesel standards. New desulphurization capacity in Africa and Latin America is projected at 0.4 and 0.5 mb/d, respectively, and are spread across a range of projects. This indicates further progress on these continents towards tighter sulphur-content fuel standards.

The concentration of additions in mainly non-OECD countries partly reflects recent trends towards cleaner products within these regions. It also reflects the efforts of export-oriented refineries to provide low or ULS products that better comply with quality regulations in developed – and, increasingly, developing – countries.

Octane units

Octane unit additions are estimated at 22% of incremental distillation in the medium-term. This is moderately above the 19% level for base global refinery capacity as of early 2017. With lead phase-out essentially complete, this upward move reflects the fact that octane levels are being raised and/or total gasoline output is being increased essentially across all developing regions. In line with this, additions are again predominantly in the Middle East and Asia (around 0.6 mb/d each), followed at the much lower levels by Africa and Latin America (0.2 mb/d and 0.05 mb/d, respectively). In the US & Canada and in Europe, additions are minimal, below 0.1 mb/d in each case; in Russia & Caspian they are 0.12 mb/d. The 0.8 mb/d of FCC additions by 2022 will serve to add an appreciable volume of higher octane blendstocks in the form of FCC gasoline (plus feedstock for alkylation units). However, these project additions again bring home the difference in trends between the Atlantic and Pacific Basins. In the former (again taken as US & Canada, Latin

America, Europe and Africa), octane additions total just over 0.3 mb/d over the medium-term. In contrast, Pacific Basin additions (the Middle East plus Asia) total over 1.2 mb/d.

The 1.7 mb/d of octane unit additions is comprised mainly of catalytic reforming at 1.2 mb/d or 73% of the total. The remainder is split between isomerization (0.2 mb/d), alkylation (0.15 mb/d) and methyl tertiary butyl ether (MTBE) units (0.1 mb/d). In Europe, MTBE consumption levels are flat. In the US, the use of MTBE was effectively banned in 2006, though some 40,000 b/d is still exported from merchant units on the US Gulf Coast. There also continues to be interest in expanding MTBE use in Asia as a means to meet rising gasoline pool octanes. Thus, the potential for a growing role for MTBE, and whether this could represent an opportunity for exporters, should be monitored.

Implications for refined products supply/demand balances

In assessing the effects of capacity additions on regional product balances, it needs to be borne in mind that refiners have some flexibility to optimize their product slate depending on market circumstances and seasonality, either by altering feedstock composition and/or by adjusting process unit operating modes. Accepting the fact that refiners do have the flexibility to optimize their product slate, Table 5.8 presents an estimation of the cumulative potential incremental output of refined products resulting from existing projects. The estimates assume that these new units are run at 90% utilization rates and are grouped into major product categories.

These estimates continue the pattern seen in recent outlooks in terms of the proportions of incremental supply organized by major product category. What is seen is a predominance of light, clean products, led by distillates and no incremental supply of residual fuel oil. This, in turn, reflects a continuation of broadly similar proportions of new secondary processing, especially upgrading, relative to new distillation capacity. Close to half (46%) of the increase by 2022 is for middle distillates (3.4 mb/d) and another 2.4 mb/d (33%) for light products, specifically naphtha and gasoline. Assuming that new secondary units are fully used at the 90% level, the

Table 5.8
Global cumulative potential for incremental product output,* 2017–2022 *mb/d*

	Gasoline/Naphtha	Middle distillates	Fuel oil	Other products	Total
2017	0.4	0.4	–0.1	0.2	1.0
2018	0.8	0.9	–0.2	0.5	2.0
2019	1.2	1.6	–0.3	0.8	3.3
2020	1.7	2.2	–0.3	1.1	4.7
2021	2.0	2.8	–0.3	1.5	6.0
2022	2.4	3.4	–0.2	1.8	7.4

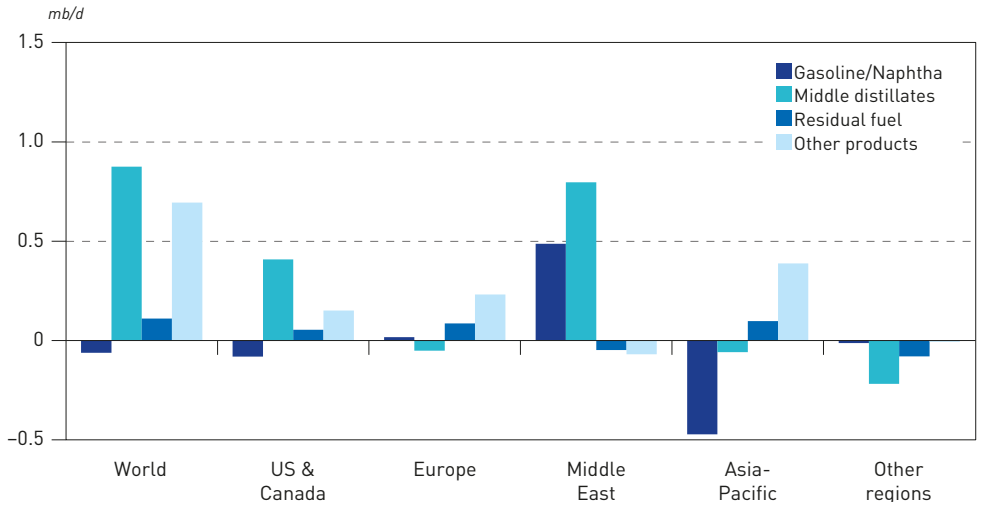
* *Based on assumed 90% utilization rates for the new units.*

ability to produce fuel oil is set to decrease slightly, by 0.2 mb/d, while the ability to produce 'other products' is projected to rise by 1.8 mb/d (25% of the total incremental output).

Figure 5.17 compares the potential additional regional outputs by major product group from the assessed projects (as detailed in Table 5.8) to projected incremental regional demand for the period 2017–2022. In assessing net incremental requirements by product, Figure 5.17 takes into account product supply coming from non-refinery streams, notably additional biofuels, CTLs, GTLs and NGLs. The results are presented by product group as a net surplus/deficit, both globally and regionally. Globally, the outlook is for a cumulative surplus in each of the four product categories by 2022, totalling 1.6 mb/d. This trend towards a growing excess of refinery output potential compared to refined product requirements was previously described from the perspective of overall distillation capacity, since it is based on the same underlying figures. However, here it is expressed from the perspective of the main product groups rather than total product potential.

At the regional level, the picture is shifting to one where surpluses in most products across several regions are being replaced by closer balances and/or deficits in other regions. The most visible of these is in the Middle East, where a 0.5 mb/d gasoline/naphtha surplus seen by 2022 is almost exactly offset by a deficit of an equivalent magnitude in the Asia-Pacific.

Figure 5.17
Expected surplus/deficit* of incremental product output from existing refining projects, 2017–2022



* *Declining product demand in some regions contributes to the surplus. This is especially the case for gasoline/naphtha and fuel oil demand in Europe, which show emerging surpluses despite few capacity additions in the region. Gasoline and fuel oil are affected in other regions as well.*

This has clear implications for product trade. With its growing export refinery capacity, the aggregate surplus in the Middle East will be dominated by gasoline/naphtha, but as well as by middle distillates.

The Asia-Pacific is projected to be in overall balance, having moved from a cumulative deficit of 0.3 mb/d by 2021 projected a year ago. On the product level, however, the Asia-Pacific is not projected to see balance. The US & Canada is expected to have an aggregate surplus of 0.5 mb/d in 2022, which includes a small gasoline/naphtha deficit plus surpluses led by middle distillates. This has implications both for gasoline imports, with US & Canada projected to see 0.35 mb/d of gasoline demand growth in the period 2016–2022, and for distillate exports. Europe and 'other regions' (comprising Russia & Caspian, Africa and Latin America) are each expected to be essentially in balance in 2022, with only minor surpluses or deficits for each product group.

The WOO 2015 Outlook stressed that "balances show a continuation of projects that produce too much naphtha/gasoline" but that the projected cumulative surplus was also lower, at 0.8 mb/d by 2020. (It was around 1.4 mb/d in the 2014 Outlook.) In last year's Outlook, the gasoline/naphtha cumulative surplus dropped again to 0.4 mb/d by 2021. This year, the Outlook is for a slight net gasoline/naphtha deficit of less than 0.1 mb/d by 2022. Conversely, a net middle distillates surplus that was projected at around 0.35 mb/d for 2020 in the WOO 2014 Outlook – and which was on the order of 0.6 mb/d in each of the 2015 and 2016 Outlooks – is cumulatively at nearly 0.9 mb/d by 2022 in this year's Publication (despite an allowance for some increase in distillate demand because of MARPOL Annex VI).

For residual fuel, the market shows a slight global surplus of around 0.1 mb/d for 2022, which is considerably lower than the estimated surplus of around 0.5 mb/d for 2021 shown in last year's Outlook. The major reason for this lower figure is the revised view on the implementation of the IMO regulations on bunker fuels. Fuel is projected to remain an important component of the bunker fuel, either through usage in vessels with scrubbing facilities or as a blending component in low sulphur fuel, compliant with the regulation.

These regional imbalances have implications for product trade, particularly for increasing movements of gasoline/naphtha and middle distillates from the Middle East to Asia. Beyond that, surpluses in nearly every region – apart from a residual fuel deficit in 'other regions' – point to increasing competition for product markets.

What do IMO regulations mean for refining?

Chapter 3 describes the Reference Case assumptions surrounding the implementation of the IMO regulation from 2020, including the rate of compliance and the possible bunker fuel mix. Given the assumed path of the implementation of the IMO regulations, there are several issues in the downstream sector worth pointing out.

It is assumed that the first step that refiners forming part of the global refining system will take it to use their flexibility in diesel and LSFO production without increasing overall refinery runs. However, the nature of the processing changes that are needed may lead to a

requirement that they process additional crude. Thus, firstly, to upgrade unwanted high sulphur residual streams, the refining sector will tend towards maximizing coker throughputs. Since a part of their liquid feed is 'rejected' as solid coke by-product, this alone necessitates running additional crude. Secondly, shifting to the global fuel standards tends to increase processing intensity, as well as hydrogen and refinery fuel consumption. Part of these increases will again come from crude oil.

According to the Reference Case, there is a need for additional refinery runs of around 0.5 mb/d in 2020 (over and above a case where no IMO regulation is adopted) to meet the required (partial) move to the global fuel standard in 2020. Another factor considered, primarily in 2020, is the expectation that the market will react by enabling additional sales of high sulphur heavy oil (at relatively depressed prices) to the electric power sector. This again tends to create a need for additional crude runs. However, based on the Reference Case assumptions, the need to run extra crude is a temporary phenomenon which is set to fade in the years following 2020. This projection is based on the assumption that the penetration of scrubbing technology will progress at scale from 2020 onward, leading to a partial reversion back to high sulphur heavy bunkers demand. Depending on the degree of strain in markets in 2020, price elasticity effects could also curb demand for land fuels, namely gasoil/diesel, jet/kero and gasoline, though on a temporary basis.

Since the final target of refiners is to produce more distillate fuel, which could be blended with off-spec fuel oil, increasing runs are most likely to be seen in those regions with complex refining systems. US refiners are natural candidates for additional runs due to their high complexity. At the same time, potential also exists in Europe, where the refining capacity is underutilized. Further potential for additional production exists in the Middle East and parts of the Asia-Pacific (for example India).

The operating changes that refineries will need to make in order to adapt to the Global Sulphur Rule and the likely resulting market may lead to rising margins for some refiners – and lower margins for others. This means that the price implications of the IMO decision should not be overlooked. The effect of changing marine fuels demand will impact not only fuel oil, but also all other products and especially middle distillates. The expected effect of the decision is a strong increase in middle distillate cracks, as well as LSFO cracks, with the latter possibly being priced at a premium to crude oil. As expected, the crack for HSFO should decrease strongly in 2020. In an extreme case (assuming high compliance and low penetration scrubbers) leading to large fuel oil oversupply, this could see HSFO competing against natural gas and ultimately coal in the power generation sector, which means that the price of HSFO could collapse on a temporary basis around 2020. Consequently, the spread between LSFO and HSFO should widen significantly, thus supporting the decision of shipowners to install scrubbers. After the initial shock, this spread could narrow somewhat, but still remain wide enough to allow for additional scrubber retrofitting. In addition, diesel-IFO differentials are expected to widen significantly in 2020. Since the primary refining split is between light products and heavy products, and since the production and economics of the primary light clean products (diesel/gasoil, jet/kero and gasoline) are all inter-connected, strained diesel-IFO differentials are expected also for jet/kero and gasoline cracks.

Arguably complex refineries, especially those geared towards distillate fuels and which process heavy sour crude oils, would experience high margins. In part this is because the prices for their crude intake would drop. Those for simple refineries would depend on their crude and product mix. For simple refineries with sweet crude intake, margins should improve despite an increased premium for light sweet crudes, as they would be able to produce LSFO, as well as light clean products whose prices would spike. These uncertainties will continue to be monitored carefully, but the current Reference Case assumes adoption of the global standard in 2020, with progressive rather than total instant compliance, and that scrubbers will be relatively successful over the long-term.

Another important issue is the quality of marine bunkers, which is expected to change. This is due to increasing blending activity, in order to provide the fuel blend with 0.5% sulphur content, which would be compliant with the regulation. For both shipping companies and refiners, this leaves open the question as to what class of fuel to purchase or sell. The standard (ISO 8217) that covers marine fuels allows a wide range of accepted fuel types from various diesel grades to a range of progressively heavier residual type grades (often referred to as IFO). Under ISO 8217 from 2012, four distillates and 11 residual grades are specified. A 2017 update modifies the standard, primarily with regard to the inclusion of biofuels in different blend grades. To date, the broad assumption has been that the 0.5% global fuel would be predominantly marine diesel, fitting within one of the existing accepted ISO 8217 grades. However, recent experience with ECA fuels shows suppliers have also offered 0.1% sulphur residual-type IFO fuels and even 'hybrid' grades, which often closely resemble vacuum gas oil (VGO). From the refining perspective, there is a logic to producing heavier 0.5% grades in order to take advantage of the quality 'giveaway' that is present in a 0.5% marine distillate. However, shipowners and operators tend to be conservative when it comes to testing and adopting new fuel formulations – and are concerned about the potential for incompatibility between grades that could lead to on-board ship operating problems. As 2020 approaches, announcements can be expected from refiners and bunker blenders regarding new 0.5% fuel formulations. Even though a range of streams and blendstocks will be available (depending on the complexity of the refinery), there is no certainty as to how long it will take for newer fuels to be accepted in volume.

As already mentioned, the implementation of the IMO regulations brings with it an array of challenges. These stem primarily from the fact that there are different paths to achieve compliance. However, question also arise from whether the 'overnight' and 'all in' nature of the standard's introduction will lead to a period in which some regions achieve greater enforcement and compliance than others. Nevertheless, what seems to be certain from today's viewpoint is the existence of widening differentials between high and low sulphur fuels, especially around 2020. The cost structure of the shipping industry will be the hardest hit, either through the higher costs of fuel or the costs of scrubbing facilities. However, this is not just a shipping fuel or shipping industry challenge, since the co-product nature of the refining industry means that tightness in marine fuels will also carry over into land diesel and other clean fuels. The IMO position is that there will be sufficient flexibility in the refining system to allow for the maximum required 'switch volume' to meet the 0.5% standard. It also states that there will be no consideration of any delay in the regulation (to 2025) or any specific phase-in approach. It therefore remains to be seen what market adjustments will help dampen the effects of the

switch to low sulphur fuel and to what extent these will help avert extreme events such as fuel shortages and price spikes.

5.2.2 Long-term secondary capacity additions

Overview

Refining capacity is measured first and foremost by distillation capacity. However, it is the supporting capacity for conversion and product quality improvement that plays the crucial role of processing raw crude fractions into increasingly advanced finished products – and which delivers most of a refinery's 'value-added'. In fact, given the general trend towards lighter products and more stringent quality specifications for different product groups, these 'secondary' processes have become a key gauge of a refining sector's capability to meet demand.

All major projects for new refineries and large expansions essentially comprise complex facilities with high levels of upgrading, desulphurization and related secondary processing. This enables them to generate high yields of light clean products which, almost invariably, can be produced to meet the most advanced specifications, such as the Euro 5 and now Euro 6 standards. In addition, many new refineries are being designed to be able to process heavy, low quality and often high TAN crudes, as well as better quality grades, and/or to produce petrochemical feedstocks such as propylene and aromatics. (In the US and in Asian countries, such as India, FCC unit yields are often geared to maximizing propylene and catalytic reformer yields to produce aromatics.) Smaller projects in existing refineries are generally directed towards the same goals of upgrading to reduce residual fuel output and achieving quality improvements for clean products. Together, these factors are leading to greater proportions of secondary capacity per barrel of distillation. \One exception to this trend is the high volume of new condensate splitter capacity currently being built. On top of over 0.5 mb/d of additions in the US in 2015–2016, up to another 0.6 mb/d could be added to handle tight oil condensates. In addition, nearly 1 mb/d of Middle East condensate splitter projects are listed. (In both regions much lower figures were considered as firm in the Reference Case.) Even allowing for additional condensate splitter capacity, which tends to bring with it little or no secondary processing, the sustained reduction in residual fuel demand as a percentage of total demand (with nearly all growth in light, clean products) creates a pattern wherein total conversion additions as a percentage of new distillation capacity increase over time. There is some growth expected for asphalt, for example, but this is offset by anticipated declines in demand for residual fuel. Demand for lubricating oils produced from crude oil – as distinct from synthetic grades – is expected to remain flat. As shown in Table 5.9, existing projects to 2022 have conversion additions at 42% of new distillation capacity. Against this, from 2022–2030, the level is 59% and from 2030–2040 the figure is 69%.

In the period 2030–2040, secondary additions per barrel of distillation are estimated to fall back for desulphurization units after surging in the 2022–2030 timeframe. This is based on the projection that by 2030, the world's regions will have largely completed the shift to ULS fuels and that additional desulphurization capacity post-2030 will be restricted only to regions with additional demand growth for clean products. Octane units maintain appreciable additions both pre- and post-2030. This is based on the projection that, in the long-term, gasoline

octanes across the world will progressively increase or approach the levels currently seen in more industrialized countries. Moreover, levels in industrialized countries themselves are expected to move up in order to achieve improved efficiencies in engine thermodynamics.

The Reference Case projections for future required secondary processing through 2040 are presented in Table 5.9 and Figures 5.18–5.22. Similar to those for crude distillation units, projections for secondary process units take into account the 2.5 mb/d of refinery closures assumed for the period 2017–2025. These not only remove distillation but also, in many cases, the associated secondary unit capacity. As a result, projected total additions are somewhat higher than they would have been had no closures been assumed. At the global level, projections indicate the need to add some 10.7 mb/d of conversion units, 22.5 mb/d of desulphurization capacity and just above 5 mb/d of octane units in the period to 2040.

This year's Outlook has somewhat higher global gasoline, as well as distillates demand, in 2040. It also retains the somewhat strengthened upward trend over time in gasoline octane

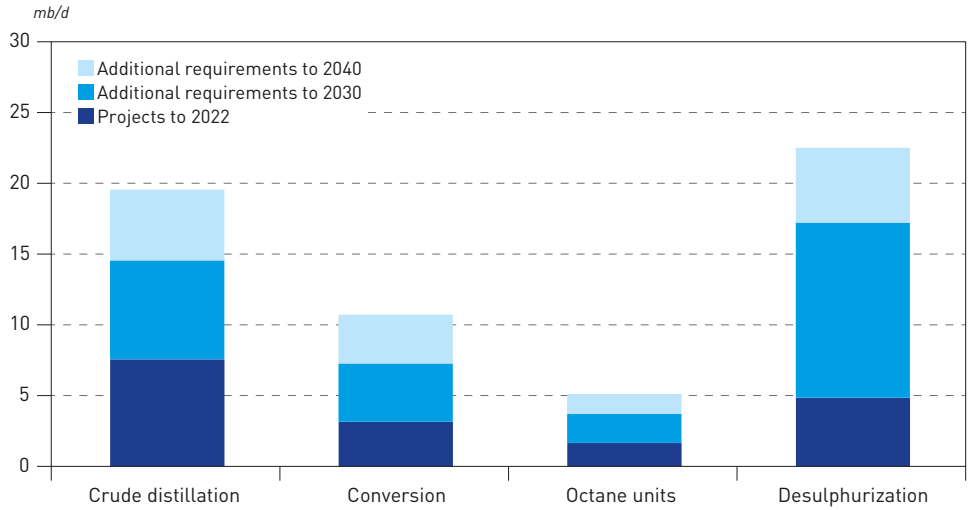
Table 5.9
Global capacity requirements by process, 2017–2040

mb/d

	Existing projects	Additional requirements		Total additions
	to 2022*	2022–2030	2030–2040	to 2040
Crude distillation	**7.6**	**7.0**	**5.0**	**19.6**
Conversion	**3.2**	**4.1**	**3.4**	**10.7**
Coking/Visbreaking	1.0	0.5	0.7	2.2
Catalytic cracking	0.8	2.4	0.9	4.1
Hydro-cracking	1.3	1.2	1.9	4.4
Desulphurization**	**4.9**	**12.4**	**5.3**	**22.5**
VGO/Resid	0.9	2.0	1.1	4.0
Distillate	3.1	9.7	2.7	15.5
Gasoline	0.9	0.6	1.4	3.0
Octane units***	**1.7**	**2.1**	**1.4**	**5.1**
Catalytic reforming	1.2	0.8	0.8	2.8
Alkylation	0.2	0.7	0.2	1.1
Isomerization	0.2	0.1	0.1	0.5
MTBE	0.1	0.4	0.2	0.7

* *Existing projects exclude additions resulting from 'capacity creep'.*
** *Naphtha desulphurization not included.*
*** *New units only (excludes any revamping).*

Figure 5.18
Global secondary capacity requirements by process type, 2017–2040



that was described in last year's Outlook. These factors, together with changes in the global crude supply, continue to drive secondary additions.

Conversion units

The 2.2 mb/d of projected additions for coking/visbreaking, which comprises predominantly coking, is essentially unchanged versus the 2.2 mb/d projected a year ago (for the period 2016–2040). The somewhat lighter global crudes slates projected in the WOO 2016, as well as this year's, plus coking additions in the past two years, have acted to reduce total new capacity required by 2040 to the current 2.2 mb/d level from close to 3 mb/d. Crude slate revisions are a factor in this. Based on updated crude production projections, the global crude slate quality is projected to increase to levels above 33° API around 2017 and is expected to remain above 33° until 2040. The level of coking/visbreaking additions drops from 1 mb/d in the six-year period 2017–2022 to around 0.6 mb/d in each of the periods 2022–2030 and 2030–2040. Additions continue throughout the period because incremental demand is overwhelmingly for light clean products where incremental supply includes significant proportions of medium and high sulphur crudes whose vacuum residues have to be upgraded.

Catalytic cracking (FCC) additions peak in the 2022–2030 period when gasoline demand growth is still strong, but then diminish post-2030 as global gasoline demand growth essentially halts. (Demand increases by more than 3 mb/d in the period 2016–2030, but only around 0.2 mb/d from 2030–2040.) In contrast, hydrocracking additions are sustained from the medium-term through to the long-term as total distillate demand grows by 5 mb/d from 2016–2030 and by almost 2 mb/d

from 2030–2040. Again, total required additions of conversion or other units are often higher than what would be justified by simply looking at the change in global total product demand. This is because certain regions have demand falling, while others have it continuing to rise, justifying new regional additions.

The hydrocracking process has high capital, process energy and hydrogen costs. Over the longer term, the need to keep investing in additional hydrocracking capacity, relative to distillation, can be expected to sustain distillate margins relative to crude oil.

Future coking additions and utilizations will, of course, be sensitive to heavy crude developments in countries such as Canada, Venezuela, Brazil, Colombia and Mexico. The overall production volume of heavy grades is expected to increase in the long-term due to the rise in synthetic crudes (Canada and Venezuela). It should be noted that the refining capacity additions and investments reported in this Outlook exclude capacity in oil sands/extra heavy oil upgraders.

As seen in previous Outlooks, the projections allow for an increased role for FCC units in producing propylene, which is a high growth product, and also for a shift to operating modes that yield more distillates. The latter is projected to occur in part because of a steady increase in the proportion of resid feed to FCCs over time, as VGO is increasingly diverted for use as a hydrocracker feedstock. (Many catalytic cracking units built in the Asia-Pacific region are resid FCCs [RFCCs].) Compared to VGO, resid in FCC feed tends to yield more distillate (cycle oil) and less gasoline. This allowance for yield and operating mode flexibility helps sustain FCC utilizations and additions. Since process and catalyst suppliers always seem to be able to develop new FCC catalyst and additive variants, it may be that FCC yield flexibility widens further over time.

The varying outlooks across specific conversion units are also reflected in utilization rates indicated by the Outlook's model runs. Hydrocracking unit utilizations are projected to be consistently high – in the low 80% range – through the period to 2040. FCC unit utilizations are projected to be close to an average of 80% through the medium-term, spurred by short-term gasoline demand growth. They then gradually trend downwards to the 76–77% range post-2025. This trend is consistent with the anticipated reduction in long-term gasoline growth. Utilizations on coking units are projected to follow a pattern similar to those for FCCs trending down post-2025 to the 75–77% range. In the shorter term, utilizations are projected to be above 80%. One factor here is the effect of the 2020 MARPOL Annex VI Global Sulphur Rule in driving refiners to maximize coker throughputs in the 2020–2022 period in order to dispose of sudden levels of excessively high sulphur heavy residual streams. By 2025, utilizations are expected to have fallen below 80% as the uptake of on-board scrubbers (as assumed in the Reference Case) leads to a partial reversion in demand for high sulphur heavy marine fuel.

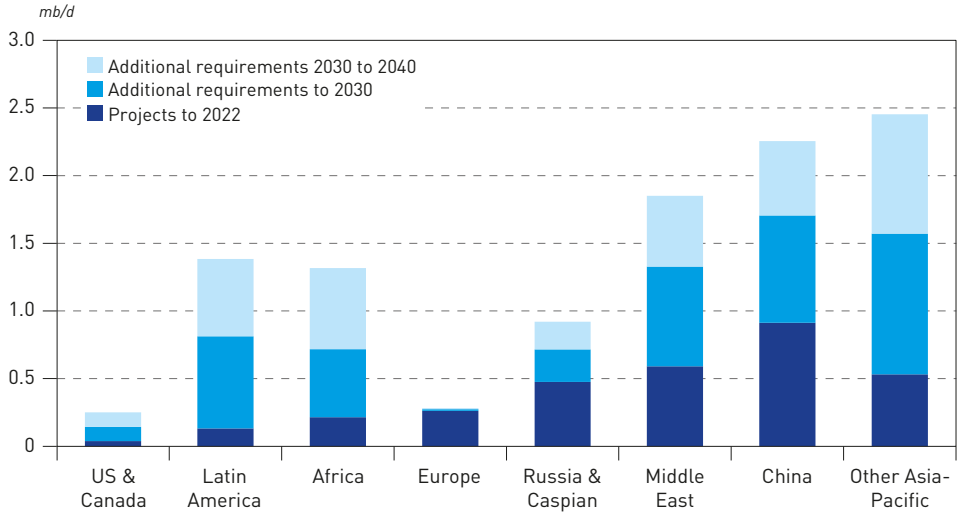
The regional distribution of total future conversion capacity additions is presented in Figure 5.19. Additions are minimal in Europe, with a total of 0.3 mb/d and almost no activity beyond current projects. Similarly, only minor debottlenecking type additions are projected for the US & Canada, with some 0.25 mb/d. Requirements are expected to be led by the Asia-Pacific, at around 44%, or 4.7 mb/d, of total future conversion additions to 2040, and the Middle East, with 17%, or 1.85 mb/d. Significant additions are also projected for Latin America and Africa, in the range of 1.3–1.4 mb/d in each region. These are driven by sustained regional product

demand growth with the bulk of additions in the longer term. In contrast, over 50% of the total 0.9 mb/d additions in the Russia & Caspian region to 2040 are associated with known projects to 2022, the result of recent tax incentives combined with flat demand longer term. Overall, it is developing regions, with their continuing demand growth, that sustain conversion capacity growth over the period to 2040. Only 14% of conversion capacity growth is expected in the US & Canada, Europe and Russia & Caspian combined to 2040. Additions are also minimal for Japan/Australasia. Looking at additions of industrialized countries, they represent 24% of the total through to 2022. Thereafter, however, they occupy only 9% of total additions, reinforcing the severe drop-off in additions to secondary, as well as primary capacity in industrialized countries.

Significant coking additions, totalling 0.3 mb/d to 2040, are projected for Latin America as heavy crude production continues to expand there. Otherwise, minor additions are expected in most regions. FCC additions are projected mainly in developing country regions, with the largest additions in China and Other Asia-Pacific. Beyond projects, minimal additions are expected for the US & Canada, Europe and the Russia & Caspian. The overall pattern is similar for hydrocracking. Appreciable additions are expected for all regions outside the US & Canada and Europe, with the leaders being Other Asia-Pacific and China, the Middle East and Latin America.

As noted, the modelling results point to most FCC additions occurring before 2030 and then slowing thereafter. Thus, especially for FCCs, there is some risk of stranded investments because of the projected levelling off in global gasoline demand. This continuing growth in developing regions combined with demand declines in the US & Canada, Europe and Japan/Australasia, will have significant implications for unit and refinery closures.

Figure 5.19
Conversion capacity requirements by region, 2017–2040



Hydrocracking and coking additions also carry a specific risk that goes beyond the normal uncertainties associated with economic and oil demand growth – namely, the potential effects of the MARPOL Annex VI Global Sulphur Rule and the degree to which this drives a shift to distillates and away from high sulphur heavy fuel oil. The Reference Case demand profile assumes a jump in demand for 0.5% sulphur marine distillates in 2020, plus additional short-term outlets for heavy fuel into the power sector, followed by a partial reversion back to high sulphur heavy fuel marine demand driven by the large-scale uptake of scrubbers. There is significant uncertainty over how the impacts of the Rule will play out, but the demand and fuel mix projection developed in this Outlook is arguably the current 'conventional' view, to the extent that there is one. As such, the prospect of a reversion back to significant demand for high sulphur heavy fuel, courtesy of assumed growing scrubber use post-2020, is likely to act as a deterrent to refiners, at least regarding any major investments geared specifically to increasing the supply of low sulphur (0.5%) marine fuels.

Research undertaken in the lead-up to this Outlook has highlighted few instances of marine fuels being cited as the primary basis for investments. What is evident is that a number of process technology developers are using the potential impacts of the Global Sulphur Rule to highlight the benefits of their technology. A handful of new processes – generally still at the pilot plant stage, but moving towards commercial demonstration – offer improved means to crack, desulphurize and even demetallize heavy crude oils, bitumen and heavy sour residual streams. Should one or more of these new technologies make it to the commercial scale, the timeframe will certainly be post-2020, but the impacts could be substantial, eating into additions for the conventional upgrading processes.

Another factor in the marine fuels market that has the potential to impact the longer term, especially post-2025 or so, is the use of LNG as a marine bunker fuel. Currently, this option is receiving a lot of attention, with frequent announcements of plans for the start of LNG bunkering in specific ports and for new ship orders with dual-fired (LNG/petroleum) capability. The Reference Case assumed growth in LNG use for marine bunkering over the longer term. Of course, growth in demand for this fuel reduces total petroleum-based marine fuel demand. Depending on the mix of marine fuels displaced, this could exert further pressure on the upgrading of unwanted IFO to clean fuels and eat into markets for marine distillates.

Desulphurization units

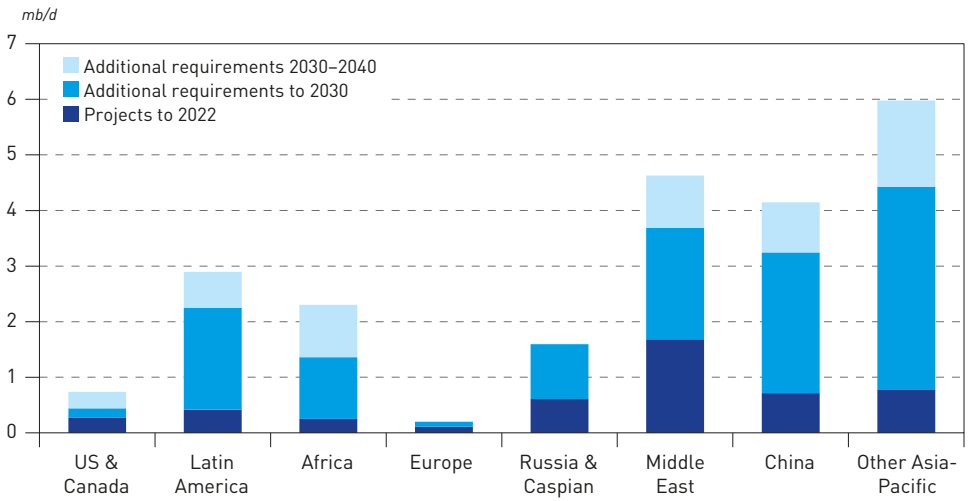
In addition to conversion, desulphurization capacity represents another important component of secondary units. Driven by the progressive move towards near universal ULS gasoline and diesel standards in the long-term, plus expected reductions in sulphur content for jet fuel, heating oils and marine fuels, desulphurization additions represent the largest capacity increase among all process units over the forecast period. With OECD regions already largely at ULS standards for gasoline and diesel, the focus is now shifting to non-OECD regions as they move progressively towards low and ULS standards for domestic fuels, and build export capacity to produce fuels at advanced ULS standards. Over and above the 4.9 mb/d of desulphurization capacity (excluding naphtha desulphurization) that is included in assessed projects to 2022 (Table 5.3 and Figure 5.1), a further 12.4 mb/d is projected to be needed by 2030, and an additional 5.3 mb/d between 2030 and 2040. This leads to additions totalling 22.5

mb/d by 2040, which compares to 19.6 mb/d of total crude distillation capacity additions by 2040.[17]

Two features stand out. Firstly, while major new refinery projects are designed with significant desulphurization capacity built in, the high level of total desulphurization additions relative to distillation, points to substantial desulphurization additions occurring at existing refineries as they adapt to meet progressively tighter fuel sulphur standards. Secondly, a considerable slowing in the pace of desulphurization capacity additions is apparent in the decade from 2030–2040, compared to 2022–2030. This follows from the projection that most regions will see gasoline/distillate fuel volumes reach ULS standards by 2030.

In terms of the regional breakdown (Figure 5.20), total additional global desulphurization capacity of 22.5 mb/d by 2040 is projected to be led by the Asia-Pacific at 10.1 mb/d, of which China comprises 4.2 mb/d. The Middle East follows with around 4.6 mb/d and then Latin America with 2.9 mb/d, driven by demand, the expansion of the refining base and stricter quality specifications for domestic fuels. Africa is likewise projected to need some 2.3 mb/d of desulphurization additions as the region also moves towards tighter standards for transport fuels. Significant additions are also projected for the Russia & Caspian region (1.6 mb/d), which is in line with the region's tightening domestic quality standards and the intent to produce diesel to ULS standard for both domestic use and export to Europe. In terms of timing, for both the Russia & Caspian and the Middle East, a high level of what projects leads to some 36–38% of

Figure 5.20
Desulphurization capacity requirements* by region, 2017–2040



* *Projects and additions exclude naphtha desulphurization.*

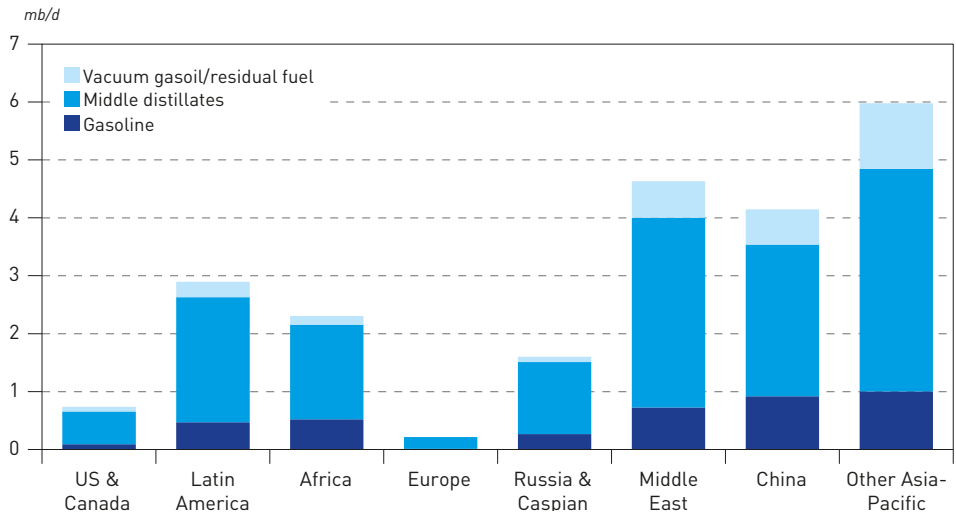
total additions projected to 2040, coming online by 2022. Conversely, for Latin America, Africa, China and Other Asia-Pacific, projects there comprise only 11–17% of the total by 2022 with the majority of additions coming in the 2022–2030 period.

The 0.7 mb/d requirements for the US & Canada comprise less than 0.3 mb/d from current projects, plus minor long-term additions to deal with high sulphur crude from oil sands. The lowest desulphurization capacity additions are projected for Europe, with a minimal 0.2 mb/d over the forecast period, where transport fuels are already at ULS standards, and both demand and refinery throughputs are projected to continue to decline.

In respect to the main product categories, of the 22.5 mb/d of global desulphurization capacity additions between 2017 and 2040 (excluding naphtha desulphurization), some 69%, or 15.5 mb/d, are estimated for distillate desulphurization, followed by 4 mb/d for gasoline sulphur reduction. The remaining 3 mb/d is for VGO/resid processing (Figure 5.21).

It is important to note that opportunities to revamp existing distillate desulphurization units could impact the required capacity addition levels indicated. The modelling incorporates relatively conservative assumptions regarding the ability of refiners worldwide to repurpose existing distillate desulphurization units into ULS services. These opportunities are quite dependent on such issues as the age and configuration of existing units. However, the performance of distillate desulphurization catalysts continues to advance. Such trends could open up

Figure 5.21
Desulphurization capacity requirements* by product and region, 2017–2040



* *Projects and additions exclude naphtha desulphurization.*

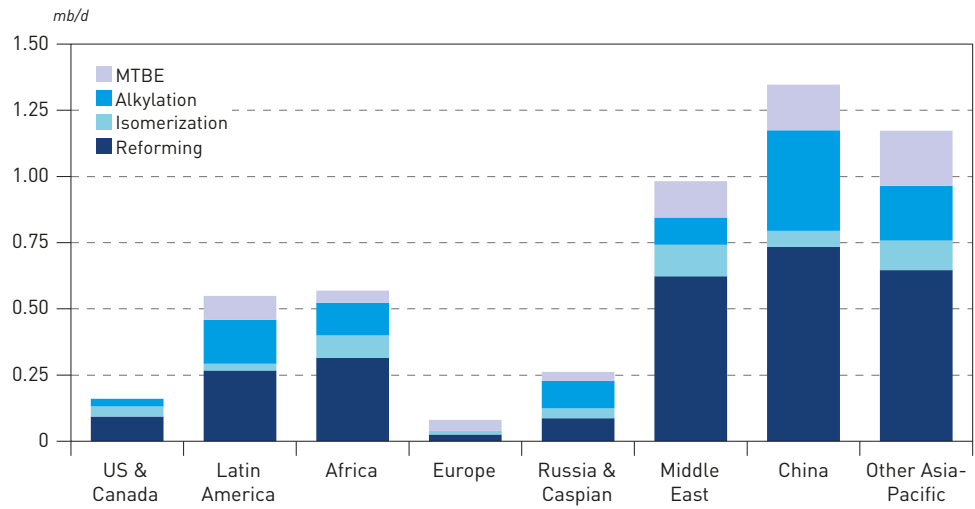
opportunities to revamp existing units to a greater degree than assumed in this Outlook. The effect would be to reduce overall costs and the level of requirements for wholly new capacity.

Octane units

For octane units, future requirements are projected at just over 5 mb/d throughout the forecast period (Figure 5.22). The majority of these units are expected to be needed in the form of catalytic reforming at 2.8 mb/d, with alkylation at 1.1 mb/d, isomerization at 0.5 mb/d and MTBE units at 0.6 mb/d. Reforming and isomerization raise naphtha octane and thus enable additional naphtha – including that from condensates – to be blended into gasoline.

In line with other secondary processes, most of these additions are projected for the Asia-Pacific and the Middle East, the two regions with the largest increases in gasoline demand and expanding petrochemical industries. Together, these account for close to 70% of the total expected octane unit additions to 2040. Latin America and Africa are also projected to have significant octane unit additions as their gasoline standards rise, each accounting for around 11% of the total. The US & Canada, Europe and the Russia & Caspian each account for 3%, 2% and 5%, respectively, of total additions. Of projected MTBE capacity additions totalling over 0.7 mb/d to 2040, some 70% are in the Middle East and the Asia-Pacific, with the balance spread across all regions except for the US & Canada where MTBE is not used. The US has the refinery and/or merchant feedstocks, but MTBE use was effectively banned in 2006. This means that all MTBE capacity there has been shut down except for about 40,000 b/d of Gulf Coast merchant units whose product is exported.[18]

Figure 5.22
Octane capacity requirements by process and region, 2017–2040

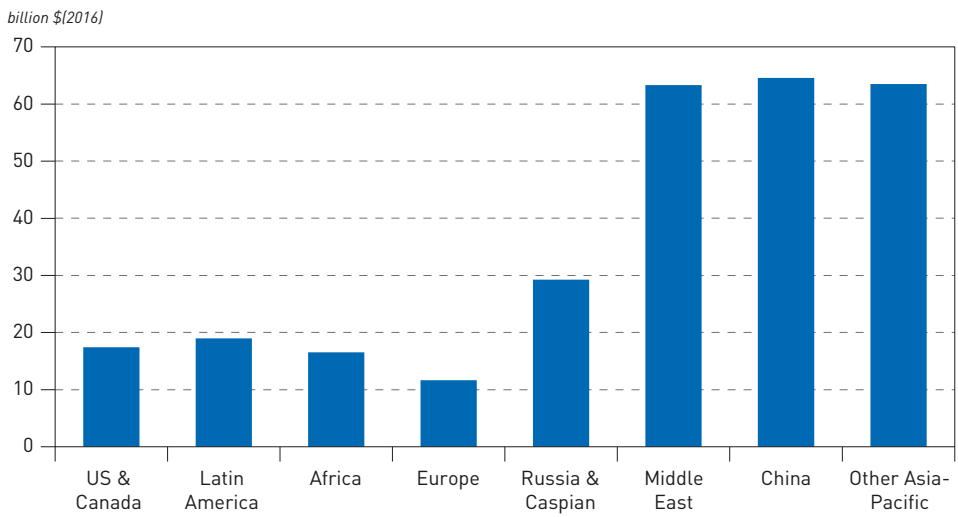


5.2.3 Investment requirements

For the purpose of this Outlook, investment requirements in the refining sector are shown in three different categories. The first category relates to identified projects, which are expected to be commissioned in the medium-term (2017–2022). The second category is related to investments in new projects in the long-term. These are refining capacities estimated as required and are in line with the assumptions in the Reference Case. The third category focuses on maintenance of the global refining system and covers necessary capital replacements.

For the first category (shown in Figure 5.23), total investment volume is estimated at around $285 billion.[19] This amount is, however, unevenly distributed between regions, and is in line with the medium-term outlook on refining capacity expansion and demand development. The largest share of investments is projected in the Asia-Pacific and the Middle East. Investment volume for the two regions combined is seen at around $190 billion, which is more than 65% of the global investment volume, up from around 60% estimated in the WOO 2016. The investment in the Asia-Pacific alone is estimated at almost $130 billion in the medium-term, of which essentially half ($65 billion) is located in China. The rest is distributed across the rest of the Asia-Pacific region (notably in projects in India, Vietnam, Malaysia and Indonesia). The major driver for this expansion is increasing demand. Additions in the Middle East during the medium-term are expected to result in an investment volume of around $63 billion, which is not only supported by increasing demand in the region, but also by efforts to increase product exports to other regions.

Figure 5.23
Cost of refinery projects by region, 2017–2022



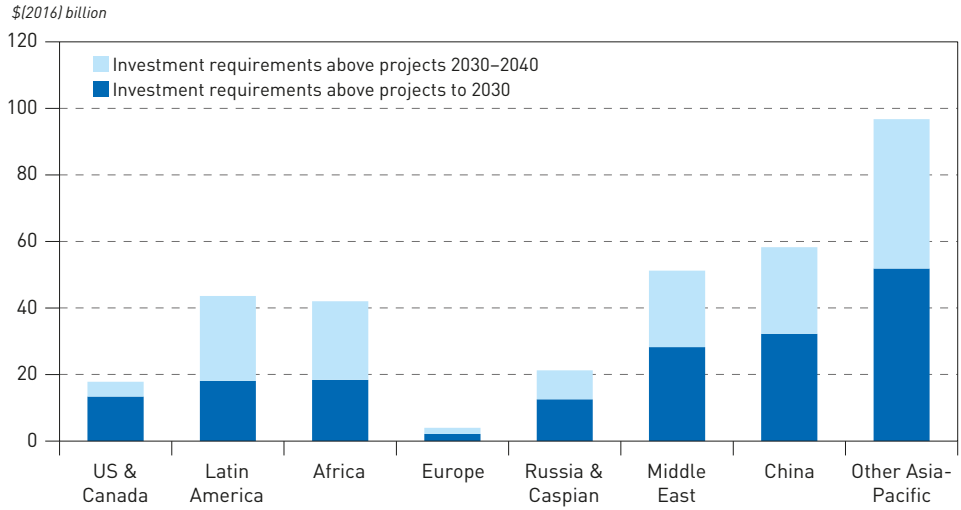
In Latin America, the volume of investments in refining projects is estimated at just below $20 billion in the medium-term, influenced by the region's overall slowdown. However, there are still a number of projects under construction and in post-FID phase, which are expected to be finalized within the medium-term, including projects in Brazil, Peru, Colombia and Argentina. In Africa, an investment volume of around $17 billion is expected in the period 2017–2022 driven by healthy demand growth and a relatively high share of product imports that stimulates capacity additions. A large share of the investment volume in Africa the in medium-term is accounted for by some large projects, notably Dangote in Nigeria and Lobito in Angola, but smaller projects and upgrades in North Africa (notably Algeria and Egypt) are also a factor.

Turning the focus to developed countries, the US & Canada region is seen to invest more than $17 billion in refinery projects in the medium-term. Recent years have already seen healthy investment activity in this region based on US tight oil and condensate feedstock, with several new condensate splitters. Several additional projects of this kind are expected in the coming years combined with limited capacity expansions and upgrades. In the Russia & Caspian region, the total investment volume in the medium-term is estimated at levels just below $30 billion. The refinery sector is dominated by expansions and upgrades of secondary capacity, which will help to reduce the output of fuel oil and increase exports of clean products. Finally, Europe is the region with the expected lowest investment activity with only $12 billion until 2022. This investment volume includes one single new refinery (Aliaga in Turkey), but also a number of upgrading and expansion projects (such as Bulgaria, the Netherlands, Belgium and Finland).

Meanwhile, looking at the capacity additions needed in the long-term (after the medium-term period ending in 2022), there are significant assessed investments needed in order to maintain sufficient refining capacity to balance market demand at the global and regional levels. All these further additions are the result of modelling based on the Reference Case supply and demand assumptions. According to the estimates, investments of around $335 billion will be needed in the period until 2040, as shown in Figure 5.24.

Similar to the medium-term estimates, the majority of investments will be located in the Asia-Pacific (excluding Japan and Australasia) and the Middle East regions, but also Latin America and Africa, mostly driven by rising demand. Developed countries should see only limited investment activity in the long-term, which reflects stagnating and declining product demand in these countries. Around $155 billion of investments is estimated for the Asia-Pacific, which is just above 45% of the global investment volume in the long-term. More than one-third is accounted for by China with almost $60 billion of investments. The fact that this investment volume is lower compared to investments in the medium-term reflects the long-term slowdown in demand growth in China. Meanwhile, investment in the Other Asia-Pacific in the long-term is estimated at levels close to $100 billion, which is considerably higher compared to the medium-term period. The main reason for this is the sustained high growth in demand projected for India and other countries in the region. In the Middle East, the investment activity in the refining sector in the long-term is set to continue, although at a slower pace compared to the medium-term. An investment volume of just above $50 billion is projected for this region in the long-term.

Figure 5.24
Projected refinery direct investments* above assessed projects



* *Investments related to required capacity expansion, excluding maintenance and capacity replacement costs.*

Africa and Latin America are regions that are likely to expand their refining sector in the long-term as demand is still expected to increase and both regions still rely on product imports. Investment volume in Africa in the long-term is estimated at around $42 billion, while at the same time, in Latin America, the outlook sees investments of around $44 billion. New projects in both regions will likely have to compete against exports from the US and Europe, which are expected to limit the number of new projects. This is also confirmed by the level of net product imports in the two regions, which are not projected to decline in the long-term.

In the Russia & Caspian region, the level of new investment is seen at around $21 billion to 2040, above firm projects. Since the region has a surplus of refining capacity and shows only minor growth in product demand in the long-term, there is no incentive to expand capacity. In addition, oil demand in the traditional export market for Russian refiners (Europe) is seen declining in the long-term, which is another reason for the relatively low investment volume. The largest share of investments is expected to occur in secondary capacity in order to comply with stricter product specifications.

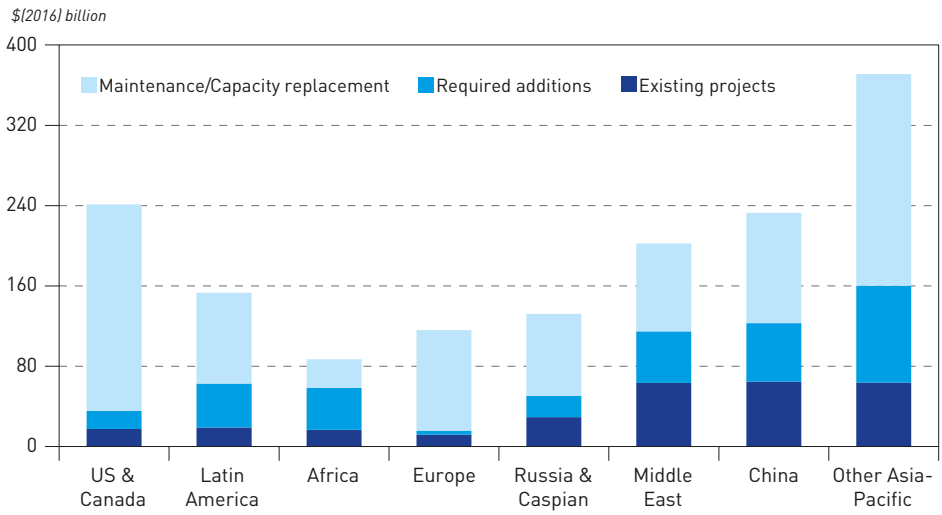
In the US & Canada, the refining sector is expected to see only minor expansions in the long-term, as demand is expected to peak and decline towards the end of the period. However, some investments can be expected, especially in secondary units as the share of heavy and sulphur-rich crudes from Canada increases. As a result, an investment volume totalling around $18 billion is expected in the long-term. Finally, investments in Europe in the long-term relate only to minor expansions (debottlenecking and secondary capacity) due to

declining long-term oil demand in the long-term in combination with strong competition from other regions such as the US, the Russia & Caspian and the Middle East. Consequently, the projected investment volume is around $4 billion between 2022 and 2040.

In total, the first two categories (identified projects in the medium-term and generic investments in the long-term) make up around $620 billion. This is the level necessary to accommodate the development of oil demand in the long-term in terms of growth and regional distribution. Moreover, stricter environmental regulations regarding product quality are also driving investments into the downstream sector. The $620 billion estimate is somewhat lower whe compared to last year's projections. It is remarkable that out of the total estimated investment volume of $620 billion, around 45% is estimated to occur in the medium-term, while the rest will be distributed in the long-term. The main reason for this is demand developments, with growth expected to slow gradually in the long-term.

Finally, maintenance and the replacement of installed refining capacity over the forecast period 2017–2040 is expected to require associated investments of around $915 billion. The assessment of this category of investment is based on the assumption that the annual capital needed for capacity maintenance and replacement is around 2% of the cost of the installed base. Based on this approach, the largest share of maintenance costs occurs in developed countries in the medium-term as these countries have the highest level of base capacity. However, in the long-term, the share of maintenance and replacement costs are anticipated to increase in favour of developing countries. This is the reason why in the US & Canada long-term maintenance and replacement costs of just above $200 billion are estimated. At the same time,

Figure 5.25
Refinery investments in the Reference Case



for Other Asia-Pacific (excluding China) they stand at $210 billion. Other regions (except for Africa) show maintenance and replacements cost levels between $80 billion and $110 billion, resulting from an increase of capacity (Latin America, Middle East, China) or high base capacity (Europe, Russia & Caspian). Africa is the only region with low maintenance and replacement costs in the long-term, estimated at just below $30 billion, based on relatively low investment activities in this region.

In summary, as shown in Figure 5.25, the total volume of the three categories of downstream investments is estimated at around $1.5 trillion in the period 2017–2040. Of this, $285 billion is expected to be invested in known projects in the medium-term, while $335 billion is anticipated to be invested in additions beyond known projects in the long-term. Thus, the investment requirement for maintenance and replacement is estimated at around $915 billion for the whole period 2017–2040.

Oil movements and trade

Key takeaways

- Global crude movements are expected to increase by around 6.5 mb/d between 2016 and 2040, moving from 37.5 mb/d in 2016 to almost 44 mb/d in 2040.
- The rise of the global crude trade is supported by the expansion of the export pipeline infrastructure, especially in North America and Russia & Caspian.
- At the global level, the Middle East will remain the region with the highest oil exports in the long-term. Crude export volumes, estimated at above 19 mb/d in 2016, are projected to increase to almost 25.5 mb/d in 2040. The share of flows to the Asia-Pacific rises to 85% in 2040, up from 75% in 2016.
- Crude oil flows from Latin America are projected to decrease gradually to below 4 mb/d in 2040 from 5.5 mb/d in 2016. This is in line with increasing domestic demand and expanding domestic refining projects.
- Oil exports from the Russia & Caspian region are projected to rise from around 6.1 mb/d in 2016 to a level slightly below 7.5 mb/d in 2040. Europe remains the most important outlet and these are increasing flows to the Asia-Pacific.
- Total export volumes from Africa are seen as rather flat at 5.5 mb/d in the medium-term, after which they are expected to decline in the long-term towards 5 mb/d by 2040 as domestic refining capacity expands.
- Oil exports from the US & Canada are projected to increase to over 3 mb/d by 2020, supported by the expansion of oil output in the US & Canada, but also by increasing imports of lower-quality grades from Latin America and the Middle East.
- After a peak around 2020, crude oil flows to the US & Canada are projected to decline gradually, as local oil demand declines and the supply of heavy grades from Canada increases.
- Total European imports are expected to increase somewhat in the period to 2020 due to expanding medium-term demand. In the long-term, however, imports are likely to witness a stepwise drop to levels around 9 mb/d (from around 10 mb/d in 2020), as expected reductions in oil demand are likely to more than offset Europe's declining indigenous production.
- Oil imports to the in Asia-Pacific are expected to increase from some 21 mb/d in 2016 to around 30 mb/d in 2040. This reflects not only the increase in demand, but also a decline of almost 3 mb/d in local production in the period 2016–2040.
- On a net import basis the Asia-Pacific is projected to more than double its product net imports between 2020 and 2040 to reach levels around 9.5 mb/d in 2040. This is mostly offset by the expansion of product net exports from the Middle East and US & Canada.

Trade movements of crude oil, products and intermediate streams between regions are what make the downstream truly integrated into the global system. In order to move physical barrels of oil from one region to another, different transportation modes can be used, such as pipelines, tankers, rail or road transportation.

6.1 Logistics developments including pipelines, ports and rail

Developments in logistics infrastructure are crucial for maintaining oil exporting capabilities and the availability of products to major markets. Crude oil and product movements tend to vary with the type of infrastructure developments in place. This applies mainly to pipelines for crude oil movements that can move important volumes and provide economies of scale and, to a lesser extent, to rail systems. Thus, developing infrastructure from pipeline, coastal terminals and berthing capacities for moving crude and oil products, including liquid hydrocarbons, is central to accessing new international markets and providing export flexibility. Some specific regions require a continuous focus of attention because of their potential to alter inter-regional crude trade. This applies especially to China, Russia & Caspian and North America regions that are important hydrocarbons resources and strategic locations.

US & Canada

The main logistics developments in the region reflect the growth in recent years of Canadian oil sands and North American tight oil. In the US, these have meant a massive build-out and re-orientation of the crude oil logistics system, primarily to take large new production volumes to the coasts – instead of bringing imported crudes inland. Pipeline capacity within western Canada, cross-border into the US and east to Sarnia and Montreal has also been expanded. In parallel, substantial crude-by-rail capacity has been developed, especially from the Bakken and other US producing regions to the coasts, as well as to carry western Canadian production to eastern Canada and US destinations.

The impact of this array of developments has led to excess capacity in some locations, notably total pipeline-plus-rail Bakken take-away capacity, and, generally, to adequate capacity – for now – in terms of moving both US and Canadian crudes to coastal markets. The primary exception is western Canadian crude oil production, which remains largely land-locked, at least via pipeline. The 300,000 b/d Enbridge 'Line 9' reversal has increased the volumes of western Canadian crude that can reach Sarnia and via shuttle tanker to Montreal. Together with new rail capacity to the area, this has meant the beginning of a small-volume of marine shipments out of Montreal to overseas markets, notably Europe. On the west coast, capacity to reach open water is still minimal and will remain so until either the Trans Mountain pipeline expansion or other pipeline/rail projects to coastal ports go ahead. Cross-border pipeline flows from western Canada into the US are also at close to capacity. According to the Canadian Association of Petroleum Producers (CAPP) in its June 2017 Outlook, western Canada takeaway capacity narrowly exceeds current production. Box 6.1 examines how this may play out over the next few years depending on the progress of four high-profile export projects that have to date been meeting some strong headwinds.

Box 6.1

Getting Canada's oil out: the story continues

As reported in the WOO 2016, four major projects have been proposed to supply additional export pipeline capacity for Western Canadian Sedimentary Basin (WCSB) crudes: Trans Mountain and Northern Gateway west to the British Columbia coast, Energy East to Montreal and the Atlantic, and Keystone XL to the US Gulf Coast. Over the last year, significant developments have taken place on these 'big four' pipeline projects.

The $7.4 billion **Trans Mountain** pipeline expansion, initially proposed by Kinder Morgan in 2013, has the potential to increase the pipeline's throughput capacity from 300,000 b/d to 890,000 b/d and carry oil sands streams, as well as light/medium crudes and products from Alberta, to a port near Vancouver, British Columbia. The expansion would comprise the construction of an additional line parallel to the current system. Adding capacity to the western Canadian seaboard would allow greater volumes of oil sands and other western Canadian crudes to reach the US West Coast, but also the Asia-Pacific market, the fastest growing crude market in the world. While the pipeline expansion is not a complete certainty – several environmental organizations have since sued to stop the expansion – it seems likely that the project will now proceed. Construction is slated to begin in late 2017 with a targeted in-service date of December 2019.

On the same day that the Trans Mountain pipeline was approved, the $6.5 billion **Northern Gateway** project was blocked. The project was proposed by Enbridge in 2006 to allow up to 525,000 b/d of crude to flow from Alberta to a west coast port in Kitimat, British Columbia. The 1,200 km pipeline project was approved by the federal cabinet in 2014, but has since faced an array of roadblocks and difficulties. Another project that has been cancelled is TransCanada's **Energy East** pipeline. In 2013, TransCanada proposed to move 1.1 mb/d of oil sands from Alberta and Saskatchewan to refineries and terminals on Canada's eastern coast with estimated costs of around $12.1 billion. The project would allow western Canadian crude to reach markets in Eastern Canada and then, via tanker, to the US East Coast, US Gulf Coast, and other international markets including Europe and India. The project would also reduce the need for imports of foreign crude. TransCanada's initial estimate was that start-up would occur by the end of 2020. Nevertheless, the project has faced regulatory delays and resistance from local Canadian officials. In October 2017, TransCanada announced that it would withdraw from the project.

Following the Republican Administration of Donald Trump taking office, the **Keystone XL** project has been revived. While no construction timeline has been announced, previous estimates indicated that the construction process would take two years. However, TransCanada has indicated that difficulties exist in confirming shipper commitments on the proposed pipeline. Owing to the high-profile regulatory nature and the environmental pushback surrounding this project, analysts predict that the project will not be fully operational until mid-2021.

It remains to be seen how the remaing active projects develop and what impact they will have on crude oil movements and economics, as they still face hurdles over regulatory and environmental issues.

The advent of broadly adequate capacity, accompanied by cuts to cash flow and a drop in US production in 2016 due to lower oil prices, has led to a slowing in the pace of infrastructure development. Moreover, several projects that are currently active, both pipeline and rail, have become the subject of intense regulatory scrutiny, often in combination with extensive grass-roots resistance. One example is the Dakota Access Pipeline that would take an initial 450,000 b/d of Bakken crude to Illinois and then, via a converted natural gas pipeline, to the Gulf Coast. This line has started up, but remains the subject of legal challenge. Similarly, a number of projects for crude-by-rail offloading terminals on the US west coast have increasing hit regulatory hurdles, leading to delays and potential cancellation. Until recently, it has been the case that projects that are entirely within the US or Canada and/or which are reversals or expansions of existing lines, or use existing rights of way, have tended to move ahead without great difficulty. The examples cited of current projects hitting hurdles indicate this may not always be the case going forward. A lot depends on location. It is noteworthy that pipeline projects in Texas, where the build-out of capacity to, and along the Gulf Coast from the Eagle Ford and the Permian basin are generally proceeding without undue hold-ups.

Against this backdrop, the Reference Case outlook is for combined US & Canadian crude and condensate production to grow from 12.5 mb/d in 2016 to nearly 17 mb/d by 2030, before dropping back to around 16 mb/d by 2040. This indicates a need for additional capacity with the main strain potentially the movement of Canadian crudes. Nameplate total crude-by-rail loading capacity stands today at close to 3.5 mb/d, of which 0.9 mb/d is in western Canada and much of the rest in the Bakken region. Off-loading capacity stands at well beyond 4 mb/d of nameplate capacity. Of this, half is on the US Gulf Coast, but appreciable capacity also exists on east and west coasts, excluding western Canada.

With the pipeline capacity build-out and the US production decline in 2016, crude-by-rail volumes have dropped and utilizations are low. In principle, this capacity should, therefore, provide a buffer to absorb and move production growth. Canadian and US regulators have put forward coordinated new standards aimed at increasing rail-car and overall crude-by-rail safety following a string of accidents. The series of deadly crude-by-rail accidents that occurred in 2013 through 2015 (essentially all involving light Bakken crude) has not been repeated since, signifying possible safety improvements. It remains to be seen whether this will be enough to quell concerns to a sufficient extent to support a new round of crude-by-rail expansion, as and when needed.

Russia & Caspian

Russia's large oil and gas resources, as well as its geographical position, offers commercial opportunities to reach major international markets, west to Europe and east to China and the rest of Asia. Currently, a large share of oil exports is exported via pipeline systems such as the Druzhba pipeline system to Eastern Europe and the Eastern Siberia-Pacific Ocean (ESPO) pipeline to China and the Pacific Ocean. Russia is continuously developing its pipeline network in order to adapt to changing dynamics in the global oil market.

In Asia, Russia continues efforts on the expansion of the ESPO pipeline system to China and the Pacific Coast. The ESPO pipeline was inaugurated in 2009 and is now an outlet for volumes of the ESPO blend to the Asia-Pacific market, which is now a well-established source of supply for refin-

ers in this region. The estimated capacity of the pipeline to East Siberia (Taishet) and to Skovorodino is around 1 mb/d, while the branch to China is estimated at around 300,000 b/d (and possibly even 450,000 b/d, including extra pumping stations). The capacity of the branch from Skovorodino to the Pacific Coast is estimated at 600,000 b/d. A further connection branch of the ESPO pipeline to the Khabarovsk refinery was completed in 2015 (120,000 b/d), while the expansion to the Kosmomolsk refinery is expected in 2018 (160,000 b/d).

The final stage of the overall ESPO expansion is ongoing and scheduled for completion by 2020. In total, by 2020 the capacity of the ESPO pipeline to Skovorodino (main line) should be increased to 1.6 mb/d and from Skovorodino to the Pacific Coast to 1 mb/d. The capacity of the spur pipeline to China's Daqing region is set to increase to around 600,000 b/d. Petrochina's 200,000 b/d Liaoyang refinery is likely to run almost entirely on ESPO Blend. The outlook assumes further expansions of the ESPO pipeline system to China and the Pacific Coast with the overall capacity anticipated to increase to 2 mb/d by 2030 and 2.4 mb/d by 2040. On the supply side, some expansions were seen in 2016 with a new line between Krasnoyask Kray and Taishet (170,000 b/d), connecting new fields with the ESPO pipeline. Furthermore, Transneft is also looking to increase the capacity of the pipelines connecting fields in West Siberia, in order to connect them with the ESPO.

On the European axis, Russia's Rosneft intends to extend part of the Druzhba pipeline system to connect with southern Germany refineries where the company holds interests. The shortest route for crude deliveries to these refineries would be an extension of the 179,000 b/d Druzhba leg, which currently ends in the Czech Republic. However, the expansion is surrounded with a lot of uncertainty. It is feared that it will prove difficult to finalize due to potential difficulties in securing financing and regulatory approvals.

Furthermore, some limited expansion of eastbound export-oriented pipeline capacity is expected in the Caspian countries. Already under construction is a joint project between the Kazakh state oil company KazMunayGas and China National Petroleum Corporation (CNPC), which is designed to double the existing line between Kazakhstan and China from the current 200,000 b/d to 400,000 b/d. This expansion, together with the ESPO, will provide more than 2 mb/d of eastward oriented crude exports from the Russia & Caspian region by 2020. Plans beyond 2020 are uncertain at this point, but the prospects for expanding production in the Caspian region, combined with Asian demand growth, make it likely that this infrastructure will be further expanded. For the purposes of this Outlook, further expansions in export capacity to the Asia-Pacific from the Caspian region over the long-term have been assumed.

Other regions

Transport infrastructure to supply the new 260,000 b/d Kunming (Anning) refinery in the landlocked Yunnan province in the south of China has already been completed. This is a joint investment between CNPC and the Myanmar Oil and Gas Enterprise. A deep sea port and a 2,400 km pipeline through Myanmar to China's Yunnan province were designed to ease China's reliance on the congested Malacca Strait, through which the bulk of oil destined for Asian market transits. This investment is one of the key elements of China's energy security strategy. The 440,000 b/d pipeline (operated by CNPC) starts at Kyauk Phyu in Myanmar's west and enters China at the border city Ruili. CNPC has already received its first Azeri Light crude oil shipment

through the new pipeline, which initiated the refinery's commissioning phase. Configured to generally run heavy, high-sulphur grades, the Kunming refinery is most likely to import Middle Eastern barrels. However, the final terms and conditions of the pipeline operation are still to be decided. Beijing and Naypyidaw are set to renegotiate some of the terms of the agreement on the oil pipeline supplying the plant. The start-up date for the Kunming refinery could also be delayed by a standoff with Myanmar over a pipeline tariff.

A significant industrial and logistics developments is also taking place in Oman. The Omani Government is seeking to develop an important area of commercial, industrial, petrochemical and logistical activity around the port of Duqm. Incentives for investors and developers are provided for the entire zone as the country moves forward in its economic diversification. Kuwait and China have recently signed an agreement with the Omani Government. The former expressed an interest to construct a refinery and the latter to create an industrial zone in the Duqm area, close to the port installations. The Port of Duqm will serve primarily as a storage facility in the initial phase, feeding the refinery, which is expected to come online in 2021 and facilitate exports. The port will also be in a position to offer bunker fuels and could displace some bunker volumes from the UAE's Fujairah bunkering facilities. It is worth highlighting that Duqm has a frontage that opens onto the Indian Ocean and is ideally placed to integrate with flows bound for Europe, passing by the Strait of Bab el-Mandeb, and then through the Suez Canal. This is essentially flows between Africa and Asia.

The recent expansion of the Panama Canal has opened the possibility for larger ships to pass through the isthmus. The $5.4 billion expansion took nine years to complete and has more than doubled the cargo capacity of the canal. The expansion added a third set of locks to the canal to accommodate ships carrying around 14,000 containers compared to the old locks that could handle ships with only 5,000 containers. The prior Panamax vessels, the largest tankers that could navigate the locks pre-expansion, could carry 300,000–500,000 barrels (length 294 m, width 32.3 m, depth 12.56 m). The 'Neo-Panamax' (or 'Post-Panamax') vessels, the largest ships now allowed in the newly expanded locks, can transport 100,000 additional barrels for a total of 400,000–600,000 barrels (length 366 m, width 49 m, depth 15 m).

The expanded canal can also accommodate Suezmax ships, with one vessel already passing through in August 2016. However, the vessel, which can normally load 1 million barrels was only partially laden. In addition, the expanded canal will still not enable Very Large Crude Carriers (VLCCs) or Ultra-Large Crude Carriers (ULCCs) to navigate through it. Therefore, the expansion is not expected to have a great impact on the crude oil trade as the majority of that trade relies on large vessels. Nevertheless, as refined products are normally transported on smaller vessels, this could lead to an increasing flow of products through the expanded canal. In turn, this would lead to lower transportation costs for shipments of products from the US Gulf Coast to Asia.

6.2 Oil movements and major factors influencing flows of crude and products

Various factors can influence the direction and volume of these trade movements, such as regional crude and product demand; the production and quality of crude and non-crude streams; product quality specifications; refining sector configurations; trade barriers, tax regimes, or policy-driven

incentives; the capacity of existing transport infrastructure and its economics; ownership interests and potential term contracts; crude and product price levels and differentials; freight rates; and, at times, geopolitics. There is an interplay among these factors, that determines the volumes traded between regions at any given time. While some factors such as ownership interests lead to long-term movements of crude or products, other factors (regional price signals) result in short-term 'arbitrage' movements. The short-term movements are normally a consequence of regional price signals for crude or products, which allows competition between different suppliers.

In general, the economics of oil movements and refining result in a preference for locating refining capacity in consuming regions due to the lower transport costs for crude oil compared to oil products. Consequently, the majority of trade – especially long-distance movements – is accounted for by crude oil. However, when costs or other hurdles exist to building the required refining capacity, or where there are substantial regional supply/demand imbalances, the result can be a significant trade in products.

The majority of consuming countries are focused on securing supplies of refined products through local refining capacity rather than imports, regardless of the economic factors. While oil producing countries also seek to satisfy local demand from their own refining system, they also seek to increase domestic refining capacity in order to benefit from the export of refined products, instead of just crude oil. As an extension of this strategy, in their efforts to secure future outlets for their crude production, some producing countries may choose to participate jointly in refining projects in consuming countries, especially where long-term contracts for feedstock supply can be arranged. This creates ownership interests, which influence trade flows of crude oil and refined products.

The relationships between the various factors mentioned can at times result in oil movements that are far from being the most economic or efficient in terms of minimizing overall global costs. In contrast, movements generated by the WORLD model are all based on an optimization procedure that seeks to minimize global costs across the entire refining and transport supply system, in accordance with existing and additional refining capacity, logistical options and assumed costs. For that reason modelling crude and product movements between the regions does not always include short-term factors (constraints) such as ownership interests, companies' policies, as well as long-term contracts, as it is impossible to predict them in the longer term. In other words, projected trade patterns in the WOO rather show optimal flows of crude and products under the consideration of the Reference Case assumptions.

Therefore, the model-based results on trade movements presented in this Chapter should provide a useful indication of future trends in crude oil and product movements, which necessarily function to resolve supply and demand imbalances at the regional level. As mentioned earlier, these projections are, of course, dependent on the Reference Case assumptions used in this Outlook (for crude supply, crude quality, product demand, refining capacity), which, if altered, could materially impact projected movements.

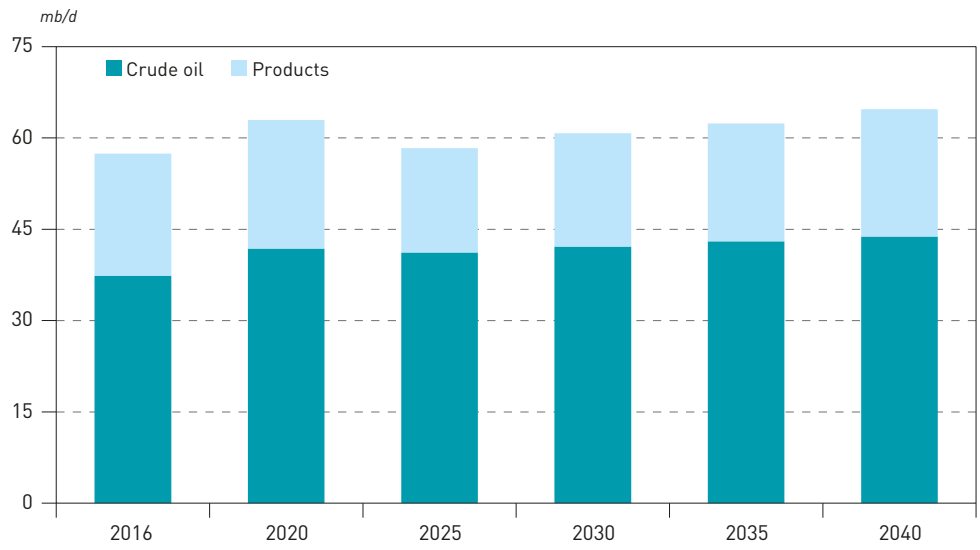
Over the longer term, the relative economics of building new refinery capacity in different regions, and the capability of existing refineries to export and compete against imports, all affect the trade patterns of crude and products. There is also the impact of freight rates on trade

flows and their interrelationship with regional refining costs. Broadly speaking, higher freight rates are likely to curb inter-regional trade and encourage more regional refining investment, while lower freight rates normally lead to greater trade between the regions and serve to provide those regions that have spare refining capacity with more opportunities to export products.

As set out in Annex C, the WORLD model represents the world as 23 regions and captures trade movements between them. For reporting purposes, these regions are aggregated into seven regions.[20] This necessarily eliminates from the reported trade activity those movements that are 'inter-regional' at the 23-region level, but which become 'intra-regional' at the more aggregated seven-region level. This is why the final reported level of trade activity is somewhat lower at the seven-region level versus the 23-region level.[21]

Figure 6.1 provides an overview of projected global oil and products trade volume to 2040, as reported on a seven-region basis. What is evident are shifts in the volumes of both total crude oil and products trade between 2016 and 2025, followed by a pattern of gradual increase in crude and products trade over the long-term.[22] The rather acute changes between 2016 and 2020 stem mainly from developments in the US & Canada region and the impact of the IMO regulations. As production in US & Canada increases, it is expected that crude exports rise significantly (described later in detail) to world markets. Although a net-importing region, the US & Canada is expected to export an appreciable share of its production, as a large portion of the crude produced is light-sweet (notably tight oil), which is sold at a premium to high-sulphur and heavier grades. Moreover, US refineries process mainly medium and heavy grades.

Figure 6.1
Inter-regional crude oil and products exports, 2016–2040



According to US Energy Information Administration (EIA) data, the US crude slate has averaged around 31.5° API between 2014 and 2016. This is well below the 40+° API levels of light tight oil streams. At the same time, imports to the US & Canada are also expected to increase by 2020 as most refineries in the US are complex and capable of converting low-quality and highly-discounted crude into high-value products, such as diesel and gasoline. The new IMO rules will put pressure on maximizing the processing and upgrading of heavy sour crudes to deal with the surplus high sulphur heavy fuel oil. As a result, both exports from, and imports to the US & Canada, are expected to increase significantly around 2020. This is also the main reason for the anticipated strong increase in the global crude trade between 2016 and 2020, from around 37.5 mb/d in 2016 to around 41.8 mb/d in 2020. In the period post-2020, the international crude trade is seen dropping somewhat by 2025, as more regions tend to use the crude locally in the newly installed refining units (for example, Latin America and Africa, as well as the Middle East). Thereafter, global trade increases gradually, in line with growing liquids demand. The overall crude and condensate trade in 2040 is estimated at just below 44 mb/d, which is almost identical to the levels seen in the WOO 2016.

Product movements are estimated at levels of around 20 mb/d in 2016. This level is projected to see a moderate increase by 2020 for two reasons. Firstly, traditional importing regions such as Africa, Latin America and the Asia-Pacific (excluding China) are estimated to witness healthy demand growth until 2020, but this is not sufficiently supported by an expansion of their refining systems. This leads to an additional need for refined products in these regions and more inter-regional trade movements. In addition, the new IMO regulations, effective as of 1 January 2020, is another reason for additional movements of refined products. The IMO regulation will likely result in extra production of high-sulphur fuel oil, which, most probably, will find its final outlet in the power generation sector. At the same time, regions with a simple refining set-up will have to increase imports of cleaner fuels (low sulphur fuel oil or diesel), while exporting high-sulphur fuel oil.

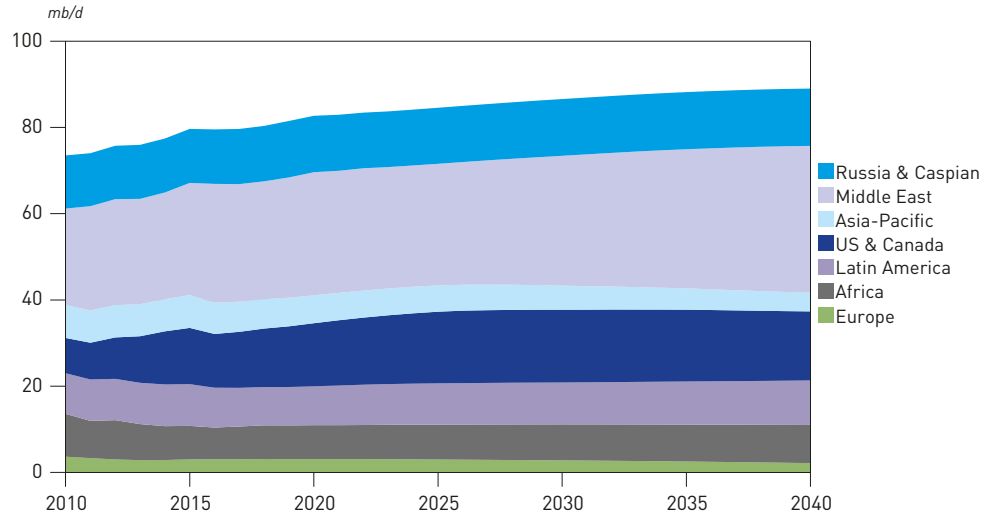
Altogether product movements are expected to rise to some 21 mb/d by 2020. However, as the system in the post IMO regulations era stabilizes and the refining system in product-importing regions expands, total product movements are projected to decrease significantly to around 17 mb/d in 2025. Another reason for this drop is the declining demand in the US & Canada, which leads to lower product imports by 2025. From this level, product movements are then seen to gradually increase to almost 21 mb/d by 2040. The trend generally follows overall demand growth to the end of the forecasting period.

6.3 Crude movements

As already mentioned, projections for crude oil movements between major regions are derived from the Reference Case assumptions on regional supply and demand patterns (Chapters 3 and 4), as well as assumptions on developments in refining capacity (Chapter 5), the installed base, and the complexity of the regional refining system. In addition, assumptions on the logistics of infrastructure development also play an important role in the future movements of crude oil.

Figures 6.2 and 6.3 portray the outlook for regional crude oil production in the outlook periods 2016–2020 and 2020–2040. While in the medium-term the US & Canada show the largest

Figure 6.2
Crude oil* supply outlook to 2040

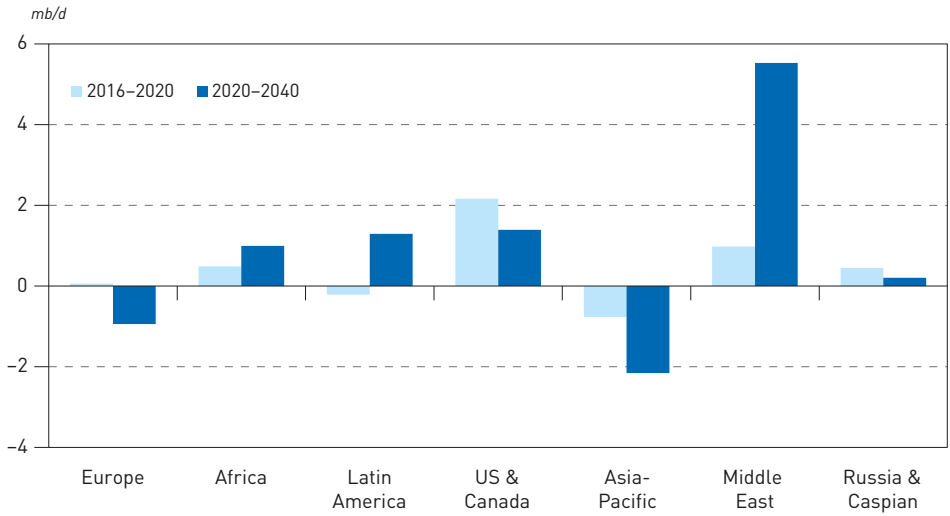


* *Includes condensate crudes and synthetic crudes.*

increase, the Middle East is the region with the most significant output addition in the long-term. Looking into more detail, in the medium-term the US & Canada is expected to add around 2.2 mb/d by 2020, mainly due to the expansion of US tight oil, while the Middle East is expected to increase by around 1 mb/d. In the same time period, minor increases are expected in Russia & Caspian and Africa, a total of around 900,000 b/d. Another important exporting region, Latin America, is estimated to see a slight decrease in the medium-term as declines in mature fields in Mexico are projected not to be offset by additions in some other countries, such as Brazil. Europe is anticipated to remain flat in the medium-term as the majority of production is already mature and starting to decline. Finally, the Asia-Pacific is likely to see a decline of almost 800,000 b/d as production is decreasing fast in several countries of the region, including China.

In the period 2020–2040, the picture is dominated by expected increases in the Middle East (mostly OPEC Member Countries) of around 5.5 mb/d. The majority of the increase comes after 2025, as elaborated in the Chapter 4. With this addition, the Middle East is set to reach output levels slightly above 34 mb/d, which is more than 38% of the global oil production (without NGLs). The US & Canada also remains an important contributor to the global supply additions in the long-term, with around 1.4 mb/d between 2020 and 2040. However, the region's output is projected to peak at almost 17 mb/d around 2030, followed by a gradual decline in the last decade of the outlook. The decline is mostly due to losses in US tight oil production, but conventional production too, although this is partly offset by growth in Canadian synthetic oil output (mostly heavy barrels).

Figure 6.3
Change in crude oil* supply between 2016 and 2040



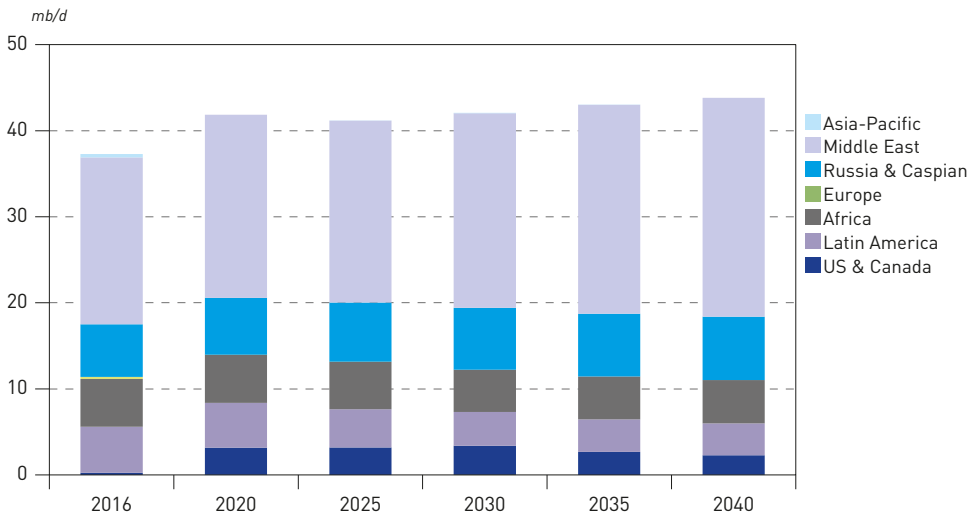
* *Includes condensate crudes and synthetic crudes.*

Latin America is projected to add around 1.3 mb/d in the long-term, to reach 10.3 mb/d by 2040. This is supported predominantly by increases in Brazil and Venezuela (heavy oil). Nevertheless several countries of the region are expected to show substantial losses in production, such as Mexico and Colombia. Africa is also expected to see a rise in production over the long-term with an increase of almost 1 mb/d between 2020 and 2040. The largest share of the increase can be attributed to the return of lost production in Libya. Further expansions of production are also expected in Russia & Caspian, although this is anticipated to be not more than 0.3 mb/d, to reach levels around 13.3 mb/d by 2040. The increase is expected to come mostly from new developments in Kazakhstan, while Russia's output is estimated to see a gradual decline in the long-term.

In Europe, the decline in production (mostly from the North Sea) is expected to continue in the long-term. Around 950,000 b/d is projected to be lost in Europe between 2020 and 2040, as North Sea production declines due to natural depletion. Similarly in the Asia-Pacific, oil output is estimated to decline by more than 2.1 mb/d, mostly due to ageing oil production in countries such as China, Malaysia, Indonesia and India.

In total, global crude oil production is expected to increase by 3 mb/d between 2016 and 2020, followed by an increase of 6.3 mb/d between 2020 and 2040. This is an increase of more than 9 mb/d for the forecasting period 2016–2040, with the Middle East covering the majority of this increase, especially in the longer term.

Figure 6.4
Global crude oil exports by origin,* 2016–2040



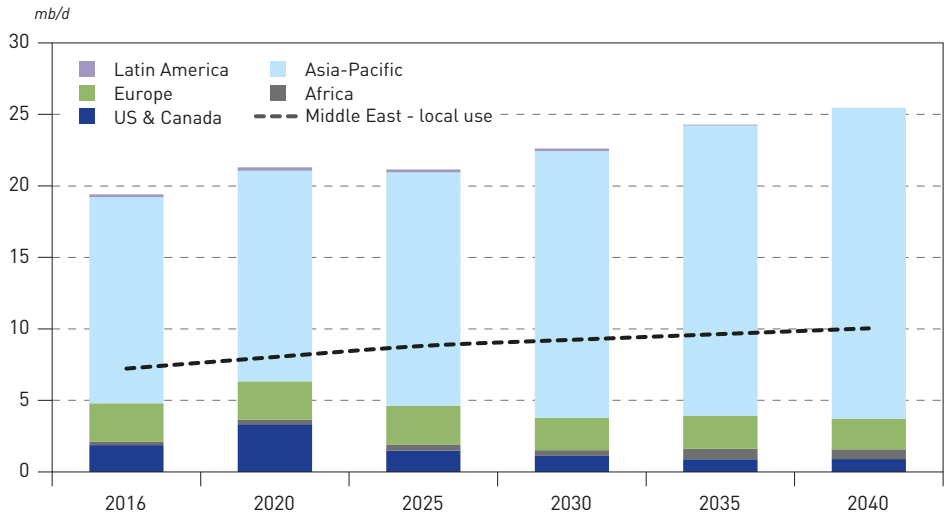
* *Only trade between major regions is considered.*

Figure 6.4 shows global crude exports in the period 2016–2040. These are expected to increase by around 6.5 mb/d. Between 2016 and 2020, the increase in global exports is likely to be significant, rising by more than 4 mb/d. This is mainly due to a strong increase in exports from the US & Canada, which jump from 200,000 b/d in 2016 to more than 3 mb/d in 2020. At the same time, imports to the US & Canada are expected to rise as US refiners are likely to look for additional barrels of lower-quality crude from Latin America and the Middle East. In the period 2020–2040, overall crude exports are seen to increase by 2 mb/d. However, some regions are expected to witness a decline, such as Africa, Latin America and the US & Canada (post-2030), but is more than offset by exports from Russia & Caspian and especially the Middle East.

In Figures 6.5–6.9, the regional outlooks for crude exports (including condensates and synthetic crudes) are shown. These focus on traditional exporting regions, as well as the US & Canada, which is set to become a major global oil exporting region. In Figures 6.10–6.12, the major importing regions are shown, the US & Canada, Europe and the Asia-Pacific. Finally, Figure 6.13 shows regional long-term net crude oil imports for all seven WORLD regions. As mentioned earlier, the figures shown are the result of the Reference Case assumptions on the regional crude oil supply and demand, as well as on the expansion of refining capacity and infrastructure.

At the global level, the Middle East will remain the region with the highest oil exports in the long-term (Figure 6.5). Export volumes, estimated at above 19 mb/d in 2016, are projected

Figure 6.5
Crude oil exports from the Middle East by major destinations, 2016–2040

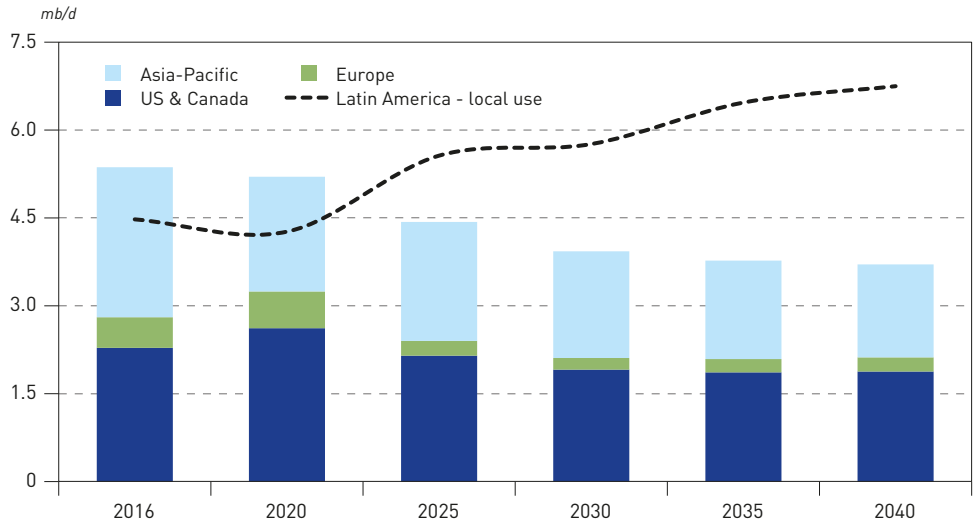


to increase to almost 25.5 mb/d in 2040. Compared with last year's outlook, Middle Eastern export volumes are around 1 mb/d higher in 2040, which is due to a higher demand outlook and lower supply from other exporting regions. The largest share of Middle Eastern exports is expected to flow to the Asia-Pacific, increasing from around 14.5 mb/d in 2016 to about 21.8 mb/d in 2040. The share of Asia-Pacific exports in overall Middle Eastern exports is seen to increase to around 85% by 2040, which is around 10 percentage points higher than in 2016.

Exports to the US & Canada region are estimated to remain significant in the period to 2020, with volumes increasing around 3.3 mb/d. This is from below 2 mb/d in 2016. This can be explained by rising exports of light sweet oil from the US & Canada, with US refiners at the same time importing heavier and sourer barrels, which normally trade at a discount to light sweet crude. As previously described, the new IMO rules create special conditions in 2020. However, after a peak around 2020, Middle Eastern exports to the US & Canada region are projected to gradually decline to just below 1 mb/d in 2040, mainly due to declining demand.

Exports from the Middle East to Europe are anticipated to remain stable at levels above 2.5 mb/d in the period to 2020, but then decline towards 2 mb/d in 2040. Compared to last year's outlook, Europe is expected to import less oil from Africa and Latin America, because of lower volumes available for exports from those regions. This leads to higher flows of Middle Eastern oil to Europe. The main uncertainties related to Middle Eastern exports to Europe are flows from the Russia & Caspian region, which increasingly focus on the Asia-Pacific.

Figure 6.6
Crude oil exports from Latin America by major destinations, 2016–2040

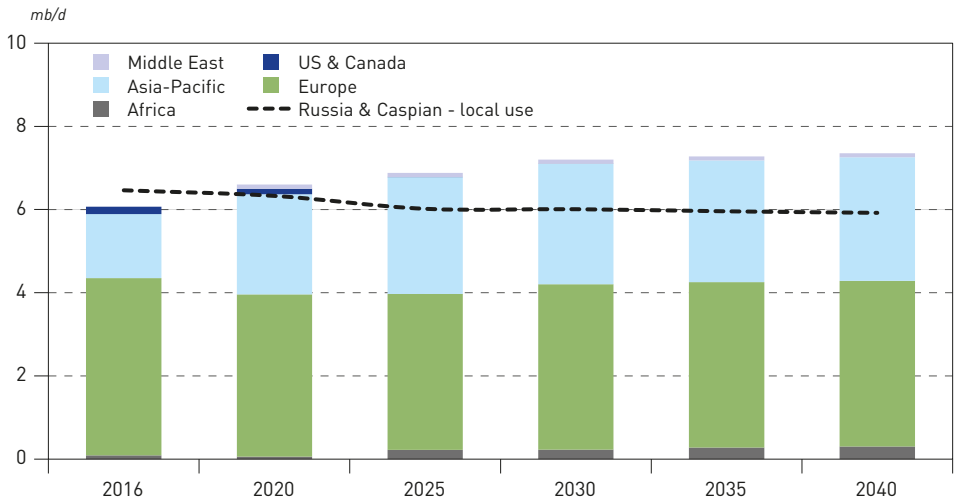


Finally, Middle Eastern exports to Africa are expected to increase gradually to levels around 700,000 b/d in 2040. This is from levels around 200,000 b/d in 2016, which reflects increasing demand in Africa and declining supply in some countries, such as Egypt. The local use of oil in the Middle East is estimated to increase from 7.3 mb/d in 2016 to 10 mb/d in 2040. This mirrors not only the increase in local demand, but also demand from export-oriented refining projects in the Middle East.

Overall oil flows from Latin America (Figure 6.6) are projected to decrease gradually, in line with increasing domestic demand and expanding refining projects, including the assumed re-start of the Aruba refinery. Flows are seen at around 5.5 mb/d in 2016, before witnessing a drop to below 4 mb/d by 2040. The majority of the flows are seen heading to the US, as the majority of US refiners are looking for low-quality oil supplies, which are discounted compared to light-sweet crude produced in the US.

Following an initial jump in exports to the US & Canada to just above 2.5 mb/d by 2020, exports are projected to decline to 1.9 mb/d by 2040. The flows to the Asia-Pacific decline by around 1 mb/d by 2040, from 2.6 mb/d in 2016. While exports to Europe are still significant by 2020 at around 500,000 b/d, they are projected to decline gradually to 200,000 b/d in 2040. The domestic use of Latin American crude declines initially to around 4.3 mb/d by 2020, which reflects the inflow of oil from the US & Canada. However, the level is estimated to increase to 6.7 mb/d by 2040, in line with expanding supply, increasing refining capacity and the overall refining utilization rate.

Figure 6.7
Crude oil exports from Russia & Caspian by major destinations, 2016–2040

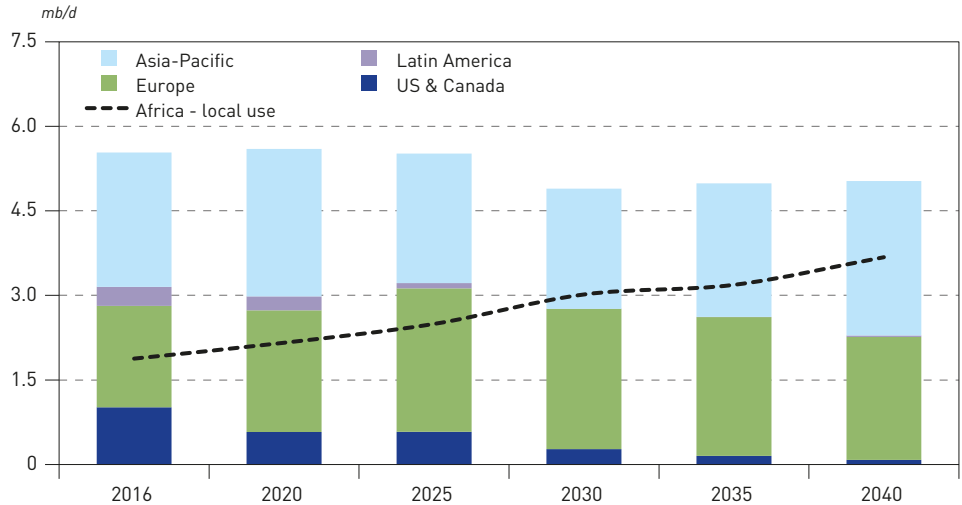


Oil exports from the Russia & Caspian region are projected to rise from around 6.1 mb/d in 2016 to a level slightly below 7.5 mb/d in 2040 (Figure 6.7). This is a situation almost identical to last year's outlook. Europe remains the most important outlet for oil from the Russia & Caspian region with volumes declining somewhat in the medium-term as supplies from the US & Canada kick-in. However, in the long-term, exports from the Russia & Caspian are seen stable at around 4 mb/d until 2040.

The second most important outlet for volumes from the Russia & Caspian is the Asia-Pacific, where exports are projected to increase gradually from 1.5 mb/d in 2016 to 3 mb/d in 2040. The increase in oil shipping to the Asia-Pacific is partly accounted for by the expansion of the pipeline capacity from Russia to China and the Pacific Coast, but also seaborne flows. Movements to the Asia-Pacific remain subject to the dynamics of the exports infrastructure development in the medium- and long-term. Furthermore, exports to the Asia-Pacific are projected to increase, competing with barrels from the US & Canada, especially around 2025, when production in the US & Canada region is expected to peak. Exports to the US & Canada, starting at 200,000 b/d in 2016 are estimated to disappear in the long-term as supplies in North America increase. The local use of oil is projected to decline from 6.5 mb/d in 2016 to just below 6 mb/d in 2040. This reflects increasing competition in the product export markets from the Middle East and North America and less demand in traditional importing regions such as Europe.

With a somewhat lower outlook for oil supply in Africa in the medium- and long-term, the outlook for oil exports is also dampened relative to the WOO 2016. Total export volumes from

Figure 6.8
Crude oil exports from Africa by major destinations, 2016–2040

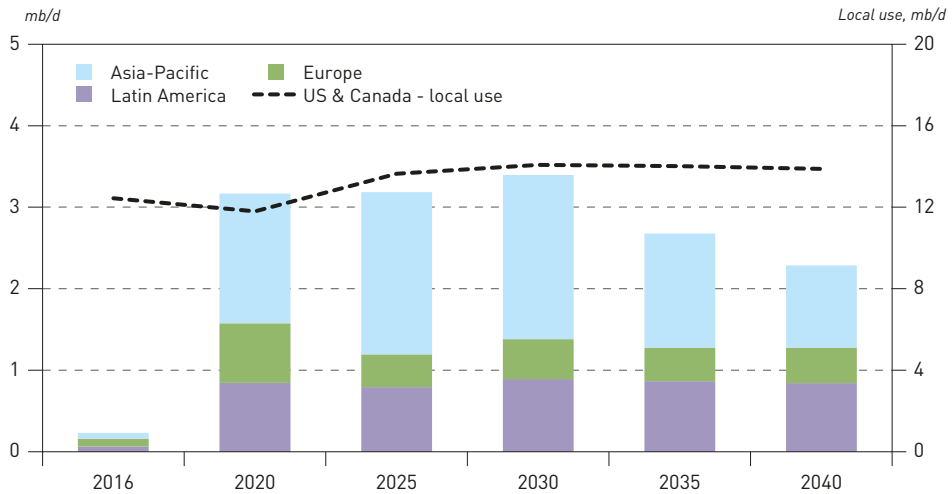


Africa are seen as rather flat at 5.5 mb/d in the medium-term, after which they decline in the long-term towards 5 mb/d in 2040. This is shown in Figure 6.8. This is in line with rising domestic refining capacity, which leads to increases in local consumption.

Exports to Europe are projected to increase from 1.8 mb/d in 2016 to 2.5 mb/d in the period 2030–2035. This is in line with growing supply in Africa and declining exports to the US. However, by 2040, oil movements to Europe are seen slightly lower, at 2.2 mb/d, as the local use of oil in Africa rises and demand in Europe eases. Looking to the Asia-Pacific, export volumes are seen to be stable in the medium-term at around 2.5 mb/d and are then projected to dip around 2030 as the flows from the US & Canada and the Middle East increase. Towards the end of the outlook period, the flows of African grades to the Asia-Pacific increase to 2.7 mb/d. Africa, which was a traditional supplier to the US, managed to raise flows to the US to 1 mb/d in 2016, from 400,000 b/d in 2015. This was due to lower US output during 2016, as well as the equilibration of markets at coastal competition points as US crude pipeline and rail infrastructure was built out. However, African flows to the US & Canada are anticipated to fall from 1 mb/d in 2016 to almost zero in 2040. The major reason is the increase in tight oil supply, which is similar in quality to African crude grades. Finally, the local use of oil in Africa is projected to almost double from 1.9 mb/d in 2016 to 3.7 mb/d in 2040.

As already highlighted in the WOO 2016, the US & Canada region is projected to become an important player on international crude markets with volumes anticipated to rise significantly in the medium-term. Following the lifting of the crude oil export ban in late 2015, the US & Canada was seen to export around 0.25 mb/d to international oil markets in 2016, with flows to Europe, Latin America and the Asia-Pacific. The relatively low volumes can be explained by

Figure 6.9
Crude oil exports from the US & Canada by major destinations, 2016–2040

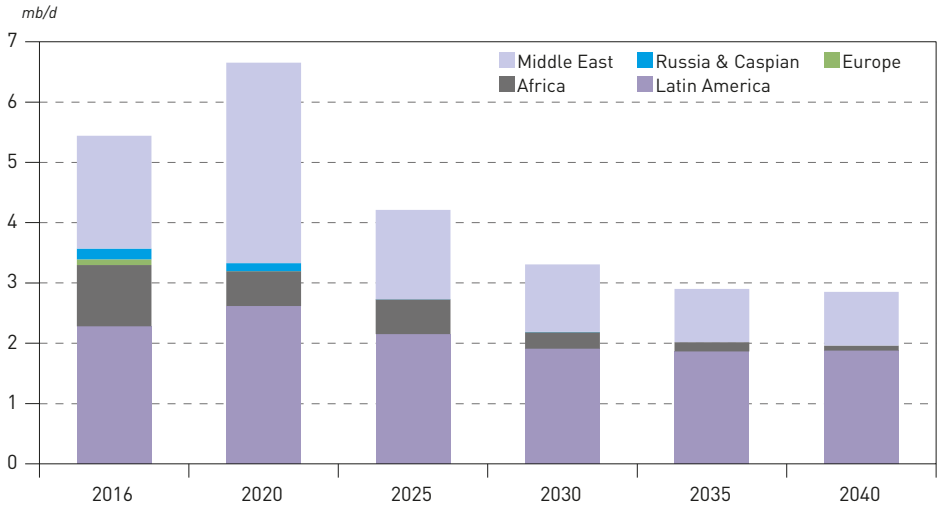


declining oil output in the US during 2016, with supplies around 12.5 mb/d, 600,000 b/d lower when compared to 2015. In line with expectations for rising oil supply in the US & Canada, oil exports are projected to increase strongly in the medium-term. In addition, the more optimistic outlook for Canadian pipelines (see Box 6.1) also supports increasing flows from the US & Canada region to international markets.

According to the Reference Case, oil exports from the US & Canada (Figure 6.9) are projected to have already increased to over 3 mb/d by 2020. This development is not only supported by the expansion of oil output in the US & Canada, but also by increasing imports of lower-quality grades from Latin America and the Middle East, which are more suitable for complex US refiners, compared to light tight oil. US & Canada exports are then seen stable at around 3.2 mb/d until 2025, before witnessing a slight decline towards 2.3 mb/d by 2040. This reflects the peak and decline in US oil production. The largest share of oil exports is expected to flow to the Asia-Pacific with volumes increasing to about 2 mb/d in 2025, before declining towards 1 mb/d by 2040. This comprises a combination of US and Canadian crudes.

Furthermore, stable, but significant volumes around 800,000–900,000 b/d are seen heading to Latin America, in the medium- to long-term, favoured by the relatively short distance and low transportation costs. Oil movements of 500,000 b/d to Europe in the longer term are also projected, which can be attributed to declines in local oil supply (mostly the North Sea). The local use of oil in the US & Canada is expected to witness a slight decline around 2020 as the region increases the import of lower-quality grades, but it then increases to levels between 13.5 mb/d and 14 mb/d in the long-term. The volume of heavy-sour barrels from Canada (notably synthetic oil) increases in the long-term, which is largely processed in the complex US refining system.

Figure 6.10
Crude oil imports to the US & Canada by origin, 2016–2040

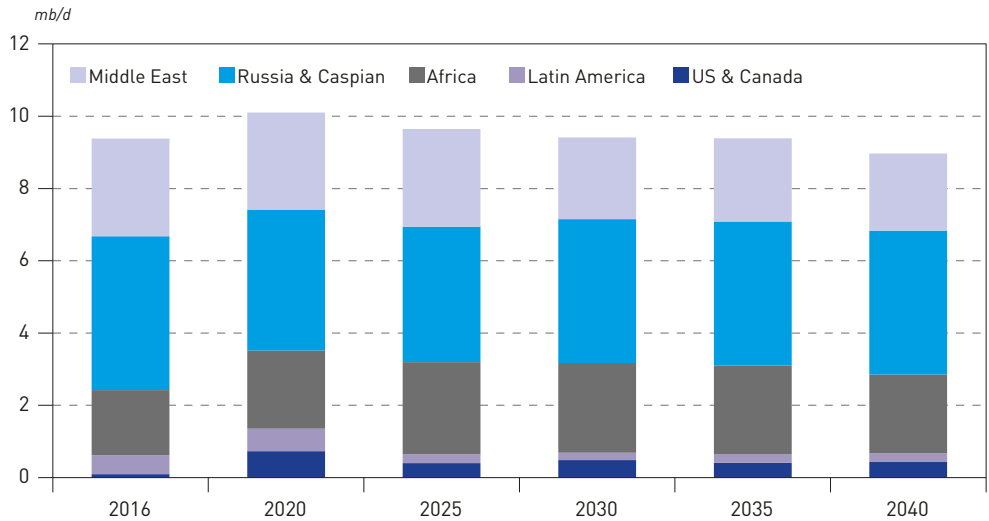


At the same time, crude oil imports into the US & Canada (Figure 6.10) are expected to increase around 2020, mainly driven by the relative economics of the different crude grades. US refiners, which prefer low-quality and discounted grades, are likely to increasingly turn their attention to supplies from Latin America and the Middle East in the medium-term. Imports of Middle Eastern volumes are expected to increase to around 3.3 mb/d in 2020, up from 1.9 mb/d in 2016. At the same time, Latin American imports are projected to climb to about 2.6 mb/d, an increase of some 0.3 mb/d from 2016. Interestingly, oil imports from these two regions are projected to decline gradually in the long-term, partly due to lower declining US oil demand, but also rising volumes of heavy supplies in Canada.

Latin American imports are seen to decrease only slightly over the longer term, due to the proximity of the region, with levels below 2 mb/d in 2040. At the same time, Middle Eastern flows are projected to fall from a peak of 3.3 mb/d in 2020 to below 1 mb/d in 2040. Imports from Africa are seen to be on a gradual decline throughout the outlook period, from 1 mb/d in 2016 to almost zero by 2040. This is mainly due to the increase of domestic supplies of sweet grades in the US, which are similar to African supplies in terms of quality.

Figure 6.11 gives an overview of European oil imports in the long-term, which after an increase in the period to 2020, witness a gradual decline. Total European imports are expected to grow in the period 2020 due to declining domestic supply (North Sea) and expanding demand, which moves from around 9.4 mb/d in 2016 to just above 10 mb/d in 2020. In the long-term, however, imports are likely to witness a stepwise drop to levels around 9 mb/d, as expected reductions in oil demand are likely to more than offset Europe's declining indigenous production.

Figure 6.11
Crude oil imports to Europe by origin, 2016–2040



The most important European oil supplier will likely remain the Russia & Caspian region. Despite seeing a slight drop in volumes in the medium-term, exports from this region to Europe stabilize at around 4 mb/d in the long-run. Oil from the Russia & Caspian region is supplied through the Druzhba oil pipeline system, but also through ports in the Baltic and the Black Sea. Some seaborne volumes also come from the Turkish port of Ceyhan (Azeri crudes) too. Although at lower levels, Middle East volumes have a significant share in the total European imports at around 2.7 mb/d until 2025, although this level is expected to decline in the long-term towards 2.1 mb/d by 2040. Similarly important are the flows from Africa, which are estimated to increase from around 1.8 mb/d in 2016 to 2.5 mb/d in 2025 as flows of African producers look for additional outlets in Europe, due to the anticipated loss of US market share. Finally, Latin American imports are projected to decline from around 500,000 b/d in 2016 to levels close to 200,000 b/d in 2040.

The Asia-Pacific remains the main importing region and is it expected to more than offset declines in other importing regions such as Europe and the US & Canada. Oil imports are expected to increase from some 21 mb/d in 2016 to around 30 mb/d in 2040. This reflects not only the increase in demand, but also a decline of almost 3 mb/d in local production in the period 2016–2040. The Middle East remains the most important supplier of crude and condensate to the Asia-Pacific, increasing from about 14.5 mb/d in 2016 to almost 22 mb/d in 2040, which represents more than 80% of the total increase in oil imports.

Imports from the Russia & Caspian are estimated to increase from 1.5 mb/d in 2016 to 3 mb/d in 2040, which is the expected result of longer term pipeline expansions, for example, the ESPO. The Russia & Caspian is expected to become the second most important supplier of

Figure 6.12
Crude oil imports to the Asia-Pacific by origin, 2016–2040

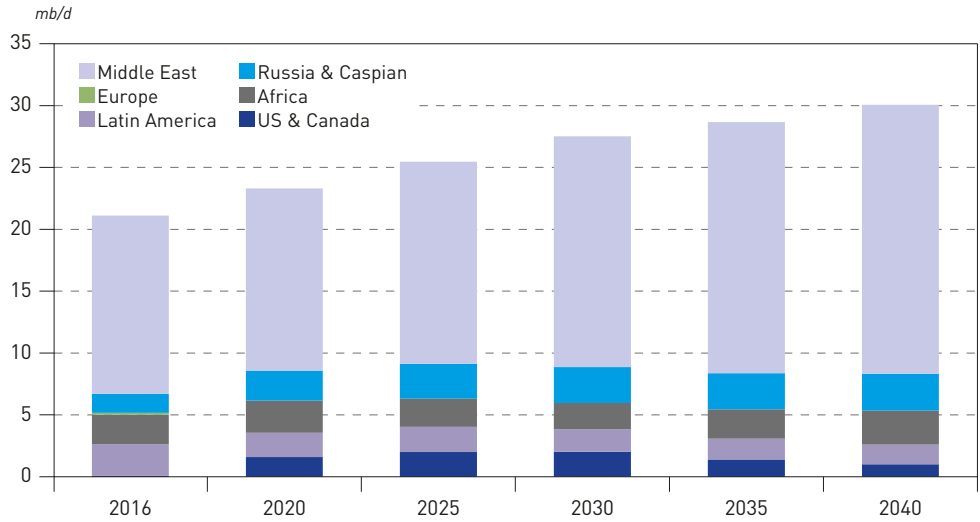
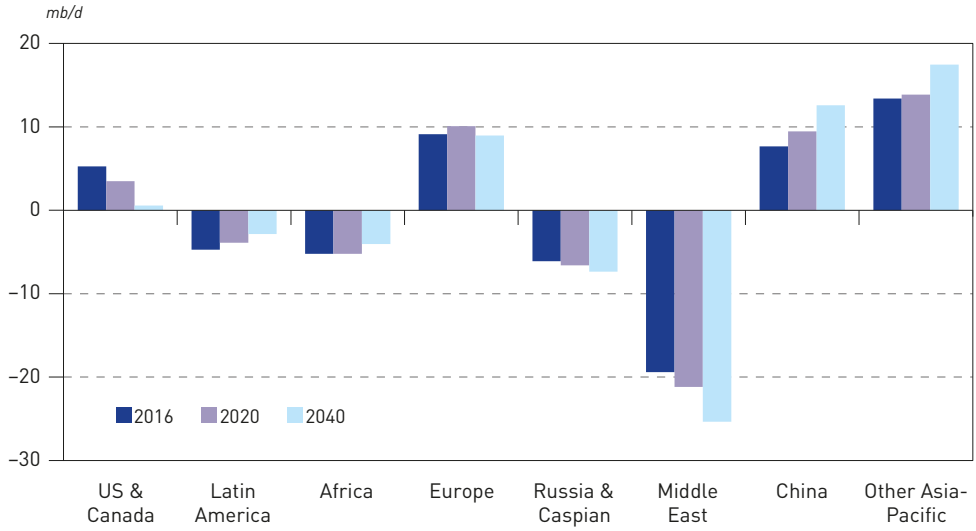


Figure 6.13
Regional net crude oil imports, 2016, 2020 and 2040



oil to the Asia-Pacific in the long-term. Oil movements from Africa to the Asia-Pacific are anticipated to decline in the Reference Case from around 2.4 mb/d in 2016 to a level around 2.1 mb/d in 2030. This can be explained by the increasing domestic use of oil in Africa. However, exports are expected to increase to some 2.7 mb/d by 2040 as supply in Africa increases. Latin American flows to the Asia-Pacific are seen on a decline throughout the period, from around 2.6 mb/d in 2016 to 1.6 mb/d by 2040. This trend is the result of declining overall exports from Latin America due to the region's increasing own usage of oil and more focus on the US market due to its proximity. Lastly, barrels from the US & Canada should see a significant market share in the Asia-Pacific in the period to 2025, increasing significantly from around 100,000 b/d in 2016 to about 1.6 mb/d in 2020 and even further to 2 mb/d by 2025. Nevertheless, US & Canada flows to the Asia-Pacific are expected to decline gradually towards 1 mb/d by 2040, as US oil output reaches a peak and declines after 2030.

Figure 6.13 shows the net effects of all inter-regional crude oil trade (imports versus exports). The patterns summarize the regional trade projections already discussed.

6.4 Product movements

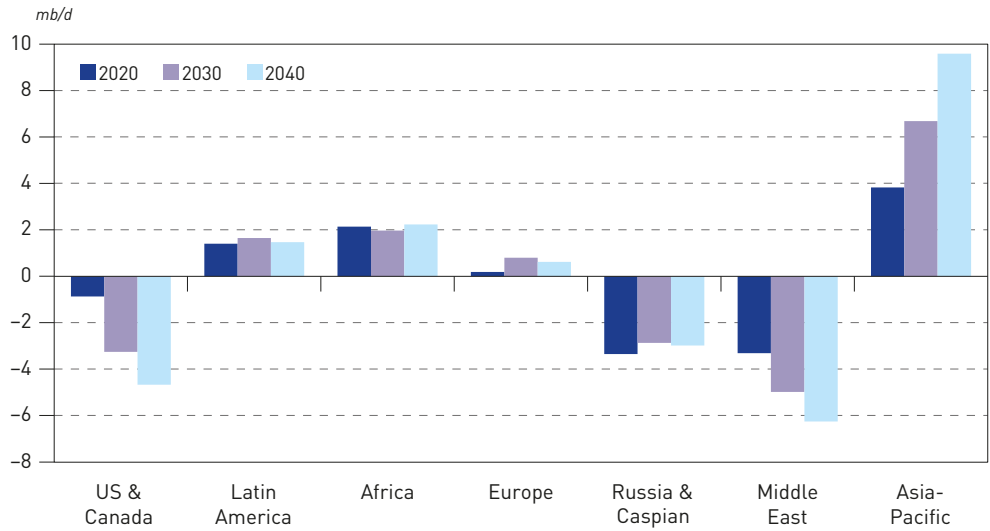
In comparison to crude movements, refined product movements between the seven major WORLD regions are significantly lower, as refined products are mostly produced and consumed within the regions. Transportation costs for clean products are normally higher relative to crude, which is another reason for lower product movements between the seven regions. As already described, the overall product trade is seen to increase slightly from around 20 mb/d in 2016 to almost 21 mb/d in 2040.

However, the expansion of the refining capacity does not follow the demand growth in several major consuming regions in the period to 2020. This, combined with the impact of the new IMO regulations, leads to higher product trade at around 21 mb/d in 2020. In the years after, product movements are projected to decline as several regions such as Latin America, Africa and the Asia-Pacific expand refining capacity, which reduces the need for imported products. In addition, regions such as US & Canada see declining demand in this period, which consequently leads to lower product imports (especially gasoline). This results in product trade of around 17 mb/d in 2025. Following the overall demand growth, product movements are then seen to increase gradually between 2025 and 2040, from 17 mb/d to almost 21 mb/d.

In order to show a simple and understandable picture of general trends for global product trade, this Chapter focuses on net flows only. Figure 6.14 presents product net imports for the major WORLD regions. Three regions show significant changes in the long-term: the Asia-Pacific with a significant increase in net imports, and the Middle East and the US & Canada with rising net exports.

Product net imports to the Asia-Pacific are projected to rise from around 4 mb/d in 2020 to 9.5 mb/d in 2040. Increasing refining capacity in the Asia-Pacific is expected to satisfy a large share of the additional demand, however, additional refinery new-build is not likely as it will have to compete with established and highly-complex refineries from the Middle

Figure 6.14
Regional net imports of liquid products, 2020, 2030 and 2040



East and the US & Canada, as well as the Russia & Caspian. High-quality products, such as LPG and naphtha, as well as middle distillates, represent the majority of the increase. Latin America and Africa are set to remain product net importers throughout the period with refining capacity additions in these regions not sufficient to reduce import flows. Latin American product net imports are relatively stable, increasing only slightly from around 1.4 mb/d in 2020 to 1.5 mb/d in 2040. Similarly, in Africa product net imports are expected to move from 2.1 mb/d in 2020 to 2.2 mb/d in 2040. Meanwhile, refiners in Europe will have to compete with imports from the US & Canada, but also from the Middle East and the Russia & Caspian. This is estimated to lead to an increase in net imports to Europe, from around 200,000 b/d in 2020 to 800,000 b/d in 2040.

On the net export side, the Middle East and the US & Canada are anticipated to increase their volumes significantly, while the Russia & Caspian is expected to witness a decline. The focus of some Middle Eastern oil producers on product exports leads to additional product net exports in the long-term, from around 3.3 mb/d in 2020 to 6.3 mb/d in 2040. The Middle East has the clear advantage of its proximity to important consuming regions, such as the Asia-Pacific, Europe and Africa, combined with ample crude supplies in the region. The majority of additional net exports are destined for markets in the Asia-Pacific.

The US & Canada region is also set to see a significant increase in product net imports. This is driven by three factors – ample crude oil supplies, declining domestic demand and highly complex and competitive refining systems. Product net exports from the US & Canada are anticipated to increase from around 1 mb/d in 2020 to almost 5 mb/d in 2040.

Finally, product net exports from Russia & Caspian are anticipated to decrease from 3.4 mb/d in 2020 to around 3 mb/d in 2040. This can be explained by declining demand in Europe, which is the main market for barrels from the Russia & Caspian. Moreover, exports to the US & Canada are also projected to diminish in the long-term. Additional competition from other regions, predominantly the US & Canada, is a further reason for less net exports.

Critical uncertainties

Key takeaways

- The energy market, and the oil market, in particular, faces uncertainties from a wide variety of sources. These include the economy, policy developments, both from the demand and supply side, the pace of technology advancement, climate change, environmental regulations, speculative financial activities, fiscal conditions, the evolution of costs, to name just a few.
- Alternative economic growth sensitivity analysis shows that oil demand in 2040 could range between 107.5 mb/d and 113.8 mb/d, compared to 111.1 mb/d in the Reference Case. This implies that the overall uncertainty emerging from the economic developments is in the range of around 6 mb/d in 2040.
- A more optimistic view on EV penetration has the potential to reduce oil demand. In the Sensitivity Case, it is assumed that the annual EV sales almost triple compared to the Reference Case so that EVs penetration in the passenger fleet increases from 12% to over 25% by 2040. In this case, global oil demand is reduced by 2.5mb/d by 2040.
- Reflecting potential for improved energy efficiency, an alternative sensitivity – the Accelerated Efficiency (AE) case - was developed assuming somewhat more aggressive efficiency improvements than those incorporated in the Reference Case. Compared to the Reference Case, the overall demand reduction in the AE case is 3.2 mb/d by 2040.
- The effect of an orchestrated push for even moderate improved efficiencies across all oil demand sectors is comparable to the impact of alternative economic developments, as well as to the much discussed impact of the faster penetration of EVs.
- Price volatility, capital investment, cost inflation, technology and the regulatory framework remain key uncertainties for the upstream sector.
- In the medium-term supply picture, tight oil shows the most significant potential upside, with higher output in the US and other existing tight oil producers, as well as new tight oil barrels emerging in China and Mexico. However, the tight oil surge is expected to peter out in the late 2020s.
- Overall non-OPEC supply in an upside sensitivity case is estimated to add a further 1.3 mb/d by 2022 and 4.6 mb/d by 2040. A downside sensitivity analysis curtails non-OPEC supply by 0.5 mb/d in the medium-term, and 3.6 mb/d in the long-term.
- Key uncertainties from the technology viewpoint relate to, if and when, large-scale power storages become available at moderate costs and how powertrain electrification evolves.
- The ongoing IT revolution poses the question as to what extent Big Data and advanced sensing will affect tight oil production and other oil upstream operations in the long-term.

The first six Chapters of the WOO focus on the Reference Case supply and demand assumptions, for both the upstream and downstream, but it is important to recognize that the energy market, and in particular the oil market, faces uncertainties from a wide variety of sources that could potentially shift the outlook. These include the economy, policy development, both from the demand and supply side, the pace of technology development, climate change, environmental regulations, speculative financial activities, fiscal conditions, the evolution of costs, to name just a few. This Chapter attempts to address some of these: specifically those that are relevant to long-term oil market prospects.

The main focus is on alternative sensitivities. Looking at the demand side, three sources of uncertainties were considered: alternative views on economic developments, on the level and speed of penetration of alternative vehicles and on the speed of adoption of energy efficiency measures across various oil demand sectors. For the supply side, upside and downside non-OPEC alternative supply sensitivities were considered.

In addition, this Chapter also explores other uncertainties, including policies and technology, as well as those that could potentially impact the refining sector.

The uncertainties presented in this Chapter are evidently not an exhaustive list. However, it provides a review and analysis of some of the issues that have the potential to impact the petroleum industry in the years ahead.

7.1 Sensitivity analysis

Demand side challenges

The first demand side challenges analyzed is the global economic outlook, a central component driving future oil demand. Therefore, a regular assessment of alternative views on future economic growth and the potential implications for oil demand is beneficial to elicit a better understanding of future challenges. The last attempt (WOO 2015) to address this issue took into account possible alternative paths for economic prospects (compared to the Reference Case) based on recent turbulences and uncertainties in critical regions/countries. This approach resulted in relatively wide variations, primarily within the medium-term horizon, while assuming a gradual 'stabilization' over the longer-term. In other words, the difference in the GDP growth rates typically occurred over the medium-term with growth rates converging back to normal (similar to those in the Reference Case) over the long-term.

This year's approach is different. Alternative sensitivities for economic prospects were developed based on the long-term factors, such as labour productivity gains and employment growth, rather than looking at short- to medium-term factors. The intention is to demonstrate that future oil demand prospects are sensitive to changes in these drivers.

The second topic relates to the uncertainty related to the future penetration of EVs. With Tesla launching its model 3, Volvo announcing its shift to electrified mobility as soon as by 2019, the UK and France aspiring to achieve 100% of new car sales to be either electric or hybrid by 2040 and Germany holding a 'Diesel summit', it is vital to explore the potential implications of

these types of developments and policies on future oil demand. Therefore, in addition to the Reference Case and economy-related sensitivities, an alternative sensitivity was developed assuming a faster penetration of alternative vehicles in the regional and global car fleet.

Turning to energy efficiency measures, in recent years these have risen up the policy agenda in both developed and developing countries. Alongside the promotion of renewables and the development of new technologies, energy efficiency has become a key component of the policy framework required to meet GHG emissions reduction targets that have been set at both national and international level – including those of the NDCs and the 2°C target of the Paris 'Climate Change' Agreement. Additionally, the UN 2030 Agenda for Sustainable Development includes a dedicated and standalone goal for energy, SDG 7, which calls to "double the global rate of improvement in energy efficiency". While recognizing that a higher potential for the implementation of energy efficiency measures exist in other energy sources, oil by no means should be excluded from these efforts. To this end, an alternative sensitivity has also been developed to explore the possible extent of implications in this area.

Upstream uncertainties

In addition to demand-side factors, based on recent experience with tight crude and unconventional NGLs, non-OPEC supply also poses a very important element of market uncertainty. One of the key areas the WOO identifies in this context is uncertainty about future price volatility, as well as price ranges, and the potential impact on upstream investment. While 2017 has seen the OPEC Reference Basket price average just below $50/b to date – meaningfully higher than in 2016, not least due to the 'Declaration of Cooperation' between OPEC Member Countries and some non-OPEC nations – there still appears to be doubt in some parts of the upstream industry as to how sustainable this is.

While the WOO's Reference Case does not per se assume a shortfall in medium-term production, other analysts have warned of the potential for a 'supply gap' to open up in this period. This is based upon the identification of a combination of cuts to upstream investment, fewer large-scale upstream projects coming online, and falling volumes from new discoveries. On the other hand, recent statements to the press by senior international oil company (IOC) executives talk of preparing their companies for 'lower' oil prices, or even in one case, 'lower forever' oil prices.

Closely related to challenges posed by price uncertainty is the issue of potential upstream cost inflation. Preliminary indications are that costs bottomed out at some point around late 2016/early 2017 and have started rising again. Companies active in the upstream have claimed that through further efficiency gains, streamlining and, in some cases, selective mergers & acquisitions, they will be able to squeeze costs further. Their success (or not) in this regard will inevitably feed into the wider uncertainty regarding upstream investment trends.

Other upstream uncertainties include technology, innovation and the regulatory framework. The US tight oil sector, in particular, but deepwater and other frontier developments too, rely upon constant technology advances in drilling, extraction and other activities. The regulatory framework continues to evolve too, which may have a key bearing in countries such as Russia,

a very established producer, Brazil, with strong growth in output projected, or in Mexico, which has just started to open up its energy sector to foreign investment.

For these and other reasons, it is necessary to remain vigilant for any development in this area and account for the implied uncertainty through sensitivity analysis. This Chapter includes a section spelling out potential upside and downside sensitivities for non-OPEC supply based upon some of the challenges described.

7.1.1 Alternative economic growth sensitivities

As highlighted in Chapter 1, economic activity is a fundamental driver of energy and oil demand despite the fact that the world is becoming less energy intense. In fact, the correlation between GDP growth and energy demand growth, at the global level, from 1970 to 2015 was 0.83. Because these two variables are closely linked (and despite the fact that this link is becoming weaker as a result of the decoupling process; for more discussion see Chapter 1) unexpected economic developments can have a significant impact on global energy and oil demand. A clear example is what happened in 2008; as a result of the financial crisis global GDP dropped by 0.3% in that year. Correspondingly, global energy demand dropped, for the first time since 1990. And oil demand dropped as well.

While in the Reference Case it is assumed that global GDP growth will follow a smooth deceleration path after the medium-term and reach 3% by 2040, with oil demand growth at 0.2% p.a. by then, there is obviously a significant degree of uncertainty as to how the global economy might evolve in the medium- and long-term. For that reason, and to account for that uncertainty, the WOO explores the possible implications that alternative GDP growth paths could have on oil demand.

Sensitivity construction

The economic growth sensitivity analysis presented in the WOO considers two alternative cases to the Reference Case: higher GDP growth (HG) and lower GDP growth (LG). The two sensitivities use different assumptions about the medium- and long-term economic prospects for the global economy and are driven by distinct factors.

In the case of the HG sensitivity, it is assumed that the world economy benefits from additional labour productivity gains and employment growth. The former could come from further efforts to advance human capital, such as better access to education and better learning techniques, particularly in developing countries. Public and private backing to foster technological upgrading, innovation and policies to support productive activities could also reinforce productivity gains. In particular, it is assumed that in the very long-run (well beyond the forecast period), labour productivity growth in the different regions converges to a higher level (0.12 percentage points higher) than in the Reference Case. At the same time, in this sensitivity, additional employment growth could result from structural reforms to sustain labour force participation, promote equal access to the labour market for men and women and protect labour rights. Specifically, it is assumed that the total number of employees in the world would reach over 4.1 billion people by 2040, more than 30 million above the level in the Reference Case.

The LG sensitivity assumes that economic growth is constrained due to gloomier labour productivity and employment growth prospects. Under this sensitivity, it is assumed that an increasing move towards protectionism limits trade and, therefore, restricts the diffusion of technological innovations. Furthermore, constraints to the movement of goods and capital would affect investment and the build-up of infrastructure. As such, productivity growth converges in the very long-term to a lower level (0.15 percentage points lower) than in the Reference Case. More importantly, limitations to the movement of people could have an important impact on employment growth, particularly in the OECD region. According to UN estimates, between 2016 and 2040, net migration into the OECD is anticipated to reach 67 million by 2040. A move towards a more restrictive migration policy would harm economic prospects. In particular, the total lost employment potential in the LG sensitivity in the OECD would reach almost 20 million people by 2040, compared to the Reference Case, and almost 50 million at the global level at the end of the forecast period.

As shown in Figure 7.1, the HG sensitivity assumes that the average GDP growth for the forecast period is 3.6% p.a. That is less than 0.2 percentage points higher than in the Reference Case. Additional labour productivity gains account for three quarters of this increase. Regionally, in the OECD, average growth is assumed to be almost 0.1 percentage points higher, with over two-thirds corresponding to additional labour productivity growth. In Developing countries it is around 0.2 percentage points higher, with further employment growth accounting for one-quarter of this.

In the LG sensitivity, average world GDP growth is assumed to be 0.2 percentage points lower than in the Reference Case, totalling almost 3.3% p.a. Lower labour productivity gains account

Figure 7.1
Average annual global GDP growth (2016–2040) under the different sensitivities

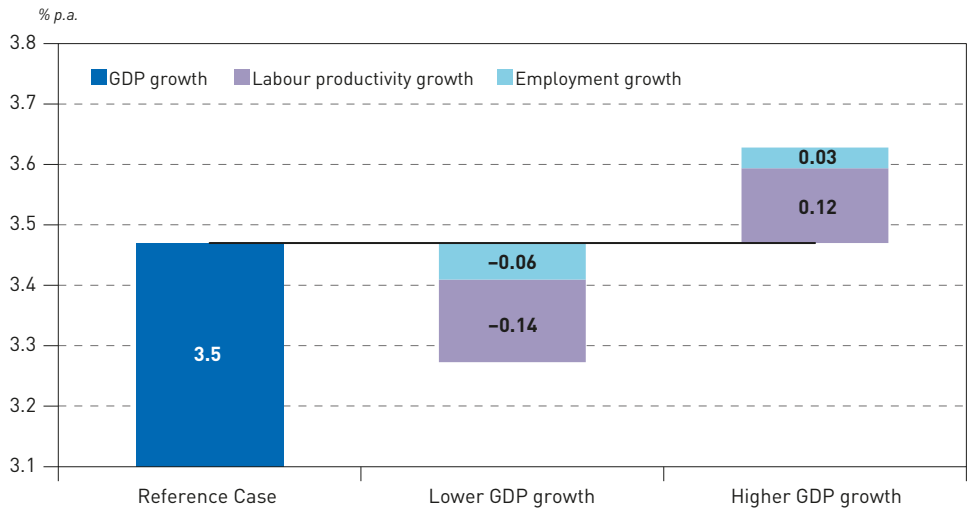
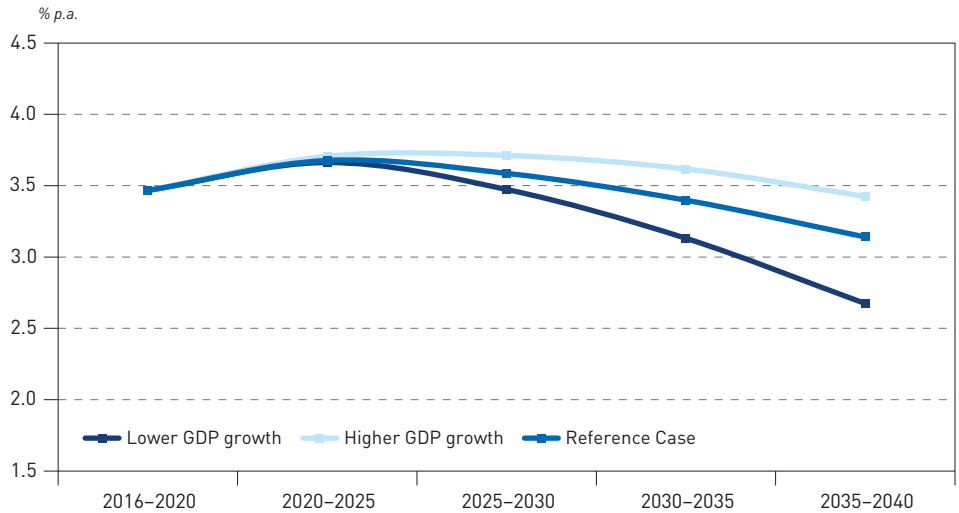


Figure 7.2
Average annual global GDP growth under the different sensitivities



for two-thirds of this drop. In the Developing countries, the average GDP growth is reduced by more than 0.2 percentage points, mainly as a result of lower labour productivity gains. However, in the OECD region, most of the reduction is on the back of lower employment growth. As highlighted in Chapter 1, this region shows a weak demographic picture with low population growth expectations and an ageing population. Measures aimed at limiting migration flows could also affect the region's economic outlook. In particular, the LG assumes that average GDP growth is reduced by more than 0.1 percentage points and lower employment growth accounts for 80% of the reduction.

Table 7.1 shows the specific alternative GDP growth rates assumed under the different sensitivities for each region. Overall, global GDP in the LG sensitivity reaches $233.5 trillion (2011 PPP) by 2040, that is $11.3 trillion (2011 PPP) – approximately half of OECD America's GDP in 2017 – less than in the Reference Case. In the HG sensitivity, world GDP is $8.5 trillion (2011 PPP) – approximately OECD Asia Oceania's GDP in 2017 – higher than in the Reference Case, totalling $253.3 trillion (2011 PPP).

Implications for oil demand

The impact that the alternative GDP growth assumptions have on oil demand is shown in Figure 7.3. A few interesting observations are worth noting. To start with, it can be seen that the impact of the alternative economic growth assumptions on oil demand is much more visible in the long-term. This is because alternative sensitivities were developed based on long-term factors. Secondly, in the case of the HG sensitivity, global oil demand reaches 113.8 mb/d

Table 7.1
Average GDP growth rates under the different sensitivities

% p.a.

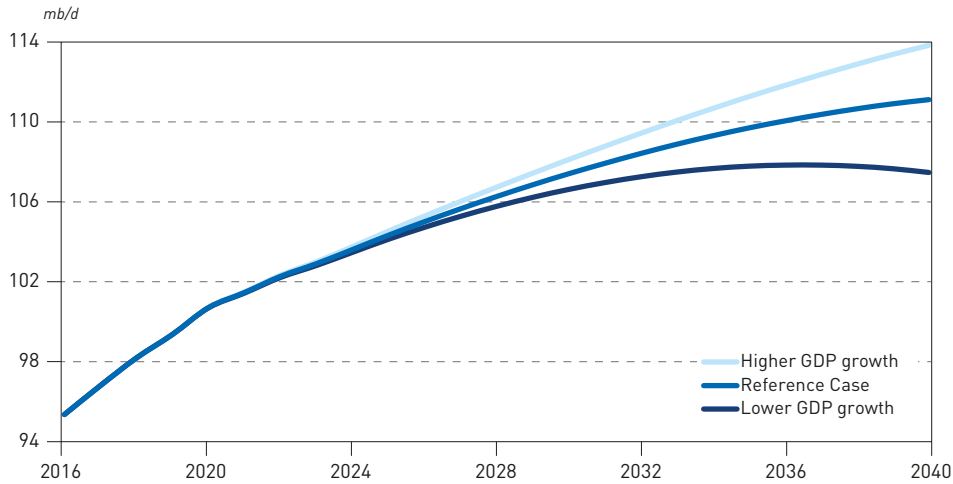
	2016–2040			2030–2040		
	Reference Case	LG	HG	Reference Case	LG	HG
OECD America	2.5	2.3	2.6	2.4	2.1	2.6
OECD Europe	1.7	1.6	1.8	1.7	1.5	1.8
OECD Asia Oceania	1.4	1.3	1.4	1.2	1.0	1.3
OECD	**2.0**	**1.9**	**2.1**	**2.0**	**1.7**	**2.1**
Latin America	2.8	2.6	3.2	2.6	2.2	3.1
Middle East & Africa	3.6	3.4	3.8	3.7	3.3	4.0
India	6.8	6.5	7.0	6.2	5.4	6.4
China	4.7	4.6	4.9	3.7	3.5	4.1
Other Asia	3.8	3.6	3.9	3.5	3.0	3.6
OPEC	3.1	3.0	3.2	3.2	2.9	3.4
Developing countries	**4.5**	**4.3**	**4.7**	**4.1**	**3.7**	**4.4**
Russia	2.3	2.2	2.4	2.4	2.1	2.6
Other Eurasia	2.7	2.5	2.8	2.6	2.2	2.8
Eurasia	**2.5**	**2.3**	**2.6**	**2.5**	**2.1**	**2.7**
World	**3.5**	**3.3**	**3.6**	**3.3**	**2.9**	**3.5**

in 2040. The LG sensitivity sees demand at 107.5 mb/d in the same year. This implies that the overall uncertainty emerging from the economic developments is in the range of around 6 mb/d by 2040. Thirdly, it is interesting to highlight that the uncertainty is skewed to the downside. While the upside oil demand potential at a global level is estimated at 2.7 mb/d in 2040, the downside potential resulting from a gloomier economic growth outlook is estimated at 3.6 mb/d at the end of the forecast period.

Clearly, a more optimistic view on the global economic prospects would have a direct positive effect on oil demand. On one hand, faster GDP growth implies that there will be more disposable income for households and, therefore, higher demand for mobility, products and services. This would push oil demand higher. However, it is important to also account for significant second-order effects that would likely arise as a result of a more prominent GDP growth and would limit oil demand growth to a certain extent.

To start with, under a higher GDP sensitivity, the disposable income of households would be higher. This could incentivize the move to more efficient, albeit more expensive, means of oil consumption. For example, households might be more willing to purchase EVs, buy more

Figure 7.3
World oil demand in the economic growth sensitivities



efficient household appliances and invest in better insulation solutions. At the same time, a higher economic growth sensitivity would also imply that governments would have more funds for subsidizing cleaner energy initiatives, such as EVs. Finally, companies have more resources to invest in advanced technological equipment and processes.

Despite the fact that these second-order effects would curb potential oil demand growth, it is highly unlikely that their impact would counterbalance the positive first-order effect that higher economic growth has on oil demand. Another factor that needs to be considered is the effect of a changing oil price. In the demand driven sensitivity, higher oil demand would likely push prices up. Higher prices, in turn, would then also curb the further potential for higher demand.

Oil demand in the HG sensitivity is estimated at 113.8 mb/d by 2040. Moreover, demand growth remains at relatively healthy levels even towards the end of the forecast period. In fact, global demand increases by 0.5 mb/d every year between 2035 and 2040. In the Reference Case, annual growth during this period was estimated at 0.3 mb/d.

As shown in Table 7.2, most of the additional demand in the HG sensitivity would come from Developing countries where demand is 2 mb/d higher than in the Reference Case. Interestingly, under the HG sensitivity, oil demand in Eurasia will not peak in 2035 as in the Reference Case, but rather plateau around 6.3 mb/d during the last few years of the forecast period.

In respect to the LG sensitivity, there are some similarities, but also some differences to the one with higher economic growth. In the first place, the demand response is asymmetric as the oil demand reduction compared to the Reference Case in the LG sensitivity is almost 1

Table 7.2
Oil demand in the higher economic growth sensitivity

mb/d

	2016	2020	2025	2030	2035	2040
OECD	46.8	47.5	45.5	43.2	40.8	38.5
Developing countries	43.2	47.5	53.0	58.7	64.1	69.0
Eurasia	5.3	5.7	6.0	6.2	6.3	6.3
World	**95.4**	**100.7**	**104.5**	**108.1**	**111.3**	**113.8**
Difference from Reference Case						
OECD	0.0	0.0	0.1	0.2	0.4	0.6
Developing countries	0.0	0.0	0.1	0.5	1.2	2.0
Eurasia	0.0	0.0	0.0	0.0	0.1	0.1
World	**0.0**	**0.0**	**0.2**	**0.7**	**1.6**	**2.7**

Table 7.3
Oil demand in the lower economic growth sensitivity

mb/d

	2016	2020	2025	2030	2035	2040
OECD	46.8	47.5	45.4	42.9	40.0	37.0
Developing countries	43.2	47.5	52.7	57.6	61.6	64.4
Eurasia	5.3	5.7	6.0	6.2	6.2	6.0
World	**95.4**	**100.7**	**104.1**	**106.6**	**107.8**	**107.5**
Difference from Reference Case						
OECD	0.0	0.0	0.0	–0.2	–0.4	–0.9
Developing countries	0.0	0.0	–0.1	–0.6	–1.4	–2.5
Eurasia	0.0	0.0	0.0	–0.1	–0.1	–0.2
World	**0.0**	**0.0**	**–0.2**	**–0.8**	**–1.9**	**–3.6**

mb/d larger than the demand increase in the HG sensitivity. It is to be noted, however, that the demand reduction would be partially offset by an expected lower oil price.

The main similarities between the two alternative sensitivities are in the distribution of demand changes. A large part of the demand reduction in the LG sensitivity comes from Developing countries. Indeed, 2.5 mb/d of the global reduction of 3.6 mb/d in 2040 is projected to

take place in Developing countries. OECD countries account for an additional 0.9 mb/d of the demand reduction, supplemented by the least affected region of Eurasia where demand is just 0.2 mb/d lower than in the Reference Case.

7.1.2 Penetration of alternative vehicles

EVs have attracted a lot of attention over the last few years and at present there tend to be regular announcements from governments, car manufacturers, industry analysts and other market players. The industry seems to be moving from an initial scepticism to a moderate enthusiasm. Driven by generous public subsidies and improved technological development, in just a few years EVs have gone from being completely unaffordable, impractical and not particularly nice, to representing a valid option for a niche pool of customers. The latest information shows that the number of global EVs reached two million in 2016. Despite this impressive figure, it is important not to forget that on a global scale, EVs currently only represent less than 0.2% of the passenger car fleet (for more details, see Chapter 3).

There is now a lot of debate about the possible impact that EVs could have on oil demand growth in the medium- and long-term. There is evidently a wide range of opinions. While some analysis suggests that oil demand will peak in the next decade partly because of EVs, many others, including OPEC's WOO, believe that oil demand growth will decelerate, but growth will continue until 2040 (the WOO does not look beyond this timeframe). One thing is true though: due to the relative low turnover rate of passenger vehicles, increasing EV sales will take a long time to be translated into a significant portion of the car fleet.

As discussed in detail in Chapter 3, in the Reference Case it is estimated that the number of EVs will reach 235 million in 2040 with BEVs totalling 126 million. This represents 12% of the expected global passenger car fleet at the end of the forecast period. In certain regions, the penetration of EVs is anticipated to be higher, such as OECD America, OECD Europe and China, each over 16%. In other regions, such as the Middle East & Africa, Other Eurasia and OPEC, the potential is forecast to be lower. The corresponding oil demand level in the passenger car segment is anticipated to increase from 24.3 mb/d in 2016 to a plateau around 26.5 mb/d toward the end of the next decade, before beginning a marginal decline in the following decade to reach 26.2 mb/d in 2040.

While the Reference Case represents OPEC's best informed forecast, it is important to analyze the possibility of further upward potential for EVs. For example, consumer preferences could change rapidly, and technological development, economies of scale and competition could drive battery costs down faster than anticipated. Moreover, range anxiety could be diminished due to a more expanded recharging infrastructure and, as explored in Chapter 3 shared mobility could further accelerate the penetration of EVs.

To account for this uncertainty, an alternative sensitivity has been developed where a more optimistic view on the penetration of EVs is adopted. This sensitivity analyzes the impact on oil demand. They show that, despite a considerably higher penetration of EVs, oil demand in the

passenger vehicle segment will not be drastically affected in the forecast period. Moreover, given the strong growth in other sectors, such as petrochemical, aviation, freight and residential, even in the most optimistic EV penetration sensitivity, it is not anticipated that global oil demand will drop meaningfully over the period to 2040

Alternative vehicles sensitivity

Focusing on the penetration of EVs in the passenger car segment, an alternative sensitivity has been developed: the Sensitivity Case. In this sensitivity, a more optimistic view is taken on the penetration of EVs. Globally, it is assumed that annual EV sales reach 80 million by 2040 (Figure 7.4). This would mean that three out of every five cars sold in 2040 would be electric. In regions such as OECD Europe, OECD America, China and India, it is assumed that two out of every three passenger cars sold would be electric by 2040. Under this sensitivity, there would be 516 million EVs on the road at the end of the forecast period. While it is interesting to analyze how oil demand would be impacted in this sensitivity, it is highly unlikely that EVs will penetrate the passenger car segment with this strength in less than 24 years. The level of investment, in terms of both the replacement of car fleet and the expansion of required infrastructure, as well as the required government support, would be rather prohibiting.

Nevertheless, several countries have publicly stated their intention to achieve an even higher share of EVs in new sales than assumed in the Sensitivity Case. This is especially the case of Europe, with the UK, France, the Netherlands and Austria, among others, targeting 100% of new sales from EVs in various time horizons.

Figure 7.4
EV sales in the Reference Case and the Sensitivity Case

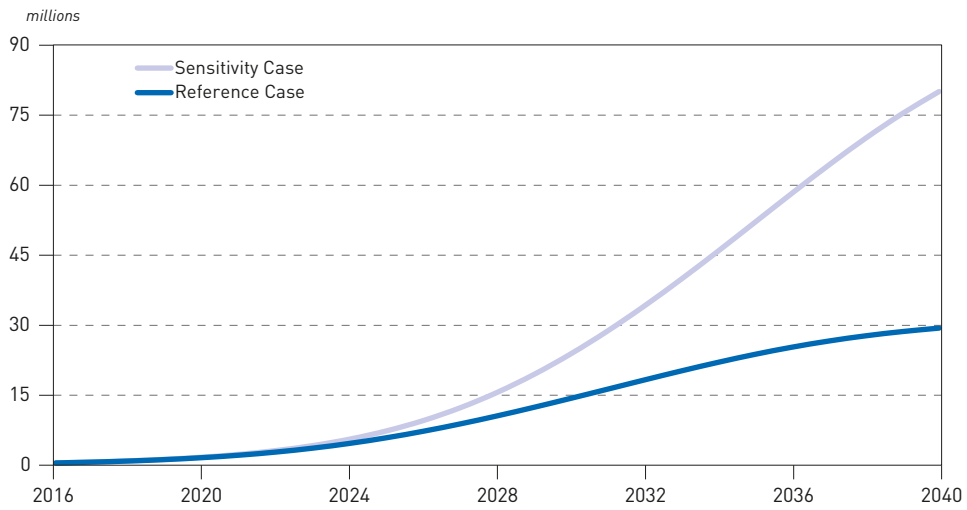
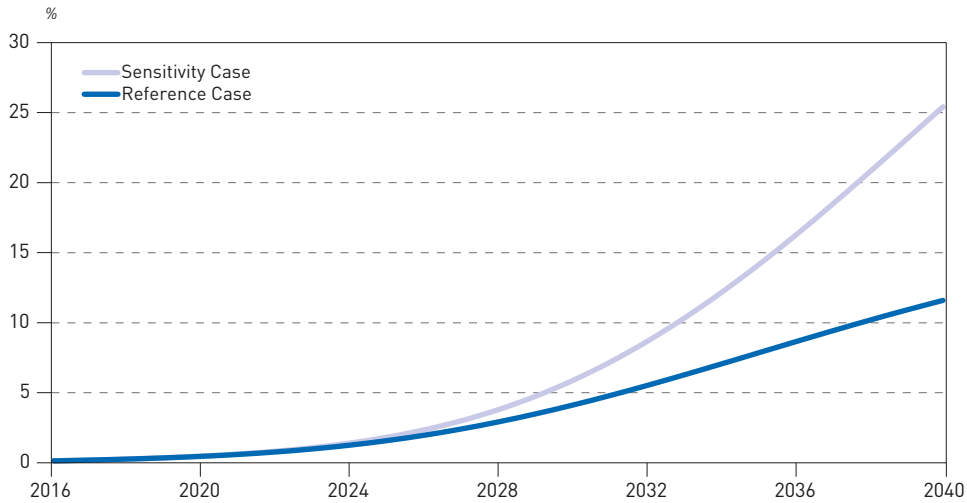


Figure 7.5
EV penetration in the car fleet in the Reference Case and the Sensitivity Case



As already mentioned, given the relatively low turnover rate of passenger cars, even high EVs sales levels take a long time to be reflected in the global car fleet. Figure 7.5 shows that, in the Reference Case, EVs are expected to represent 12% of the global fleet by 2040, up from less than 0.2% in 2016. Under the Sensitivity Case, the penetration of EVs will increase even further, so that by 2040, one-quarter of the world passenger car stock would be electric. In India and China, the penetration of EVs would reach a level over 35% in 2040.

Impact on oil demand

Figure 7.6 shows the resulting oil demand in the passenger car segment under the Reference Case and the sensitivity. It can be observed that, in the Reference Case, sectoral oil demand plateaus around 2030, at a level of 26.7 mb/d. Thereafter, a marginal decline is anticipated so that, by 2040, demand totals 26.4 mb/d. Sectoral oil demand in the Sensitivity Case is estimated at 24.1 mb/d in 2040; this is 2.2 mb/d lower than in the Reference Case. Demand is estimated to peak in 2027 and, between 2027 and 2040, oil demand from passenger cars is estimated to drop at 0.7% p.a.

In the broader context, different assumptions about the penetration of EVs would have an impact on global oil demand. As shown in Figure 7.7, in the Reference Case, oil demand is anticipated to grow steadily from 95.4 mb/d in 2016 to 111.1 mb/d in 2040 and growth averages 0.3 mb/d annually in the last five years of the forecast period. Under the assumption of increasing EV penetration in the passenger car segment in the Sensitivity Case,

Figure 7.6
Oil demand in the passenger car segment in the Reference Case and the Sensitivity Case

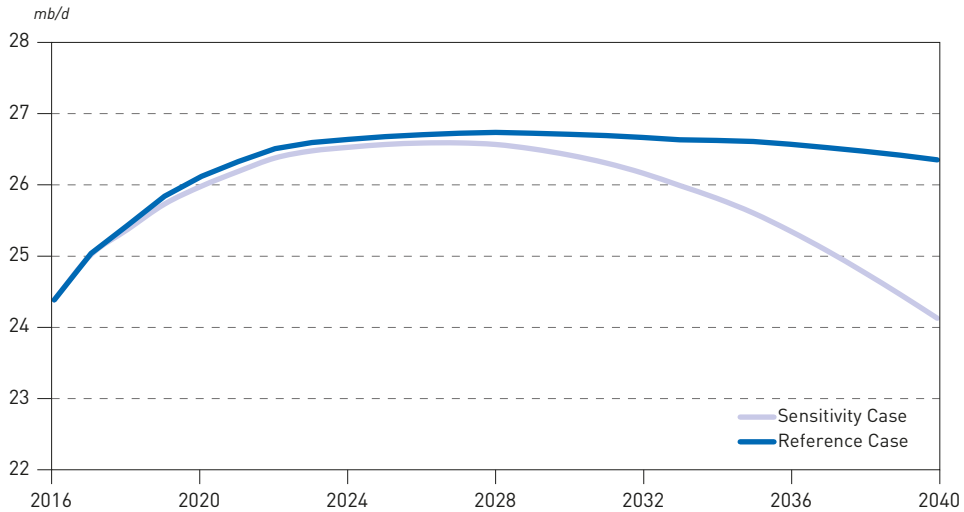
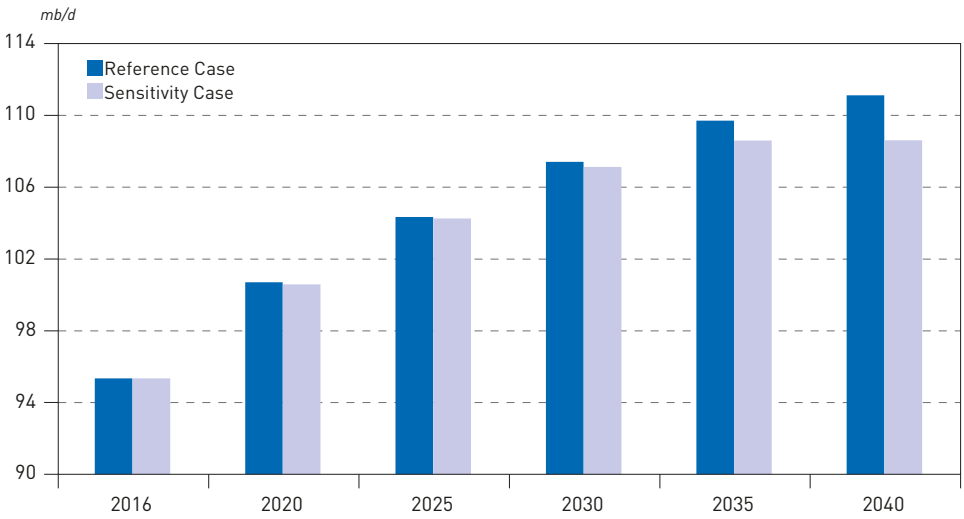


Figure 7.7
Oil demand in the Reference Case and the Sensitivity Case



as well as the expectation that this, at least partially, spreads to the commercial vehicles segment, particularly in the medium-duty segment, global oil demand is evidently lower (Figure 7.7).

Under the Sensitivity Case, oil demand in 2040 is reduced by 2.5 mb/d compared to the Reference Case, totalling 108.6 mb/d. Moreover, global oil demand is estimated to plateau around this level in the second half of the 2030s.

7.1.3 Energy efficiency

Improvements in energy efficiency have long been recognized as a key element of policies focused on reducing emissions. This is clearly reflected in a number of policies in countries and regions across the globe, which target the efficient use/consumption of energy in a variety of sectors. Typically, these policy measures include financial and fiscal instruments, such as energy audits, subsidies, loans and tax/tax credits, direct regulations in the form of minimum energy efficiency standards, building codes, various labels and certificates and other measures such as voluntary agreements.

At the same time, however, energy efficiency is not just a matter of regulation. It is also closely linked to technology developments. In fact, it is the technology that provides the ways and means for the more efficient use of energy, whereas policies can support both technology progress and its accelerated implementation in various energy consuming sectors.

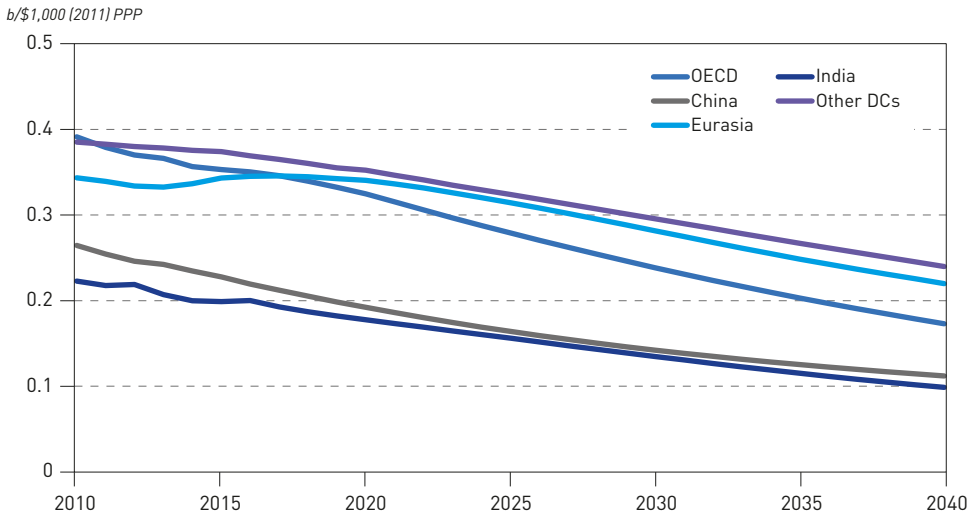
To measure developments in energy efficiency, in most cases the concept of energy intensity is used. This is despite its limitations, especially if a more disaggregated level of energy demand is considered. For example, moving from global to regional or a country level means that changes in the structure of a regional/country economy could affect energy intensity, without any real improvement in energy efficiency. Similar effects need to be considered when intensity indicators are used at the fuel level. For example, gas intensity in a country/region could be impacted by a shift from gas to renewable electricity generation, again, without any real improvement in how gas is consumed.

Despite these limitations, using the concept of oil intensity at the regional level is still believed to be a reasonable proxy for building sensitivities on energy efficiency improvements, especially under the condition that all other parameters, such as GDP growth, the oil price assumption and population growth, are kept unchanged.

In the Reference Case, as shown in Figure 7.8, oil intensities (measured as the number of barrels consumed per $1,000 (2011) of GDP on a PPP basis) are currently in the range of 0.2–0.4 in the major consuming regions. This gradually declines to the range of 0.1–0.25 over the forecast period. Translated into a relative decline, this pattern represents an average annual decline of 2.8–2.9% in OECD regions, China and India, and a somewhat smaller decline of around 1.8% in the group of Other DCs and in Eurasia.

Clearly, the declining oil intensity in major regions is, to a large extent, a reflection of the fact that the Reference Case assumes a reasonable advance in technology. Nevertheless, certain

Figure 7.8
Oil intensity in major regions



further accelerated developments in technology may improve efficiency beyond the level considered for the Reference Case.

Starting with the aviation sector, this is commonly considered a very technology-intense industry. It should be noted, however, that given that security has become the industry's decisive aspect, the introduction and penetration of new technology is rather slow, although there are non-technical advances that may decrease fuel consumption considerably, for example, improved national and cross-frontier air traffic management. In this regard, time and fuel-consuming detours may be avoided and direct point-to-point connections may become possible. The increasing reliability and a larger number of independent global positioning systems (for example, GLONASS in Russia, Galileo in Europe or Beidou in China) may push such direct connections, especially in large countries that have large national and, therefore, homogenous air traffic control.

Even the behaviour of the future average airline passenger might contribute considerably. Transferring the concept of low-cost carriers with their higher seating density and lower baggage cargo to medium- and even long-distance airline connections might increase the number of passengers transported per flight and, as a consequence, reduce the amount of fuel consumed per passenger further.

Moreover, technology-oriented developments in innovative combustion methods may increase turbine efficiency faster than expected, while limiting, or even reducing pollution. Together with a more aggressive use of lightweight materials not only for the airplane hull and wings, but also for turbine components may see a significant decrease in the overall

fuel consumption of the airplane. Counterbalancing this progress is the usual long time between airplane generations, which is likely to result in a somewhat slow advance beyond the Reference Case.

In the electricity generation sector, oil is typically used in medium or large reciprocating engines with a limited potential for future improvements. The main area for improvement in this sector relates to waste heat recovery (WHR). Improved WHR can reduce specific fuel consumption by up to 10%, but it requires significant investment. Advances may also include substantially increased injection pressures – in the case of diesel engines – or more efficient super-charger subsystems. Replacing older (and inefficient) generator equipment may drive fuel efficiency.

The same applies to efficiency improvements in marine bunkers beyond the Reference Case: in fact, the main movers of marine vessels – large reciprocating engines – are even more efficient than piston engines for the power generation sector. In addition, WHR also remains the most promising technology in this sector. More advanced hull design, as well as improved vessel management – based on global positioning system (GPS) and optimized logistic systems – could lead to improved efficiency in the sector.

Rapid advances in combustion technology, efficient heat exchangers and intelligent control systems may also improve efficiency in the industrial use of oil beyond the assumptions of the Reference Case. Moreover, the widespread application of cogeneration may not only improve thermal energy efficiency, but also generate electric power.

The petrochemical sector exhibits the lowest potential for a further oil consumption decrease, as it is already among the most efficient sectors. However, some potential remains in view of new and more efficient catalysts, optimized heat exchangers, optimized process control and WHR to produce some of the electric power consumed in petrochemical plants.

Traditionally, the residential/commercial/agricultural sector has not paid the same attention to energy efficiency as, for example, transportation. In recent years this has changed and the Reference Case considers this development. Moreover, this is not only a more dynamic development of new technologies, but also the accelerated application of technologies together with government incentives or replacement regulations. For example, the replacement of old heating equipment with modern low-temperature condensing boilers may substantially increase energy efficiency in the residential sector.

The same applies to the commercial sector that may take advantage of synergy effects when combining traditionally separated services as, for example, providing hot water on one hand, and cooling or freezing rooms or goods on the other. By using the waste heat of the chiller, hot water can be produced without any further energy input. However, infrastructure investments in this sector usually have a far longer lifetime than in the case of transportation. Nevertheless, the high potential for efficiency improvements, together with the considerable market share of this segment, offers a significant possibility for further reductions in oil consumption.

The road transportation sector, the most important single sector for the consumption of oil products, is constantly under pressure to improve vehicle energy efficiency. The Reference

Case assumes an ambitious and constant improvement in this regard. In addition, reducing vehicle weight by employing lightweight – and expensive – materials may reduce fuel consumption quicker than the Reference Case expects. A different future attitude of consumers towards individual mobility – away from personally owned to shared vehicles, for example – may also contribute in an important manner. Moreover, potential exists in terms of reducing wall heat losses in advanced future combustion engines and recovering waste heat that is currently released into the environment.

Reflecting this potential for efficiency improvements, an alternative sensitivity – AE case – was developed assuming somewhat more aggressive efficiency improvements than those incorporated in the Reference Case. In this case, oil intensity in the OECD, China and the rest of the world declines faster by 0.13, 0.17 and 0.14 percentage points compared to the Reference Case, respectively. However, it is important to mention that anticipated variations at the sectoral level are quite significant. The lowest efficiency improvements (0.01–0.02 percentage points) are assumed for the petrochemical sector where the majority of oil used in this sector serves as feedstock, thus limiting the efficiency improvements to a small portion used as fuel. Somewhat higher rates were seen for the aviation (0.03–0.07 percentage points), marine (0.06–0.12 percentage points) and the road transport (0.06–0.12 percentage points) sectors. Improvements in other sectors were in the range of 0.07–0.3 percentage points, with the largest potential seen in the residential/commercial/agriculture sector (0.23–0.3 percentage points).

It is important to note, however, that these rates of efficiency improvements do not fully explore the potential for improvement that exists in the oil sector. On the contrary, they in fact represent the moderate levels that are plausibly achievable if policymakers and technology work together in an orchestrated way in the decades to come.

Impact on oil demand

Figures 7.9 and 7.10 show the reduction in oil demand, compared to the Reference Case in 2040, in major regions and sectors resulting from the implementation of stronger efficiency improvements in the AE case. The overall demand reduction in this case is 3.2 mb/d by 2040. The larger part of this reduction, around two thirds, is assumed to take place in Developing countries where a higher potential for efficiency improvements exists. Assumed efficiency improvements in China would translate into some 0.6 mb/d lower oil demand than in the Reference Case while India contributes by another 0.3 mb/d. Because of the high overall level of oil demand in the group of Other DCs, close to 39 mb/d in the Reference Case by 2040, the potential demand reduction in this region is more than 1 mb/d.

Slightly lower efficiency improvements (compared to Developing countries) are assumed in Eurasia. Moreover, projected oil demand in this region is much lower than in Developing countries, just above 6 mb/d in the Reference Case by 2040. Accordingly, oil demand in Eurasia in the AE case is only 0.2 mb/d lower than in the Reference Case. For the OECD region, Reference Case assumes fastest efficiency improvements over the forecast period. Therefore, by 2040 further acceleration adopted in the AE case in this region is slowest among all major regions. This, however, is partly compensated by a significant base demand of almost 38 mb/d by 2040

Figure 7.9

Oil demand reduction in Accelerated Efficiency sensitivity compared to Reference Case in 2040, by region

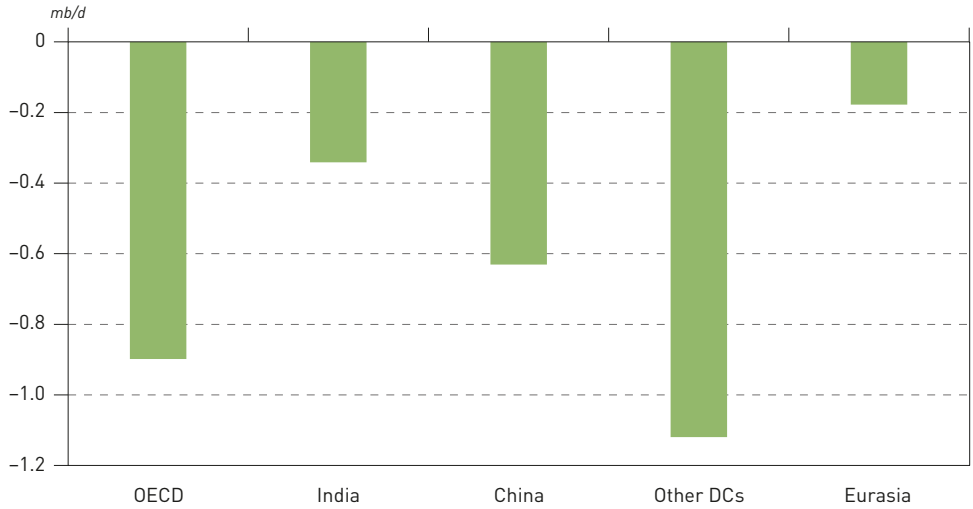
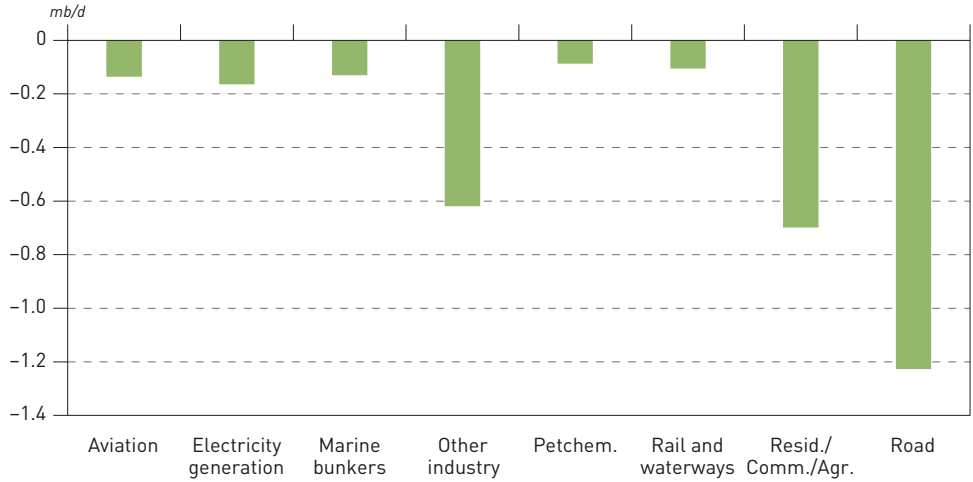


Figure 7.10

Oil demand reduction in Accelerated Efficiency sensitivity compared to Reference Case in 2040, by sector

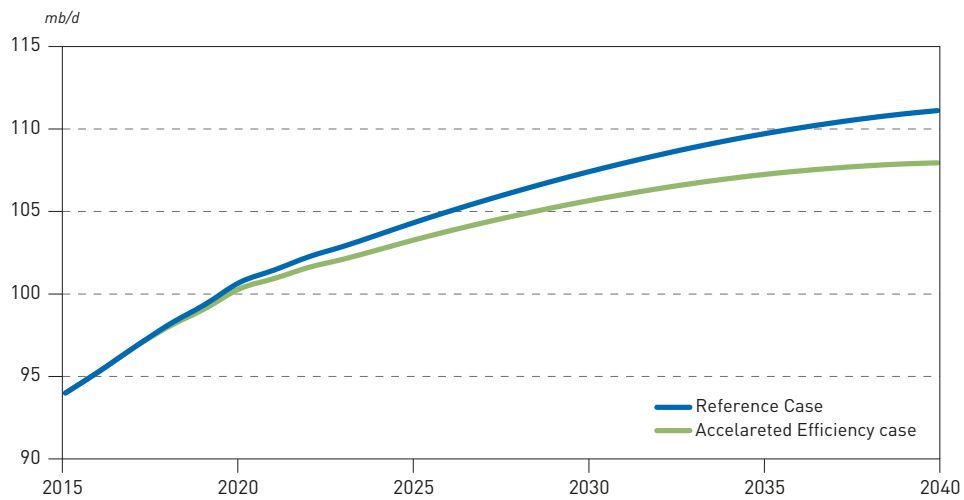


under the Reference Case. The net result is that OECD oil demand in the AE case is 0.9 mb/d lower than projected in the Reference Case by 2040.

From the sectoral perspective, the largest demand reduction in the AE case is in the road transportation sector (Figure 7.10), primarily because this sector has the largest share in overall oil demand. The road transportation sector is already one of the most efficient sectors of energy demand since it has been at the centre of attention of policymakers for a long time. Moreover, the Reference Case also assumes further efficiency improvements over the entire forecast period resulting not only from increased penetration of alternative vehicles, but also from more efficient ICEs. Therefore, it would not be realistic to assume much higher efficiency improvements than in the AE case, without stretching possibilities to the limits or assuming a technology breakthrough in ICEs. Yet, even a moderate improvement in energy efficiency in this sector results in a significant oil demand reduction at the global level.

The other two sectors with the largest demand reductions are residential/commercial/agriculture and 'other industry' sectors. The resulting demand reduction in these two sectors is a combination of their size and assumed efficiency improvements. After the road transportation and petrochemical sectors, these are the two largest sectors accounting together for almost 26 mb/d of oil demand in the Reference Case by 2040. Moreover, these are also the two sectors with the highest potential for improving efficiency. Accordingly, combined they could potentially contribute an oil demand reduction in the AE case in the same order as the road transportation sector, around 1.3 mb/d by 2040.

Figure 7.11
Oil demand in the Accelerated Efficiency sensitivity compared to the Reference Case



The potential oil demand reduction in the remaining sectors is rather limited, all in the range of 0.1–0.2 mb/d by 2040. There are two large sectors among them, petrochemicals (more than 16 mb/d of oil demand in the Reference Case by 2040) and aviation (close to 9 mb/d by 2040). However, the potential for efficiency improvements in these two sectors is rather limited.

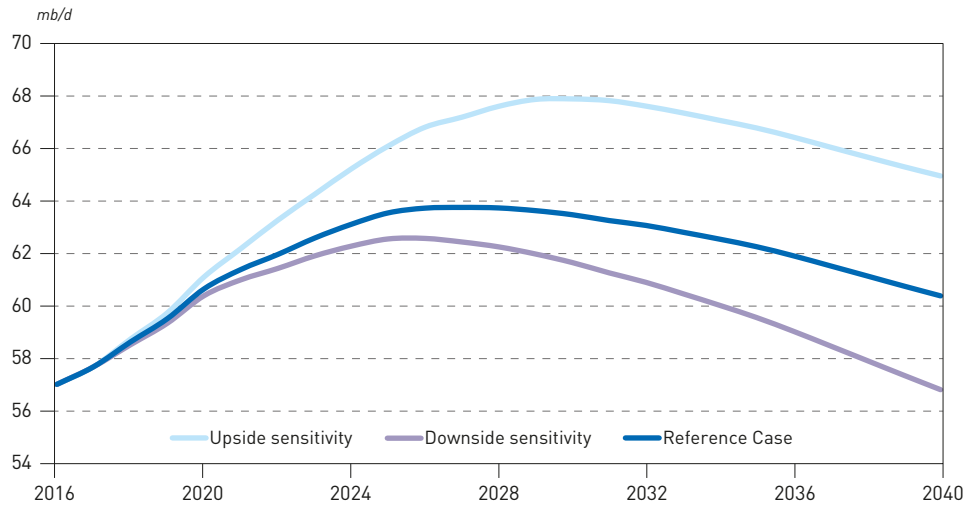
However, some potential exists in the marine sector, in electricity generation and in the rail and domestic waterways sector. Nonetheless, all of them are in the range of just 2–5 mb/d of oil demand by 2040, hence, the net effect in terms of demand reduction is relatively small. If all these sectors are combined together, their potential contribution to the demand decline in the EA case by 2040 is 0.4 mb/d.

Figure 7.11 compares global oil demand in the Reference Case and the AE case. It clearly shows that the net effect of an orchestrated push for even a moderate improved efficiency across all oil demand sectors is comparable to the impact of alternative economic developments, as well as to the much discussed impact of a faster penetration of EVs.

7.1.4 Oil supply sensitivities

On the supply side, a number of non-OPEC supply sensitivities, both to the upside and downside, have been developed for the WOO. These are constructed explicitly as a function of country-specific factors, including technology, regulation, taxation, innovation and others.

Figure 7.12
Non-OPEC supply in the upside/downside supply sensitivities



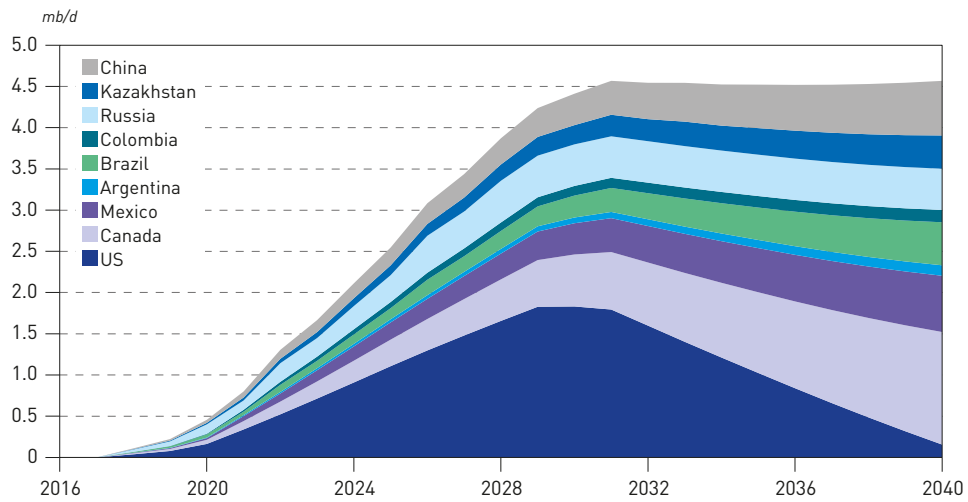
The upside sensitivity shows a greater potential, with 1.3 mb/d more non-OPEC oil production achieved by 2022, widening to around 4.6 mb/d by 2030 and remaining at close to this level in the last decade of the long-term timeframe (Figure 7.12). By contrast, the downside sensitivity sees non-OPEC supply around 0.5 mb/d lower by 2022, widening to 3.6 mb/d by 2040.

Upside supply sensitivity

In the upside supply sensitivity, the main contributor to higher production in the medium-term is tight oil, and predominantly in the US. Here, the assumption is that technology improvements and efficiency gains continue to bring down costs in the tight oil sector specifically, leading to increased drilling activity and a wider geographical focus. In the longer term, new offshore areas increasingly become available, including a renewed interest in Alaskan acreage, as well as continued activity offshore in the Gulf of Mexico and the Atlantic Coast. In sum, the US makes the largest contribution to higher non-OPEC supply in the upside sensitivity. At its peak, the US contribution adds 1.8 mb/d around 2030 (Figure 7.13). However, the assumed surge in US tight oil also leads to a more rapid depletion of these resources. Thus, higher US liquids supply is not expected to persist after 2030.

Higher tight oil production is also projected for Canada, Argentina and Russia and, in addition, it is stimulated in both China and Mexico, where the Reference Case otherwise assumes no output. In the upside sensitivity, combined higher tight crude and NGLs makes up nearly 50% of the higher supply throughout the 2020s.

Figure 7.13
Additional supply in the upside sensitivity by country, compared to the Reference Case



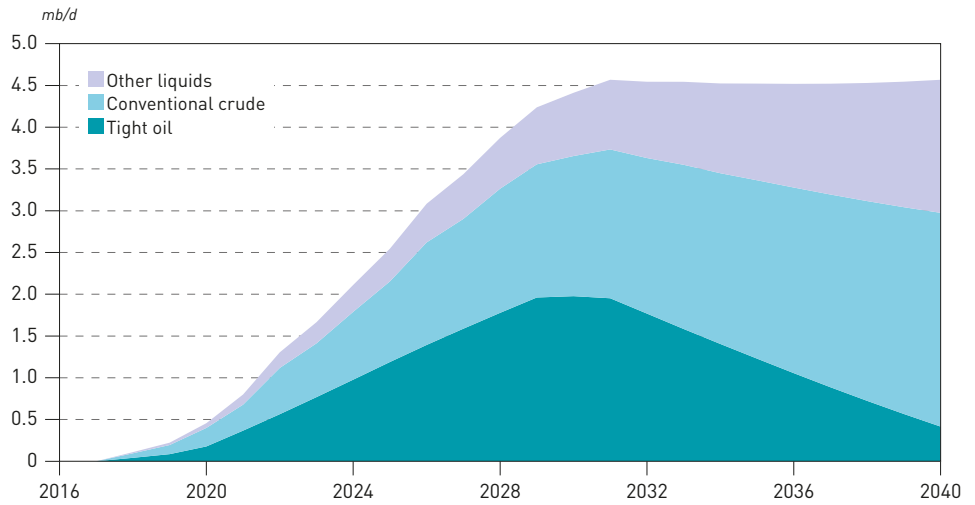
Technology advancements, strong demand for heavier crudes and new export outlets are assumed to stimulate higher production from Canadian oil sands, making Canada the second-largest contributor to higher non-OPEC supply in the upside sensitivity. As this takes longer to materialize, production is assumed to be a modest 150,000 b/d higher by 2022, but later widens to 1.4 mb/d, taking into account more output from oil sands, tight crude and unconventional NGLs.

In Mexico, besides some tight crude and unconventional NGLs production, the ongoing energy reform is presumed to stimulate significant investment in the country's upstream sector. The result is a bottoming out of the decline in the country's production seen in recent years. By 2022, oil production in the upside supply sensitivity is expected to be at 2.1 mb/d, before gradually rising again to reach 2.3 mb/d by 2040.

In Russia, additional supply is expected to be stimulated by a fiscal and regulatory environment that encourages continued investment and high profitability in the upstream sector. Thus, the country's oil production continues to grow in the upside supply sensitivity, reaching 11.5 mb/d by 2022, briefly peaking at 11.7 mb/d in the late 2020s, and then stabilizing at 11.6 mb/d in the longer term.

In Brazil and Kazakhstan, countries that in any case are forecast to see continued growth in oil production (and where there is evidently a significant resource base), the assumption for the upside sensitivity is that new upstream projects are developed at a faster pace than in the

Figure 7.14
Additional supply in the upside sensitivity by source, compared to the Reference Case



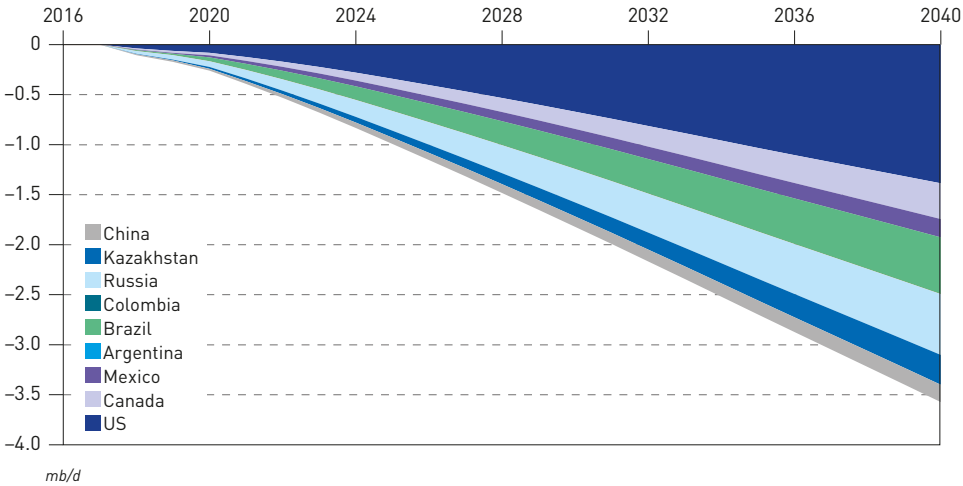
Reference Case. In Brazil, this mainly concerns deepwater production from the pre-salt fields, while in Kazakhstan, it is assumed that expansions to the huge Kashagan field are developed. As a result, respective production in Brazil and Kazakhstan is 0.5 mb/d and 0.4 mb/d higher in this sensitivity by 2040.

Breaking down the larger projected volumes in the upside sensitivity into different types of liquids (Figure 7.14), tight crude and related unconventional NGLs make the most significant contribution of just under 50% in the medium-term, but their relative share declines thereafter, following a peak in US tight crude supply. By 2040, the most significant share of higher supply comes from conventional crude supplies, followed by other liquids, which is largely from Canadian oil sands.

Downside supply sensitivity

In the downside sensitivity, overall non-OPEC production is seen at a modest 0.5 mb/d lower by 2022 (compared to the Reference Case), before the difference rises to 3.6 mb/d by 2040 (Figure 7.15). Again, US production sees the most significant change. It is 170,000 b/d lower by 2022, which widens to 1.4 mb/d by 2040. Here the assumption is that tight oil, in particular, disappoints, as further technological advances and cost savings fail to materialize, cost inflation becomes an issue again, and as environmental and other regulations are further tightened. This may also prevent the development of new frontier producing areas in Alaska, the Atlantic Coast and the eastern part of the Gulf of Mexico.

Figure 7.15
Reductions to liquids supply in the downside supply sensitivity by country, compared to the Reference Case

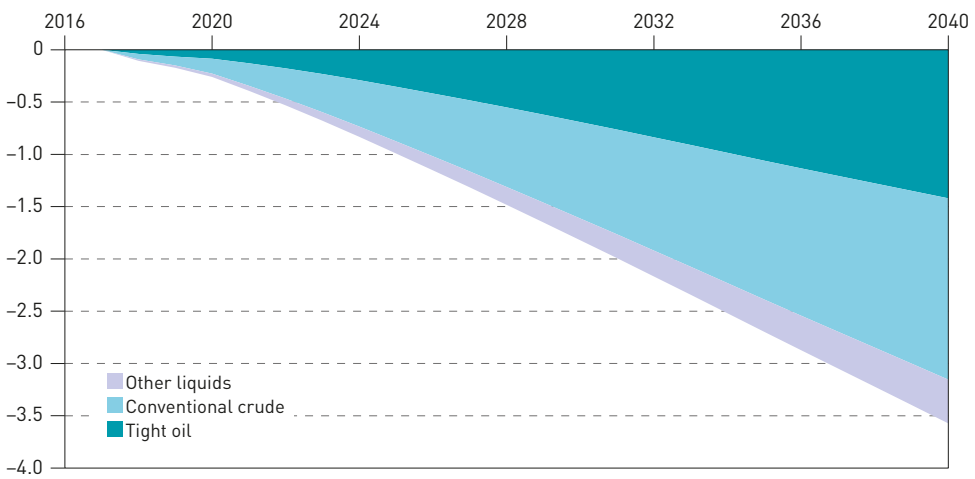


Furthermore, compared to the Reference Case, tight oil outside of the US is assumed not to grow further in the downside sensitivity, and also not to materialize in countries other than the US, Canada, Argentina and Russia. In the latter, tweaks to the taxation framework are assumed to reduce the profitability of developing major new resource basins, and decline rates in mature producing areas accelerate. As a result, Russian production only grows modestly in the medium-term, peaking at 11.3 mb/d in 2020, before facing a gradual decline thereafter, to reach 10.4 mb/d by 2040.

For countries like Canada, Brazil and Kazakhstan, which in the Reference Case are major contributors to overall non-OPEC supply growth, the assumption in the downside sensitivity is simply that growth takes place at a slower rate. This is for a number of reasons. Canadian oil sands production is assumed to face environmental pressures, as well as limitations on export capacity, as major new outlets take longer or entirely fail to materialize. Major offshore projects in Brazil face delays coming online due to technical complications, while in Kazakhstan, the further expansion of major fields is deferred – notably the super-giant Kashagan field.

Broken down by source, it is tight and conventional crude that make up the lion's share of the reduced production in the downside sensitivity at around 75% (Figure 7.16). Tight crude is around 1 mb/d lower than in the Reference Case by 2040, while unconventional NGLs are seen to be reduced by around 0.5 mb/d. Conventional crude sees a downside of 1.7 mb/d by 2040, while other liquids (predominantly Canadian oil sands) is assumed to be reduced by 0.4 mb/d by the end of the forecast period.

Figure 7.16
Reductions to liquids supply in the downside supply sensitivity by source, compared to the Reference Case

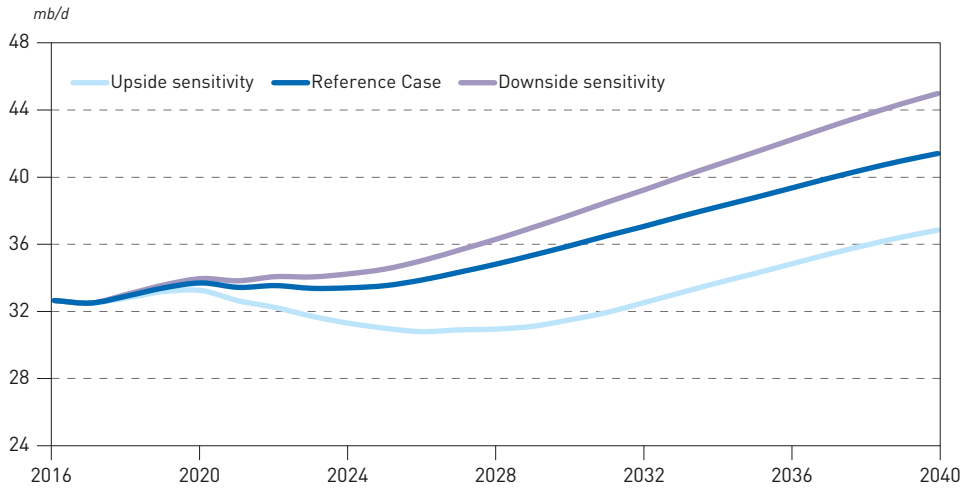


Impact on demand for OPEC crude

Based upon the upside non-OPEC supply sensitivity, the demand for OPEC crude is reduced to 32.2 mb/d by 2022 and to a low of around 30.8 mb/d in the latter half of the 2020s, before US tight oil peaks and the demand for OPEC crude rises again. By 2040, the latter increases significantly, to 36.8 mb/d by 2040, albeit still 4.6 mb/d lower than in the Reference Case (Figure 7.17).

The demand for OPEC crude in the downside non-OPEC supply sensitivity remains relatively flat at just over 33 mb/d in the medium-term horizon, coming in at 34.1 mb/d in 2022. Thereafter, it rises steadily, topping 40 mb/d in the mid-2030s and reaching 45 mb/d by 2040, some 3.6 mb/d higher than in the Reference Case, and a full 8.1 mb/d higher than in the upside sensitivity estimate.

Figure 7.17
Upside/downside supply sensitivities: impact on demand for OPEC crude



7.2 Other challenges and uncertainties

7.2.1 Policies

As highlighted in Chapter 1, the Reference Case takes into account those policies that are already in place, but also reflects the expectation that policies evolve over time. However, while policy announcements provide an indication as to the general future direction that policymakers aspire to reach, a variety of factors lend to uncertainty regarding the implementation of these plans.

Uncertainties often result from ambitious targets that are politically desirable, but practically difficult to achieve, particularly in the absence of transparent, actionable strategies. Additionally, given that the policy climate has the potential to change over time, to reflect shifting political beliefs and different interests, it is important to focus on highlighting some of the potential uncertainties and challenges related to the current policy sphere.

Following the inauguration of President Donald Trump in January 2017, the future development of US energy policies through the new US Administration is beset with uncertainties. The new Administration has made clear its intentions to redefine US energy policy, with a number of aims focused on reversing or revising previous goals. Among the policy developments so far is the announcement of the US withdrawal from the Paris Agreement, as well as the activation of the Congressional Review Act to roll back policies that were instated by the previous Administration. The review process has resulted in several energy policies undergoing appraisal and evaluation, with their potential outcomes unknown. These include the RFS and CAFE standards.

The announcement of the US's withdrawal from the Paris Agreement lends uncertainty to the future development of the global environmental accord. While the decision reflects the position of the new US Administration and the direction of federal level policy, it should be noted that some initiatives at the state, city, corporate and private level have indicated alternative positions. For example, the US Climate Alliance, a coalition of 14 US States plus Puerto Rico, has pledged to maintain their commitment to the Paris Agreement. Similarly, another US coalition consisting of over 200 cities and counties, and about 1,650 private businesses have also affirmed their intentions to remain aligned with the accord. As such, the future direction of the US vis-a-vis this agreement, especially in the longer-term, is uncertain.

Elsewhere, the EU, China, and India have indicated their intentions to remain in the Paris Agreement. However, how the share of US emissions, as well as financing commitments, would potentially be taken care of by the remaining parties to the agreement is unclear. Furthermore, it remains to be seen how the US decision may impact the resolve of other parties, particularly developing countries, to remain committed to the agreement.

Moreover, there are a number of other uncertainties related to the Paris Agreement that have the potential to significantly impact future developments in the energy scene. An important issue regarding the outcomes of COP21 is how the Paris Agreement bridges the mitigation deficit between what was announced under the NDCs and what is required to meet the Agreement's 2°C temperature target. This is expected to be addressed in the future, given that the Paris Agreement only sets a five-year cycle for Parties' contributions. The reason behind the five-year cycle is the aim to increase Parties' ambitions in the future. The Agreement calls for a 'facilitative dialogue' in 2018, to have an early assessment of NDCs, and for the first global stocktake in 2023. The global stocktake will also be taken in five-year cycles and two years prior to the periodic submission of NDCs. How this process evolves will certainly affect future energy demand levels, as well as the overall energy mix.

Additionally, in the US, there remain uncertainties surrounding the RFS that requires oil companies to blend biofuels into the gasoline and diesel they produce. The RFS sets a minimum

volume of renewable fuel required to be blended into transportation fuel, moving from 9 billion gallons in 2008 to 36 billion gallons by 2022. Currently, the US EPA is undertaking a review of the RFS standards for 2018, which may lead to a potential change in the standard.

The development of regional fuel economy and emissions standards also presents some uncertainties. In the US, the Congressional Review Act has been activated by the incoming US Administration to re-open a mid-term review of the CAFE standards for model year 2022–2025 vehicles, which would require a maximum fleet-wide average of 54.5 miles per gallon (mpg) by 2025. The US National Highway Traffic Safety Administration (NHTSA) is expected to complete the mid-term review in April 2018, which may result in changes to CAFE standards.

In India, following the implementation of Bharat Stage IV fuel emissions standards in April 2017, an ambitious target of 'leap-frogging' to Bharat Stage VI standards by April 2020 is envisaged by the Indian Government. The Bharat Stage VI standards were originally planned for 2024. The intermediate Bharat Stage V standards, initially planned to be implemented in 2019, were actually eliminated entirely in 2016 as the government seeks to expedite the tightening of fuel emission standards. The Bharat Stage VI deadline is considered challenging for automakers to meet. This could potentially lead to high stocks of unsold vehicles, as well as costly investments in upgrading technologies in order to achieve compliance with the standards.

The transportation sector has also received the attention of policymakers in the area of vehicle electrification goals. From Europe to Asia, several policymakers have announced their intentions to mandate restrictions on conventional vehicles in the long-term. In April 2017, India announced its aim for all new vehicle sales to be EVs by 2030. A few months later, in July 2017, France announced its intentions to ban the sale of gasoline and diesel vehicles by 2040, and the UK made a similar proclamation only a few weeks later. Then in September 2017, China announced that it is studying a deadline for implementing a similar ban. However, in all of these cases, more details beyond the initial announcements are yet to be observed. This leads to high uncertainty regarding the absence of clear definitions, infrastructure plans, implementation strategies, and whether technological innovation and consumer preferences will align with these agendas.

In the power sector, some policymakers have set ambitious targets for renewable energy to contribute to their future long-term energy mix. India, for example, announced plans in December 2016 for 57% of the country's total electricity capacity to be generated by non-fossil fuel sources by 2027. Notably, this goal exceeds India's Paris Agreement NDC target of 40% of renewables in power generation by 2030. However, the policy is at odds with nearly 370 coal-fired power plants that are planned to be constructed through to 2030. It should be noted that between 2006 and 2016, 139 GW of coal-fired capacity was brought on-line. By developing all of its future planned coal-fired capacity, India would increase its coal generating capacity by 123%, defeating its ability to meet its NDC targets.

Meanwhile, in January 2017, China's NEA cancelled over 100 coal power plant projects that were planned or under construction, eliminating 120 GW of future coal-fired capacity. While this plan is in line with the government's goal of capping coal generation capacity at 1,100 GW by 2020, the closure of the plants is arguably due to over-capacity in the power sector. An

increasing share of renewables in the power sector presents several challenges for China, among them the distant locations of renewable power generators, the lack of grid connectivity and delays in grid expansion plans.

7.2.3 Technology

The Reference Case assumes an evolutionary development of existing or readily available technologies until the end of the forecast period. Nevertheless, it should be noted that while it typically takes decades of steady development for technology evolution, on occasions, groundbreaking leaps can be achieved within a few years. In turn, these are then often the base for the next extended period of steady development.

The appearance of jet planes in the 1940s marks such a revolutionary leap, which have been followed by steady improvement since. A more recent historical example is the microprocessor revolution in the late 1970s and early 1980s when every new microchip generation was a leap forward, which was later replaced by – albeit still relatively fast – a more constant development.

Today massive data processing using advanced IT equipment is progressing swiftly, encompassing innovative methods of extracting useful data from a very large amount of data, quasi in real time. This 'Big Data' approach is rapidly becoming an important factor in the US tight oil industry, as well as elsewhere in the upstream sector. It is, however, currently unclear as to what extent this non-hardware approach will contribute to an increase in the efficiency of tight oil production.

In addition, EOR may benefit substantially from these highly innovative shifts away from pure hardware to far more 'intelligent' control and coordination over a broader range of information. Examples might be the real-time monitoring of the effect of water and CO_2 injection into mature fields. The ultimate goal – the so-called transparent soil – might significantly affect the upstream sector, although in what manner, remains unclear. The refining sector may also benefit, for instance, by adding intelligent means that may allow for a far better adaption of the concerned refining process to the fluctuating characteristics of the crude being processed.

The future global challenge to reduce GHG emissions may also revive nuclear energy beyond the level assumed for the Reference Case. However, it is evident that any revival will require more innovative and commercially mature technologies. It is evident that China and Russia are making progress in terms of inherently safe reactor designs that are focussed on the avoidance of large-scale nuclear disasters in the future. Such reactors are automatically switched off and the decay heat is dissipated without active means as, for example, in emergency cooling cycles. On the other hand, the still unsolved problem of the final storage of nuclear waste may represent a serious obstacle to a future large-scale expansion. Eventually, the associated expenses may increase the specific power generation costs of nuclear substantially beyond the level of renewables.

Among renewables, onshore wind has already reached a competitive cost level in a number of regions, and in others under certain assumptions – mainly by not taking into account the cost for back-up plants or a substantial extension of the grid. The Reference Case considers further development of onshore wind in a steady manner. It is possible that, by the 2030s,

offshore wind power costs will be approximating that of onshore wind power and, hence, conventional power production. An important question is how fast and to which extent the grid can be expanded to the level needed for an efficient and large-scale redistribution of the generated power. For example, offshore wind power has the highest potential of all renewable power sources in Western Europe, but the remote offshore generated power must be transmitted to consumers.

The other renewable energy with the largest potential is solar. This also requires a substantial expansion of the grid to replace conventional power generation beyond a certain level. While today's commercial PV cells (mono or poly crystalline silicon) have a peak efficiency of 15–20%, future cells commercially available by the end of the 2020s or early 2030s may easily lift that value beyond 30%. Nevertheless, the redistribution of generated power remains a general issue for renewables due to their intermittent nature.

Strong government, or market, incentives, as well as an appropriate legal framework may accelerate the construction of the required future 'power highways' beyond the commonly expected level. On the other hand, public resistance against such projects, which may have a significant impact upon the environment, may also stall the build-up of the required grid infrastructure.

Storing the power generated by intermittent energies, and in sufficiently large storage spaces, may ease this challenge related to renewables. However, such large-scale storage that is capable of complying with the necessary efficiency and low-cost requirements are currently unavailable. Nevertheless, cheap power storage systems are anticipated to be a key component of future renewable power generation. The development of a scalable, efficient and cheap storage technology has the potential to accelerate the penetration of renewable energy in power generation substantially beyond the Reference Case assumptions.

Biofuels offer the characteristics of inherent energy storage, which can be viewed as a challenge for wind and solar. However, it remains unclear whether they will play an important role in the energy future. First and second generation biofuels are characterized by modest yields and turned out to be expensive when compared to conventional fuels, while their ecologic advantages remained questionable. Some optimism in terms of third-generation biofuels remain, but technical and commercial challenges associated with conversion efficiency endure, especially when considering the costs of wind and solar, which are decreasing quicker than previously expected.

Technology improvements do not only change the base of useable primary energy, but may also impact energy demand as a whole, and the fuel market, in particular, by shifting the type of energies adequate for emerging technologies. For example, nuclear technology opened a completely new – and unforeseen – energy type for human use and created a demand for uranium as a previously unknown energy source; and the perfection of diesel technology for passenger vehicles has caused diesel fuel demand to rise substantially in Europe.

Road transportation, as the single largest consumer of petroleum products, plays a key role for the oil business. Apart from the ever increasing request for cleaner and more fuel efficient

gasoline and diesel vehicles, today electric mobility imposes increasing pressure on engineers to comply with both government regulations and consumer expectations. While powertrain electrification – not to be confused with EVs – will be a reality for larger and more luxury passenger vehicles very soon, conventional gasoline and diesel engines may remain and occupy a continued large sales share if technology advances sufficiently and quickly enough towards fuel saving and clean engines.

A broad co-existence of a larger variety of technologies – encompassing gasoline, diesel, various hybrids, battery electric and fuel cell vehicles – may be possible, especially when considering the vast investments required for electric mobility at a global scale. ICEs still have a substantially higher potential to increase fuel efficiency than commonly expected and, in turn, may put pressure on BEVs and FCVs for an extended time period. However, it is expected that monetary issues – overall costs for conventional versus electrified vehicles – will largely define the share of each technology.

The current standard technology for the electrification of road transportation is lithium-ion batteries, which is expected to continue to be the case for the foreseeable future. However, the limited and regionally concentrated occurrence of lithium has led to research and development (R&D) into other battery forms. The successful development of, for example, aluminium-ion (Al-ion) batteries may change the outlook substantially as aluminium is available in abundant quantities and at a lesser cost than lithium. It is possible that the first commercial Al-ion batteries will become available by the end of the 2020s or early 2030s. It should also be noted that in the case of BEVs or PHEVs with large batteries and strong electric motors, it is often forgotten that a shortage of required non-lithium materials (cobalt, neodymium and other rare earths) may be a limiting factor too. It is currently uncertain whether the required large quantities of these materials in the future will be available at reasonable costs.

The IT revolution has, and is expected to further change, not only the upstream sector by pushing tight oil developments, for example, but also on all energy consuming businesses far beyond what can be viewed today. While several decades ago engine control started to become intelligent by means of microprocessors – an evolution that is still underway – far more powerful IT devices will start to coordinate the linked-in nature of the vehicle fleet as a whole. For example, current and future ride, vehicle or transport service sharing relies, and will rely to a greater extent, on such intelligent controls. It is, nevertheless, unclear as to what extent consumers will adapt to such services in terms of replacing personally owned vehicles, or whether the development simply points towards a broader variety of transport means that are used according to the momentary desire – and availability.

Such cooperation is not limited to passenger or commercial transport, but may penetrate all segments of daily life. Intelligent grids are one example in the case of electric power and the 'Internet of things' may allow the use of existing sources far better in an automated manner, while reducing the specific primary energy consumption per task accomplished. However, it should be noted that IT also consumes power. Overall, the behaviour of the population in view of the adaption of new technologies impacting living habits is difficult to foresee.

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Footnotes

1. The 2016 and 2017 GDP growth figures from the WOO 2016 are based on OPEC's July MOMR.
2. The EC defines the principle of 'nearly zero energy buildings' as buildings with high energy performance. The low amount of energy required should be covered to a significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
3. However, the LNG tax reduction is reported to be currently facing resistance from the western Indian state of Gujarat, through which 90% of the LNG used in India passes (World Oil, 17 February 2017).
4. At the 27th Extraordinary Session of the African Union, held in 2016 in Kigali, Rwanda.
5. Renewable Capacity Statistics 2017, IRENA.
6. For the list on non-Annex I countries, refer to: http://unfccc.int/parties_and_observers/parties/non_annex_i/items/2833.php
7. For the list of Annex I countries, refer to: http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php
8. World Bank, The 2017 Atlas of Sustainable Development Goals
9. The World Oil Refining Logistics and Demand (WORLD) model is supplied by EnSys Energy & Systems, Inc. OPEC's version of the model was developed jointly with EnSys.
10. The seven regions that form the basis of crude and product trade reporting are: US & Canada, Latin America, Africa, Europe, Russia & Caspian, Middle East and Asia-Pacific.
11. 'Capacity creep' most often focuses on small expansions in crude distillation and major upgrading units. The extent of these additions typically varies quite significantly between regions. For the purpose of this year's Outlook, it is assumed that additions achieved annually through 'capacity creep' are around 0.2% of established capacity, or about 0.9 mb/d globally in respect to crude distillation capacity from 2017 through 2022. Some sources refer to much higher levels of capacity creep, but these stem from a rather variable definition of 'capacity creep', which sometimes includes not only larger projects but every expansion that is not a new refinery. The conservative estimate of 'capacity creep' applied here is tightly linked to the very detailed list of projects that was used for capacity assessment. In other words, what is considered to be within the category of 'capacity creep' (that is, expansions in the range of 5,000–10,000 b/d or more) by other sources was often explicitly identified as individual projects within the list used for projects assessment. Consequently, only a small level of creep was allowed in order to cover minor expansions that are 'under the radar' of the detailed projects lists. As a result of adding in the effect of 'capacity creep', crude distillation capacity is projected to increase by approximately 8.4 mb/d by 2022 from the base level at the end of 2016.
12. A 90% level is considered the maximum sustainable utilization rate over the longer period for a region.
13. Candidates for closure were picked from the refinery database based on a risking assessment. This risking of refineries involved a combination of factors, such as refinery complexity; location (and, thus, exposure to competition); past utilization rates; ownership structure; options to select processed crudes; and local markets specifics. Whether

or not a refinery had been reported as under consideration for sale or closure was also an important factor.

14. Global refinery utilizations averaged 81.4% from 2010 through 2016 according to the *BP Statistical Review of World Energy 2017*.
15. In June 2015, the US EPA announced it was working with the International Civil Aviation Organization, a body of the UN, to develop GHG emissions standards for civil aviation aircraft. In August 2016, the EPA and the US Department of Transportation's National Highway Traffic Safety Administration jointly announced finalized standards for heavy- and medium-duty vehicles. The standards call for a 25% reduction in heavy-duty vehicle carbon emissions and somewhat less for medium-duty vehicles. Currently, the heavy-duty truck sector is characterized by high growth, vehicles that average around six miles per US gallon and which contribute around 20% of total transport sector GHG emissions, despite comprising only 5% of total vehicles.
16. The decline in Other Asia-Pacific utilizations after 2020 reflects appreciable run reductions in Japan & Australasia, partially offsetting gains elsewhere in the region.
17. The stated gasoline desulphurization additions exclude those for naphtha desulphurization, which is mainly associated with a front-end step in catalytic reforming. Naphtha desulphurization capacity additions were included in Table 7.1.
18. MTBE has been the cause of wide ranging ground-water contamination in the US and a raft of related lawsuits. By way of comparison, authorities in Europe examined the risks of using MTBE in gasoline and concluded that these were manageable, apparently because of the existence of extremely tight storage controls and monitoring. With a need to raise gasoline octanes, there is discussion in a number of regions regarding increasing MTBE use since it is a high octane component that also 'dilutes' adverse gasoline properties including sulphur, benzene and total aromatics. MTBE is an allowed gasoline component under the Euro 5/6 regulations. Thus, since most countries are implementing regulations based on the Euro standards, this in itself would appear to allow for a role for MTBE. The 0.65 mb/d of MTBE modelling additions 2022–2040 is consistent with current growth in the compound's use. Current projects total 0.07 mb/d.
19. It should be mentioned that this cost has been estimated on the assumption that all investments related to a specific project are only considered at the time of project start-up. In reality, however, such investments are spread across several years of construction. Furthermore, since several projects in this category are already at an advanced stage of construction, part of the investment has already been covered.
20. The seven regions that are the basis of the crude and product trade reporting are: US & Canada, Latin America, Africa, Europe, Russia & Caspian, Middle East and Asia-Pacific.
21. For example, crude oil trade reported at the 23-region level for a 2016 WORLD model case, run in association with this Outlook, showed inter-regional trade volume at close to the 43 mb/d. The 23-region level translates to around 36 mb/d when trade reporting is converted to the seven-region basis.
22. The crude trade volumes referenced here reflect total crude oil trade, which comprises conventional and non-conventional crude oils and condensates. Product trade volumes include finished products, intermediates and non-crude supply streams. Together, the latter equate to total non-crude 'liquids' trade.

23. The WORLD model used to generate projections for crude differentials is based on an optimization technique. It is equally important to bear in mind that prices generated via the modelling are also very sensitive to changes in assumptions and, therefore, need to be regarded more as indicators of trends rather than as absolute projections.

Annex A
Abbreviations

ACG	Azeri-Chirag-Guneshli
AE	Accelerated Efficiency
API	American Petroleum Institute
ARA	African Refiners Association
AU	African Union
b/d	Barrels per day
BEV	Battery electric vehicles
boe	Barrels of oil equivalent
bt	Billion tonnes
CAFC	Corporate Average Fuel Consumption
CAFE	Corporate Average Fuel Economy
CAPEX	Capital expenditure
CAPP	Canadian Association of Petroleum Producers
CCPP	Combined Cycle Power Plants
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CFC	Carbon fibre-reinforced compound
CFTA	Continental Free Trade Area
CHP	Combined heat and power
CNG	Compressed natural gas
CNOOC	China National Offshore Oil Corporation
CNPC	China National Petroleum Corporation
CO_2	Carbon dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPP	Clean Power Plan
CTLs	Coal-to-liquids
CSP	Concentrated solar power
CTO	Coal-to-olefins
DI	Direct injection
EC	European Commission
ECA	Emission Control Area
ECAC	European Civil Aviation Conference
ECB	European Central Bank
EIA	Energy Information Administration (US)
EOR	Enhanced oil recovery
EPA	Environmental Protection Agency (US)
EPE	Empresa de Pesquisa Energética
ESPO	Eastern Siberia-Pacific Ocean
ETBE	Ethyl tertiary butyl ether
EU	European Union
EV	Electric vehicle

FCC	Fluid catalytic cracking
FCV	Fuel cell vehicles
FED	US Federal Reserve
FONAR	Fuel Oil Non-Availability Request
GDP	Gross Domestic Product
GHG	Greenhouse gas
GPS	Global Positioning System
GST	Goods and Services Tax
GTLs	Gas-to-liquids
GW	Gigawatt
HDV	Heavy-duty vehicle
HGG	Higher GDP growth
HELP	Hydrocarbon Exploration and Licensing Policy
HEV	Hybrid electric vehicle
HSFO	High sulphur fuel oil
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICE	Internal combustion engine
IEA	International Energy Agency
IED	Industrial Emissions Directive
IFO	Intermediate fuel oil
IMO	International Maritime Organization
IMF	International Monetary Fund
IOC	International Oil Company
IPO	Initial Public Offering
IRENA	International Renewable Energy Agency
kg	Kilogramme
km	Kilometre
KNPC	Kuwait National Petroleum Company
kW	Kilowatt
LCCs	Low Cost Carriers
LGG	Lower GDP growth
LH	Liquefied hydrogen
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LSFO	Low sulphur fuel oil
M&A	Mergers and Acquisitions
MaaS	Mobility as a Service
MARPOL	International Convention for the Prevention of Pollution from Ships

mb/d	Million barrels per day
mboe	Million barrels of oil equivalent
MEPC	Marine Environmental Protection Committee
MOMR	Monthly Oil Market Report (OPEC)
mpg	Miles per gallon
MSEs	Micro-and-small enterprises
mt	Million tonnes
MTBE	Methyl tertiary butyl ether
MTO	Methanol-to-olefins
MTOMR	Medium-Term Oil Market Report (IEA)
MW	Megawatts
N_2	Nitrogen
NDC	Nationally Determined Contribution
NEA	National Energy Administration (China)
NGLs	Natural gas liquids
NGV	Natural gas vehicle
NHTSA	US National Highway Traffic Safety Administration
NOCs	National Oil Companies
NO_x	Nitrogen oxides
NUA	New Urban Agenda
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
OPV	Oil use per vehicle
ORB	OPEC Reference Basket (of crudes)
ORC	Organic Rankine Cycle
ORTM	OPEC Road Transportation Model
OWEM	OPEC World Energy Model
p.a.	Per annum
PADD	Petroleum Administration for Defense Districts
PDH	Propane dehydrogenation
PEMEX	Petróleos Mexicanos
PHEV	Plug-in hybrid electric vehicles
ppm	Parts per million
PPP	Purchasing power parity
PPR	Pollution prevention and response
PV	Photovoltaic
QP	Qatar Petroleum
R&D	Research & Development
RFCC	Resid fluid catalytic cracking
RFS	Renewable Fuel Standard
RPK	Revenue Passenger Kilometre

SAGD	Steam assisted gravity drainage
SCF	Standard cubic feet
SDGs	Sustainable Development Goals
Sinopec	China Petrochemical Corporation
SO_x	Sulphur oxides
SPC	Supreme Petroleum Council
SPR	Strategic Petroleum Reserves
SUV	Sport utility vehicle
TAN	Total acid number
TEN-T	Trans-European Transport Network
TWh	Terrawatt hour
UAE	United Arab Emirates
UK	United Kingdom
ULCCs	Ultra-large crude carriers
ULEZ	Ultra-Low Emission Zones
ULS	Ultra-low sulphur
UN	United Nations
UNDP	UN Development Programme
UNFCCC	UN Framework Convention on Climate Change
VGO	Vacuum gasoil
VLCCs	Very large crude carriers
VMT	Vehicle miles travelled
WCSB	Western Canadian Sedimentary Basin
WHR	Waste heat recovery
WOO	World Oil Outlook (OPEC)
WORLD	World Oil Refining Logistics Demand Model
WTI	West Texas Intermediate

A

Annex B
OPEC World Energy: definitions of regions

OECD

OECD America
Canada
Chile
Guam
Mexico
Puerto Rico
United States of America
United States Virgin Islands

OECD Europe
Austria
Belgium
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Luxembourg
Netherlands
Norway
Poland
Portugal
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom

OECD Asia Oceania
Australia
Japan
New Zealand
OECD Asia Oceania, Other
Republic of Korea

DEVELOPING COUNTRIES

Latin America
Anguilla
Antigua and Barbuda
Argentina
Aruba
Bahamas
Barbados
Belize
Bermuda
Bolivia (Plurinational State of)
Brazil
British Virgin Islands
Cayman Islands
Colombia
Costa Rica
Cuba
Dominica
Dominican Republic
El Salvador
French Guiana
Grenada
Guadaloupe
Guatemala
Guyana
Haiti
Honduras
Jamaica
Martinique
Montserrat
Netherlands Antilles
Nicaragua
Panama
Paraguay
Peru
St. Kitts and Nevis

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St. Lucia
St. Pierre et Miquelon
St. Vincent and the Grenadines
Suriname
Trinidad and Tobago
Turks and Caicos Islands
Uruguay

Middle East & Africa

Bahrain
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Chad
Comoros
Congo
Côte d'Ivoire
Democratic Republic of the Congo
Djibouti
Egypt
Eritrea
Ethiopia
Gambia
Ghana
Guinea
Guinea-Bissau
Jordan
Kenya
Lebanon
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mayotte
Morocco
Mozambique
Namibia
Niger
Oman
Réunion
Rwanda
Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Somalia
South Africa
South Sudan
Sudan
Swaziland
Syrian Arab Republic
Togo
Tunisia
Uganda
United Republic of Tanzania
Western Sahara
Yemen
Zambia
Zimbabwe

INDIA

India

CHINA

People's Republic of China

Other Asia

Afghanistan
American Samoa
Bangladesh
Bhutan
Brunei Darussalam
Cambodia
China, Hong Kong SAR
China, Macao SAR
Cook Islands
Democratic People's Republic of Korea

Fiji
French Polynesia
Indonesia
Kiribati
Lao People's Democratic Republic
Malaysia
Maldives
Micronesia (Federated States of)
Mongolia
Myanmar
Nauru
Nepal
New Caledonia
Niue
Pakistan
Papua New Guinea
Philippines
Samoa
Singapore
Solomon Islands
Sri Lanka
Thailand
Timor-Leste
Tonga
Vanuatu
Viet Nam

OPEC

Algeria
Angola
Ecuador
Equatorial Guinea
Gabon
IR Iran
Iraq
Kuwait
Libya
Nigeria
Qatar
Saudi Arabia
United Arab Emirates
Venezuela

EURASIA

Russia

Russian Federation

Other Eurasia

Albania
Armenia
Azerbaijan
Belarus
Bosnia and Herzegovina
Bulgaria
Croatia
Cyprus
Georgia
Gibraltar
Kazakhstan
Kyrgyzstan
Latvia
Lithuania
Malta
Montenegro
Republic of Moldova
Romania
Serbia
Tajikistan
The Former Yugoslav Republic of Macedonia
Turkmenistan
Ukraine
Uzbekistan

A

Annex C
World Oil Refining Logistics and Demand: definitions of regions

US & CANADA

United States of America
Canada

LATIN AMERICA

Greater Caribbean

Anguilla
Antigua and Barbuda
Aruba
Bahamas
Barbados
Belize
Bermuda
British Virgin Islands
Cayman Islands
Colombia
Costa Rica
Cuba
Dominica
Dominican Republic
Ecuador
El Salvador
French Guiana
Grenada
Guadeloupe
Guatemala
Guyana
Haiti
Honduras
Jamaica
Martinique
Montserrat
Netherlands Antilles
Nicaragua
Panama
Puerto Rico
St. Kitts & Nevis
St. Lucia
St. Pierre et Miquelon
St. Vincent and The Grenadines
Suriname
Trinidad and Tobago
Turks And Caicos Islands
United States Virgin Islands
Venezuela, Bolivarian Republic of

Mexico

Mexico

Rest of South America

Argentina
Bolivia (Plurinational State of)
Brazil
Chile
Paraguay
Peru
Uruguay

AFRICA

North Africa/Eastern Mediterranean

Algeria
Egypt
Lebanon
Libya
Mediterranean, Other
Morocco
Syrian Arab Republic
Tunisia

West Africa

Angola
Benin
Cameroon
Congo
Côte d'Ivoire
Democratic Republic of Congo
Equatorial Guinea

A

Gabon
Ghana
Guinea
Guinea-Bissau
Liberia
Mali
Mauritania
Niger
Nigeria
Senegal
Sierra Leone
Togo

East/South Africa

Botswana
Burkina Faso
Burundi
Cape Verde
Central African Republic
Chad
Comoros
Djibouti
Ethiopia
Eritrea
Gambia
Kenya
Lesotho
Madagascar
Malawi
Mauritius
Mayotte
Mozambique
Namibia
Réunion
Rwanda
Sao Tome and Principe
Seychelles
Somalia
South Africa
South Sudan
Sudan
Swaziland
Uganda
United Republic of Tanzania
Western Sahara
Zambia
Zimbabwe

EUROPE

North Europe

Austria
Belgium
Denmark
Finland
Germany
Iceland
Ireland
Luxembourg
Netherlands
Norway
Sweden
Switzerland
United Kingdom

South Europe

Cyprus
France
Gibraltar
Greece
Italy
Malta
Portugal
Spain
Turkey

Eastern Europe

Albania
Belarus
Bosnia and Herzegovina
Bulgaria
Croatia

Czech Republic
Estonia
Hungary
Latvia
Lithuania
Montenegro
Poland
Republic of Moldova
Romania
Serbia
Slovakia
Slovenia
The Former Yugoslav Republic of Macedonia
Ukraine

RUSSIA & CASPIAN

Caspian Region
Armenia
Azerbaijan
Georgia
Kazakhstan
Kyrgyzstan
Tajikistan
Turkmenistan
Uzbekistan

Russia
Russian Federation

MIDDLE EAST

Bahrain
IR Iran
Iraq
Jordan
Kuwait
Oman
Qatar
Saudi Arabia
United Arab Emirates
Yemen

ASIA-PACIFIC

Pacific Industrialized
Australia
Japan
New Zealand

Pacific High Growth
Brunei Darussalam
Indonesia
Malaysia
Philippines
Republic of Korea
Singapore
Thailand

China
People's Republic of China

Rest of Asia
Afghanistan
American Samoa
Bangladesh
Bhutan
Cambodia
Cook Islands
Fiji
French Polynesia
Guam
India
Democratic People's Republic of Korea

A

Kiribati
Lao People's Democratic Republic
Maldives
Micronesia, Federated States of
Mongolia
Myanmar
Nauru
Nepal
New Caledonia
Niue
Pakistan
Papua New Guinea
Samoa
Solomon Islands
Sri Lanka
Timor-Leste
Tonga
Vanuatu
Viet Nam

A

Annex D
Major data sources

Accenture Consulting
Advanced Resources International Inc.
Africa Progress Panel
African Union
Airbus
American Chemical Society (ACS)
American Petroleum Institute (API)
Argus
Asia-Pacific Economic Cooperation (APEC)
Baker Hughes
Barclays Research
Bloomberg
Boeing
BP Statistical Review of World Energy
Brazil, Ministry of Mines and Energy
Brookings Institute
Bunkerworld
Canada, National Energy Board
Canadian Association of Petroleum Producers
Canadian Energy Research Institute
Center for Strategic and International Studies (CSIS)
China National Petroleum Corporation (CNPC)
Citigroup
Climate Action Tracker
Consensus forecasts
Daily Caller
Deloitte
Deutsche Bank
E&P Magazine
East African Community
The Economist
Economist Intelligence Unit online database
Elsevier
Energy Research Institute of the Russian Academy of Sciences (ERI RAS)
Energy Intelligence Group
EnSys Energy & Systems, Inc
Ernst & Young
EUREL
European Automotive Manufacturers Association (ACEA)
European Commission (EC)
European Council
European Environment Agency
Eurostat
Evaluate Energy
Financial Times
Global Carbon Capture and Storage Institute (GCCSI)

Global Commission on the Economy and Climate
Global Wind Energy Council
Goldman Sachs
GSMA Intelligence
Harvard Business Review
Haver Analytics
HSBC
Hydrocarbon Processing
International Commodities Exchange
IEA Monthly Oil Data Service (MODS)
IEA Oil Market Report
IEA World Energy Outlook
IHS Markit
IMF, Direction of Trade Statistics
IMF, International Financial Statistics
IMF, Primary Commodity Prices
IMF, World Economic Outlook
India, Ministry of Petroleum & Natural Gas
Institute of Energy Economics, Japan (IEEJ)
Institut Français du Pétrole (IFP)
Interfax Global Energy
Intergovernmental Panel on Climate Change (IPCC)
International Air Transport Association (IATA)
International Association for Energy Economics (IAEE)
International Atomic Energy Agency (IAEA)
International Civil Aviation Organization (ICAO)
International Council on Clean Transportation (ICCT)
International Maritime Organization (IMO)
International Monetary Fund (IMF)
International Renewable Energy Agency (IRENA)
International Road Federation, World Road Statistics
International Union of Railways (UIC)
Japan, Ministry of Economy, Trade and Industry (METI)
Japan Automobile Manufacturers Association, Inc (JAMA)
Joint Aviation Authority (JAA)
Joint Organisations Data Initiative (JODI)
Journal of Petroleum Technology
Kennedy School of Government, Harvard University
McKinsey Global Institute
National Development and Reform Commission (NDRC)
National Energy Administration of the People's Republic of China (NEA)
National Renewable Energy Laboratory
Natural Gas World Magazine
Nexant
Norton Rose Fulbright
New York Mercantile Exchange

OECD Trade by Commodities
OECD/IEA, Energy Balances of non-OECD countries
OECD/IEA, Energy Balances of OECD countries
OECD/IEA, Energy Statistics of non-OECD countries
OECD/IEA, Energy Statistics of OECD countries
OECD/IEA, Quarterly Energy Prices & Taxes
OECD, International Trade by Commodities Statistics
OECD International Transport Forum, Key Transport Statistics
OECD, National Accounts of OECD Countries
OECD Economic Outlook
Oil & Gas Journal
OPEC Annual Statistical Bulletin (ASB)
OPEC Fund for International Development (OFID)
OPEC Monthly Oil Market Report (MOMR)
OPEC World Oil Outlook (WOO)
Oxford Economics
Oxford Institute for Energy Studies
Petrobras
Petroleum Economist
Petroleum Intelligence Weekly
Platts
PricewaterhouseCoopers
REN21 – Global Status Report 2017
Reuters
Rystad Energy
Seatrade
Siemens AG
Society of Petroleum Engineers (SPE)
Statoil
Stratas Advisors
Sustainable Energy for All
The Economic Times
Turner, Mason and Company
UN, Department of Economic and Social Affairs
UN, Energy Statistics
UN, Food and Agriculture Organization (FAO)
UN, International Trade Statistics Yearbook
UN, National Account Statistics
UN Conference on Trade and Development (UNCTAD)
UN Development Programme (UNDP)
UN Economic and Social Commission for Asia and the Pacific (UNESCAP)
UN Educational, Scientific and Cultural Organization (UNESCO)
UN Environment Programme (UNEP)
UN Framework Convention on Climate Change (UNFCCC)
UN International Labour Organisation (ILO)
UN Statistical Yearbook

UN World Tourism Organization (UNWTO)
US Bureau of Labor Statistics
US Department of Energy (DoE)
US Department of the Interior (DoI)
US Energy Information Administration (EIA)
US Environmental Protection Agency (EPA)
US Geological Survey (USGS)
Wall Street Journal
World Bank
World Coal Association
World Coal Institute
World Energy Council
Wood Mackenzie
World Economic Forum
World Nuclear Association
World Resources Institute
World Trade Organization (WTO), International Trade Statistics
Xinhua

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Organization of the Petroleum Exporting Countries
Helferstorferstrasse 17
A-1010 Vienna, Austria
www.opec.org
ISBN 978-3-9503936-4-4

www.opec.org

ISBN 978-3-9503936-4-4