Chapter 3

Outlook for oil

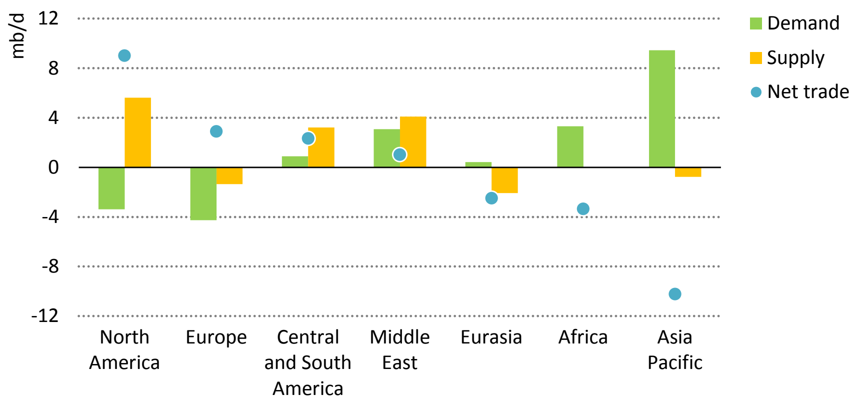
Summit fever?

SUMMARY

- Global oil demand continues to grow in the Stated Policies Scenario, but it loses momentum over the next two decades. From 97 million barrels per day (mb/d) in 2018, demand rises by around 1 mb/d on average every year to 2025. There is a material slowdown after 2025, but this does not lead to a definitive peak in oil use. Demand increases by 0.1 mb/d each year on average during the 2030s and ends up at 106 mb/d in 2040. By contrast, oil demand peaks very soon in the Sustainable Development Scenario and falls back to 67 mb/d by 2040, a level last seen in 1990.
- Thanks to determined policy action, China's period of rapid oil demand growth is set to end soon in the Stated Policies Scenario. Demand in China reaches a peak of 15.7 mb/d in the early 2030s. China nonetheless becomes the world's largest oil consumer just before 2040 as consumption falls steadily in the United States. Demand in India nearly doubles from today's level to 9 mb/d in 2040.
- US tight crude oil production grows in the Stated Policies Scenario from 6 mb/d in 2018 to a maximum of 11 mb/d in 2035. The majority of this growth comes from the Permian Basin, which by itself produces more crude oil than the continent of Africa soon after 2030.
- The outlook for US tight oil is not set in stone. Alongside uncertainties on the demand side, changing assumptions on future technology development and resource availability could each increase or decrease production in 2030 by more than 2 mb/d. Concerns about social and environmental issues, such as the level of flaring in the Permian Basin, and the ability of operators to raise affordable finance are other important variables that could affect production prospects.
- The increase in US output accounts for 85% of the global increase in production to 2030 in the Stated Policies Scenario. There are also notable increases in deepwater output in Brazil (the third-largest source of growth globally after the United States and Iraq) and in Guyana. These changes have profound implications for the share of OPEC countries plus Russia in total production, which drops to 47% in 2030 (from 55% in the mid-2000s). Continued investment in new sources of supply in OPEC and Russia nonetheless remains important to long-term oil market stability in this scenario, and their projected share of the oil market rises in the 2030s.
- In the Stated Policies Scenario, more than 30 million electric cars are sold each year by 2040, and the 330 million electric cars on the road in 2040 avoid 4 mb/d of oil demand. By the late-2020s, sales of cars with traditional internal combustion engines are in decline globally and oil use in passenger cars has peaked. This scenario assumes that the rising popularity of sports utility vehicles (SUVs) levels off: if the consumer preference for SUVs were to continue to increase, it would boost

projected 2040 oil demand by nearly 2 mb/d, since these vehicles are larger, generally less fuel-efficient and more difficult to electrify than others.

Figure 3.1 ⊳ Change in oil demand, supply and net trade position in the Stated Policies Scenario, 2018-2040



There is a marked shift in the geography of global oil trade towards Asia; North America becomes the world's second-largest oil exporter by 2030

Notes: Positive net trade values are increases in net exports, negative values are increases in net imports. Demand figures here include international aviation and marine bunkers.

- The changing geography of oil supply and demand in the Stated Policies Scenario transforms global oil trade. Asia takes an increasing share of global imports, and gross oil exports from the United States overtake those from Saudi Arabia by the mid-2020s. Refineries steadily adapt to the additional supply of light crudes. However, the United States also remains a major importer of heavier crudes: gross crude oil imports in 2030 are only one-third lower than in 2010.
- Growing trade volumes and rising geopolitical risks surrounding key chokepoints in oil markets highlight the need for policy makers to keep a close watch on oil security. By 2040, nearly 26 mb/d of oil passes through the Strait of Malacca in the Stated Policies Scenario and around 20 mb/d through the Strait of Hormuz. Any impediment to shipments could materially tighten markets. Emergency oil stocks continue to play an important role in helping to weather potential disruptions.
- Some traditional producers and exporters are seeing increasing pressure on their development model as a result of changing oil market dynamics. They face the prospect of a world where markets for their ample oil resources are not guaranteed, and where reduced income from hydrocarbons hampers their ability to maintain upstream spending and constrains the investments necessary to diversify their economies. A shift towards the lower demand and lower price environment of the Sustainable Development Scenario would further underscore the urgency of economic reform and diversification.

Introduction

What does a regular year for oil markets look like? The year 2018 saw a steady rise in demand of 1.2 million barrels per day (mb/d), but in other ways it confounded expectations. The leading source of consumption growth was not China or India, but rather the United States. Sales of electric vehicles set new records in 2018, though are yet to make a very visible dent in oil consumption trends. The main increases in oil product demand came from gasoline and diesel but there were also sizeable contributions from ethane, liquefied petroleum gas (LPG) and naphtha as the use of oil as a petrochemical feedstock continues to grow in importance.

On the supply side, US tight oil defied talk of infrastructure constraints and its growth to date matches the fastest pace ever seen in the history of oil markets. Geopolitics also came to the fore, as economic, political and security issues affected supply from Venezuela, Libya and Iran. Attacks on oil tankers and processing infrastructure in the Middle East have heightened awareness about risks to oil supply from the region, including via some key choke points in international trade. The oil price has generally remained subdued despite these events. The level of new resource developments appears to be rebounding from its post-2014 slump, with notable prospects for new offshore projects in Latin America.

So where do we go from here? As ever, the *World Energy Outlook* sets out a number of pathways. In the Stated Policies Scenario, demand growth is robust to 2025, but growth slows to a crawl thereafter and demand reaches 106 mb/d in 2040, while the Current Policies Scenario sees continued annual growth in line with historical averages. In the Sustainable Development Scenario, the unprecedented scale, scope and speed of changes in the energy landscape paints a very different picture for oil markets: demand soon peaks and drops to under 67 mb/d in 2040. Against this backdrop, we examine three key issues that shape the future of oil markets:

- **Impact of changes in vehicle ownership:** While passenger cars remain the largest single element of oil demand today, there are some signs that the world is moving beyond traditional modes of car ownership and oil-powered cars. However, recent years have also seen consumers opting for heavier and less efficient cars. We explore the impact of these trends on oil demand.
- **Outlook for US tight oil:** The growth in tight oil in the United States has arguably been the biggest story for oil markets over the past decade. We examine how tight oil operators fared in the wake of the 2014 oil price crash, discuss the outlook for US tight oil and explore some key uncertainties and sensitivities that could affect this outlook.
- **Outlook for oil security:** The consequences of the rise in US production have been felt well beyond North America and beyond the energy sector. At the same time, recent events have highlighted the risks of physical disruption to oil supply. We explore how these various dynamics influence patterns of oil trade and oil supply security: we also look at how they impact, and are impacted by, crude oil quality.

Figures and tables from this chapter may be downloaded from www.iea.org/weo2019/secure/.

Scenarios

3.1 Overview

Table 3.1 ▷ Global oil demand and production by scenario (mb/d)

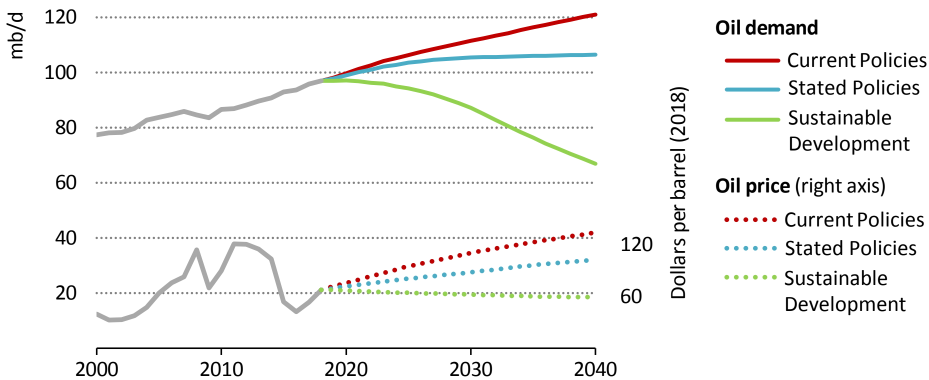
	2000	2018	Stated Policies 2030	Stated Policies 2040	Sustainable Development 2030	Sustainable Development 2040	Current Policies 2030	Current Policies 2040
Road transport	30.1	42.2	45.5	44.5	36.7	22.8	48.9	53.4
Aviation and shipping	8.3	12.0	14.5	16.8	11.2	9.4	15.7	19.2
Industry and petrochemicals	14.4	18.3	21.5	22.9	18.9	18.5	21.5	23.0
Buildings and power	14.3	12.3	10.5	9.2	8.4	5.8	11.5	11.1
Other sectors	10.2	12.0	13.3	13.1	12.0	10.4	13.8	14.2
World oil demand	**77.4**	**96.9**	**105.4**	**106.4**	**87.1**	**66.9**	**111.5**	**121.0**
Asia Pacific share	*25%*	*33%*	*36%*	*37%*	*37%*	*38%*	*36%*	*37%*
World biofuels	0.2	1.9	3.5	4.7	6.3	7.7	2.8	3.6
World liquids demand	**77.6**	**98.8**	**108.9**	**111.1**	**93.4**	**74.6**	**114.3**	**124.6**
Conventional crude oil	64.5	67.1	65.1	61.9	52.7	36.9	68.5	70.6
Existing fields	64.5	67.1	39.6	25.9	39.6	25.9	39.6	25.9
New fields	-	-	25.5	36.0	13.1	11.0	28.9	44.7
Tight oil	-	6.3	12.0	13.4	10.1	9.2	13.1	15.5
Natural gas liquids	9.0	17.3	20.4	21.7	17.7	14.8	21.2	23.1
Extra-heavy oil and bitumen	1.0	3.8	4.0	4.9	3.3	2.9	4.3	6.3
Other production	0.6	0.8	1.3	1.6	1.2	1.2	1.5	2.2
World oil production	**75.1**	**95.4**	**102.8**	**103.5**	**85.0**	**65.1**	**108.7**	**117.7**
OPEC share	*41%*	*39%*	*37%*	*39%*	*37%*	*37%*	*37%*	*39%*
World processing gains	1.8	2.3	2.6	2.9	2.2	1.8	2.8	3.3
World oil supply	**76.9**	**97.7**	**105.4**	**106.4**	**87.1**	**66.9**	**111.5**	**121.0**
IEA crude oil price ($2018/barrel)	**40**	**68**	**88**	**103**	**62**	**59**	**111**	**134**

Notes: Other production includes coal-to-liquids, gas-to-liquids, additives and kerogen oil. Historical supply and demand volumes differ due to changes in stocks. See Annex C for definitions.

In the **Stated Policies Scenario**, global oil demand rises by around 1 mb/d on average every year until 2025 (Table 3.1). Oil use in passenger cars peaks in the late-2020s and during the 2030s demand increases by only 0.1 mb/d on average each year (Figure 3.2). There is no definitive peak in oil use, given increases in petrochemicals, trucks and the shipping and aviation sectors. The largest increases in production between 2018 and 2040 come from the United States, Iraq and Brazil. The share in oil production from countries in the Organization of the Petroleum Exporting Countries (OPEC) plus Russia falls to 47% for much of the 2020s, a level not seen since the 1980s. The oil price required to balance supply and demand in this scenario edges higher to nearly $90/barrel in 2030 and $103/barrel in 2040.

The **Current Policies Scenario** provides a reminder that, if the effects of new policies and alternative technologies are discounted, there is scope for more rapid growth in oil demand. In this scenario, global oil demand rises by 1.1 mb/d on average every year to 2040, similar to the average increase seen since 2000. Without strengthened policies on fuel efficiency or the use of alternative fuels, there is little restraint on the pace of oil demand growth. Growth is led by road transport, accounting for nearly half of the increase to 2040, and there are major increases in petrochemicals and aviation. The oil price rises steadily to just under $135/barrel in 2040.

Figure 3.2 ▷ Global oil demand and crude oil price by scenario



In the Stated Policies Scenario, demand growth slows substantially after 2025, while the Sustainable Development Scenario paints a very different picture for demand and prices

In the **Sustainable Development Scenario**, determined policy interventions lead to a peak in global oil demand within the next few years. Demand falls by around 2 mb/d each year on average during the 2030s and is 30 mb/d below today's level by 2040. Demand falls by more than 50% in advanced economies between 2018 and 2040, and by 10% in developing economies. Reductions in oil use in road transport are particularly significant. By 2040, 50% of cars are electric (with 900 million electric cars on the road), as are most of the world's urban buses; almost 2 million barrels of oil equivalent (mboe) per day of biofuels are consumed in the aviation and shipping sectors; and almost 20% of the fuel used by trucks worldwide is low-carbon. The only sector to see demand growth is petrochemicals: while the rate of plastics recycling more than doubles (from around 15% today to 35% in 2040), demand increases by almost 3 mb/d to 2040.

Tight oil production in the United States continues to grow for a number of years: it has a rapid decline rate and so is relatively well suited to a world where the outlook for demand and prices is uncertain. In very challenging market conditions, OPEC is assumed to continue to pursue efforts at market management, meaning that its production falls by 5 mb/d over the period to 2025. The oil price remains below $70 per barrel and falls to just under $60/barrel in 2040.

3.2 Oil demand by region

Table 3.2 ▷ Oil demand by region and scenario (mb/d)

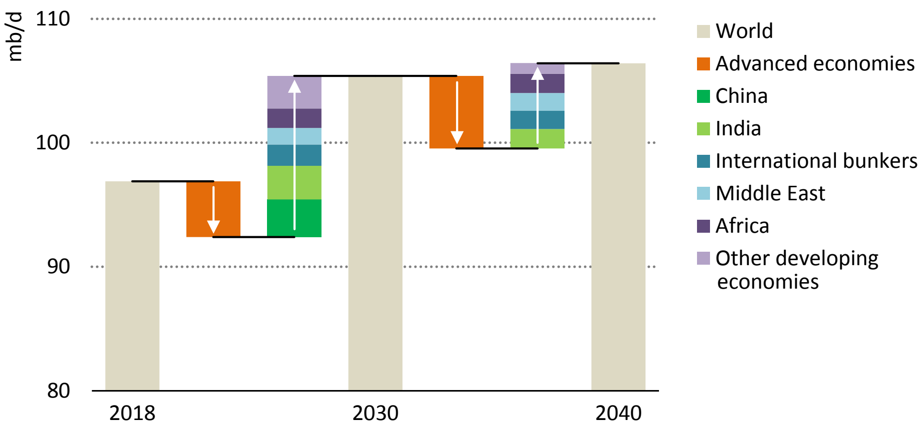
			Stated Policies				Sustainable Development	
	2000	2018	2025	2030	2035	2040	2030	2040
North America	23.5	22.8	22.5	21.5	20.3	19.1	17.7	11.7
United States	19.6	18.5	18.4	17.4	16.3	15.1	14.2	9.1
Central and South America	4.5	5.8	6.1	6.2	6.4	6.5	4.9	3.8
Brazil	1.9	2.4	2.6	2.7	2.8	2.8	2.1	1.6
Europe	14.9	13.2	12.4	11.1	9.7	8.7	9.2	5.0
European Union	13.1	11.1	10.1	8.8	7.4	6.3	7.3	3.5
Africa	2.2	3.9	4.9	5.5	6.2	7.0	4.9	5.2
South Africa	0.4	0.5	0.6	0.6	0.7	0.7	0.6	0.5
Middle East	4.3	7.5	8.4	8.8	9.6	10.2	6.7	6.3
Eurasia	3.1	3.9	4.3	4.3	4.2	4.2	3.8	3.1
Russia	2.6	3.2	3.4	3.4	3.3	3.2	3.0	2.4
Asia Pacific	19.4	31.6	35.8	38.0	38.9	39.2	32.4	25.4
China	4.7	12.5	14.5	15.6	15.6	15.5	12.7	9.3
India	2.3	4.7	6.4	7.5	8.4	9.0	6.5	6.1
Japan	5.1	3.6	3.0	2.7	2.3	2.0	2.3	1.2
Southeast Asia	3.1	5.3	6.3	6.6	6.9	6.9	5.8	4.7
International bunkers	5.4	8.2	9.3	10.0	10.7	11.4	7.6	6.4
World oil	**77.4**	**96.9**	**103.5**	**105.4**	**106.0**	**106.4**	**87.1**	**66.9**
World biofuels	0.2	1.9	2.8	3.5	4.1	4.7	6.3	7.7
World liquids	77.6	98.8	106.4	108.9	110.1	111.1	93.4	74.6

Note: See Annex C for definitions.

In the Stated Policies Scenario, there is a 0.9 mb/d average annual increase in demand in developing economies between 2018 and 2030 and a 0.4 mb/d average annual decrease in demand in advanced economies (Figure 3.3). This swing has major consequences for oil trade flows and oil security dynamics. There is a marked slowdown in global oil demand growth during the 2030s: demand fluctuates on an annual basis but there is no definitive peak in overall use. The average annual increase in the 2030s is 0.1 mb/d.

Road transport accounts for half of total oil demand in advanced economies today, and changes in this segment are the key determinant of overall demand trends. In the United States, reductions in the use of oil in passenger cars account for over 90% of the overall decline in demand between 2018 and 2040. The implementation of efficiency standards is central to this decline. Electric cars also play an increasingly important role: on average there are nearly 2.5 million electric cars sold each year during the 2030s and in 2040 there are nearly 30 million electric cars on the road (just over 10% of the total US car stock).

Figure 3.3 ▷ Change in oil demand by region in the Stated Policies Scenario



Demand growth in many developing countries stalls after 2030 and global demand growth tails off, however the first peak in oil demand will not necessarily be the last

In Europe, oil demand falls by around 0.2 mb/d each year on average to 2040. Most of this decline comes from passenger cars, but there is also a decrease in oil demand for buildings given stated policies to ban the installation of oil boilers in new houses and phase out existing equipment.

In China, oil demand growth remains robust until the early 2020s but grinds to a halt in the 2030s. Oil use in petrochemicals rises steadily between 2018 and 2040, as does demand for aviation, stemming from increasing domestic tourism. However, with widespread electrification (150 million cars in China are electric in 2040) and an ever more efficient car fleet, oil use in cars reaches a peak in 2030 and then slowly declines. The use of oil in buildings also falls and total oil demand peaks in the early 2030s at 15.7 mb/d.

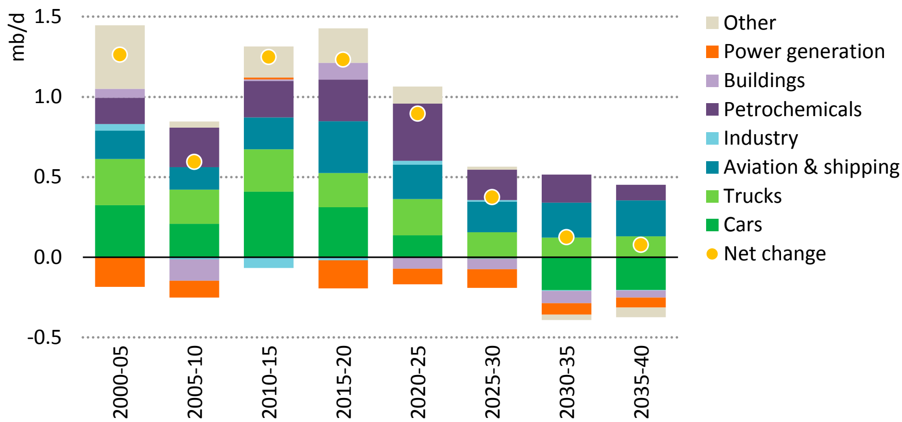
In India, demand nearly doubles between 2018 and 2040, the largest absolute growth of any country. One-third of the growth comes from trucks; another quarter comes from passenger cars, with the Indian car fleet growing by a factor of seven between 2018 and 2040; a further 15% of the growth comes from the use of oil as a petrochemical feedstock.

In the Middle East, the largest contributor to demand growth is the petrochemical sector, which many countries see as having the potential to help them gain more value from their oil reserves. There is also an increase in oil use in power as large volumes of heavy fuel oil are displaced from the shipping sector around 2020, though the use of oil then declines as the heavy fuel oil market rebalances and prices start to rise.

In Africa, demand growth is largest in transport, but demand also increases for diesel (to use in back-up generators) and for LPG, which, by 2040, helps to provide clean cooking facilities to over 260 million people previously relying on traditional uses of biomass (see Chapter 9).

3.3 Oil demand by sector

Figure 3.4 ⊳ Annual average change in global oil demand by sector in the Stated Policies Scenario



Petrochemicals, aviation & shipping and trucks account for the bulk of the growth in oil demand, offsetting declines in other sectors. Oil use in cars peaks in the late-2020s.

In the Stated Policies Scenario, oil use as a **petrochemical** feedstock is particularly strong in the period to 2025 given the announced plans of many companies to add new capacity, most notably in the United States, China and the Middle East (Figure 3.4). Today around 15% of plastics are recycled globally and an increasing number of countries aim to curb single-use plastics. However, most future growth in plastics comes from developing countries with relatively low levels of recycling and so the global average remains less than 20% in 2040. If the average global recycling rates were instead to reach 35%, this would avoid around 1.7 mb/d of oil demand in 2040; even in this case, however, the use of oil as a feedstock would still increase by 3 mb/d between 2018 and 2040.

Around 15 mb/d of oil is consumed by **trucks** today and the increase in demand to 2040 is the second-largest of any sector (after petrochemicals). The 25% increase in oil demand, however, is much less than the 90% increase in global freight activity over this period. A number of alternatives to the use of oil gain ground: there is an increase in the use of natural gas and biofuels, primarily in China and the United States, and there is some electrification of light commercial vehicles. In total these fuels avoid around 1.5 mb/d of oil demand growth between 2018 and 2040. However, efficiency measures play a bigger role, avoiding a further 4.5 mb/d increase in demand to 2040.

Oil demand for **passenger cars** peaks in the late-2020s. This occurs despite the number of cars on the road globally increasing by 70% between 2018 and 2040. In 2040, there are 330 million electric cars on the road – 15% of the global car fleet – which avoid 4 mb/d of oil demand. The average gasoline or diesel-based car on the road in 2040 is also 25% more efficient than today: this avoids nearly 9 mb/d of oil demand in 2040. This increase in efficiency occurs despite the recent trend, seen across all major car markets, for purchasing larger and heavier cars such as sports utility vehicles (SUVs) (see section 3.9).

There is a 50% increase in oil use in **aviation** between 2018 and 2040 and it accounts for 10% of total oil demand in 2040 (from 7% in 2018). Biofuels are one of the few alternatives to oil use in aviation and they comprise around 5% of liquids demand in the sector in 2040.

The International Maritime Organization (IMO) regulation to limit the sulfur content of oil use in **shipping** to no more than 0.5% by 2020 leads to an 2 mb/d drop in high sulfur fuel oil consumption after the regulation comes into force, together with offsetting increases of 1 mb/d in marine gasoil (a type of diesel), and 1 mb/d in "very low sulfur fuel oil". Over time, there is an increase in the use of liquefied natural gas (LNG) as a bunker fuel (which avoids 0.9 mb/d of oil in 2040) and a modest increase in biofuels. However, total oil use increases by nearly 1.5 mb/d between 2018 and 2040.

Oil combustion in **industry** is mainly used to generate steam and process heat in the chemicals and cement sub-sectors and to power equipment in manufacturing. There are many alternatives to oil for these processes: however, oil is often preferred if it is subsidised or if there is an established distribution network, since site-specific or process-specific constraints can make fuel switching an expensive proposition. Oil consumption in industry remains broadly constant at just over 6 mb/d between 2018 and 2040.

Today, around 65% of oil use in **buildings** occurs in developing economies, with LPG and kerosene used for cooking and lighting, and heavy fuel oil used in some countries for heating. The use of oil in buildings increases modestly in Africa, India and Southeast Asia, but this is offset by losses elsewhere: the United States and Europe see falls of around 70% and 80% respectively.

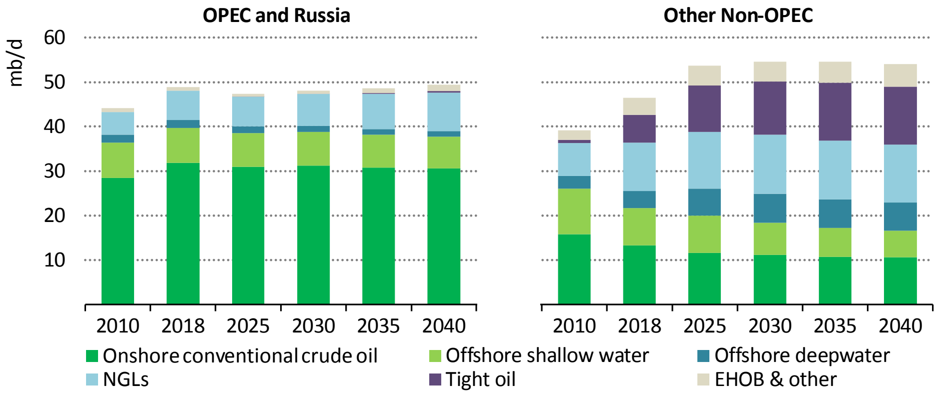
Oil is generally used in **power generation** only in countries with major subsidy regimes or where there is a legacy fleet of stations. The new IMO regulation on shipping fuels leads to a surplus of heavy fuel oil, which in turn leads to a near-term boost in oil use in power. In the longer term, subsidies are assumed to be phased out, and, as renewable-based electricity becomes an increasingly attractive option, the consumption of oil in power generation falls by 40% globally between 2018 and 2040.

Half of the energy used by **trains** today is oil (0.6 mb/d), which is mostly used for freight rather than passenger trains. Oil use in trains declines as electricity becomes the preferred option and demand falls by 0.1 mb/d to 2040. Electric **bus** sales have soared recently in China, which accounted for 99% of global electric bus sales in 2018. There is a 35% increase in the number of buses on the road globally between 2018 and 2040, and so while 25% of urban buses in 2040 are electric, oil use in buses increases by 0.1 mb/d to 2040.

There are limited viable alternatives to oil in sectors such as agriculture, petroleum refineries, oil extraction and non-energy uses like asphalt, bitumen and lubricants. Oil consumption across these sectors increases by just over 1 mb/d over the *Outlook* period.

3.4 Oil supply by type

Figure 3.5 ▷ Oil production by type in the Stated Policies Scenario



OPEC and Russia's share of the oil market remains below 50% to 2040; NGLs and unconventional oil comprise more than two-thirds of other non-OPEC production by 2030

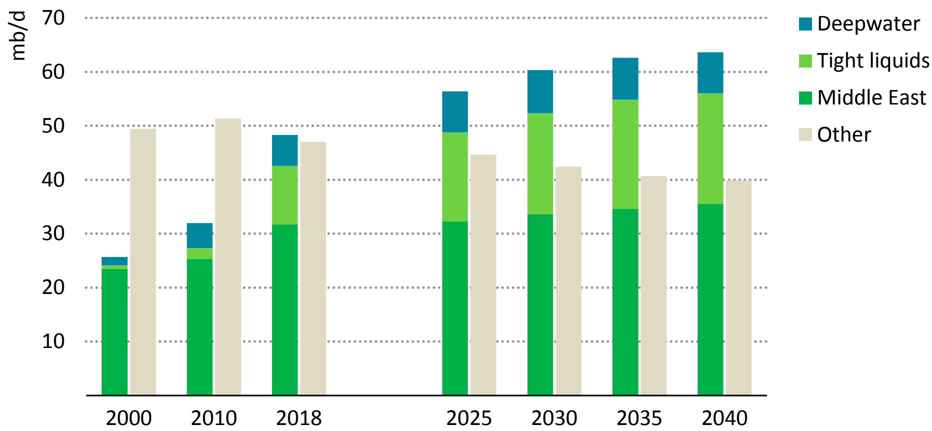
Notes: NGLs = natural gas liquids; EHOB & other = extra-heavy oil and bitumen, kerogen oil, coal-to-liquids, gas-to-liquids and additives.

Conventional crude oil is by far the largest source of oil production today (67 mb/d) (Figure 3.5). However many currently producing fields are mature (almost 40% of production today comes from fields older than 40 years) and replacing declining production from these fields is difficult. Globally, conventional production drops in the Stated Policies Scenario by around 5 mb/d by 2040 and its share in global supply falls from 70% today to 60% in 2040.

Onshore conventional crude oil comes mostly from the Middle East and Russia, which today account for 65% of the 45 mb/d total produced globally. Most of the onshore oil in Russia comes from the Western Siberian Basin. This is a mature province and production declines steadily to 2040. There are other onshore resources elsewhere in Russia, but the harsh environment and lack of infrastructure make these difficult to develop. Total onshore crude oil production falls slightly but stabilises just above 41 mb/d after 2030, with new production coming online from Iraq and North Africa in particular.

Offshore conventional crude oil production remains broadly at today's level (22 mb/d) to 2040. Shallow water oil production from the Middle East grows as Saudi Arabia ramps up production, but continued declines elsewhere, especially in Europe and Southeast Asia, mean that global shallow water production falls by 3 mb/d in the period to 2040. This decline is offset by a near 2 mb/d increase in deepwater production in the same period. There has been a recent uptick in deepwater investment, and most of the increase in production is set to take place before 2030, with notable increases in the United States, Brazil, Mexico and the newly discovered giant fields in Guyana. Deepwater production in Africa falls to around 1.5 mb/d to 2040.

Figure 3.6 ⊳ Composition of global production in the Stated Policies Scenario



Investment and growth is increasingly concentrated in a handful of areas: US tight liquids dominate the near term, but the Middle East and deepwater production also play vital roles

Note: Tight liquids include tight crude oil, condensate and NGLs.

Natural gas liquids (NGLs) play an important role in the economics of gas developments and production increases by 4.5 mb/d to reach 22 mb/d in 2040. Growth in NGLs production generally follows increases in gas production, with the largest increases in the United States, Saudi Arabia and Russia.

Tight crude oil production globally expands from 6.3 mb/d in 2018 to around 13.5 mb/d by 2040 (Figure 3.6). Production in the United States reaches a maximum of 11 mb/d in 2035 but declines slightly in later years (see section 3.10). Production also increases in Argentina, China, Canada, Mexico and Australia. The Vaca Muerta Basin in Argentina has received more attention in recent years, and its production grows to more than 1 mb/d by 2040. Countries outside of the United States produce almost 25% of global tight oil by 2040. The growth in tight oil leads to a large increase in the volumes of light crude oil available. This is not projected to cause major issues for markets: refiners are assumed gradually to adjust the configuration of refineries to accept these volumes and to meet the steady shift in global oil demand towards lighter products (see section 3.11).

Extra-heavy oil and bitumen production increased by 9% each year on average between 2000 and 2015, but growth has stagnated recently. In Canada, Alberta imposed a production curtailment order from January 2019 to bring supplies more closely in line with available pipeline capacity. In Venezuela, production has been severely impacted by its economic and political difficulties. Concerns about the wider social and environmental impacts of production weigh on prospects for major new greenfield developments: extra-heavy oil and bitumen production nevertheless increases in Canada by 0.6 mb/d to 3.7 mb/d in 2040, and in Venezuela by 0.4 mb/d to 1.2 mb/d in 2040.

3.5 Oil supply by region

Table 3.3 ▹ Non-OPEC oil production in the Stated Policies Scenario (mb/d)

	2000	2018	2025	2030	2035	2040	2018-2040 Change	2018-2040 CAAGR
North America	14.2	23.0	28.4	29.6	29.7	28.6	5.6	1.0%
Canada	2.7	5.4	5.7	5.8	6.0	6.0	0.6	0.5%
Mexico	3.5	2.1	1.9	2.1	2.4	2.8	0.8	1.4%
United States	8.0	15.5	20.9	21.7	21.3	19.8	4.3	1.1%
Central and South America	3.2	4.5	6.3	6.8	7.1	7.8	3.3	2.5%
Argentina	0.9	0.6	0.7	0.9	1.1	1.6	1.0	4.7%
Brazil	1.3	2.7	3.9	4.1	4.4	4.7	2.0	2.6%
Europe	7.1	3.7	4.0	3.3	2.8	2.6	-1.0	-1.5%
European Union	3.6	1.7	1.5	1.1	0.9	0.7	-0.9	-3.6%
Norway	3.3	1.9	2.4	2.0	1.8	1.7	-0.1	-0.3%
Africa	1.3	1.5	1.8	1.9	1.7	1.6	0.1	0.4%
Middle East	3.0	3.2	3.3	3.5	3.8	4.0	0.8	1.0%
Qatar	0.9	2.0	2.1	2.3	2.6	2.8	0.8	1.6%
Eurasia	7.9	14.5	14.1	13.6	13.0	12.4	-2.1	-0.7%
Kazakhstan	0.7	1.9	2.0	2.2	2.2	2.3	0.4	0.8%
Russia	6.5	11.5	11.1	10.6	9.9	9.4	-2.1	-0.9%
Asia Pacific	7.8	7.6	6.9	6.5	6.4	6.4	-1.2	-0.8%
China	3.2	3.8	3.4	3.2	3.1	3.0	-0.9	-1.2%
India	0.8	0.8	0.9	0.8	0.8	0.8	-0.1	-0.5%
Southeast Asia	2.8	2.3	2.0	1.8	1.6	1.5	-0.8	-1.9%
Conventional crude oil	37.0	35.9	36.0	34.2	32.0	30.6	-5.3	-0.7%
Tight oil	-	6.3	10.5	11.9	13.1	13.2	6.9	3.4%
United States	-	5.9	9.8	10.8	11.1	10.1	4.2	2.5%
Natural gas liquids	6.4	11.9	13.9	14.5	14.7	14.5	2.6	0.9%
Canada oil sands	0.6	3.1	3.4	3.4	3.5	3.7	0.6	0.8%
Other production	0.5	0.7	1.0	1.1	1.3	1.4	0.7	3.1%
Total non-OPEC	**44.5**	**58.0**	**64.8**	**65.2**	**64.6**	**63.4**	**5.5**	**0.4%**
Non-OPEC share	*59%*	*61%*	*64%*	*63%*	*63%*	*61%*	*0%*	*n.a.*
Sustainable Development			59.2	53.8	46.7	40.8	-17.2	-1.6%

Notes: CAAGR = compound average annual growth rate; n.a. = not applicable. See Annex C for definitions.

Non-OPEC production grows by nearly 7 mb/d to 2025, led by increases in the United States. While OPEC provides nearly 40% of global production today, with a continuing strategy of moderating production to support prices, its share of the market falls to a low of 35% in the early 2020s. Russia has joined OPEC's market management efforts, and Russia and OPEC members together see a fall in market share to a low of 47% in 2025 (from a recent high of 55% in the mid-2000s). While OPEC and Russia's share of the market rises in later years, as US tight oil production reaches a peak, it stays below 50% through to 2040.

Table 3.4 ▷ OPEC oil production in the Stated Policies Scenario (mb/d)

							2018-2040	
	2000	2018	2025	2030	2035	2040	Change	CAAGR
Middle East	20.5	28.5	28.9	30.1	30.8	31.6	3.1	0.5%
Iran	3.8	4.6	3.8	4.1	4.3	4.5	-0.1	-0.1%
Iraq	2.6	4.7	5.3	5.8	6.2	6.5	1.8	1.5%
Kuwait	2.2	3.1	3.1	3.2	3.2	3.2	0.1	0.2%
Saudi Arabia	9.3	12.4	12.6	12.9	13.0	13.1	0.8	0.3%
United Arab Emirates	2.6	3.8	4.0	4.1	4.2	4.4	0.6	0.6%
Non-Middle East	10.1	8.9	7.3	7.5	7.9	8.5	-0.4	-0.2%
Algeria	1.4	1.5	1.3	1.3	1.3	1.3	-0.2	-0.8%
Angola	0.7	1.5	1.3	1.3	1.2	1.2	-0.3	-1.0%
Congo	0.3	0.3	0.1	0.1	0.1	0.1	-0.3	-6.7%
Ecuador	0.4	0.5	0.4	0.4	0.3	0.3	-0.2	-2.4%
Equatorial Guinea	0.1	0.2	0.1	0.1	0.1	0.1	-0.1	-5.2%
Gabon	0.3	0.2	0.1	0.1	0.1	0.1	-0.1	-2.1%
Libya	1.5	1.0	1.0	1.1	1.3	1.5	0.5	1.9%
Nigeria	2.2	2.1	2.1	2.1	2.2	2.3	0.2	0.5%
Venezuela	3.2	1.5	0.8	0.9	1.2	1.6	0.1	0.2%
Conventional crude oil	27.5	31.1	30.1	30.9	31.0	31.3	0.1	0.0%
Natural gas liquids	2.7	5.4	5.5	5.9	6.6	7.2	1.8	1.3%
Venezuela extra-heavy oil	0.4	0.8	0.5	0.6	0.8	1.2	0.4	2.1%
Other production	0.1	0.1	0.1	0.2	0.3	0.4	0.3	6.7%
Total OPEC	**30.6**	**37.4**	**36.2**	**37.6**	**38.7**	**40.1**	**2.7**	**0.3%**
OPEC share	*41%*	*39%*	*36%*	*37%*	*37%*	*39%*	*0%*	*n.a.*
Sustainable Development			32.7	31.2	27.6	24.3	-13.1	-1.9%

Notes: CAAGR = compound average annual growth rate. See Annex C for definitions.

In the **United States**, total oil production grows to a peak of 22 mb/d in 2030 and it accounts for 85% of the total global increase in this period. In 2030, production in the United States is almost 70% greater than the next largest country (Saudi Arabia). Tight oil production peaks in 2035 and, alongside a drop in deepwater and NGLs production, this leads to a 1.5 mb/d decline in US production between 2035 and 2040. The tax credits offered for enhanced oil recovery (EOR) using carbon dioxide (CO_2) lead to a doubling in today's CO_2-EOR production to 0.8 mb/d in 2040.

The focus in **Mexico** has returned to developing shallow water and onshore projects, with less immediate emphasis on deepwater projects. Total production declines to 2025 until deepwater production starts to pick up. There is also some tight oil development.

Brazil registers the second-largest increase of any country over the period to 2040. The majority of this growth occurs before 2025 as production ramps up from new developments and extensions at the deepwater Buzios, Mero, Iara and Lula fields.

Guyana has seen a number of major deepwater discoveries in recent years. These lead to large increases in production over the *Outlook* period. Production grows from negligible levels today to 0.8 mb/d in 2025 and, with further discoveries, to 1 mb/d in 2040.

The tight oil resources of **Argentina** have received a great deal of attention recently. Tight oil production today is less than 60 kb/d, but major investment helps this to increase to 1 mb/d in 2040, and this accounts for 70% of total oil production in Argentina at that time.

Production in **Norway** increases to 2025 as major projects such as Johan Sverdrup come online: this project alone accounts for more than one-quarter of total production in 2025. Despite some further new oil field developments and expansions, total production then declines by around 2% each year on average between 2025 and 2040.

Production in **China** peaked in 2015 at 4.3 mb/d and has since declined by 3.5% on average each year. This slows to an annual average 1% decline through to 2040.

Iraq nearly doubled its oil production over the past decade to 4.7 mb/d despite formidable challenges. Future growth is contingent on a stable political and security environment, attracting sufficient foreign capital and the successful development of new projects to provide the vast quantities of water needed for reinjection.

Production in **Saudi Arabia** remains largely flat until 2025 but then grows by around 0.5 mb/d to reach 13 mb/d in 2040. Around a third of Saudi Arabia's current oil production comes from offshore fields and there are notable increases at the Marjan and Berri fields.

In **Iran,** production fell in 2018 following the reimposition of US sanctions. While Iran has vast oil resources, for the moment we project only a gradual recovery in production, meaning that Iran does not exceed its previous output peak (6 mb/d in 1974) any time before 2040.

In **Venezuela**, the production outlook is strongly affected by political uncertainty and profound economic difficulties. In the absence of conditions that allow for a pickup in investment, we assume that output declines to a low of 0.8 mb/d in 2025 before the situation stabilises, inward investment picks up and production slowly recovers.

Russia's agreement to join OPEC's market management efforts, along with the maturing of many of its largest fields, means that oil production there does not grow materially above today's level. Nonetheless, production remains above 11 mb/d until the mid-2020s before declining by around 1.5 mb/d by 2040. Near-term prospects for developing new tight oil resources and projects in the Arctic are constrained by sanctions and high costs.

Production in **Africa** falls in the coming years because of declines in Angola and Nigeria. But after 2025, production grows in Nigeria as new deepwater fields are developed while Angola stems declines. Production in non-OPEC African countries creeps upwards to 2030: there are increases from smaller producers such as Uganda, Kenya and Senegal. Additions from these countries are relatively small at a global level, but the revenue generated can make a significant difference domestically (see Chapter 11).

3.6 Oil product demand and refining

Table 3.5 ▷ World liquids demand by scenario (mb/d)

		Stated Policies				Sustainable Development	
	2018	2025	2030	2035	2040	2030	2040
Total liquids	**98.8**	**106.4**	**108.9**	**110.1**	**111.1**	**93.4**	**74.6**
Biofuels	1.9	2.8	3.5	4.1	4.7	6.3	7.7
Total oil	96.9	103.5	105.4	106.0	106.4	87.1	66.9
CTL, GTL and additives	0.8	1.0	1.2	1.4	1.5	1.1	1.2
Direct use of crude oil	1.0	0.6	0.4	0.2	0.1	0.2	0.1
Oil products	95.1	101.9	103.8	104.4	104.8	85.8	65.6
LPG and ethane	11.9	14.2	14.8	15.3	15.2	13.5	11.6
Naphtha	6.7	7.2	8.0	8.5	9.1	7.6	8.3
Gasoline	24.6	25.2	25.4	24.4	23.4	20.2	11.0
Kerosene	7.6	8.4	9.0	9.8	10.7	6.8	5.8
Diesel	27.8	30.5	30.6	30.5	30.7	24.3	17.8
Fuel oil	6.6	5.7	5.7	5.8	5.8	4.1	3.0
Other products	10.0	10.6	10.4	10.2	9.9	9.3	8.0
Fractionated products from NGLs	10.6	12.1	12.6	12.8	12.8	11.7	9.5
Refinery products	84.5	89.8	91.2	91.6	92.0	74.1	56.1
Refinery market share	*86%*	*84%*	*84%*	*83%*	*83%*	*79%*	*75%*

Notes: CTL = coal-to-liquids; GTL = gas-to-liquids; NGLs = natural gas liquids; LPG = liquefied petroleum gas. See Annex C for definitions.

Petrochemical feedstocks (ethane, LPG and naphtha) and kerosene account for over 90% of the net increase in total oil product demand to 2040. This contrasts with the trend since 2000, when gasoline and diesel provided two-thirds of the growth in total oil products. Gasoline and diesel remain very important in developing economies, however, with their combined demand growing by nearly 40% between 2018 and 2040.

Gasoline demand peaks globally in the late-2020s and is 1.2 mb/d lower than today by 2040. Diesel demand is boosted around 2020 due to the IMO sulfur regulation, which prompts shippers to look for alternatives to heavy fuel oil. But the pace of growth slows later in the *Outlook* period as a result of the rise of alternative fuels and efficiency improvements in trucks. Demand for heavy fuel oil gradually recovers after 2020 as refineries adapt to produce compliant fuels and scrubbers are installed on large vessels.

The amount of new refining capacity coming online in 2019 is set to be the largest since 2010. This suggests greater competition in the refining sector in the future, especially as demand growth slows after 2025, and as biofuels and NGLs make a growing contribution to liquids demand. These non-refinery sources meet some 40% of the incremental liquids demand between 2018 and 2040. As a result, refineries see their market share of liquids demand decline from 86% today to 83% in 2040.

Table 3.6 ▹ Refining capacity and runs by region in the Stated Policies Scenario (mb/d)

	Refining capacity			Refinery runs			Capacity at risk
	2018	2030	2040	2018	2030	2040	2040
North America	22.7	22.4	22.1	19.2	19.6	18.3	1.7
Europe	16.2	15.0	14.5	13.5	10.7	9.6	5.3
Asia Pacific	35.2	41.3	43.0	29.3	33.8	35.9	3.9
Japan and Korea	7.0	6.6	6.0	6.1	5.2	4.3	1.9
China	15.7	19.2	19.2	12.0	14.4	14.8	2.1
India	5.2	6.3	7.7	5.1	6.1	7.5	-
Southeast Asia	5.1	6.8	7.6	4.2	6.1	7.0	-
Middle East	9.3	12.2	12.7	7.9	10.8	11.4	-
Russia	6.6	6.4	6.4	5.7	4.9	4.6	1.5
Africa	3.5	4.4	4.8	2.0	3.5	4.0	0.2
Brazil	2.2	2.5	2.5	1.7	2.2	2.2	-
Other	4.8	4.8	4.8	2.6	3.0	3.2	1.1
World	**100.4**	**109.0**	**110.7**	**82.1**	**88.6**	**89.1**	**13.7**
Atlantic Basin	55.4	55.0	54.6	44.5	43.5	41.4	9.8
East of Suez	45.0	54.0	56.2	37.7	45.1	47.8	3.9
Sustainable Development	100.4	96.1	77.9	82.1	71.9	54.3	44.2

Notes: Capacity at risk is defined as the difference between refinery capacity and refinery runs, with the latter including a 14% allowance for downtime. Projected shutdowns beyond those publicly announced are also counted as capacity at risk.

The immediate challenge facing the refining industry is to adapt to the major shift in product demand triggered by the IMO regulation which will require a move away from high sulfur fuel oil for shipping. Refiners are responding in diverse ways, which include investing in residue cracking or desulfurisation units, adjusting configurations to increase the yield of diesel at the expense of gasoline, and introducing a new low sulfur fuel by blending gasoil and high sulfur fuel oil (IEA, 2019a).

The long-term challenge is to secure assets that can maintain competitiveness. Many developing Asian countries are actively expanding refining capacity in the light of rising domestic demand. Saudi Arabia is trying to extract more value from its oil by pursuing refining and petrochemical investment opportunities in Asia. Other countries are integrating petrochemical facilities with refining capacities to adapt to changing demand patterns. In the Stated Policies Scenario, some 15 mb/d of new capacity comes online between 2018 and 2040, primarily in developing economies in Asia and the Middle East. This upends the traditional order of the global refining industry. China and the Middle East both overtake Europe in terms of refining activity and the combined share of developing Asia and the Middle East in global refinery runs increases from 37% today to 48% in 2040.

In the Sustainable Development Scenario, refinery runs in 2040 are around 40% lower than in the Stated Policies Scenario. Higher shares of biofuels and lighter products demand mean that the market share of refiners in liquids demand falls from 86% today to 75% in 2040.

3.7 Trade[1]

Table 3.7 ⊳ Oil trade by region in the Stated Policies Scenario

Net importer in 2040	Net imports (mb/d)				As a share of demand			
	2000	2018	2030	2040	2000	2018	2030	2040
China	1.7	9.4	12.9	13.3	34%	71%	78%	79%
Other Asia Pacific	2.2	7.1	9.8	10.7	36%	70%	79%	79%
India	1.5	3.7	6.7	8.4	64%	77%	88%	90%
European Union	10.8	10.9	9.6	7.5	74%	83%	88%	89%
Japan and Korea	7.3	6.1	5.2	4.2	98%	96%	97%	97%
Rest of world	-1.6	0.3	0.4	0.7	n.a.	11%	14%	28%
Net exporter in 2040	**Net exports (mb/d)**				**As a share of production**			
	2000	2018	2030	2040	2000	2018	2030	2040
Middle East	18.9	23.5	24.2	24.6	80%	74%	71%	68%
North America	-9.6	-0.1	7.6	8.9	n.a.	n.a.	25%	30%
Russia	3.9	8.1	6.9	5.8	59%	69%	64%	61%
Central and South America	2.2	0.5	1.5	2.8	31%	7%	18%	28%
Caspian	0.8	2.3	2.1	2.0	59%	75%	69%	66%
Africa	5.4	4.2	2.2	0.8	68%	50%	28%	10%

Global oil trade becomes increasingly centred on Asia in the Stated Policies Scenario. A combination of rising demand and declining domestic production leads to growing import dependency, rising from 76% today to 83% in 2040. China soon overtakes the European Union as the world's largest oil importer and holds that position to 2040, despite the flattening of its oil demand in the 2030s. India's oil import requirements more than double between 2018 and 2040 and its level of import dependency reaches 90%, one of the world's highest. The growing concentration of trade flows to Asia increases the amount of oil passing through major global chokepoints, with implications for global oil security (see section 3.11).

The United States becomes a net oil exporter soon after 2020 and North America becomes the world's second-largest oil exporter by 2030 (overtaking Russia). Gross oil exports (crude oil and refined products) from the United States are five-times higher in 2030 than in 2010, but because its refineries are geared towards heavy crude oil while its production consists mostly of light crude oil, US gross oil imports in 2030 are only one-third lower. More oil will be flowing into and out of US ports than before the shale boom and the United States therefore becomes more connected with global markets.

Net oil exports from Russia decline through to 2040 due to Russia's subdued production outlook. While Africa and Central and South America remain net crude oil exporters, they increasingly rely on imports for refined products.

[1] Unless otherwise stated, trade figures in this chapter reflect volumes traded between regions modelled in the *WEO* and therefore do not include intra-regional trade.

3.8 Investment

Table 3.8 ▷ Cumulative oil and natural gas supply investment by region in the Stated Policies Scenario, 2019-2040 ($2018 billion)

	Total oil and gas	Upstream oil and gas	Transportation		Refining oil	Annual average upstream oil and gas
			Oil	Gas		
North America	5 492	4 547	141	665	139	207
Central and South America	1 817	1 558	115	103	40	71
Europe	1 618	1 201	18	320	80	55
Africa	1 911	1 623	68	167	54	74
Middle East	2 711	2 098	183	291	140	95
Eurasia	2 496	2 089	36	329	42	95
Asia Pacific	3 284	2 052	80	747	405	93
Shipping	402	n.a.	286	116	n.a.	n.a.
World	**19 730**	**15 167**	**927**	**2 737**	**899**	**689**
Sustainable Development	13 227	10 085	332	2 272	538	458

Total oil and gas upstream investment in 2018 was $475 billion. This is 42% below the peak levels seen in 2014. The difference is less stark when adjusted for the decline in upstream costs over this period (based on the IEA Upstream Investment Cost Indices [IEA, 2019a]): on this basis, cost-adjusted investment in 2018 was 16% lower than the peak level in 2014.

In the *World Energy Outlook-2018,* we warned of a possible shortfall in supply in the mid-2020s to meet rising demand if US tight oil did not maintain its record-breaking pace of growth or if there was not a pickup in conventional crude oil approvals. Tight oil production has been revised upwards in this *Outlook* and there are some signs of an increase in project approvals in 2019. We continue to monitor carefully the long-term adequacy of oil supply.

In the Stated Policies Scenario, annual upstream oil and gas spending averages $650 billion between 2019 and 2030 and $730 billion thereafter. Between 2019 and 2030, around $380 billion (60% of total upstream investment) is spent on average each year developing new capacity; the remainder is spent at already producing fields.[2] On average $90 billion is spent globally on tight oil between 2019 and 2040.

In the Sustainable Development Scenario, fewer new developments are required, but continued investment in both new and existing oil fields is an essential element of energy transitions, even as overall production declines in line with climate goals (see Chapter 2). Around $510 billion is spent on average each year on upstream oil and gas between 2019 and 2030, while $390 billion is spent between 2030 and 2040.

[2] This *World Energy Outlook* includes a new method for estimating investment levels based on capital spending over time rather than "overnight" capital expenditure. This provides further insight on spending differences over time and between types of field. The cumulative outcome remains the same as in previous editions.

Key themes

3.9 Passenger cars: are we approaching the peak of the "ICE age"?

There are over 1.1 billion passenger cars on the road today, nearly 50% more than the number just a decade ago, and cars currently account for just under one-quarter of global oil demand.[3] The level of private car ownership in developing economies is still far below that of most advanced economies, and so continued growth in the global car fleet cannot be ruled out.

The latest data show that the number of electric cars has grown rapidly in recent years. There were over 5 million electric cars on the road in 2018, an increase of nearly 65% from 2017. Sales continued to rise during the first-half of 2019, although the rate of increase has declined from 65% to around 45%, mainly because of an overall shrinking car market and because of reforms that have reduced subsidies for electric cars in China.

Many countries aim to phase out conventional vehicles in the coming decades, and various car manufacturers have announced plans to roll out new electric car models. Electric car sales therefore look set to continue to grow. This growth is likely to spread to other vehicle types (trucks, buses and two/three-wheelers), and thus to encompass road transport as a whole, which accounts for nearly half of today's global oil demand.

While the number of electric car sales is still relatively small, there are signs of a slowdown in sales of conventional cars, and this has given rise to the idea that a peak in sales might come sooner than expected. The year 2018 was particularly challenging for car manufacturers: in several key markets, including China, United States and Europe, the total number of cars sold either stagnated or fell for the first time since the 2008 recession. This trend has continued so far into 2019: passenger car sales have dropped by 14% in China, 10% in India, 3% in Europe and 2% in the United States.

What does all of this mean for oil demand from passenger cars? The answer is not straightforward. Many factors influence the decisions people make about whether to buy a car and what type of car to purchase. Consumers do not make their choices based only on economic factors, and trends visible today may or may not persist in the coming decades. For example, the increasing prospects for ride-sharing, vehicle digitalisation and automation as well as improving public transport systems could spell a wholesale shift in how many, and how much, cars will be used in the future. Range anxiety and slow progress in building up recharging infrastructure could slow the pace at which electric mobility grows. There could be a rebound in conventional car sales as the world's population grows and becomes richer. Finally, there could be a continuation of the recent steady rise in consumers choosing to buy larger and heavier cars. There has been a marked rise in sales of sports utility vehicles, which on average consume around 25% more fuel than medium-size

[3] Passenger cars here include passenger vans. Electric cars include both plug-in hybrid electric and battery electric cars. Conventional cars are any car that primarily relies on an internal combustion engine (ICE) including hybrid vehicles.

cars and can be challenging to electrify fully because of power and battery size requirements (IEA, 2019b). This trend could bolster future oil demand from passenger cars.

The following section looks at these countervailing forces and assesses their effect on the outlook for passenger cars and the evolution of future oil demand. We start by examining recent developments in electric car and SUV sales, and what they might mean for the future. We examine how these trends, along with announced transport sector policies and fuel economy targets, could impact global oil demand in the Stated Policies Scenario, focusing in particular on whether the rise of SUVs could offset gains from the electrification of the car fleet.

Rise of electric vehicles

There are many reasons to believe that electric vehicle (EVs) sales will continue to increase. The largest vehicle manufacturers have announced ambitious deployment targets (Box 3.1). Many governments have also announced policies that support the deployment of electric cars, including by: increasing the stringency of fuel economy or emissions targets, introducing restrictions or penalties on the use of conventional cars (such as low emission zones in urban environments), committing to phase out conventional cars sales (as discussed in the *World Energy Outlook-2018*), and investing in new EV recharging infrastructure. Plus battery costs continue to fall. Today, the battery in electric cars costs less than $180 per kilowatt-hour (kWh), down from around $650/kWh five years ago. In the Stated Policies Scenario, this falls to less than $100/kWh in the mid-2020s, by which time electric cars in several key markets are cost competitive with conventional cars on a total cost of ownership basis.[4]

Box 3.1 ▻ Announced plans of vehicle manufacturers for electric cars

The largest manufacturer of electric cars globally today is Tesla, a dedicated electric car company. There are also a number of other EV-only manufacturers in China and elsewhere looking to expand operations. In China, many car manufacturers were quick to embrace electric models and some already focus exclusively on producing electric cars. In 2018, China accounted for 55% of global electric car sales. Car manufacturers in China aim to produce around 12 million electric cars within the next decade.

However, for the largest auto companies worldwide, EVs make up only a small fraction of their overall sales. How quickly this share grows is a crucial variable for the future. Over the past two years, these manufacturers have been turning their attention to electric cars. The number of models and the share of electric car sales are expected to rise significantly (Table 3.9).

The plans of the 20 largest car manufacturers, which account for 75% of current global car sales, suggest a tenfold increase in electric car sales from 2 million today to more

[4] Regional variations occur depending on fuel taxation levels, consumer preferences on car size and driving habits i.e. average daily trip distances (IEA, 2018a).

than 20 million in 2030. This would increase the sales of electric cars as a share of total car sales from around 2% to 15% over the same period. The automotive industry also plans to spend $300 billion on electro-mobility research, development and demonstration over the next decade, and by 2025 there will be over 350 electric car models available globally. However there is a large degree of uncertainty about what will actually happen. While the pace of change could accelerate, few of the car manufacturers have provided concrete plans on how their targets will be achieved in practice.

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Table 3.9 ▹ Electric car targets of the world's 20 largest car manufacturers

Manufacturing alliance or brand	Total car sales in 2018 (million)	Electric car share of sales in 2018 (%)	Automaker plans for electric cars for given year		
			Sales (million)	Share of company sales	Number of models
VW group	9.4	0.7%	0.4 (in 2020) 22* (by 2030)	25% (in 2025)	80 (by 2025)
Volkswagen	6.5	0.8%			
Audi	1.8	0.9%	0.8 (in 2025)		
Skoda	1.2	0.0%		25% (by 2025)	10 (by 2022)
Toyota	8.0	0.6%	1 (by 2030)		more than 10 (by early 2020s)
Renault-Nissan	6.8	2.2%			12 (by 2022)
Nissan	4.7	2.1%	1 (by 2022)		
Renault	2.2	2.4%		20% (in 2022)	
Hyundai-Kia	6.8	1.2%			12 (by 2020)
Hyundai	4.2	1.1%			
Kia	2.6	1.5%			
Ford	5.2	0.2%			40 (by 2022)
Honda	5.1	0.4%		15% (in 2030)	
Chevrolet (GM)	3.7	1.3%			20 (by 2023)
Suzuki	3.1	0.1%	1.5 (in 2030)		1 (in 2020)
FCA group	2.8	0.1%			28 (by 2022)
Jeep	1.4	0.0%			14 (by 2022)
Fiat	1.4	0.2%			2 (by 2022)
Mercedes (Daimler)	2.5	1.5%		15-25% (by 2025)	50 (by 2022)
SAIC	2.4	4.1%	0.6 (by 2020)		
BMW	2.0	6.4%		15-25% (in 2025)	25 (by 2025)
Geely	1.5	4.7%	1 (in 2020)	32% (in 2020)	30 (by 2020)
Peugeot (PSA group)	1.5	0.3%	0.9 (in 2022)		40 (by 2025)
Mazda	1.4	0.0%		5% (by 2030)	1 (in 2020)

* Target refers to cumulative sales.

Notes: GM = General Motors; FCA = Fiat Chrysler Automobiles; PSA = Peugeot Société Anonyme; SAIC = Shanghai Automotive Industry Corporation. Figures show only the top-20 car brands globally; targets are given for brands within manufacturing alliances where specified.

Sources: IEA analysis based on IHS Markit (2018); EV Volumes (2019); China Association of Automobile Manufacturers (2019); IEA (2019b); car manufacturer announcements.

Policy support and declining costs for electric cars does not necessarily mean the end of conventional car sales. A consumer may still prefer to purchase a conventional car despite higher lifetime expenses, perhaps because of the lower upfront cost or anxiety concerning the driving range of an electric car. Further, car sales have historically been driven by population and economic growth, and there are major differences in the number of cars per household between various markets, depending on the availability of public transport, geography and cultural preferences. A peak in conventional car sales in one market does not necessarily mean a peak in all markets, especially given the shift in global car markets towards Asia.

Shared mobility services could also impact car ownership and mobility patterns, particularly in cities. Services such as ride-sourcing (e.g. Uber) and micro-mobility (e.g. electric scooters) have emerged and spread rapidly in just a few years. There are already more than 1 billion active users of ride-sourcing services worldwide, taking over 50 million rides per day. Survey data from major cities in the United States indicate that around 40% of ride-sourcing trips are displacing private cars and taxis, and around 50% of trips are displacing public transit, walking or cycling (Schaller, 2018). Preliminary findings for micro-mobility suggest that around 30% of e-scooter rides today replace trips in cars and 20% of trips connect to public transit (Bird, 2019; Lime, 2019). However, usage patterns may change over time and it is still too early to discern the long-term impact of these trends on car ownership.

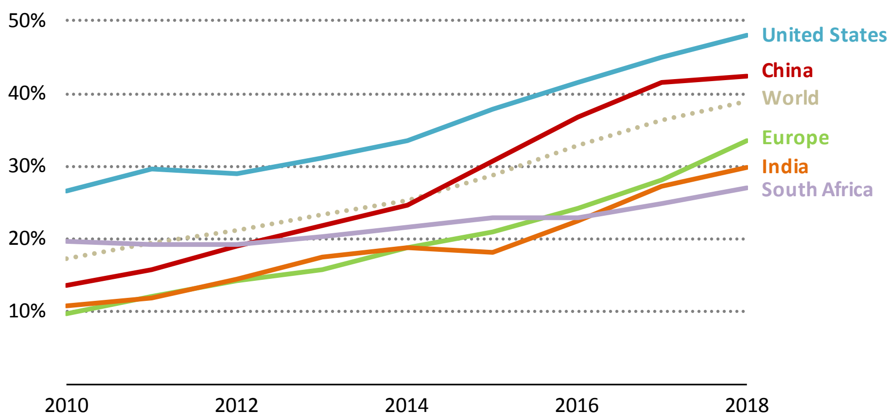
Rise of SUVs

While an increasing number of consumers are choosing to buy electric cars, there is also a growing appetite for bigger and heavier cars. This is not simply a phenomenon confined to North America or advanced economies: the share of SUVs has also increased very significantly in both India and China in recent years (Box 3.2). In 2018, the number of SUV sales reached a record high, accounting for around 40% of global car sales, more than double the share they had ten years ago (Figure 3.7). The boom in SUVs came mainly at the expense of small cars, whose share of the market fell by ten percentage points over the same period (IEA, 2019c).

Box 3.2 ▹ Why buy an SUV?

Today nearly 50% of the cars sold in the United States and one-third of the cars sold in Europe are SUVs (Figure 3.8). There has been a surge in the number of SUV models available to attract new customers, particularly in the past three years. This preference for SUVs has increased both in countries with low gasoline prices and in regions where more and more consumers can afford the higher upfront cost. Cost-effectiveness does not seem to be what dictates a consumer's choice when purchasing such vehicles: SUVs are more expensive and tend to have higher running costs than smaller cars. The available evidence suggests that geographical, social and behavioural factors are all relevant. For example, SUVs are more likely to be purchased by male and younger consumers, and by households that lease rather than purchase a new vehicle, and these consumers often attach a high value to attributes such as safety and engine power (Kitamura et al., 1999). Another factor is that SUVs tend to provide higher profit margins for manufacturers, and nearly all car manufacturers have increased advertising for SUVs.

Figure 3.7 ▷ Share of SUV sales in key car markets



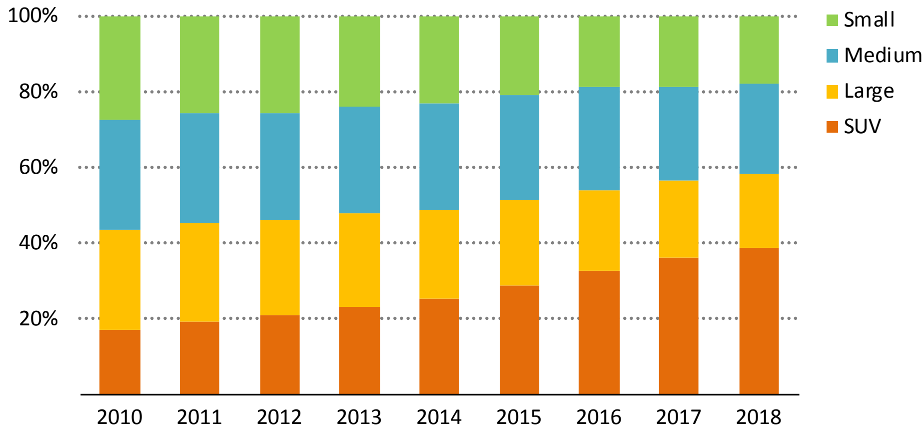
There has been a steady rise in SUV sales across all major markets in recent years

Source: IEA analysis based on IHS Markit (2018).

In recent years, there has been a noticeable upturn in SUV sales in developing economies. In China, SUVs are considered symbols of wealth and status. In India, sales are currently lower, but consumer preferences are changing as more and more people can afford SUVs. Similarly in Africa, the rapid pace of urbanisation and economic development means that demand for premium and luxury vehicles is relatively strong; the poor condition of roads in many African countries also increases the attractiveness of SUVs (Automotive World, 2018).

A SUV today consumes around 25% more oil than a medium-size car per kilometre travelled. The rise of SUV sales therefore has important implications for oil use in the future. Efficiency standards to moderate future oil demand cover around 85% of global car sales, but they often differentiate the required level of improvement by car size. Even if the required rate of improvement were the same for different car segments, a shift to SUVs would increase oil use. In some regions such as the European Union, policy makers have committed to monitor trends closely in an effort to achieve targets for improving the average fuel economy of new car sales, but major uncertainties remain about the overall development of the market and the implications for oil use.

Figure 3.8 ▷ Historical global trends in car sales by size



The share of SUVs in total sales globally has increased significantly in recent years

Note: Cars sizes based on Euro NCAP segment classification: small = A & B; medium = C; large = D-F & S; SUV = J & M.

Source: IEA analysis based on IHS Markit (2018).

Outlook for car sales and oil demand

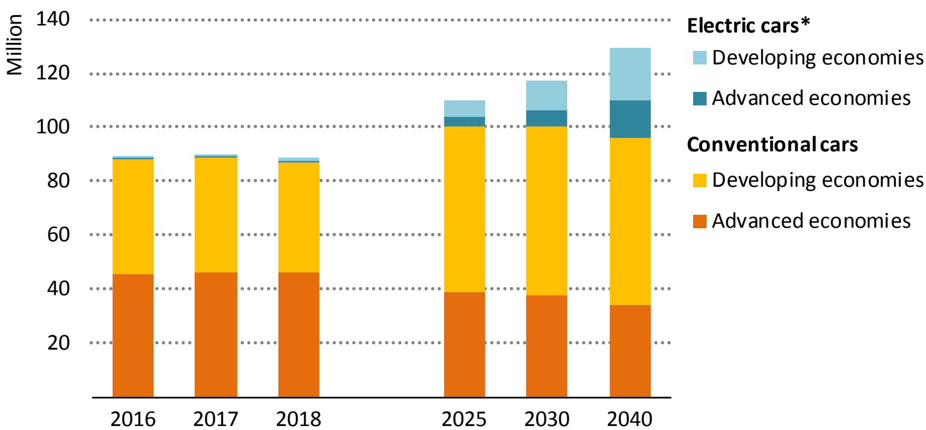
Oil consumption in passenger cars grew by 3.3 mb/d between 2010 and 2018. Most of this growth was caused by an increase in the size of the car fleet, but the rise in the share of SUVs on the road caused around 15% (or 0.5 mb/d) of the overall increase. This effect is five-times larger than the oil displaced by electric cars over the same period (less than 0.1 mb/d). Besides electrification, fuel efficiency standards avoided a further 2 mb/d of additional oil demand increase over this period.

Total car sales grow steadily to 2040 in the Stated Policies Scenario, but with differences by region (Figure 3.9). Car sales remain on a plateau in advanced economies at around current levels (just under 50 million a year), while sales in developing economies double from 40 million today to 80 million in 2040. Even with this increase, car ownership in 2040 in developing countries (160 cars per 1 000 people) remains well below that of advanced economies (540 cars per 1 000 people).

In the Stated Policies Scenario, conventional global car sales rebound in the early 2020s from the declines occurring in 2018 and 2019, and peak by the late-2020s. Annual electric car sales grow from 2 million today to around 20 million in 2030, and over 30 million in 2040. This is broadly in line with the existing plans of car manufacturers. Electric cars account for more than three-quarters of the increase in sales between 2018 and 2040. In 2040, there are 1 700 million conventional cars on the road compared with 330 million electric cars. The increase in electric car sales in combination with fuel economy improvements leads to a peak in oil demand from passenger cars in the late-2020s.

By 2040, the 330 million electric cars on the road displace around 4 mb/d oil use, while more stringent fuel economy standards displace nearly 9 mb/d. In total, oil use in cars falls slightly from 22 mb/d in 2018 to 21 mb/d in 2040.

Figure 3.9 ▷ Passenger car sales in the Stated Policies Scenario



Conventional car sales peak by the late-2020s and electric cars account for over three-quarters of the growth in sales between 2018 and 2040

* Includes battery electric, plug-in hybrids and fuel cell cars.

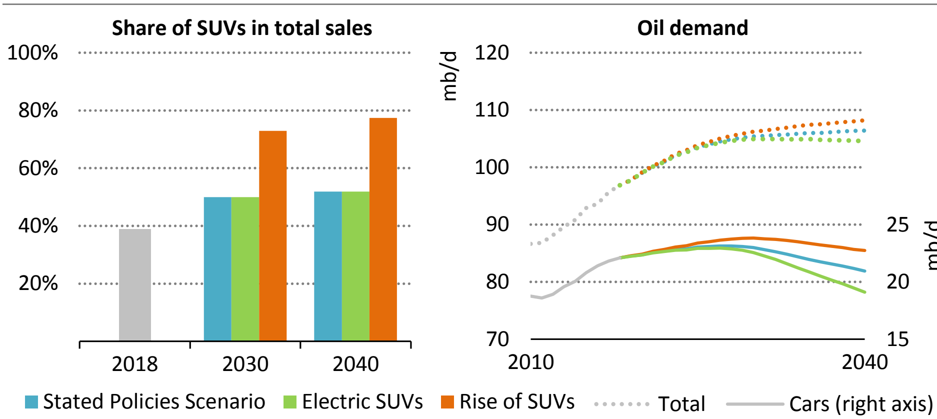
There is a steady increase in the market share of SUVs in the Stated Policies Scenario from around 40% today to just over 50% in 2040. This increase is slower than the rate of increase recorded in recent years as the appetite of consumers for heavier cars is assumed to saturate in key markets over the course of the next decade and fuel economy standards put pressure on the heavier car segments.

The rise of SUVs in the Stated Policies Scenario is accompanied by a partial electrification of this segment, mitigating some of the upward pressure on oil demand from SUVs. Plug-in hybrids are the main electric option for SUVs in most markets today, reflecting the fact that they can be difficult to electrify fully. Powering a heavier car for long ranges needs a larger battery, and the additional technical and financial costs involved mean that non-SUVs currently have around double the electrification share of SUVs (IEA, 2019c). Nonetheless, car manufacturers in many countries are now looking into fully electric SUV models (IEA, 2019b). In 2018, China reported sales of 1.1 million electric cars, of which 280 000 were SUVs (China Passenger Car Association, 2019). With the roll out of more electrified SUV models, we project that around 20% of SUVs will be electrified globally in 2040, narrowing the electrification gap between the two segments and contributing nearly 40% of the growth in total electric car sales.

There are two key uncertainties in this *Outlook* with implications for the future trajectory of passenger car oil demand. The first is that a stronger-than-expected continuation of consumer preferences for SUVs could increase oil demand. The second is that a faster electrification of SUVs could have the opposite effect.

On the one hand, the share of SUVs in total car sales could increase at a similar pace to that seen in recent years (the "Rise of SUVs" case in Figure 3.10). In this case, SUVs would reach close to 80% of total car sales by 2040, and the average new conventional car sold in 2040 would consume around 10% more fuel than the level projected in the Stated Policies Scenario. This would increase total oil consumption by nearly 2 mb/d in 2040, offsetting the oil displacement impact of close to 150 million electric cars. The increase in global oil demand between 2018 and 2040 would therefore be 20% higher than the 9.5 mb/d increase in the Stated Policies Scenario.

Figure 3.10 ▹ Share of SUVs in total sales and oil demand in the Stated Policies Scenario and two cases examining differences in the SUV market



A continuation of historic trends in SUV sales would add nearly 2 mb/d to oil demand in 2040, but further electrification of SUVs would curb the oil demand increase beyond 2030

Note: The Electric SUVs case assumes 20% of the SUV fleet is electrified in 2040 compared to 10% in the Stated Policies Scenario; the Rise of SUVs case assumes SUVs sales reach close to 80% of total sales.

On the other hand, the SUV fleet could be electrified more quickly than projected in the Stated Policies Scenario (the "Electric SUVs" case in Figure 3.10). If SUVs were to follow a similar electrification trajectory to that of small and medium cars, this would add over 100 million electric cars by 2040, helping the total number of electric cars to reach around 450 million. The result would be a reduction in oil demand by nearly 2 mb/d over the same period of time, relative to the Stated Policies Scenario.

More transformational changes to passenger car transport are possible. In the Sustainable Development Scenario, a much stronger push for electrification leads to a peak in conventional car sales in the mid-2020s, followed by a much steeper decline than in the

Stated Policies Scenario. As a result, over 80 million electric cars are sold each year by 2040, accounting for three-quarters of total car sales, and conventional car sales are only 30% of today's level. By 2040 there are nearly 900 million electric cars on the road. In this scenario, all small, medium and large cars sold are electric by 2040, as are 40% of all SUVs. The average conventional car sold in 2040 consumes nearly 45% less fuel than an average car sold today (compared with a 25% reduction in the Stated Policies Scenario). The combination of the rapid rise in electric cars, downsizing of the car fleet, and efficiency improvements in conventional cars mean that oil demand in passenger cars falls from 22 mb/d today to 8 mb/d in 2040.

One conclusion to draw from this is that, while discussions surrounding the perspectives for oil demand for cars often focus on fleet electrification and fuel economy standards, the segmentation of the car fleet is an equally important consideration. Unless there is a major change in consumer preferences, the recent boom in SUV sales could be a major obstacle towards developing cleaner car fleets and reducing overall oil demand.

3.10 Pushing the boundaries of US tight oil

The rise of tight oil in the United States has been remarkable. From less than 0.6 mb/d production in 2010, tight crude oil production rose to nearly 6 mb/d in 2018 – an increase that already matches the fastest rise seen previously in oil markets (Saudi Arabia in the late 1960s). This was initially spurred by publicly funded research and development efforts, and then by the ingenuity of hundreds of small, independent companies, fuelled by ample external sources of capital. However the tight oil race is only half run. If tight oil alone is to satisfy the 8.5 mb/d increase in global oil demand to 2030 in the Stated Policies Scenario, the pace of growth to date will need to be maintained for a prolonged period. This possibility should not be ruled out: resource estimates in many of the major areas of activity continue to be revised upwards, while the larger international oil companies, initially hesitant to devote large levels of capital to shale production, have significantly increased their exposure to tight oil.

But there are also some signs of fatigue: the steep decline rates of individual tight oil wells mean that, despite continued drilling, some of the largest shale plays may have already reached their production peak. There are a number of distribution infrastructure bottlenecks in key regions. Concerns over water use, local disruption and flaring of associated gas could also impede production activities. In addition, with less than 35% of US shale companies currently achieving positive cash flows, investors are demanding more capital discipline, and there has been a high degree of consolidation within the sector, with many companies acquired by larger operators (Lukash, 2019).

This section examines the dynamics of tight oil production since the oil price crash in 2014. It describes the outlook for tight oil in the Stated Policies and Sustainable Development scenarios, assesses the impact of key sensitivities on these outlooks, and discusses the implications for global oil markets.

Box 3.3 ▷ Some key features of tight oil

Tight oil is generally considered an "unconventional" source of production. Tight oil rocks have low permeability (fluids cannot easily flow) and low porosity (there is limited void space within the rock). They need to be hydraulically fractured using a mixture of water, proppant (generally sand) and chemicals to extract the oil. The vast majority of tight oil wells are horizontal. Lateral lengths of a single well can be as long as 4.5 kilometres (km), but they average around 3 km. The total lateral length of all tight oil wells drilled in 2017 and 2018, if set end-to-end, would circle the Earth's circumference.

Production from a tight oil well tends to decline by between 60% and 70% within 12 months of first production (compared with a decline of around 6% for a conventional well). This means that high levels of drilling are required to maintain production levels: nearly 12 000 tight oil wells were drilled in 2018, 40% of which were needed just to keep production constant. Over time the decline rate of tight oil wells slows, and they often have a long tail of low-level production. The large number of wells drilled to date – over 80 000 horizontal tight oil wells have been drilled in the United States since 2000 – means that these "tails" can provide an important long-term baseload of production. Tight oil wells mainly produce a light, sweet crude oil, together with some condensate and associated gas. In addition to the 6 mb/d tight crude oil production in 2018 in the United States, there was 0.5 mb/d tight condensate and 3.1 mb/d NGLs produced from shale gas wells.

A key characteristic used to assess the productivity of a tight oil well is its estimated ultimate recovery (EUR). The EUR is an estimate of the total volume of oil and gas that will be extracted over the lifetime of the well (generally taken to be 30 years). It is a function of the specific geology of the "play",[5] the length of the laterals that have been drilled and the completion technique.

There are at least 30 different tight oil plays in the United States, but the top-five plays account for nearly 90% of tight crude oil and condensate production today and are the focus of this analysis. Recently, the largest share of tight oil drilling has taken place in the Permian Basin in Texas and New Mexico. There are many geological layers containing tight oil prospects within the Permian Basin; it is common to differentiate resources by geography into the Permian-Midland and Permian-Delaware. The other most important plays are the Bakken (in North Dakota), the Eagle Ford (in Texas) and the Niobrara (mainly in Colorado and Wyoming).

Estimates of the remaining recoverable tight oil resources in the United States have been revised upwards on a number of occasions. For example, the United States

[5] A play is strictly one or more geologically related prospects that must be evaluated by drilling to determine whether it contains commercial quantities of oil or gas (AAPG, 2000). In this *World Energy Outlook*, we model 23 individual tight oil plays each separated into four areas according to productivity.

Geological Survey (USGS) recently estimated that the Permian-Delaware contains around 50 billion barrels of technically recoverable tight oil (USGS, 2018), an area whose technical potential had not previously been assessed. For this edition of the *WEO*, the estimate for remaining US tight crude oil and condensate is 155 billion barrels, a major increase from the 115 billion barrels estimate in the *WEO-2018* (IEA, 2018a).[6]

Evolution in tight oil production costs

Prior to 2015, the cost of drilling, hydraulically fracturing and connecting a tight oil well to distribution infrastructure, and paying taxes and royalties meant that operators required, on average, an oil price over $80/barrel to generate a reasonable rate of return. The crash in the oil price in 2014 from over $100/barrel to less than $50/barrel in the space of nine months presented a major challenge for tight oil operators. The response took a number of forms (Figure 3.11):

- Operators focussed activity on the most productive areas they owned to generate larger and faster returns on investment.[7] Across the five main plays, 40% of wells drilled in 2012 were in these core areas; by 2018 this had increased to 67%.
- Operators increased the volumes of oil and gas produced from a given well. The horizontal length of the average tight oil well drilled today is 50% greater than the average well drilled in 2012, and it uses three-times more water and proppant. There have also been continuous improvements in completion strategies such as the placement and mechanism for producing fractures.
- Operators significantly reduced the unit costs of drilling and completing tight oil wells, for example by drilling multiple wells from a single location, and by drilling multiple wells so as to produce oil simultaneously from different shale layers. They were helped by reductions in the cost of oil field services. The cost of hiring a drilling rig, for example, fell by almost 50% between 2012 and 2016.

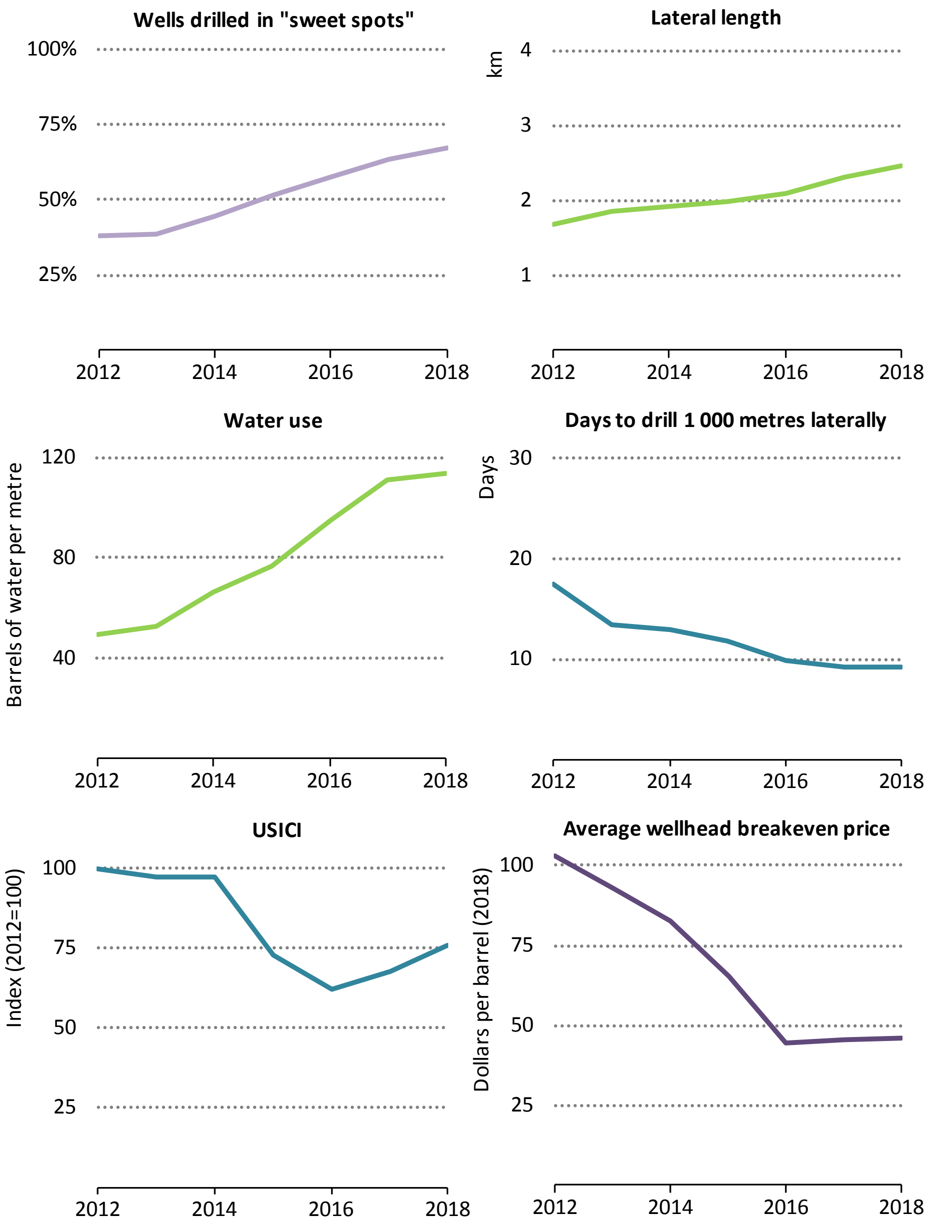
The aggregate effect of these changes is that the wellhead breakeven price for tight oil production is now around 60% lower than it was in 2012.

Can these impressive rates of improvement be maintained in the future? There are certainly further improvements that could be made (Box 3.4). However, there are also signs that rates of improvement are slowing and that costs cannot be expected to continue to fall in the future in the same way as the past. The costs of drilling and completion services have risen in recent years, although they remain below 2012 levels, and we expect future

[6] In previous editions of the *World Energy Outlook*, we directly used the resource estimates from the US Energy Administration Information (EIA), but this year we shift to a composite approach, taking the most recent estimate coming from either the USGS or EIA for each play.

[7] These are often referred to as the play “sweet spots”. These are defined here to be an area where well breakeven prices are less than the play median. We assume that this area remains fixed geographically.

Figure 3.11 ▹ Changes in the average efficiency and economics of US tight oil production, 2012-2018



There were major technological improvements and changes in operating procedures following the oil price crash, but the rate of improvement appears to have slowed recently

Note: USICI = IEA Upstream Shale Investment Cost Index.

Source: IEA analysis based on Rystad Energy (2019).

costs broadly to follow changes in the oil price, as is the case for conventional resources. It is becoming increasingly difficult to continue to concentrate drilling only in sweet spots: although the spacing between adjacent wells could be reduced, this runs the risk of having a negative impact on production. There is also evidence of a slowdown in the rate of reduction in the number of days to drill a well, and in the rate of increase in volumes of water and proppant that are used to complete a tight oil well.

Box 3.4 ⊳ Possible future technology breakthroughs for tight oil operations

Currently only around 5-15% of the oil in the ground can be extracted during tight oil operations, whereas conventional resources tend to produce between 15% and 40% after primary and secondary recovery. For conventional resources this percentage can be increased by applying tertiary recovery methods such as enhanced oil recovery (IEA, 2018b). While the use of these methods for tight oil wells is still in its infancy, more than 150 tight oil wells used enhanced oil recovery in 2018 (either injecting CO_2 or natural gas); this was found to approximately double the recovery factor (Jacobs, 2019).

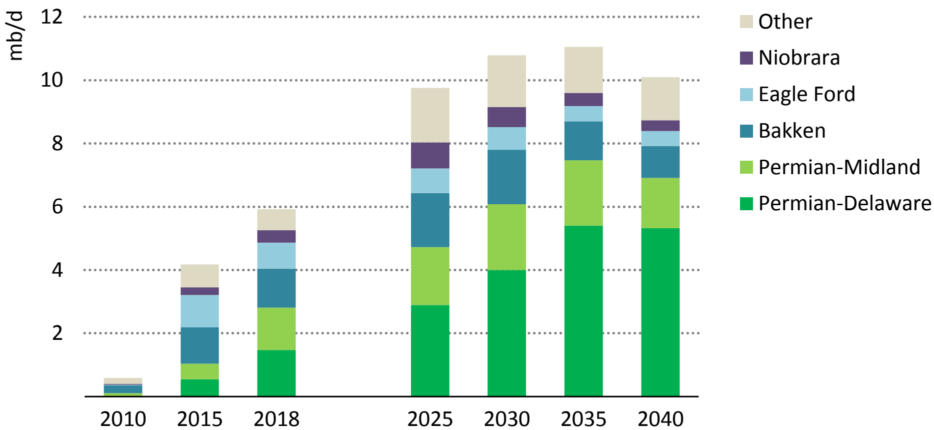
Another option to increase productivity and extend the life of existing wells is through "re-fracking". This applies newer and more effective fracking technologies to older wells that are typically one-third to one-half of the way through their expected decline. While there is significant potential for re-fracking, the major hurdle is cost. Re-fracking an old well costs around 25-35% of the cost of drilling and completing a new well. Although re-fracking increases the amount of oil recovered by around 60% (Oruganti et al., 2015), a large share of this additional oil is often not recovered until many years later, meaning that payback periods can be long. Wells therefore need to be assessed carefully prior to re-fracking. To date more than 800 wells have been re-fracked in the United States (Rystad Energy, 2019).

In addition, wider adoption of digitalisation could lead to cost reductions. To take one example, the use of AI-enabled horizontal drilling equipment that can interpret data autonomously in real time could boost productivity and reduce drill wear-and-tear. It could also allow operators to spend less time on data interpretation and to oversee a higher number of wells than would otherwise be possible.

Outlook for US tight oil and implications for other producers

In the Stated Policies Scenario, US tight crude oil production rises from close to 6 mb/d today to a maximum of 11 mb/d in 2035 before declining to 10 mb/d in 2040 (Figure 3.12). The majority of the growth in this period comes from the Permian-Delaware and Permian-Midland: soon after 2030, crude oil production from the Permian Basin surpasses crude oil production from the continent of Africa. Total tight liquids production, which also includes tight condensate and tight NGLs, grows to a maximum of 16.5 mb/d in 2035, a level that is 30% higher than that of the next largest oil producer globally.

Figure 3.12 ▷ US tight crude oil production in the Stated Policies Scenario



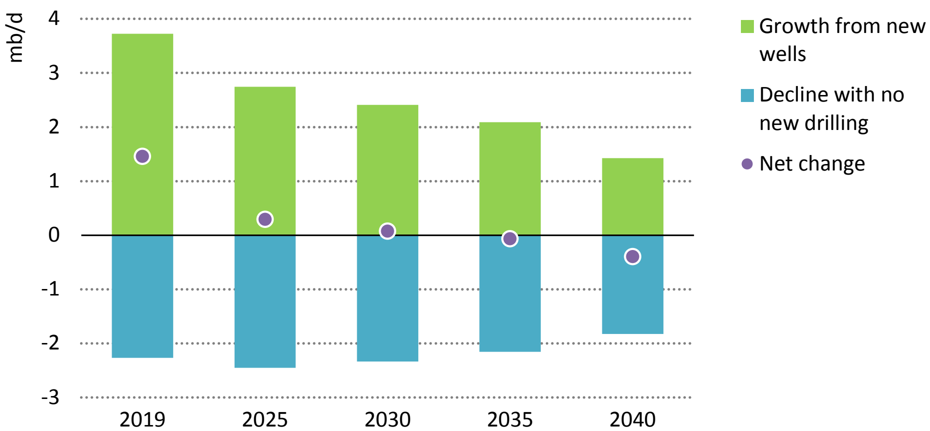
US tight crude oil rises to a maximum of 11 mb/d in 2035. Production from the Permian Basin alone surpasses crude oil production from the continent of Africa in the early 2030s.

An increasing number of wells need to be drilled to realise this rate and level of growth, but we assume that operators exercise a degree of capital discipline that ensures financially sustainable returns. By 2030, over 16 000 tight oil wells are drilled annually, around 40% more than were drilled in 2018. As tight oil production grows, an increasing share of activity is required simply to maintain production (Figure 3.13). By the mid-2020s, if drilling were to stop, tight crude oil production would fall by over 2.5 mb/d within 12 months. This rate of decline drops slightly after the 2030s as the long tail of production from older wells provides an increasing bedrock of production and as the overall level of production begins to decline.

Our projection for US tight crude oil in this *Outlook* in 2025 is 0.6 mb/d higher than in the *WEO-2018*, in which production reached around 9.2 mb/d in 2025. Subsequent years show a larger difference. The 35% increase in the resource base from the *WEO-2018* means that, even though the oil price in the Stated Policies Scenario is lower to 2040, production reaches a plateau later and only declines slowly thereafter. In 2040, tight crude oil production is 3 mb/d higher than in the 2018 projection.

This trajectory poses a stark challenge for many of the world's producer economies, especially those that rely heavily on oil and gas revenues (IEA, 2018b). In the Stated Policies Scenario, members of OPEC are assumed to adjust production in an attempt to manage markets. What this means in practice is that the aggregate production of OPEC countries only exceed its 2018 level in 2030, by which time demand growth has slowed markedly compared with today. An alternative approach for some resource-rich countries could be to prioritise their share of the oil market and therefore boost production over this period. This would lead to a major drop in the oil price and would probably curtail the levels of other sources of production, including tight oil. Members of OPEC chose to do this in 2014: while this temporarily stemmed the rise in tight oil, the drop in the oil price also led to 40-70% fall in net income in these countries. Whether OPEC countries would be able to maintain this strategy for a prolonged period hinges, in many cases, on the extent of their structural economic reliance on hydrocarbon revenues and on the steps taken to address this.

Figure 3.13 ▷ Year-on-year growth from new wells and underlying declines from existing wells in the Stated Policies Scenario



By 2030, over 16 000 tight oil wells are drilled each year, the vast majority of these are needed just to offset underlying declines in production

Note: Declines are the 12-month drop in production within that year if drilling stops on 1 January; growth is the 12-month increase from wells completed within that year.

It is possible that new policy measures and accelerated technology developments in the future will reduce oil use beyond what is projected in the Stated Policies Scenario; the Sustainable Development Scenario provides an illustration of such a case. US tight crude oil production grows at a slower pace in this scenario but it still exceeds 9 mb/d in 2030. Faced with uncertainty about the future, tight oil could be a logical choice for many looking to produce oil, as its high decline rates reduce the need for a long-term outlook on demand and prices.

Whether or not there are such new policy measures, the extended growth in US tight oil to the 2030s is set to squeeze the oil income for some of today's major conventional producers and exporters. Alongside the pressing need in many cases to create employment opportunities for a large and youthful population, this reinforces the case for strengthening and accelerating their programmes of diversification and economic reform.

Technical and economic uncertainties in US tight oil production

There are a number of technical and economic uncertainties that could affect the long-term outlook for US tight oil. Here we quantify the impact on tight crude oil production in 2030 of four key issues by running individual sensitivity cases that examine a "low" and "high" variant of each:

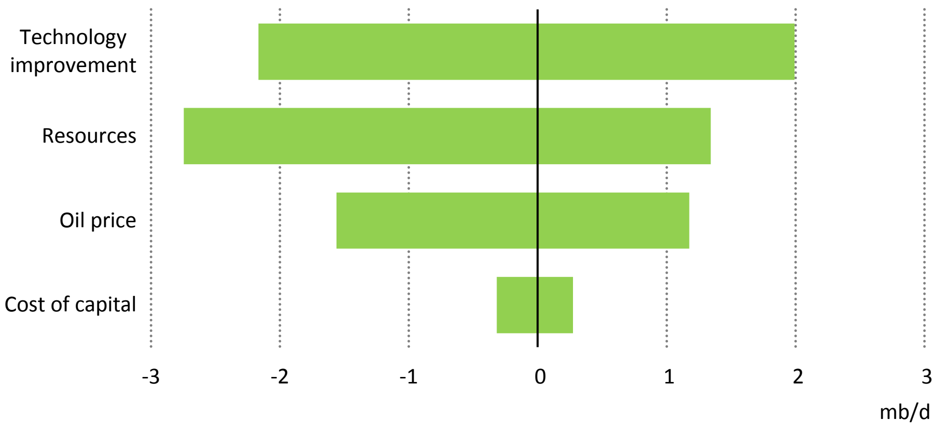
- **Technology improvement:** There is uncertainty over the permanency of the cost reductions seen to date and the extent to which future technological innovation can continue to reduce costs, while some more advanced drilling and completion strategies have been demonstrated but not yet adopted by all operators. In the Stated Policies Scenario, we include a variety of technology improvements that reduce costs or increase recovery.[8] For our sensitivity cases we assume either no future technology learning or a doubling in these rates of improvement.
- **Resources:** Remaining technically recoverable tight oil resources have increased substantially in recent years. The *WEO-2011* (IEA, 2011) assumed 24 billion barrels of recoverable tight crude oil and tight condensate resources; we now assume 155 billion barrels. For our sensitivity cases, we assume either the lowest current publicly available estimate for each shale play (totalling 100 billion barrels) or the highest estimate, with an allowance for increased deployment of new and emergent technologies (totalling 200 billion barrels).
- **Oil price:** The oil price affects the number of rigs operating, production costs (via inflation in the oil field services), and the number of wells that can be drilled economically. For the sensitivity cases, we examine the impact of trajectories for the oil price reaching $65/barrel and $110/barrel in 2030 (compared with $88/barrel in the Stated Policies Scenario).
- **Cost of capital:** Low interest rates and the ability of tight oil operators to access low-cost capital has undoubtedly helped underpin tight oil production growth to date. There is no guarantee that this will continue indefinitely. A related factor is that the major international oil companies also plan to increase investment levels in tight oil areas. These companies have very different costs of capital than the smaller, independent companies that have been responsible for the majority of spending to date. In the Stated Policies Scenario, we assume that tight oil operations must achieve a 12% rate of return to be economic; for our sensitivity cases we examine the impact of changing this to 8% and 16%.

The rate of future technology availability, resource availability and the oil price all have a major impact on the level of US tight crude oil production in 2030 (Figure 3.14). If the rate of technology learning is double the level assumed in the Stated Policies Scenario, then tight crude oil production in 2030 would be more than 2 mb/d higher (at around 13 mb/d).

[8] These factors include: a 20% reduction in the cost of drilling and completing a well for every doubling in cumulative production from 2018 across each play. A 1% increase per year in the EUR of a given well and a 1% increase per year in the number of wells that can be drilled by a rig. These factors broadly match the rates of learning observed historically and are independent of any changes in drilling location or the oil price.

However, the sensitivities examined here are slightly weighted to the downside. If remaining technically recoverable resources are 100 billion barrels, then production would peak much sooner and by 2030 would be nearly 3 mb/d lower than in the Stated Policies Scenario. Changes in the cost of capital have a smaller, but nevertheless important, impact on production.

Figure 3.14 ▷ Sensitivity of US tight crude oil production in 2030 to technical and economic uncertainties



There are major uncertainties in the outlook for US tight oil. Future technology development and resource availability could each affect production by more than 4 mb/d in 2030.

Note: Changes in production are relative to the 2030 level in the Stated Policies Scenario (10.8 mb/d).

Policy uncertainties, social and environmental issues

There are also potential policy uncertainties affecting tight oil, especially in relation to social and environmental issues. This is a fast-moving area and there have been significant changes in both regulation and industry performance in recent years. Future trends in policy and regulation naturally are difficult to assess but, if social and environmental concerns are not adequately addressed, they could have a significant impact on long-term production prospects.

- **Regulatory oversight**: In 2018, over 80% of US tight oil production came from privately owned lands and just over 10% from federal lands. Hydraulic fracturing is currently exempt from many federal environmental laws, and applicable rules can differ from state to state, which can have a major impact on production prospects in different regions. For example, the State of Colorado recently passed a bill to expand the authority of local communities over drilling operations, including the issuing of permits and the setting of minimum distances between drilling operations and homes or schools.

- **Water use:** Tight oil operations require a lot of water. Today around 0.3 million barrels of water are needed on average to drill and complete a new well, and water use for hydraulic fracturing has grown by a factor of five since 2010. Although still a small percentage of overall water use, around 50% of wells drilled in the Permian are located in areas at high risk of water stress (Freyman, 2016).
- **Handling produced water:** Up to ten barrels of water are extracted from the ground with every barrel of tight oil (Wood Mackenzie, 2018). This water requires careful handling because it is usually saline and because it contains some of the chemicals used in the fracking process as well as metals, minerals and hydrocarbons from the reservoir rock. Since 2016, the discharge of wastewater into publicly owned water treatment plants has been prohibited, and today most wastewater is injected back underground using disposal wells (US EPA, 2019). In some locations this has led to a major increase in seismic activity (Magnani et al., 2017). An alternative option is to recycle it by using it to fracture new wells. This has the added benefit of reducing water extraction in water-stressed areas. There has been some progress in this area, but on average only 10% of the water produced today from tight oil wells is recycled (GWPC, 2019), implying that additional regulations or incentives are likely to be needed to boost recycling.
- **Local consent for infrastructure projects:** The steep rise in production from the Permian Basin caused distribution bottlenecks and led to major discounts in local crude oil prices. This was relieved only as new pipelines were rapidly commissioned and constructed and new infrastructure will be crucial to the future of tight oil growth. The prospects for such infrastructure can be significantly influenced by public and political support or opposition.
- **Air quality:** Local air pollution can be caused by flaring, truck traffic, and noise and fumes from the diesel generators required to power drilling and completion equipment. Between 2 000 and 6 000 truck journeys are required to transport drilling and completion materials equipment for a single well (Quiroga et al., 2016). In addition to negative effects on air quality, this can lead to congestion, wear-and-tear on local infrastructure and, if not managed carefully, can increase road accidents.
- **Flaring:** Large volumes of associated natural gas produced alongside tight oil are currently being flared. In the Permian region, for example, pipeline infrastructure for associated gas has not kept pace with the expansion in oil production. Although flaring is only allowed if a permit has been issued, applications for permits are rarely (if ever) turned down. The volumes of gas flared have soared, particularly in the second-half of 2018. Flaring across the whole of the United States jumped by 50% in 2018 compared with 2017 to over 14 billion cubic metres (bcm) (World Bank, 2019). Another concern is the level of methane emissions. Methane is a much more powerful greenhouse gas than CO_2 and the incomplete combustion of flares can result in a large level of methane emissions to the atmosphere (see Chapter 5). The combination of flaring and methane leaks means that tight oil can have relatively high lifecycle emissions intensity (IEA, 2018b).

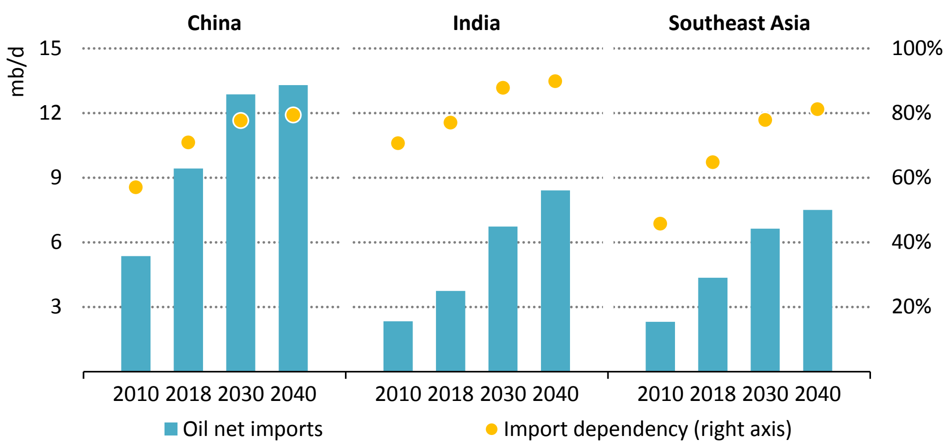
In 2012, the IEA provided a set of principles – the *Golden Rules for a Golden Age of Gas* – to help policy makers, regulators, operators and members of the public understand and address the environmental and social impacts of shale operations (IEA, 2012). Our judgement at the time was that there is a critical link between the way that governments and industry respond to these impacts and the prospects for production. Seven years on, this link is even more visible: a continuous drive to improve performance remains essential if public confidence is to be earned or maintained.

3.11 Can the world afford to relax about security of oil supply?

Changing oil market dynamics offer some grounds for an upbeat assessment about the prospects for oil security. In the Stated Policies Scenario, US tight oil production continues its upward climb and the growth in global oil demand slows markedly. These developments could alleviate some concerns over security of supply.

But there are also reasons for caution. Despite the relentless growth of US tight oil, shrinking contributions from other non-OPEC countries after 2025 in the Stated Policies Scenario mean that the world continues to rely heavily on investments made by traditional resource holders, notably those in the Middle East. On the demand side, a flattening of demand in China contributes to the slowing global pace of growth, but there is still a marked shift in demand towards Asia. Oil consumption in Asia rises by 8 mb/d between 2018 and 2040 (close to 80% of the growth in global oil demand). With declining domestic production, Asia's import requirements grow by 10 mb/d, raising import dependency across the board (Figure 3.15).

Figure 3.15 ▷ Oil net imports and import dependency in selected developing Asian economies in the Stated Policies Scenario

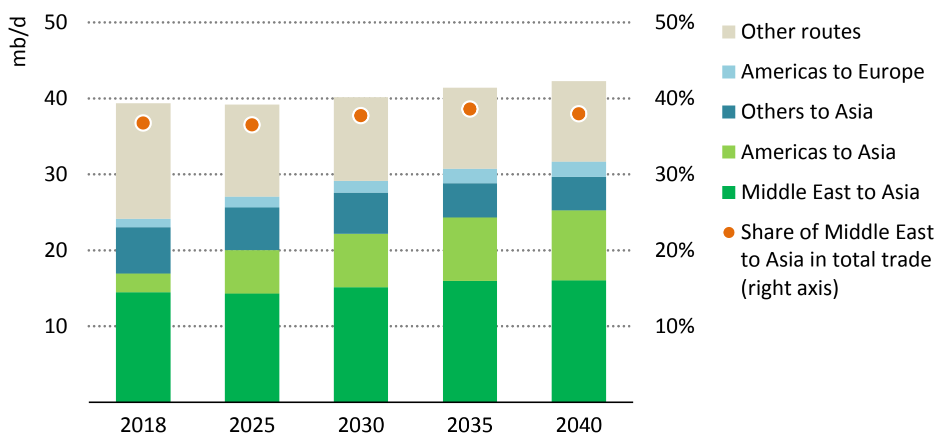


By 2040, over 80% of oil demand in developing economies in Asia is met by imports, stimulating a strong acceleration in oil trade flows to Asia

Note: Import dependency = net oil imports divided by demand including international bunkers.

Asian importers tap into a wider variety of supply sources, and there is a major increase in flows from North and South America to Asia. However major suppliers in the Middle East maintain their position of primacy (Figure 3.16). In the Stated Policies Scenario, despite the major changes in oil markets over the period to 2040, the share of seaborne crude oil trade from the Middle East to Asia remains remarkably consistent.

Figure 3.16 ▷ Seaborne crude oil trade by route in the Stated Policies Scenario



Despite the rapid growth of tight oil output, trade flows from the Middle East to Asia are set to remain the mainstay of global crude oil trade

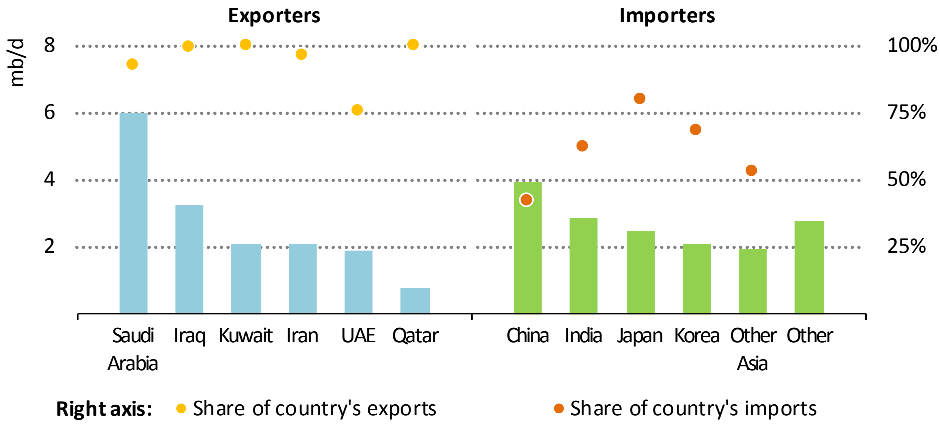
Growing pressure on trade chokepoints

Escalating geopolitical tensions in the Middle East have brought the risks of physical disruption in the world's busiest trade passage, the Strait of Hormuz, back into the spotlight. The Strait of Hormuz is a narrow bend of water between Oman and Iran that connects oil producers around the Gulf with global markets. It carries some 16 mb/d of crude oil and 4 mb/d of oil products (around one-third of global seaborne oil trade): primarily from Saudi Arabia, Iraq and Iran to major importers in Asia, Europe and Africa (Figure 3.17). In 2018, around 80% of crude oil imports to Japan came through the Strait, as did 40% of China's oil imports. In addition, over a quarter of global LNG trade flows through the Strait: a large share of Asia's gas needs is met by LNG imports, primarily from Qatar and the United Arab Emirates (UAE).

In the Stated Policies Scenario, the volume of crude oil and oil products passing through the Strait of Hormuz remains high through to 2040. LNG trade via the Strait also grows, reflecting the strong position of Qatar as a low-cost exporter, although its share in global LNG trade gradually declines as Asian countries diversify their sources of imports, notably from the United States and Australia.

Any impediment to shipments through the Strait of Hormuz could materially tighten markets and leave importers rushing to find alternatives sources of supply. It could also render unavailable the vast majority of OPEC's spare production capacity. Only Saudi Arabia and the UAE have pipelines that can circumvent the Strait. These two countries have a combined pipeline capacity that bypasses the Strait of around 6.8 mb/d, of which around 3.8 mb/d is currently unused.[9] The complete closure of the Strait, while unlikely, would therefore result in a blockage of around 16 mb/d of crude oil and oil products, or around 17% of global oil supply. The recent attack on Saudi Arabia's oil facilities in Adqaiq and Khurais that led to a temporary loss of 5.7 mb/d of processing capacity (making it the largest supply disruption in history) led to a short-lived 20% spike in the oil price. Impacts on gas markets would also be significant, especially if any closure were to occur during the winter season: gas consumption in Asia is typically highest in winter months when underground gas storage in other regions (e.g. Europe) is also being drawn down.

Figure 3.17 ▻ Major exporters and importers of crude oil traded via the Strait of Hormuz, 2018



Over 80% of the oil traded via the Strait of Hormuz flows to Asia; most of the world's exporters and importers rely heavily on trade flows via the Strait

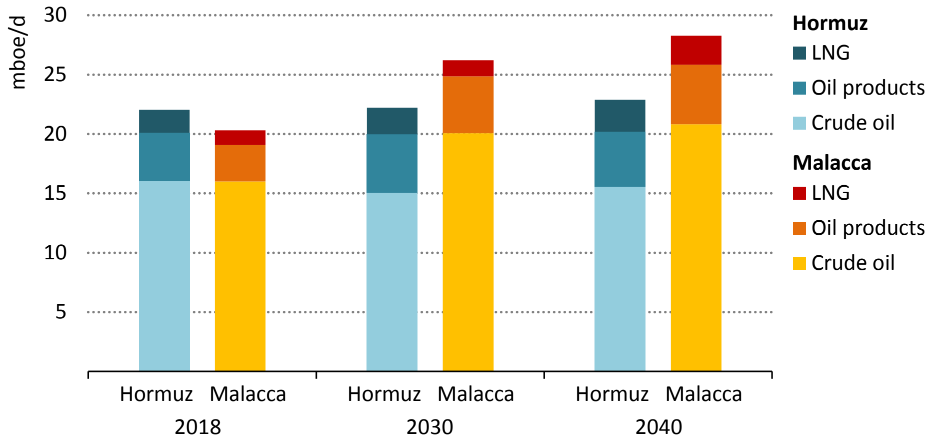
Notes: UAE = United Arab Emirates. Other importers include: Europe (with 8% of total imports flowing through the Strait of Hormuz), Africa (6%), Americas (2%) and other Middle Eastern countries.

The Strait of Hormuz is not the only chokepoint for oil trade. The Strait of Malacca is a key stretch of water between Malaysia and Indonesia that connects exporters in the Middle East and Africa with Asian importers. Around 19 mb/d of crude oil and oil products pass through the Strait of Malacca today. It is also a crucial location for fuel storage, blending and ship refuelling. In the Stated Policies Scenario, the volume of oil flowing through the

[9] Saudi Arabia plans to expand the capacity of its East-West pipeline from 5 mb/d to 7 mb/d although the timing of completion is uncertain. It is also assessing a reopening of the Ipsa pipeline and another 1 mb/d link from Iraq's Basrah oil hub to the Red Sea. If completed, these would increase the capacity that bypasses the Strait of Hormuz, although it would raise the reliance on another chokepoint, the Bab al-Mandab. Iran also plans to build a pipeline from Goreh to a port terminal at Jask, located just outside the Strait of Hormuz.

Strait of Malacca increases strongly, underpinned by robust demand growth in developing economies in Asia. LNG flows also increase as a result of supplies going to both traditional and emerging LNG importers in Asia. As a result, the Strait of Malacca becomes the largest chokepoint for global oil and gas trade by 2030 (Figure 3.18).

Figure 3.18 ▷ Oil and gas trade volumes via major chokepoints in the Stated Policies Scenario



The Strait of Malacca takes over from the Strait of Hormuz as the largest potential chokepoint for global oil and gas trade

Note: mboe/d = million barrels of oil equivalent per day.

Growing traffic and the narrow nature of the Strait of Malacca pose potential risks of physical congestion, collision or attacks, which could have major implications for global oil and LNG markets. Finding alternative routes is not a straightforward task. The Sunda Strait, which separates the Indonesian islands of Java and Sumatra, is the closest alternative, but is too shallow and narrow to accommodate large oil vessels. The Lombok Strait between the Bali and Lombok islands represents the most viable alternative due to its width and depth, but is constrained by the lack of adequate infrastructure, notably port facilities and refuelling stations. Such a diversion would also increase voyage times between the Middle East and Asia, causing delays and incurring additional costs.

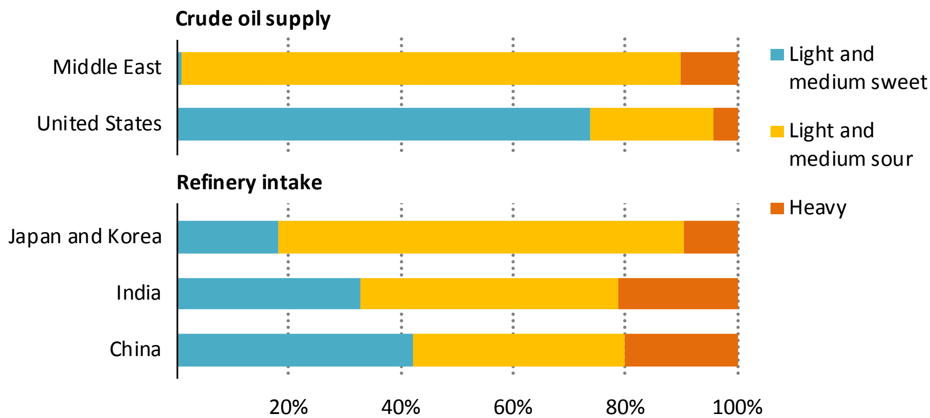
Quality matters: US tight oil is helpful, but not a panacea

Crude oil exported from the Middle East consists mainly of light and medium sour crude oil.[10] Since Asian refiners have been importing Middle Eastern oil for many years, many of their refineries are configured precisely to process these crude oil grades. For example, over 70% of the crude oil processed in refineries in Japan and Korea is light and medium

[10] Light and medium sour crude oil has a density greater than 24 °API and sulfur content more than 1% (see Spotlight).

sour crude oil. There is also a large appetite for these grades from refiners in China and India, although they process a slightly more diverse range of different crude oil grades (Figure 3.19). A potential output disruption either in the Middle East or in the chokepoints discussed would therefore have a particularly large impact on the global supply of the oil most wanted by Asian refiners.

Figure 3.19 ▷ Crude oil quality of selected producers and refiners, 2018



Asian refineries are configured to produce crude oil grades produced in the Middle East; quickly shifting to US crude oil could pose major short-term issues

If a sudden disruption in the Middle East were to occur, these supplies in theory could be replaced by increased output from other regions. A key candidate would be the United States, where tight oil production could likely ramp up relatively quickly in the event of a disruption. However, because of differences in crude quality, this is more difficult than it initially looks. Crude oil produced in the United States is mostly light and sweet: only 20% of the crude oil it produces is the light and medium sour crude oil preferred by Asian refiners. This would limit the ability of additional US crude oil to fill a sudden drop in the supply of medium sour grades. Asian refiners could switch to refine a lighter, sweeter crude oil feedstock, but this would take time. It would also require a careful assessment of a number of technical and economic factors. A change in feedstock would result in a major shift in product yield, which would affect the economics of refinery operations and, for complex refineries, would come at the cost of lower utilisation of upgrading units. The forced intake of light oil in the event of a supply disruption would therefore be likely to incur additional costs, weighing on already thin refining margins.

There are also major differences between US tight oil and OPEC spare capacity. Unlike OPEC's spare capacity, US tight oil production is determined by the responses of numerous market participants and is therefore not amenable to central direction. The scalability of US tight oil and its ability to respond to market signals should not be taken for granted given the numerous uncertainties that can impact production levels (see section 3.10).

The dynamics would be different if any disruption in oil supply from the Middle East were to extend for a longer period. If US tight oil were to respond to market signals, Asian refiners would adapt over time to make use of the higher volumes of US crude oil available on the market. Refineries in Asia have been processing growing volumes of US crude oil in recent years and they are already the largest export market for US crude oil (IEA, 2019d). This trend continues in the Stated Policies Scenario, with US crude oil comprising a growing share of Asian refiners' crude intake, particularly in China. In addition, global oil demand increasingly shifts towards lighter and sweeter products as a result of rising demand for petrochemicals and the need to meet tightening sulfur specifications (such as the IMO regulation). US tight oil yields higher volumes of these types of products and so is well positioned to help meet this changing demand pattern.

S P O T L I G H T

Crude quality: from heavy to light and onward to where?

To stay competitive, refiners not only need to anticipate and adapt to changes in the demand for oil products but also adapt to changes in the types of crude oil that are available. The question of changes in the quality of crude oil has rapidly risen up the agenda as a result of the rise in tight crude oil and NGLs production in the United States, escalating geopolitical and economic tensions in several producer economies, as well as the tightening regulations on sulfur content in oil products (such as the Euro emissions standards on road vehicles and the IMO regulation on marine fuels).

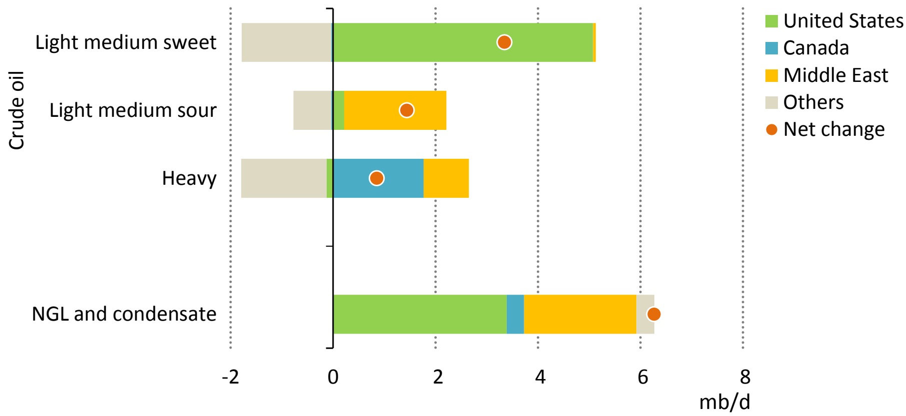
There are two factors that are widely used to define the quality of crude oil: density and sulfur content. Density is generally measured using American Petroleum Institute (API) gravity (an inverse proportional measure of petroleum density relative to that of water). Light crude oil is lighter than 32 °API; medium crude oil lies between 32 °API and 24 °API; and heavy crude oil is less than 24 °API. Crude oil is "sour" if it has sulfur content higher than 1% and "sweet" if it contains less.

Heavy crude oil tends to produce more low-value residue streams than light crude oil unless it is upgraded in a more complex refinery. Sour crude requires energy-intensive processing to remove the sulfur. Light and sweet crude oil therefore has historically been valued more highly than heavy and sour crude oil.

In the past, it was anticipated that crude oil available on the market was going to become increasingly heavy because major production increases were expected from Canada, Mexico and Venezuela. Refiners invested heavily in upgrading capacity that could produce a larger proportion of valuable products from lower priced heavy crude oil. Complexity became a mantra of the refining industry.

The rapid growth of US tight oil output turned this expectation on its head. Over the past decade, light and medium sweet crude oil supply accounted for almost 60% of the increase in crude oil supply; heavy crude oil represented just 15% (Figure 3.20). This was compounded by a major increase in very light NGLs. This trend looks set to continue, even though there is still uncertainty over how long and to what level US production can grow.

Figure 3.20 ▷ Change in global oil production by type, 2008-2018



Light and medium sweet crude oil, and NGLs accounted for the majority of oil supply growth over the past decade

Note: Crude oil includes conventional crude oil, tight crude oil and extra-heavy oil and bitumen.

In the Stated Policies Scenario, US tight oil production nearly doubles between 2018 and 2030. In response, refiners are likely to strengthen efforts to adapt to changes in the quality of crude oil coming onto the market. This could undermine the attractiveness of heavy crude oil and weaken the case for related new investments.

The sulfur content inherent in crude oil is another important element. Refineries today need to remove some 70-75% of the sulfur from crude oil. They are likely to need to remove even higher proportions in the future. Many countries, including China, have already reduced the permissible sulfur content of road transport fuels to under 15 parts per million (ppm). Constraints are also extending beyond road transport, with the IMO stipulating that, by 2020, 40% less sulfur will be allowed in oil products than in 2005.

Traditionally, crude quality has been a constant in the decision making processes of refiners, and refiners have focussed on optimising operations for the specific type of crude oil processed. In the future, crude quality is likely to be a variable as the grades of crude oil that are available change; the range of products demanded by consumers is also likely to change. The ability to process a wider range of crude oil and optimise operations depending on market conditions looks set to be an increasingly important element in refinery competitiveness. For refiners, the era of complexity could be shifting towards an era of flexibility.

Producer economies matter for consumers

The enduring importance of traditional producers as a key source of global oil supply means that any social, economic or geopolitical turmoil in these regions will have material impacts on oil consumers. Many of these producers rely on hydrocarbon revenue to finance a significant proportion of their national budgets. In the *WEO-2018 Special Report: Outlook for Producer Economies*, we highlighted the vulnerabilities that these economies might face in a changing energy system and the case for fundamental changes to their development models (IEA, 2018b).

One year on, the factors that put pressure on producer economies to reform their resource development models have all heightened. In this *Outlook*, US tight oil production remains higher for longer and there are longer term uncertainties over the strength of oil demand. Despite this, some of the momentum behind reform seems to have waned with higher oil prices in 2018.

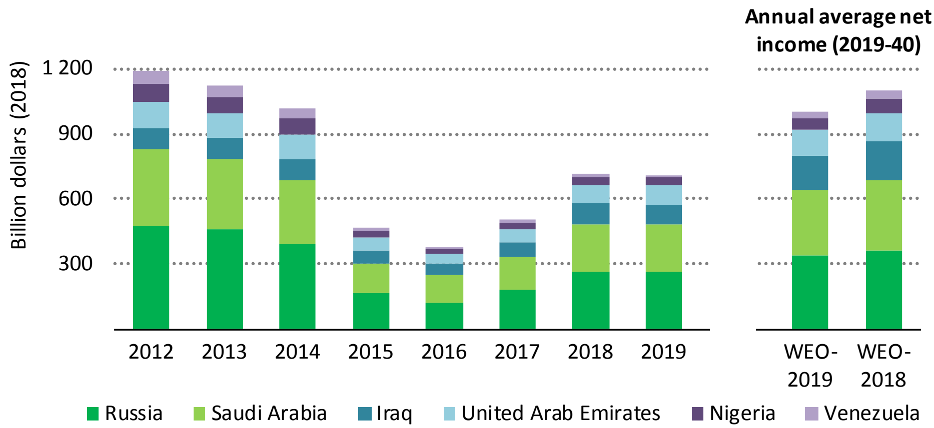
When oil prices were low, many governments in producer economies were keen to implement energy sector reforms and promote economic diversification. There was some positive progress in this area. Many countries made notable reductions in fossil fuel subsidies by raising regulated prices, which helped ease the strain on public finances. Their deployment of renewable technologies also gathered pace and ambitious targets have been introduced in a number of countries. In Saudi Arabia, broader economic reforms (such as the introduction of a value-added tax) have helped spur an increase in non-oil revenues.

However, history suggests that short-term pressure for reform tends to lessen when the oil price increases. Net income from oil and gas production in major producer economies almost doubled between 2016 and 2018. Some countries delayed proposed cuts to subsidies, leading to an increase in subsidy volume and energy intensity. In Nigeria, longstanding uncertainties around the Petroleum Industry Bill, which have been constraining upstream investment, remain unresolved. The pace of growth in non-oil gross domestic product has also moderated in many countries.

The changing dynamics of global energy markets pose major long-term questions about the durability of this relief. In this *Outlook*, cumulative net income from oil and gas production in major producer economies is around 10% lower over the period to 2040 than in the *WEO-2018* (Figure 3.21). This would reduce to an even greater degree if countries were to accelerate efforts to tackle climate change. Producer economies are increasingly heading towards a future world where markets for their ample resources are not guaranteed.

A long-term reduction in income would not only hamper the ability of governments to make the investments necessary to diversify their economies but also limit their capacity to respond to any potential periods of economic disruption. This could risk short-term supply interruptions ballooning into more sustained outages, with obvious implications for oil importers. While many producer economies achieved notable progress on reforms in recent years, the easing pressure for further reform matters for consumers as well as for the producers themselves.

Figure 3.21 ▷ Net income from oil and gas production in selected producer economies in the Stated Policies Scenario

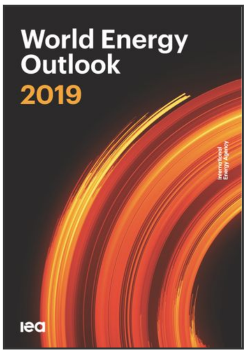


Recent increases in net income have diminished the pressure for producer economies, but the rapidly changing dynamics of global energy raises increasing questions going forward

Conclusion

Despite some positive developments in recent years, there are plenty of reasons for policy makers to continue to pay close attention to oil market security. While there is a marked slowdown in the pace of overall global oil demand growth in the Stated Policies Scenario, demand continues to grow briskly in Asia and much of the supply to meet it flows through major chokepoints. The rise of US tight oil output offers Asian importers opportunities for supplier diversification, but increases the pressure on producer economies, some of which are facing escalating geopolitical tensions.

Against this backdrop, the role of emergency oil stocks to help weather sudden supply disruptions remains vital. The effectiveness of such stocks will be greater with broader participation and with increased attention to changes in crude quality and product demand. It will also be important for refiners to improve the flexibility of their operations; for importing countries to promote energy efficiency and alternative technologies to moderate the pace of growing import dependency; and for producer economies to expedite their efforts to reform and diversify their economies. The changing market environment requires a broad and sustained approach to oil security.



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