
Organization of the Petroleum Exporting Countries
2023
World
Oil
Outlook
2045

2023

World Oil Outlook

2045

Organization of the Petroleum Exporting Countries

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OPEC's World Oil Outlook (WOO) is part of the Organization's commitment to market stability. The publication is a means to highlight and further the understanding of the many possible future challenges and opportunities for the oil industry. It is also a channel to encourage dialogue, cooperation and transparency between OPEC and other stakeholders within the industry.

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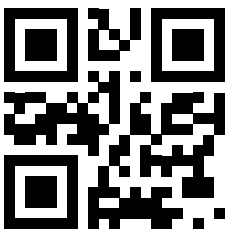

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ISBN 978-3-9504890-6-4

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

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Over the past year, we have witnessed a significant shift in the narrative related to energy transitions and the intertwined issues of energy security, energy availability and the need to reduce emissions.

Governments and political parties are reevaluating their sustainable energy pathways, taking into account the realities on the ground and the views of populations. There has been pushback against the opinion that the world should see the back of fossil fuels, as policies and targets for other energies falter due to costs and a more nuanced understanding of the scale of the energy challenges. Moreover, we are now seeing more focus on the capacities and national circumstances of all countries in the energy transitions agenda, not just a select few.

These were evidently on display at the 8th OPEC International Seminar, held in early July in Vienna, with a focus on the need for all energy sources, all relevant technologies and unprecedented investment, collaboration and support.

At OPEC, we believe that the future needs to see energy transition pathways that strive for an inclusive 'all-peoples, all-fuels and all-technologies' approach. We need to follow sustainable paths that enable economic growth, enhance social mobility, boost energy access, and reduce emissions at the same time.

These issues are part of the thinking and analysis that form the backbone of this year's World Oil Outlook (WOO), as the Organization looks to share its data-driven views on how the future energy landscape may evolve, ones that offer some differing perspectives compared to past editions.

What is clear is that the world will continue to need more energy in the decades to come as populations expand, economies grow, and given the pressing need to bring modern energy services to those who continue to go without.

In this year's WOO, global energy demand is seen expanding by 23% in the period to 2045, or on average by around 3 million barrels of oil equivalent a day every year. The only way this can be realized is through huge investments in all energies.

Recent developments have led the OPEC team to reassess just what each energy can deliver, with a focus on pragmatic and realistic options and solutions. In this regard, our Reference Case sees oil demand reaching 116 million barrels a day (mb/d) by 2045, around 6 mb/d higher than in the WOO 2022, and with the potential to be even higher.

For this to be achieved, oil sector investment requirements out to 2045 total $14 trillion, or around $610 billion on average per year. It is vital that these are made; it is beneficial for both producers and consumers.

Calls to stop investments in new oil projects are misguided and could lead to energy and economic chaos. History is replete with numerous examples of turmoil that should serve as a warning for what occurs when policymakers fail to acknowledge energy's interwoven complexities.

While the world needs more energy, alongside this there is also the need to continually reduce emissions, subscribing to global best practices and cutting edge, best-in-class technologies. For example, carbon capture utilization and storage, direct air capture, clean hydrogen technologies, the circular carbon economy, and others. These form part of the WOO's spotlight on technologies that should play a key role going forward.

The platform for building a sustainable energy future for all also comes from stability in energy markets, which remains the core focus of OPEC and its partners in the Declaration of Cooperation. The continued proactive, preemptive and multilateral approach to balanced and stable markets and the voluntary production adjustments have proven beneficial over the past year. It will continue to be a guiding principle in the years to come.

Nonetheless, the future requires all industry stakeholders to work together, no-one can work alone. Collaboration needs to be based on the realities we see before us, to ensure a long-term investment-friendly climate for all energies.

In putting together this year's WOO, I would like to thank all those involved: management, analysts, editors, designers and all others that played a role. The OPEC team should be proud of this achievement, which is central to the Organization's embrace of transparency through dialogue and cooperation.

We are excited to introduce the WOO 2023 to our valued readership. We believe it offers a forward-thinking approach and a visionary blueprint to help meet energy security concerns, lessen energy poverty and reduce emissions. We look forward to any feedback you may have.

Haitham Al Ghais
Secretary General

Executive Summary

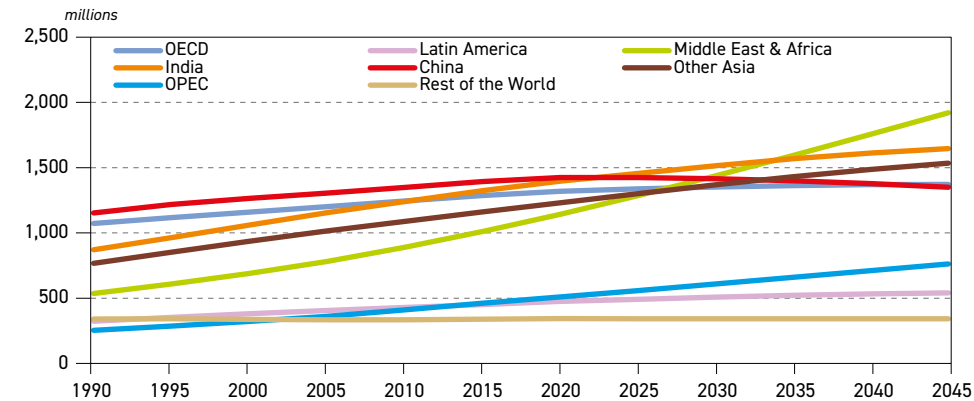
Balanced energy policies and innovative technologies are key to a sustainable future

Sustainable energy and economic prosperity for all requires the use of all sources of energy and the deployment of all relevant technologies with unprecedented levels of investment and collaboration. Recent shifts and the re-consideration of energy transition policies and targets by governments across the world are placing greater emphasis on energy security. This outlook takes all these recent developments into account to provide a forward thinking and realistic outlook, that is based on a scientific approach and hard data. This outlook takes a relatively conservative approach as it assumes that already-enacted, let alone announced energy policies, will be comprehensively implemented.

Population growth drives energy demand requirements

Global population is expected to expand by around 1.5 billion from nearly eight billion in 2022 to about 9.5 billion by 2045. This will be driven by strong population growth in the Middle East & Africa and Other Asia. The global working-age population (aged between 15–64) is set to increase globally by 826 million over the forecast period, while the global urbanization rate is anticipated to rise from 57% in 2022 to 66% by 2045.

World population trends, 1990–2045



Source: OPEC.

Average global economic growth is seen at 3% p.a. over the long-term

Global economic growth is expected to average 3% per annum (p.a.) over the forecast period. Thus, over the entire outlook, global GDP is set to almost double from $138 trillion in 2022 to

Long-term annual real GDP growth rate

% p.a.

	2022–2028	2028–2035	2035–2045	2022–2045
OECD Americas	1.5	2.2	2.2	2.0
OECD Europe	1.4	1.5	1.1	1.3
OECD Asia-Pacific	1.3	1.3	1.1	1.2
OECD	**1.5**	**1.8**	**1.6**	**1.6**
Latin America	1.9	2.2	1.8	1.9
Middle East & Africa	3.1	3.9	4.5	4.0
India	6.1	6.3	5.9	6.1
China	4.9	4.2	3.0	3.8
Other Asia	4.3	4.1	3.0	3.7
OPEC	3.0	3.1	3.2	3.1
Russia	1.0	1.4	1.2	1.2
Other Eurasia	2.5	2.5	2.3	2.4
Non-OECD	**4.1**	**4.1**	**3.5**	**3.8**
World	**3.0**	**3.1**	**2.8**	**3.0**

Source: OPEC.

$270 trillion in 2045 (on a 2017 PPP basis). With average long-term growth of 6.1% p.a., India is expected to remain the fastest-growing major developing country. China and India alone are set to account for more than a third of the global economy in 2045.

Global primary energy demand to increase by 23% to 2045, driven by non-OECD

Global primary energy demand is set to increase from around 291 million barrels of oil equivalent per day (mboe/d) in 2022 to close to 359 mboe/d in 2045, an increase of 68.3 mboe/d, or 23% over the outlook period. Growth is expected to slow gradually from the relatively high short-term rates to more modest long-term increments, in line with moderating population and economic growth. Energy demand growth will be driven by the non-OECD region, which is set to increase by 69 mboe/d over the outlook period. Around 28% of non-OECD growth is expected to come from India alone. At the same time, energy demand in OECD countries is set to marginally decline in the outlook period.

Total primary energy demand by region, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	55.4	55.4	56.4	56.6	56.4	55.9	0.5	0.0	19.0	15.6
OECD Europe	33.7	34.0	33.9	33.4	32.7	32.0	–1.7	–0.2	11.6	8.9
OECD Asia-Pacific	17.5	17.7	17.9	18.0	18.0	18.0	0.5	0.1	6.0	5.0
OECD	**106.6**	**107.1**	**108.2**	**108.0**	**107.1**	**105.9**	**–0.7**	**0.0**	**36.7**	**29.5**
China	71.3	75.2	78.1	78.7	78.1	77.4	6.1	0.4	24.5	21.6
India	19.2	21.3	25.4	29.7	34.1	38.5	19.3	3.1	6.6	10.7
OPEC	20.3	22.8	26.4	29.6	32.6	34.7	14.4	2.4	7.0	9.7
Other DCs	50.3	54.2	61.1	68.2	75.0	77.1	26.8	1.9	17.3	21.5
Russia	15.7	15.5	15.4	15.3	15.2	15.2	–0.5	–0.1	5.4	4.2
Other Eurasia	7.5	7.8	8.3	8.9	9.5	10.4	2.9	1.4	2.6	2.9
Non-OECD	**184.3**	**196.8**	**214.7**	**230.3**	**244.5**	**253.3**	**69.0**	**1.4**	**63.3**	**70.5**
World	**290.9**	**303.9**	**322.9**	**338.3**	**351.6**	**359.2**	**68.3**	**0.9**	**100.0**	**100.0**

Source: OPEC.

Wind and solar grow at the fastest rate; oil retains the largest share in the energy mix

Demand for all primary fuels is set to increase in the long-term, with the exception of coal due to energy policy and climate commitments. The strongest growth is expected for other renewables (notably wind and solar), which will increase by 34.3 mboe/d, based on strong

World primary energy demand by fuel type, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
Oil	90.7	96.4	102.0	104.3	105.3	106.1	15.4	0.7	31.2	29.5
Coal	75.9	74.6	71.1	65.9	60.0	54.4	–21.5	–1.4	26.1	15.1
Gas	67.1	69.6	75.0	80.2	84.4	87.0	20.0	1.1	23.1	24.2
Nuclear	15.0	15.9	17.4	19.4	21.7	23.8	8.8	2.0	5.2	6.6
Hydro	7.7	8.2	8.9	9.6	10.2	10.5	2.8	1.3	2.7	2.9
Biomass*	26.6	27.9	30.2	32.3	34.1	35.2	8.6	1.2	9.1	9.8
Other renewables**	7.9	11.2	18.5	26.7	35.8	42.2	34.3	7.5	2.7	11.7
Total	**290.9**	**303.9**	**322.9**	**338.3**	**351.6**	**359.2**	**68.3**	**0.9**	**100.0**	**100.0**

* *Biomass includes solid biomass, waste, biogas, biofuels and charcoal.*
** *Other renewables include wind, solar, geothermal and tidal energy.*
Source: OPEC.

policy support in many regions. The share of other renewables in the energy mix is set to rise from around 2.7% in 2022 to 11.7% in 2045. Oil demand will grow strongly too, and even though its share in the energy mix declines modestly, oil will remain the fuel with the largest share by 2045 at 29.5%. Natural gas demand is set to increase by 20 mboe/d over the outlook period, reaching 87 mboe/d in 2045. The share of fossil fuels in the energy mix will drop from above 80% in 2022 to about 69% in 2045, due to the decline of coal. In the same period, the combined share of oil and gas in the energy mix still represents 54% in 2045.

Oil demand shows strong medium-term growth; long-term oil demand rises to 116 mb/d by 2045

Global oil demand is set to reach a level of 110.2 million barrels a day (mb/d) in 2028, representing an increase of 10.6 mb/d compared to 2022. Non-OECD oil demand is expected to increase by a robust 10.1 mb/d, reaching a level of 63.7 mb/d by 2028. OECD demand will also increase by 0.5 mb/d over the medium-term.

In the long-term, global oil demand is expected to increase by more than 16 mb/d between 2022 and 2045, rising from 99.6 mb/d in 2022 to 116 mb/d in 2045. Non-OECD oil demand is expected to increase by almost 26 mb/d between 2022 and 2045. In contrast, OECD oil demand is set to contract by around 9.3 mb/d.

Long-term oil demand by region *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	25.0	25.5	25.8	24.8	23.2	21.5	–3.5
OECD Europe	13.5	13.5	13.1	12.0	10.8	9.8	–3.7
OECD Asia-Pacific	7.4	7.5	7.2	6.6	6.0	5.4	–2.0
OECD	**45.9**	**46.5**	**46.0**	**43.4**	**40.0**	**36.7**	**–9.3**
China	14.9	16.8	17.8	18.2	18.5	18.8	4.0
India	5.1	5.9	7.3	8.8	10.2	11.7	6.6
Other Asia	9.0	9.9	11.1	12.1	12.9	13.6	4.6
Latin America	6.4	6.9	7.8	8.4	8.7	9.0	2.5
Middle East	8.3	9.4	10.0	10.7	11.4	11.9	3.6
Africa	4.4	4.9	5.9	6.6	7.4	8.2	3.8
Russia	3.6	3.8	4.0	4.0	3.9	3.9	0.3
Other Eurasia	1.2	1.2	1.3	1.4	1.5	1.5	0.3
Other Europe	0.8	0.8	0.9	0.9	0.8	0.8	0.0
Non-OECD	**53.6**	**59.6**	**66.0**	**71.0**	**75.4**	**79.4**	**25.7**
World	**99.6**	**106.1**	**112.0**	**114.4**	**115.4**	**116.0**	**16.4**

Source: OPEC.

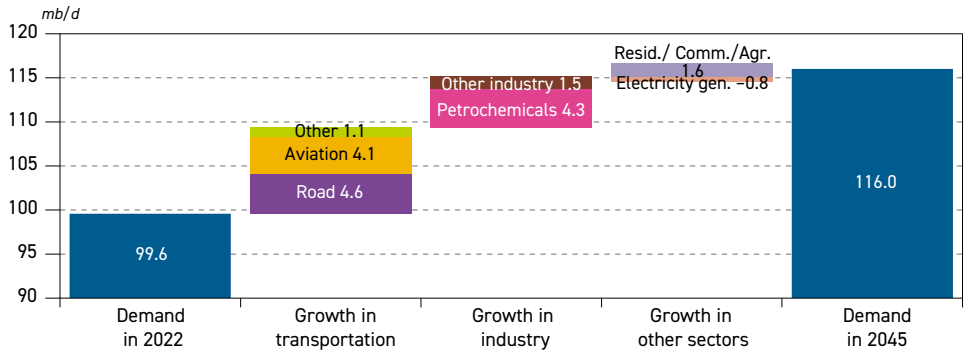
India leads in driving oil demand growth

The largest contributions to the non-OECD oil demand increase are set to come from India, Other Asia, China, Africa and the Middle East. India will add 6.6 mb/d to oil demand over the forecast period. Other Asia's oil demand is set to increase by 4.6 mb/d, China's by 4 mb/d, Africa's by 3.8 mb/d and the Middle East's by 3.6 mb/d.

Road transport, petrochemicals and aviation are key to oil demand growth

The largest incremental demand over the forecast period is projected for the road transportation, petrochemical and aviation sectors. Oil demand in these sectors is set to increase by 4.6 mb/d, 4.3 mb/d and 4.1 mb/d, respectively. With respect to refined products, major long-term demand growth is expected for jet/kerosene (4 mb/d) followed by ethane/liquefied petroleum gas (3.6 mb/d), diesel/gasoil (3.1 mb/d), naphtha (2.5 mb/d) and gasoline (2.5 mb/d).

Oil demand growth by sector, 2022–2045



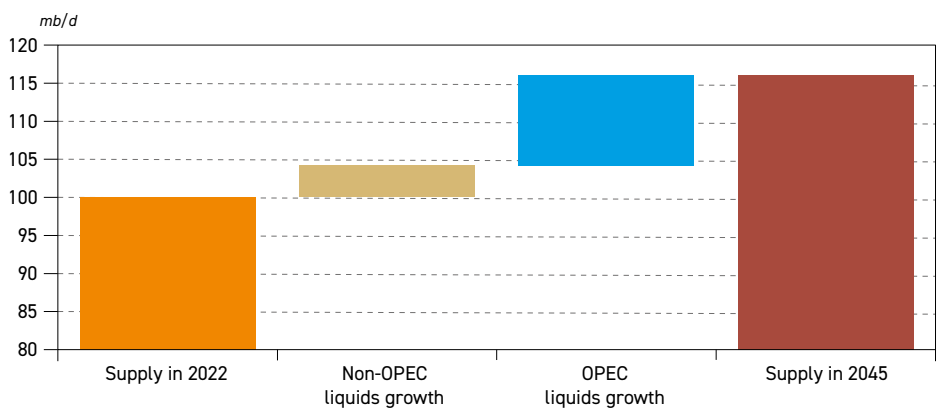
Source: OPEC.

Strong medium-term non-OPEC liquids supply growth, led by the US

Non-OPEC liquids supply is expected to grow from 65.8 mb/d in 2022 to 72.7 mb/d in 2028, or by almost 7 mb/d. Incremental supply in the US makes up nearly half of this, at 3.4 mb/d, with other major drivers being Brazil, Guyana, Canada, Qatar and Norway.

With US liquids supply set to peak around the end of the current decade, overall non-OPEC production starts declining from the early 2030s, eventually falling to 69.9 mb/d by 2045. Guyana, Canada, Argentina, Brazil and Kazakhstan are some of the few non-OPEC producers set to expand beyond the medium-term, but non-crude liquids including biofuels and other unconventionals will also keep increasing.

Composition of global liquids supply growth

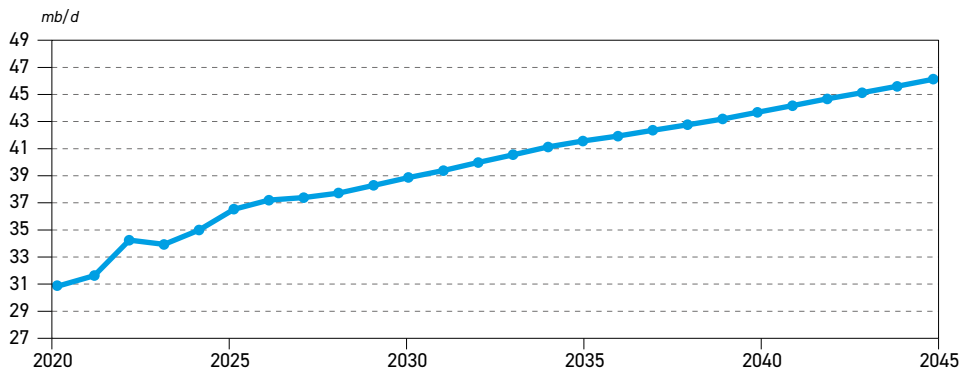


Source: OPEC.

OPEC's share of global liquids supply rises from 34% in 2022 to 40% in 2045

OPEC liquids will rise steadily in the medium-term from 34.2 mb/d in 2022 to 37.7 mb/d, and further to 46.1 mb/d by 2045. Thus, OPEC's share of global liquids supply will increase from 34% in 2022 to 40% in 2045.

OPEC total liquids supply outlook

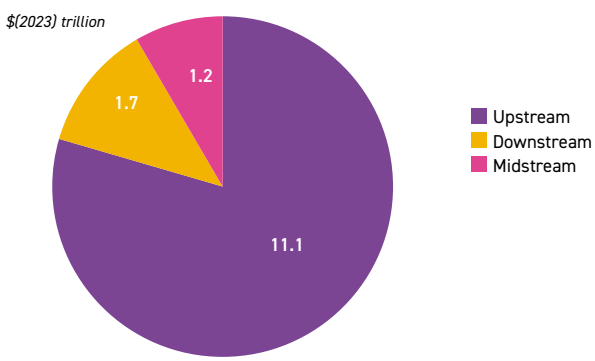


Source: OPEC.

Oil investment requirements total $14 trillion by 2045

Investment requirements for the overall oil sector, between 2022 and 2045, are estimated at a cumulative $14 trillion (in 2023 $US), or around $610 billion p.a. on average. Of this, $11.1 trillion is expected to be required in the upstream sector, or an average of $480 billion p.a. Downstream and midstream requirements are estimated at $1.7 and $1.2 trillion, respectively. If these investments do not materialize, it represents a considerable challenge and risk to market stability and energy security.

Cumulative oil-related investment requirements by segment, 2023–2045



Source: OPEC.

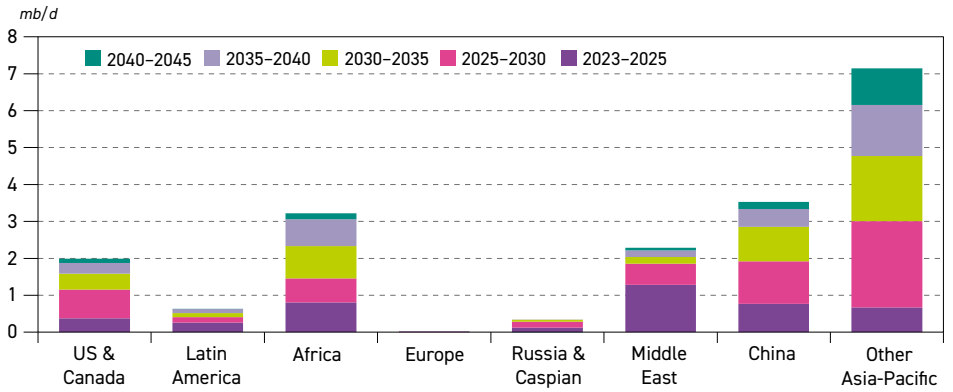
Asia-Pacific, Middle East & Africa drive medium-term refinery expansions

Around 6.6 mb/d of refining capacity additions are projected between 2022 and 2028. Most of this new capacity will be in the Asia-Pacific (3.1 mb/d), Middle East (1.6 mb/d) and Africa (1.2 mb/d). Additions in other regions are minor and mostly limited to the expansion of existing refineries.

New crude distillation capacity requirements at 19.2 mb/d through 2045

In the long-term (2023–2045), global refining capacity additions are set at 19.2 mb/d (including capacity creep). Similar to oil demand growth, additions are front-loaded, with a slowdown in the rate towards 2045. Around 85% of long-term additions are expected in the Asia-Pacific, Middle East and Africa. This continued trend of refining capacity migration from developed to developing countries mirrors the shifts in regional demand.

Crude distillation capacity additions, 2023–2045

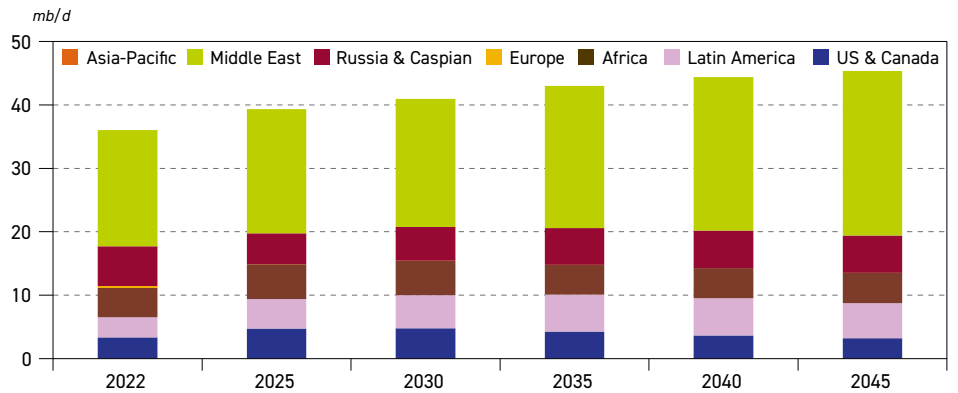


Source: OPEC.

Long-term crude and condensate trade flows rise to above 45 mb/d by 2045

Driven by strong demand growth, global interregional crude and condensate trade is expected to reach levels above 39.3 mb/d in 2025, up by more than 3 mb/d relative to 2022 levels. After 2025, total crude and condensate flows are set to increase gradually to 45.3 mb/d by 2045, driven by rising oil demand and declining supply in importing regions. Major contributors to the export growth are the Middle East, Latin America and the US & Canada.

Global crude and condensate exports by origin, 2022–2045*



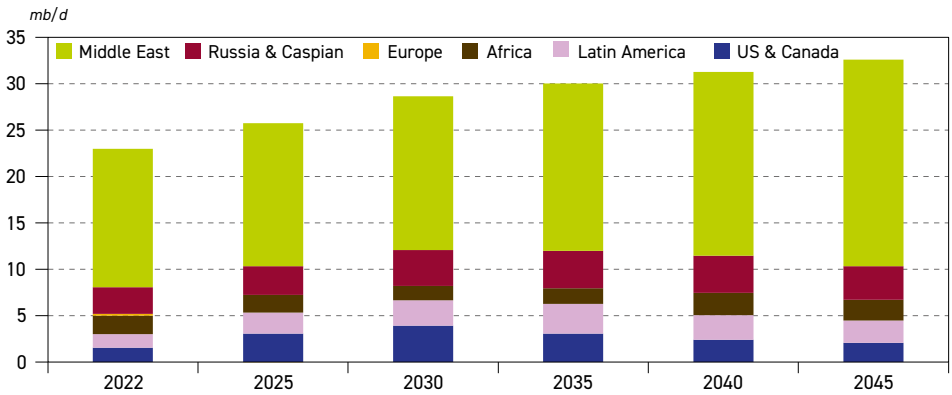
* *Only trade between major regions is considered, intratrade is excluded.*

Source: OPEC.

Asia-Pacific remains by far the largest destination for crude exports

The Asia-Pacific remains by far the main destination for global crude and condensate exports. Total imports increase gradually from 23 mb/d in 2022 to 32.6 mb/d in 2045. This translates into its share of the global interregional trade rising from around 64% in 2022 to almost 72% in 2045.

Crude and condensate imports to the Asia-Pacific by origin, 2022–2045



Source: OPEC.

The Outlook considers two alternative scenarios relative to the Reference Case

An 'Advanced Technology' Scenario illustrates a technology-driven means of limiting the global temperature increase to well below 2°C. This includes a much greater diffusion of carbon capture utilization & storage (CCUS), carbon capture and storage (CCS) and direct air capture (DAC) technologies in industrial sectors, stronger investment in hydrogen supply networks, and the increasing adoption of a circular carbon economy (CCE) framework across the global economy. Primary energy demand in this scenario will be almost 55 mboe/d lower by 2045 compared to the Reference Case. Oil demand, after stabilizing at over 100 mb/d until around 2035, will then drop slightly towards 98 mb/d by 2045, which is 18 mb/d lower than in the Reference Case.

The 'Laissez-Faire' Scenario, which is a more optimistic and more equitable outlook for developing economies, assumes a faster return to higher economic growth during the medium-term and maintains this stronger growth in the long-term, especially for developing countries. Policies will tighten in the future, contributing to improved efficiencies and supporting the further expansion of renewables; however, in an isolated manner given the absence of a coordinated move to reduce future emissions. Moreover, protectionism and unilateralism will play a more important role in prioritizing local development needs over global issues. In this scenario, both primary energy demand and oil demand will be consistently higher than the Reference Case. Oil demand surpasses 113 mb/d by 2030 and continues growing to 122 mb/d in 2045. Compared to the Reference Case, this represents a difference of more than 1 mb/d by 2030, which then expands to 6.3 mb/d in 2045.

Introduction

The global energy landscape has undergone significant changes during 2022 and 2023. The start of the conflict in Eastern Europe in early 2022 led to an energy crisis that redirected energy flows and exacerbated record-high energy prices. This was especially the case for spot natural gas and coal prices, as well as electricity prices in many major consuming regions.

Moreover, the period has also seen a broad realization across many societies on the need for energy security to go hand-in-hand with economic development and reducing emissions, with many policymakers re-evaluating their approach to energy transition pathways. This is true of many of the early adopters of net zero targets in the Global North. It is also true that countries in the Global South have now made it clear what energy transitions mean for them.

This renewed focus on energy security and energy affordability has led to a variety of developments. Many developed countries have turned to fossil fuels, including coal, to meet short-term energy needs, while also enhancing targets related to low-carbon energy and energy efficiency improvements, which are also in line with climate change policies.

Increasing the deployment of renewable energy and/or nuclear energy is seen by these countries as a means to address the dual challenge of energy security and sustainability. However, these ambitious targets increasingly stand at odds with realities on the ground. The required investments are significantly lagging, as policymakers in many countries re-direct expenditures to more pressing issues such as the cost-of-living crisis, inflation and recession worries and welfare spending. There is also a rising chorus of voices questioning the viability and actual benefits of these policies and targets, and asking whether there are other options to help reduce emissions while ensuring energy security and economic development.

At the same time, many developing countries, in their quest to raise the level of energy security, have increasingly turned to domestic energy supplies, predominantly coal. Moreover, there has also been a refocus on the critical need to continue to utilize fossil fuels going forward, while at the same time reducing emissions. Increasingly, calls for more equitable growth come from developing nations where people need more energy and where countries need to be able to utilize their resources to the fullest, while not undermining the UN's goal to ensure affordable, reliable and modern energy services for all by 2030. As a result, the focus of policymakers is turning to improved energy access and energy poverty eradication, while utilizing all energy sources.

This clearly depicts a major difference between developed and developing countries. In the former, energy demand has been increasing only marginally, or even declining in recent years. This allows for a faster penetration of low-carbon energy sources in the energy mix, albeit not at levels to meet many of the targets set. At the same time, developing countries, with rapidly growing populations and economies are likely to see a strong increase in total energy demand, which cannot be met by renewables alone. The deployment of renewables is capital intensive, and most developing countries do not have sufficient access to financing. This is why the increase of low carbon energy sources in the mix is considerably slower, when compared to developed countries.

Alongside a recovery from the pandemic, these developments have also helped to support oil demand growth in recent years. Following the turbulent years of 2020 and 2021, global oil demand continued growing in 2022, despite the fact that the last quarter of 2022 and the beginning of 2023 were marked by high inflation and continued geopolitical tensions.

High energy prices that prevailed during most of 2022 started declining towards the end of the year as it became clearer that the energy supply crisis in Europe was easing, supported by a relatively mild winter. Adding to this was Russia's ability to redirect its oil exports, mainly to Asia, after the new set of EU sanctions came into force, which, with a few minor exemptions, banned Russian oil imports to the EU.

Major central banks have increased key interest rates in an effort to tame inflation. This, combined with high debt levels in several regions, lowered the prospects for economic growth during 2023. Despite this outlook, oil demand proved to be relatively resilient to downward revisions during 2023. It remains to be seen, however, how the link between oil demand and the level of economic activity will develop in the years to come as mixed signals are emerging on factors that have the potential to steer this relationship in the future.

On the one hand, energy security is still on the top of agenda for policymakers as many of them have learned lessons from recent developments. Moreover, several major energy companies have signalled a shift in their investment strategy towards more investments in oil and gas projects, acknowledging a more balanced all energies approach to the energy transitions.

On the other, there are new policy initiatives aiming at emission reductions, such as the adoption of the 'Fit for 55' package by the European Parliament in April 2023 and the Inflation Reduction Act in the US adopted in August 2022. Additionally, there is the Long-Term Aspirational Goal (LTAG) for international aviation to achieve net-zero CO_2 emissions by 2050 adopted by the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) in October 2022. Additionally, recent investments by car manufacturers to shift production lines towards electric mobility, especially in China and Europe, is another area to be closely monitored as the evolving composition of the car fleet could have a significant impact on future oil demand.

On the supply side, a considerable degree of uncertainty regarding the medium- and long-term outlook for non-OPEC liquids persists too. Against the backdrop of transitioning towards a lower-emissions future, persistent long-term concerns remain around investment in the oil and gas sector, especially given concerns related to financing, shareholder pressure, and environmental, social and governance (ESG) interests. However, recent liquids production has remained robust, with non-OPEC supply healthy and OPEC+ continuing to act proactively, continuously and pre-emptively, ensuring global oil market stability.

The outlook for non-OPEC liquids supply retains the pattern described in recent Outlooks – healthy medium-term growth, followed by a peak in the early 2030s, after which output gradually declines again. Combined with oil demand growing in the long-term, albeit at a slower pace, this implies a rising requirement for OPEC liquids, and hence an increasing market share for OPEC producers.

Cognizant of all the uncertainties, this year's World Oil Outlook again sketches alternative energy trajectories. An 'Advanced Technology' Scenario illustrates a technology-driven means of limiting the global temperature increase to well below 2°C, with a much greater diffusion of CCUS, CCS and DAC technologies in industrial sectors, stronger investment in hydrogen supply networks, and the increasing adoption of a CCE framework across the global economy. The 'Laissez-Faire' scenario assumes a faster return to higher economic growth during the medium-term and maintains this stronger growth in the long-term, especially for

developing countries. Policies will tighten in the future, contributing to improved efficiencies and supporting the further expansion of renewables; however, in an isolated manner given the absence of a coordinated move to reduce emissions. Moreover, protectionism and unilateralism will play a more important role in prioritizing local development needs over global issues.

This Outlook once again underscores the major questions and challenges the world faces when imagining a common energy future. In this regard, OPEC continues to strive for a transparent, open-minded and facts-based dialogue to help enable a sustainable energy and economic future for all. This should focus on all energy sources, all relevant technologies, and the views of all stakeholders, and it is hoped this publication contributes to that end.

Key assumptions

Key takeaways

- Sustainable energy and economic prosperity for all requires the use of all sources of energy and the deployment of all relevant technologies with unprecedented levels of investment and collaboration, and with energy security, economic development and reducing emissions going hand-in-hand.
- This outlook takes all this on board, including recent shifts and the re-consideration of policies and targets related to energy transitions by governments across the world, to provide a forward thinking and realistic outlook that is based on a scientific approach and hard data.
- This outlook takes a relatively conservative approach as it assumes that already-enacted, let alone announced energy policies will be fully or comprehensively implemented.
- The global population is estimated to expand by around 1.5 billion from its present level of almost eight billion in 2022 to around 9.5 billion by 2045.
- Driven by the Middle East & Africa and other Asia, non-OECD population growth is projected to be much higher than the Organisation for Economic Co-operation and Development (OECD).
- The relative share of the global working-age population is expected to decline from 65% in 2022 to 63% in 2045, despite increasing by 826 million over the outlook period.
- The global urbanized population is projected to grow by 1.7 billion, increasing from 57% in 2022 to 66% by 2045.
- Global GDP growth between 2022 and 2045 is expected to remain robust and increase at an average rate of 3% p.a.
- With an average GDP growth of 6.1% p.a. over the projection period, India is set to remain the fastest-growing major developing country.
- Global GDP is projected to almost double, from around $138 trillion in 2022 to $270 trillion in 2045, all in 2017 purchasing power parity (PPP) terms.
- China and India alone are set to account for more than a third of the global economy in 2045. The OECD region's share of the global economy is expected to drop from 46% in 2022 to 34% in 2045.
- Existing and future technologies will significantly contribute to shaping the future energy landscape. The development and deployment of various technologies also helps to set the scene for the Reference Case.
- Hydrogen is perceived in the context of energy transitions as a possible solution to some climate challenges, playing the role of an energy carrier.

Multiple key assumptions are made to establish this year's WOO. These include demographic projections and trends, possible economic growth in the midst of the current expedited monetary tightening, and the expected influence of technology advancements on the energy sector. With regard to energy policies, the Outlook incorporates recent shifts in thinking and targets related to energy transitions by governments across the world. Compared to previous WOOs, it takes a more conservative approach towards assuming that already-enacted, let alone announced energy policies, will be fully implemented, thus providing a forward thinking and realistic outlook. What is clear is that a sustainable energy and economic future for all requires all energy sources, all relevant technologies, unprecedented investment and collaboration, and with energy security, economic development and reducing emissions going hand-in-hand.

1.1 Population and demographics

With advancements in healthcare, nutrition, sanitation, among other factors to improve quality of life, the average age of the global population has risen considerably in recent decades. Today, the world's population continues to grow although the general development is a slowing trend. Looking ahead some developing countries may also see a similar transitions pathway as the OECD, but many others will defy this trend. In this chapter, various demographic fundamentals are considered and thoroughly evaluated as a means to help evolve the WOO's Reference Case projections.

Last year, the United Nations Department of Economic and Social Affairs published their 2022 Revision of World Population Prospects (UNDESA, 2022). The 27th edition of the UN's official population estimates and projections reflect many key demographic indicators addressed in this section.

A key element highlighted is the sustained momentum of a decline in fertility rates. Regarding the projection for this year's Outlook, total global population is estimated to expand by around 1.5 billion close to eight billion in 2022 to around 9.5 billion by 2045 (Table 1.1).

Regionally, the Middle East & Africa (excluding OPEC countries), as per the WOO's regional groupings (see Annex B), is expected to drive 48% of the population growth. Other Asia, India and OPEC each contribute between 15% and 19%. In the OECD, population growth for 2022-2045 is also estimated to be considerably less than the 184 million expansion in its population over the 1998–2022 period. Growth in OECD Americas will more than offset a 12 million decline in OECD Asia-Pacific. Overall, the non-OECD dominates the projections, accounting for more than 97% of the population growth compared to marginally less than 3% in the OECD.

The main anomaly for the non-OECD is the expectation that China's population drops by almost 76 million over the outlook period. This also reflects by far the largest decline of the major economies. This compares to population growth of 192 million in the previous 24 years (1998–2022), as seen in Figure 1.1. Furthermore, 2023 marked the year that China's population was overtaken by that of India (Figure 1.2). Going forward, India's population is set to continue expanding, with an estimated increase of 229 million over the period 2022–2045, albeit less than the 396 million added to its' population in the previous 24 years.

The Middle East & Africa region and OPEC are currently undergoing rapid population growth. This trend is projected to maintain its momentum through to 2045. In fact, the region is set to have the largest overall population by the end of the forecast period, a level it achieves around 2035. The Middle East & Africa and OPEC are the only regions expected

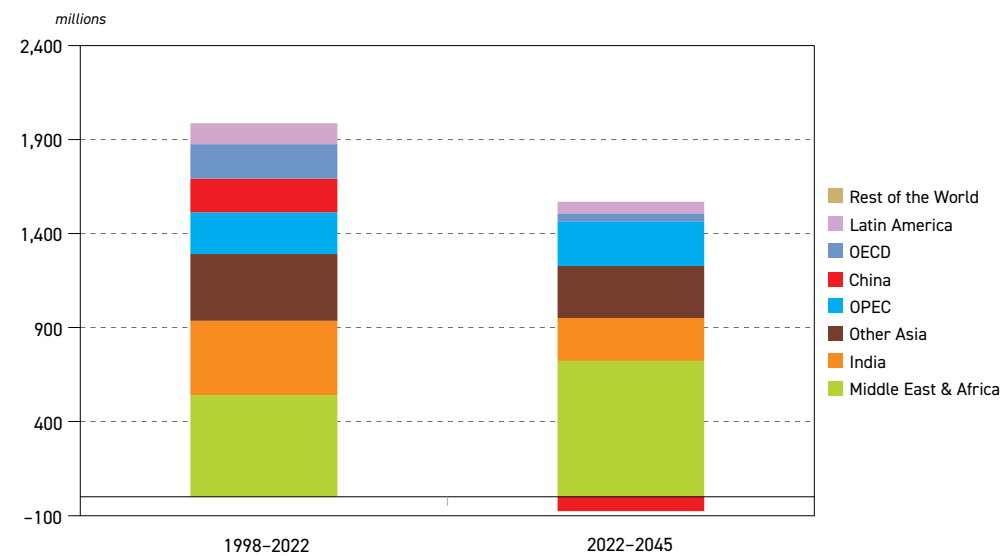
Table 1.1
Population by region

millions

	Levels						Growth
	2022	2025	2030	2035	2040	2045	2022–2045
OECD Americas	527	537	551	564	575	583	56
OECD Europe	583	585	587	587	587	584	1
OECD Asia–Pacific	216	215	214	211	208	205	–12
OECD	**1,327**	**1,337**	**1,351**	**1,363**	**1,370**	**1,372**	**46**
Latin America	482	492	508	522	533	541	59
Middle East & Africa	1,197	1,284	1,436	1,594	1,756	1,920	723
India	1,417	1,455	1,515	1,568	1,612	1,646	229
China	1,426	1,424	1,416	1,400	1,378	1,350	–76
Other Asia	1,258	1,300	1,368	1,430	1,486	1,535	277
OPEC	527	558	609	660	712	762	234
Russia	145	143	141	139	137	135	–10
Other Eurasia	196	198	201	203	205	207	11
Non-OECD	**6,649**	**6,855**	**7,195**	**7,516**	**7,818**	**8,095**	**1,447**
World	**7,975**	**8,192**	**8,546**	**8,879**	**9,188**	**9,468**	**1,492**

Source: United Nations (UN).

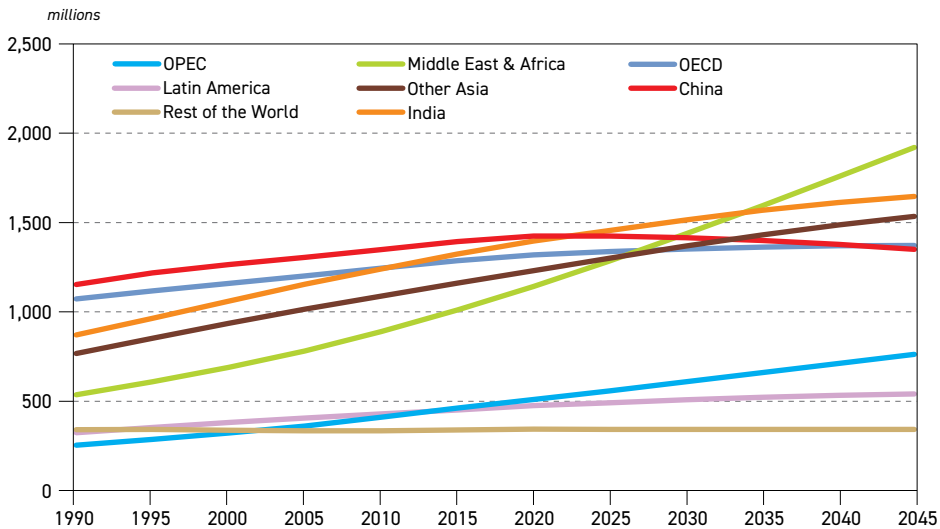
Figure 1.1
World population growth, 1998–2022 *versus* 2022–2045



Source: UN.

to see a significant rise in their growth rate, adding 723 million and 234 million people between 2022 and 2045, respectively. This compares to 541 million and 220 million added from 1998–2022.

Figure 1.2
World population trends, 1990–2045



Source: UN.

1.1.1 Working-age population

The global working-age population (aged between 15 and 64) is projected to grow by 826 million to reach six billion by 2045 (Table 1.2). Despite this large growth, and mainly due to the general ageing of the population, the share of the working age population is set to fall from 65% in 2022 to 63% in 2045. From a regional perspective, the share of the working-age population in non-OECD countries is forecast to drop only slightly, from 65% in 2022 to 64% in 2045, while the change in OECD countries is more pronounced, falling from 64.6% in 2022 to 59.6% in 2045.

Table 1.2
Working population (age 15–64) by region *millions*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	346	350	355	359	361	363	17
OECD Europe	376	374	367	360	351	342	–34
OECD Asia–Pacific	135	133	130	125	118	113	–22
OECD	**857**	**857**	**852**	**843**	**830**	**818**	**–39**
Latin America	327	334	344	351	354	354	28
Middle East & Africa	683	743	850	961	1,076	1,194	511
India	961	995	1,043	1,079	1,102	1,117	156
China	984	987	972	931	867	822	–162
Other Asia	825	855	901	942	976	1,005	180
OPEC	317	339	377	413	447	478	160
Russia	96	94	93	92	89	85	–11
Other Eurasia	127	128	130	132	132	131	4
Non-OECD	**4,321**	**4,475**	**4,710**	**4,900**	**5,044**	**5,187**	**866**
World	**5,178**	**5,332**	**5,562**	**5,744**	**5,874**	**6,005**	**826**

Source: UN.

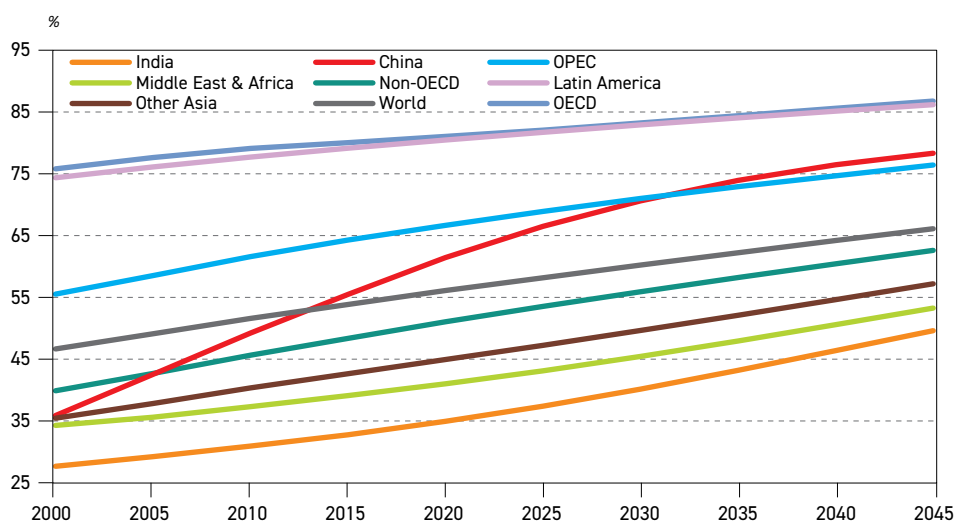
In the OECD, only OECD Americas is set to see a slight increase in the working-age population, mainly due to immigration. A 16% decline in the working- age population is forecast for OECD Asia-Pacific over the forecast period. The decline for OECD Europe is set to be smaller, at 9%, but this is evidently still significant.

China's working age population is projected to decline by 162 million between 2022 and 2045, while India's working-age population is projected to increase by 156 million. The highest absolute growth is forecast for the Middle East & Africa, with an increase of 511 million in the working-age population. Other Asia and OPEC are also expected to see significant growth.

1.1.2 Urbanization

Urbanization is closely linked to improved energy access and a key factor in helping alleviate energy poverty as both economic development and energy consumption tend to increase. The urbanization rate measures the percentage of the total population living in urban areas. In 2022, about 4.5 billion people, which is almost 57% of the world's population, lived in urban areas (Figure 1.3). This is a sharp increase from 44% only three decades ago. Urbanization is projected to grow in the coming decades, with 66% of the global population, equivalent to over 6.2 billion people, living in urban areas by the end of the forecast period.

Figure 1.3
Urbanization rate for selected regions, 2000–2045



Source: UN.

OECD and Latin America are the most urbanized regions, with more than 80% of the population living in urban areas. OECD Asia-Pacific has the highest urbanization rate at 89%, followed by OECD Americas at 83%. This trend is set to continue, despite already high rates of urbanization. OECD and Latin America are projected to have urbanization rates of 87% and 86%, respectively, by 2045, with OECD Asia-Pacific at over 90%.

China's urbanization has changed dramatically over the past three decades, driven by rapid economic development. While the country's urbanization rate was 28.2% in 1992, it increased significantly to 64% in 2022. Due to a mature domestic economy, urbanization is expected to continue at a slower pace, resulting in an urbanization rate of 78.3% by 2045.

India had an urbanization rate similar to that of China in 1992. However, in contrast to China's rapid urbanization, India's rate has only increased to 36% in 2022. India has been the region with the lowest urbanization rate since 1989, when it was overtaken by China. This is expected to continue until the end of the forecast period, when its rate is expected to be 50%. Urbanization in Other Asia follows India's trend throughout the projection period, albeit from a higher level.

OPEC Member Countries currently have an urbanization level of 68%, and this is expected to reach 76% by 2045. The Middle East & Africa region is anticipated to experience significant increased urbanization in the coming decades. However, the majority of Africa's population is set to remain rural, with 43% of the population expected to live in urban areas by 2045.

1.1.3 Migration

Migration is another dynamic element in the demographic disparities that exist at the regional level. Net migration, as shown in Table 1.3, measures the change in population between the UN's medium variant case and the zero migration variant case.

The COVID-19 pandemic had a significant impact on both mobility and international travel, severely affecting migration across regions and countries. The impact of COVID-19 on migration, however, has diminished as travel restrictions have eased. In the short-term, net migration figures are strongly influenced by geopolitical instability, leading to a large outflow of people from one region to another.

Table 1.3
Net migration by region *millions*

	2020–2025	2025–2030	2030–2035	2035–2040	2040–2045
OECD Americas	5.2	5.9	6.3	6.3	6.2
OECD Europe	5.8	1.7	3.3	3.4	3.5
OECD Asia-Pacific	1.4	1.5	1.5	1.5	1.5
OECD	**12.5**	**9.1**	**11.1**	**11.2**	**11.1**
Latin America	–0.6	–1.1	–0.8	–0.8	–0.7
Middle East & Africa	–1.3	–1.1	–1.9	–1.8	–1.8
India	–1.8	–2.4	–2.4	–2.5	–2.5
China	–1.2	–1.6	–1.5	–1.6	–1.5
Other Asia	–3.5	–4.2	–4.1	–4.1	–4.1
OPEC	–2.0	0.5	–0.3	–0.4	–0.4
Russia	1.4	0.3	0.5	0.5	0.5
Other Eurasia	–3.4	0.6	–0.5	–0.5	–0.5
Non-OECD	**–12.4**	**–9.1**	**–11.1**	**–11.2**	**–11.1**

Source: UN.

In the medium- and long-term, net migration is anticipated to return to historical patterns, with a steady flow of people from non-OECD regions moving to OECD countries. However, evolving geopolitics may have a significant impact on future migration patterns.

1.2 Economic growth

The key economic developments as summarized and described in last year's WOO have broadly continued. The issues include deglobalization, rising debt levels, skilled labour shortages, the consequences of the conflict in Eastern Europe, with a variety of spillover effects, and the accelerated financial tightening across the world, triggered by strong rises in inflation.

Of these issues, notably the effects of monetary tightening and deglobalization have accelerated, while the other issues remain, but have not necessarily progressed in terms of their overall economic impact.

1.2.1 Current situation and short-term growth

While the COVID-19 pandemic is now generally considered to be in the rear view mirror, it has had major economic effects. The strict lockdown measures in 2020–2021 were particularly impactful, but the reopening of economies has helped to support economic growth.

Throughout 2022, global supply chain issues prevailed, both on account of geopolitical developments in Eastern Europe and the China's zero-COVID policy. Positively, the situation improved towards the end of 2022, and the majority of these supply issues now appear to have been overcome.

While inflation has remained notably low in China, it has been a central challenge for most economies in 2022 and 2023. General inflation levels rose considerably in 2022, but it is now core-inflation that is persistently high. Expectations for ongoing firm inflation, at least in the medium-term, means that interest rates will likely remain above pre-pandemic and pandemic levels in many key economies, importantly in the United States (US), the Euro-zone and the United Kingdom (UK). India and Brazil have more room to manoeuvre and, in China, a more accommodative monetary policy is possible and likely at least in the medium-term.

In 2023, global economic growth has remained uneven among regions. However, upside potential in the short-term may come from less accentuated inflation, which would provide central banks with room for relatively more accommodative monetary policies. Emerging Asia, particularly India, but also Brazil and Russia could surprise further to the upside, with domestic demand and external trade accelerating. An even stronger-than-anticipated rebound in China after the reopening of its economy may provide further support to the global economy. Moreover, the US may keep its momentum and potentially could see growth turning out higher-than expected.

1.2.2 Medium-term economic growth

The carry-over effects of the main short-term issues will also likely provide influential forces for the medium-term economic growth dynamic. The following major assumptions and dynamics are made for the Reference Case.

Inflation is expected to gradually slow in the medium-term. After global inflation reached more than 8% in 2022, the consumer price index is forecast to slow to around 6% in 2023. From 2023 onwards, the medium-term inflation path sees a gradual slowdown, reaching around 2.5% by 2028. The medium-term global inflation average is forecast at 3.2%.

While inflation is forecast to be relatively contained in the medium-term, monetary tightening is expected to continue into 2024 and beyond. However, it is forecast that the pace of interest rate hikes in 2022 and 2023, particularly in the US, will not be repeated and that interest rates in the US, the Euro-zone and the UK will peak by the end of 2023. From 2024 onwards, the monetary policy focus will be on a reduction of balance sheets. Global liquidity will, therefore, be reduced, but only gradually. In the OECD, interest rates are expected to be lowered from 2024 onwards. Japan is forecast to continue a more accommodative monetary policy and is anticipated to keep its key policy rates around 0% up to the end of the medium-term period. Interest rates in the major emerging markets are expected stay at relatively higher levels throughout the period.

Assumptions about the conflict in Eastern Europe are challenging. It is assumed that there is no escalation of the conflict, nor any spill over into other arenas, especially neighbouring economies.

In connection with inflation and interest rate trends, the debt related challenges in various economies need to be closely watched. Escalating debt levels have become an increasing concern, particularly given the rapid rise in key policy rates across the world in response to rising inflation. Global debt rose to $305 trillion in 1Q23, which is $45 trillion above pre-pandemic levels and it is expected to rise further, according to the Institute of International Finance (IIF). No major dislocation from this situation is assumed in the forecast, but it is clear that some highly indebted economies may face potentially mounting issues, of which fiscal constraint would be only a minor one. Moreover, some countries may potentially face default in the medium-term.

In periods of elevated debt, various types of taxes such as those on assets, capital gains, property, inheritance, top-tier incomes, and corporate earnings are often raised to pay for rising debt services and/or to mitigate debt levels. It is also expected that more environmental taxes may be introduced in the coming years, particularly in developed economies.

In the medium-term outlook, it is presumed that potential tax hikes do not hinder the global economic rebound. It is assumed that these will mainly be sourced from well-off and secure entities with the tax collection well-directed. However, the introduction of further taxes has the potential to slightly suppress certain growth aspects, but this is expected to be on a minor scale. If consumer taxes increase, or those impacting the middle and lower income groups escalate, a more substantial inhibiting effect on GDP growth may become evident.

For the medium-term forecast, it is also assumed that there will be no further escalation in conflicts that may dampen the global economic recovery going forward. Generally, domestic inequalities within economies will be successfully managed via multilateral cooperation, redistribution effects or other policy measures.

In addition, it is forecast that the trend of global fragmentation continues, which provides some dampening effect, albeit gradually. It is also assumed that global trade becomes more regionally dominated, with a steady increase in the interactions between the three main trading hubs that have been established in recent decades. One is the US-centred trade region of the Americas, dominated by North America. Another is the European region, with its dominant

forces of Germany, France and the UK, while the third is the Asian region, centred on China, India and the Middle East. Trading within Latin America is likely to increase over the medium-term, again with rising regional engagements led by Brazil.

A potential consequence of less globalized trading could be further regional inequalities, as wealth transfers via exports shift towards wealthier economies. These changes, however, will take time to evolve and may only become visible slowly over the medium-term.

It is important to note that emerging and developing economies are forecast to outgrow advanced economies in the medium-term, but they will also likely face decelerating growth momentum amid maturing domestic economies. In addition, a potentially lessening global trade dynamic may support this trend. Similarly, to previous WOOs, China and India, constituting the two largest emerging economies, are expected to follow this pattern. This is reflected in both medium- and long-term forecasts.

Another important element in connection to economic growth is productivity. In advanced economies, in particular, productivity was already in decline in the pre-pandemic years. While current forecasts anticipate productivity gains to remain low, the current severe staff shortages in combination with the drive towards digitalization may lead to a pick-up in productivity. This would come via the effective utilization of new technologies and robotics, including utilizing artificial intelligence (AI). Productivity growth would not only be in the process of industrial production, but the services sector too. This has the potential to lift global economic growth significantly. The challenge associated with such potentially significant productivity improvements, however, is how best to utilize human resources that could be idled and how best to avoid social conflict.

Table 1.4
Medium-term annual real GDP growth rate

% p.a.

	2022	2023	2024	2025	2026	2027	2028	Average 2022–2028
OECD Americas	2.3	1.8	0.7	1.5	1.8	1.9	2.0	1.5
OECD Europe	3.8	0.6	1.0	1.4	1.7	1.8	1.8	1.4
OECD Asia-Pacific	2.0	1.2	1.2	1.3	1.4	1.4	1.4	1.3
OECD	**2.9**	**1.2**	**0.9**	**1.4**	**1.7**	**1.8**	**1.8**	**1.5**
Latin America	4.0	1.7	1.6	2.0	2.1	2.2	2.3	1.9
Middle East & Africa	3.4	2.6	2.9	3.2	3.3	3.4	3.4	3.1
India	6.7	5.6	5.9	6.2	6.3	6.3	6.4	6.1
China	3.0	5.2	4.8	4.8	5.0	4.9	4.8	4.9
Other Asia	4.6	3.6	3.8	4.5	4.5	4.6	4.6	4.3
OPEC	5.6	3.3	2.9	2.8	2.9	3.0	3.0	3.0
Russia	–2.1	0.6	1.0	1.0	1.2	1.3	1.4	1.0
Other Eurasia	–3.0	2.5	2.8	2.5	2.5	2.4	2.4	2.5
Non-OECD	**3.6**	**3.9**	**3.9**	**4.1**	**4.3**	**4.3**	**4.3**	**4.1**
World	**3.2**	**2.7**	**2.6**	**2.9**	**3.1**	**3.2**	**3.3**	**3.0**

Source: OPEC.

After the 2023 GDP growth forecast of 2.7%, it is expected that growth slows to around 2.6% in 2024. Thereafter, growth is anticipated to mean revert towards the medium-term growth potential of around 3.2%. At the end of the medium-term period in 2028, growth is forecast at 3.3%, supported by a gradual recovery in both the OECD and non-OECD. However, emerging economies will likely experience a maturing growth dynamic, relative to advanced economies, a trend that is expected to continue in the long-term too.

Growth by region

In **OECD** economies, the rapidly rising interest rate environment of 2022 and 2023 will dampen economic growth. While 2023 GDP growth is forecast to be materially supported by the services sector, it will be the industrial side of OECD economies that dampens growth significantly. Over the course of the medium-term period, however, the growth pattern is set to normalize again. The OECD is expected to see growth of 0.9% in 2024 and then rise to 1.8% at the end of the medium-term period in 2028. This compares to an OECD pre-pandemic average growth level (2010–2019) of 2.1%.

OECD Americas will be particularly impacted by the interest rate regimes of the US Fed and the central bank of Canada. High interest rates will lead to growth of only 0.7% in 2024, compared to a pre-pandemic average (2010–2019) of 2.3%. By 2025, however, GDP growth in OECD Americas is forecast to rebound to a level of 1.5% and then continue rising to 2% in 2028. A major positive effect from 2024 onwards is set to come from monetary easing as inflation is expected to retract materially over the medium-term. On the flip side, very high US debt levels, in combination with any sustained relatively high interest rate regime, could challenge the growth momentum.

OECD Europe's growth is forecast to be significantly challenged by ongoing high interest rates, amid high inflation, a situation that is likely to impact GDP growth in the region in 2024 and beyond. In addition, the conflict in Eastern Europe and its political outcome, as well as its ripple effect on both Europe's energy supplies and energy prices, will also continue to impair economic development, at least at the beginning of the medium-term. Moreover, debt-related issues in some EU economies, particularly Italy, and potentially Greece, may re-emerge, at a time of rising interest rates and slowing GDP growth. Positively, however, interest rates are forecast to be lowered by the ECB over the medium-term, given that inflation is forecast to recede from 2023 onwards. This dynamic will lead growth higher to stand at 1.8% in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 2% and 1% in 2024.

In **OECD Asia-Pacific**, Japan is forecast to witness a relatively stable medium-term growth dynamic. The region's major trading partner, China, also provides helpful guidance for future growth, given its importance as a customer for input goods from OECD Asian economies. While China is forecast to see less dynamic growth, the other important group of trading partners, the G7 economies, are forecast to accelerate. Monetary stimulus is forecast to taper off in most OECD Asia-Pacific economies, but the Bank of Japan's (BoJ) monetary policy is expected to be more accommodative, compared to its G4 central bank peers. For OECD Asia-Pacific, growth is set to stand at 1.2% in 2024 and reach 1.4% in 2028. This compares to an OECD Asia-Pacific pre-pandemic average growth level (2010–2019) of 2%.

The medium-term growth outlook in **non-OECD** countries remains relatively diverse. While China is forecast to see a less dynamic growth pattern, India is anticipated to see growth gradually expand. Moreover, the other Asian regions, as well as Latin America and the Middle

East & Africa, are forecast to see GDP levels expand over the medium-term. This is driven more by the anticipation of improving domestic activity in these economies than external factors. In this respect, high population growth will play a pivotal role, an aspect that will be especially relevant in the longer-term.

In **Latin America**, the two major economies, Brazil and Argentina, will likely shape growth patterns. Brazil is expected to benefit from fiscal reform and selective governmental support measures. The ongoing deceleration of inflation and the expectation of a consequent accommodative monetary policy adds further support to medium-term growth. Argentina still has to deal with a number fiscal challenges, at least at the beginning of the medium-term period. Considering the high debt levels, Argentina has limited fiscal space for manoeuvre and the medium-term growth momentum is set to be low. Growth in Latin America is forecast at 1.6% in 2024 and reaches 2.3% in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 2.2%.

In the **Middle East & Africa**, medium-term growth is expected to rise from 2023 levels. This is supported by the anticipation of steady commodity demand, growing regional domestic demand and supported by an expansion of the middle class. Additionally, a continued expansion in the global growth dynamic is forecast to lift foreign investment into the region. Growth in the Middle East & Africa is expected at 2.9% in 2024 and reaches 3.4% in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 3.3%.

China is forecast to witness growth of 4.8% in 2024. The economy's growth is forecast to remain relatively stable over the course of the medium-term period. While challenges in external trade are expected to remain, domestic demand is set to only gradually pick-up. Furthermore, it is anticipated that the central government will counterbalance any material deviation from the government's growth target. Growth of 4.8% in 2024 is the same level expected at the end of medium-term in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 7.7%.

India's growth is forecast to see some acceleration from 2024 onwards. The economy is set to benefit from the country's population growth, a rising middle-class and major infrastructure projects over the medium-term. An ongoing deceleration of inflation and the expectation of a consequent accommodative monetary policy is set to add further support to medium-term growth. India's growth is forecast to stand at 5.9% in 2024 and reaches 6.4% in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 7.1%.

Other Asia is forecast to see sound medium-term growth. In 2024, growth is forecast at 3.8% and this rises to 4.6% by 2028. This compares to a pre-pandemic average growth level (2010–2019) of 5%.

The **OPEC** region is supported by continued diversification efforts, an expanding and relatively young population, rising domestic economic activity and steady growth momentum in commodity markets. Growth is forecast to stand at 2.9% in 2024 and reaches 3% in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 2.2%.

In **Eurasia**, Russia constitutes the most important economy. It is evident that growth has been, and will be, impacted by geopolitical issues including the associated effects of sanctions. It is expected, however, that Russia will continue to witness a rebound in its growth to 1% in 2024, following 0.6% in 2023. This growth level is then anticipated to lift further

and is seen at 1.4% in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 2.1%.

Other Eurasia is forecast to see a deceleration in its medium-term growth rate. Growth is set to stand at 2.8% in 2024 and reaches 2.4% in 2028. This compares to a pre-pandemic average growth level (2010–2019) of 2.7%.

1.2.3 Long-term economic growth

Forecasting long-term economic growth is inherently challenging, especially in the aftermath of the COVID-19 pandemic that has introduced a multitude of uncertainties and variations in regards to its impacts at the macro level. The complexity of this task has been heightened even further this year due to the entwined nature of the substantial global economic uncertainties discussed in both the short- and medium-term outlooks.

Making assumptions about the conflict in Eastern Europe is an exceedingly difficult task. While some degree of global re-balancing has been witnessed thus far, the current outlook remains unclear with many uncertainties regarding the conflict's status and the potential ramifications for the global status quo. Additionally, further geopolitical tensions add another layer of complexity to the potential consequences for the global economic growth trajectory.

In addition to the COVID-19 legacy and geopolitical tensions, several other systemic issues necessitate continuous monitoring, such as the ongoing global economic fragmentation that entails evolving shifts in trade, investment, skills, knowledge, and scientific transfers. Furthermore, the complexities arising from the further increase in public debts across economies and the advent of higher inflation and interest rates, add further challenges to the current landscape for economists, and for policymakers, who must navigate these multifaceted issues and formulate effective strategies accordingly.

Likewise, the potential energy sector transformations may have a substantial impact on economies. While transitions towards alternative energy sources, particularly renewables, have accelerated in recent years, there is a growing discussion about the benefits and competitiveness of fossil fuels within a sustainable energy mix, particularly due to an increased focus on energy security. This emerging narrative recognizes the need to balance environmental concerns with the economic considerations associated with energy security, highlighting the importance of finding sustainable solutions for all.

The ongoing energy transitions and the associated rise in energy prices has the potential to affect the long-term structure of the global economy and support prolonged levels of high inflation. The shift towards more expensive renewable energy systems may result in higher prices, potentially constraining consumer demand and business investments. Other sources of elevated inflation in the long-term include demographics changes, such as population ageing and labour market shortages, particularly in advanced economies, unsustainable levels of public debt, and potential tax increases. Another significant driver of the elevated inflation regime is the trend toward global economic fragmentation. As countries re-evaluate their global dependencies, it is evident that many may prioritize domestic production and self-sufficiency as regionalization becomes more noticeable.

In summary, the current developments unfolding around the world are marked by their complexity and systemic nature, posing substantial challenges for forecasting. Over the last

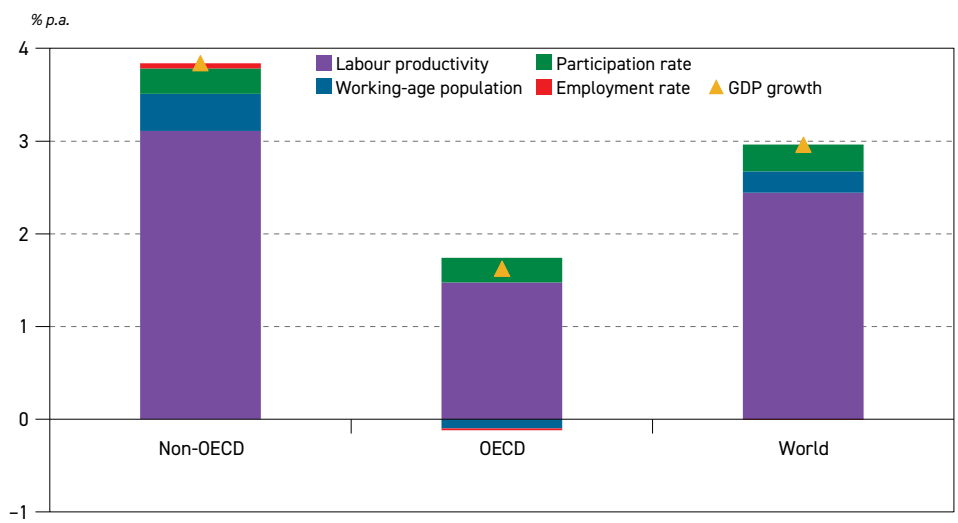
two years, it could be said that the world has witnessed an unprecedented transition phase driven by geopolitical dynamics and a shift towards a multipolar world with diverse value systems. Nevertheless, the outcome, and full implications of this transition, remains uncertain.

For example, since 2022, the group of countries known as BRICS (Brazil, Russia, India, China and South Africa) have witnessed a notable rise in prominence, drawing interest from more than 30 countries that have expressed an interested in joining the group and it's New Development Bank. Saudi Arabia, the United Arab Emirates, IR Iran, Egypt, Ethiopia and Argentina will join the BRICS group as early as 2024. These developments signify the evolving nature of the BRICS platform in facilitating the establishment of new development, investment and trade institutions within the bloc.

Based on the aforementioned, and taking into account current developments, the assumptions underlying long-term economic growth developments continue to revolve around productivity growth, demographic trends, and labour market dynamics. These are the key long-term growth trend factors shaping the trajectory of economies.

These factors are relatively well understood and continue to play a major role in driving long-term economic growth. In that context, labour productivity has been the largest contributor, both regionally and globally (Figure 1.4). Additional productivity growth could come from the pandemic-driven trend towards digitalization, robotics and AI, and the more effective use of these evolving technologies.

Figure 1.4
Long-term GDP growth rates by components, 2022–2045



Source: OPEC.

The increase in the working-age population will be another important demographic trend for most non-OECD economies. A young and vibrant population, coupled with advancements in education, healthcare and social support systems will play a pivotal role in driving future growth in these regions.

Various economic regions and individual economies, particularly in advanced and maturing emerging economies, are expected to be significantly affected by a decline in the working-age population. This demographic shift is evident in regions like OECD Europe, OECD Asia-Pacific, and emerging markets such as Russia and China. As a consequence, these economies may face some constraints on their growth potential, despite forecasts of increasing labour productivity. The combination of a shrinking workforce and the need to support an ageing population can pose challenges to sustained economic development in these regions, requiring careful attention and strategic planning to mitigate the impact and help foster long-term growth.

In regions like the Middle East, Africa, and OPEC, where labour productivity may be comparatively lower, the positive impacts of rapidly expanding populations, the rise of the middle class, and government-led investments in domestic economies play a crucial role. To some extent, these factors may help offset the productivity gap by providing a larger labour force, stimulating consumer demand and driving economic growth. Additionally, sovereign investments in key industries and infrastructure projects contribute to diversification, job creation and overall productivity. By leveraging these factors, and focusing on sustainable economic strategies, these regions can achieve better relative long-term economic resilience.

In addition to the core factors already mentioned, several gradual changes observed over the medium-term will also influence the long-term economic landscape. One significant aspect is the potential positive impacts of digitalization, AI, and robotics on productivity growth. The increasing integration of technology and automation in various industries has the potential to enhance efficiency, streamline processes and improve overall productivity levels. As these advancements evolve and mature, they are expected to contribute to long-term economic growth and development. Embracing digitalization, AI and robotics can unlock new opportunities, reshape industries and drive innovation, further bolstering productivity in the years to come. This is a benefit that is likely to be seen more in advanced economies, rather than developing and emerging economies, at least at the beginning of the long-term period.

Global GDP growth between 2022 and 2045 is expected to remain robust and increase at an average rate of 3% p.a. This is the same level as in the previous WOO edition and takes into account increasing global economic risks, and the uncertainties around high inflation and interest rates, rising debt levels and geopolitical tensions.

Global growth to 2045 will be dominated by non-OECD countries (Table 1.5). This is in line with assumptions made in previous editions of the WOO. Even if the pace of GDP growth will slow slightly over the forecast period, these countries are expected to grow by an average of 3.8% p.a., due to improving labour productivity and an expanding working-age population. The growth dynamic for the entire forecasting period is expected to remain relatively consistent with the previous year's WOO.

Looking more closely at the OECD group of countries, economic growth is forecast to average 1.6% p.a. between 2022 and 2045.

OECD Americas is the fastest growing OECD region with a long-term growth rate of 2% p.a. This takes into account the effects of monetary tightening and increased inflation. While growth expectations are comparably low in the medium-term at 1.5% p.a., rates in the periods 2028–2035 and 2035–2045 are expected to remain strong at levels of around 2.2%. This trend is supported by an increase in the size of the labour force as a result

Table 1.5
Long-term annual real GDP growth rate

% p.a.

	2022–2028	2028–2035	2035–2045	2022–2045
OECD Americas	1.5	2.2	2.2	2.0
OECD Europe	1.4	1.5	1.1	1.3
OECD Asia Pacific	1.3	1.3	1.1	1.2
OECD	**1.5**	**1.8**	**1.6**	**1.6**
Latin America	1.9	2.2	1.8	1.9
Middle East & Africa	3.1	3.9	4.5	4.0
India	6.1	6.3	5.9	6.1
China	4.9	4.2	3.0	3.8
Other Asia	4.3	4.1	3.0	3.7
OPEC	3.0	3.1	3.2	3.1
Russia	1.0	1.4	1.2	1.2
Other Eurasia	2.5	2.5	2.3	2.4
Non-OECD	**4.1**	**4.1**	**3.5**	**3.8**
World	**3.0**	**3.1**	**2.8**	**3.0**

Source: OPEC.

of immigration to the US and, to some extent, Canada. Further upside may come from labour productivity growth.

OECD Europe is expected to follow a similar pattern, with a slowdown in the dynamism of the economy. A drop in the population, in general, and the labour force, in particular, supports this trend. While the conflict in Eastern Europe mainly affects the short-term outlook, rising inflation, interest rate increases and demographic challenges are expected to limit growth potential to 1.5% over the period 2028–2035, which then falls to 1.1% in the last decade of the outlook. The average annual growth rate over the forecast period is 1.3%, only slightly above the growth rate for OECD Asia-Pacific.

In **OECD Asia-Pacific**, a deceleration of economic growth over time is expected. The strongest growth in this region is projected for the period 2022–2035 at an average annual rate of 1.3%. A shrinking labour force, due to an ageing population, and the projected economic maturation in China, the region's main trading partner, drive the economic growth slowdown. Growth is set to drop to an average of 1.1% p.a. in the last decade of the forecast period, resulting in an average growth rate of 1.2% over the entire forecast period.
In non-OECD regions, the Middle East & Africa, OPEC and Other Asia are expected to show accelerating long-term growth trends, with similar or even higher growth rates than China in the 2035–2045 period.

Latin America is expected to see ongoing support from commodity markets and an expanding young population in most economies. However, the region's economy may face downward pressure due to sluggish employment growth and limited productivity gains.

Despite the country's robust economic fundamentals, Brazil's long-term trend growth faces limitations due to insufficient domestic savings and a significant debt burden, which may require continual fiscal consolidation. The country will also likely encounter the challenge of a shrinking working-age population. From a structural perspective, the trend growth would benefit from the implementation of more ambitious reforms aimed at improving infrastructure, facilitating the ease of doing business and further developing its financial markets.

Elsewhere in **Latin America**, Argentina is grappling with persistent structural issues, including high debt, a significant fiscal deficit and intense inflationary pressures. Comprehensive reforms are crucial to address Argentina's weak macroeconomic fundamentals and stimulate the necessary investment to drive structural economic diversification, capital accumulation, and productivity. By implementing these reforms, Argentina has the potential to overcome the obstacles it faces and create a more favourable environment for sustainable and inclusive economic long-term growth. Latin America is projected to experience relatively higher growth in the early years of the forecast period, resulting in an average annual growth rate of 1.9% over the entire period.

In the **Middle East & Africa**, growth is estimated to average 4% p.a. A young and expanding population and rising income levels, as more people enter the middle class, are expected to benefit the region and provide additional consumption abilities. As global growth picks up, the region should also benefit from support from commodity markets. Moreover, structural and economic reforms in less productive economies could provide further growth potential. These reforms would enhance economic complexity, improve competitiveness and increase labour participation. By diversifying their economies, focusing more on non-energy sectors, and prioritizing productivity improvements, these countries can boost their economic resilience. In turn, this would contribute to an increase in savings and investments, and help establish them as manufacturing hubs. However, rising debt levels, especially in low-income countries, pose a downside risk.

China is anticipated to be the second fastest growing major economy, averaging 3.8% p.a. over the projection period. This steady momentum in the economic forecast is an outcome of the country's ageing population and a maturing stage of domestic economic development that has moved onto a path of slowing growth. China's growth pattern has become more volatile in the last few years, but it is expected to return to a more stable dynamic in the long-term.

Considering the government's successful track record in driving economic development, China is expected to continue to support economic development, if needed. This approach is anticipated to provide support to China during its ongoing transition phase, with a focus on achieving 'high-quality' sustainable growth, and hence, ensuring stability. Key priorities for the country include boosting domestic and external demand, promoting technological innovation, and effectively managing economic risks. Nonetheless, this transition is expected to be accompanied by various challenges related to addressing existing structural bottlenecks.

It is also important to note that while population growth has played a role in China's economic development, the expansion of human resources, characterized by a well-educated and healthy population, is the primary catalyst for sustained development. As China continues to invest in education and healthcare, its population is expected to become increasingly productive.

India is forecast to continue to be the fastest growing major non-OECD country, with an average growth rate of 6.1% p.a. Growth is expected to be strongest between 2028 and 2035, as the country benefits from a young and dynamic population, a growing middle class and continued, albeit reduced, fiscal stimulus.

Despite notable prominence in selected sectors, such as IT and pharmaceuticals, India faces several structural, social, and political challenges that hinder its potential for accelerated growth. Addressing these challenges could significantly bolster the country's resilience and, subsequently, advance its growth potential. The current assumption is that the implementation of structural reforms will likely be gradual, resulting in moderate productivity enhancements. At the end of the projection period, the Indian economy is expected to mature, with growth slowing to 5.9% p.a. for the 2035–2045 period.

Long-term economic growth in **Other Asia** is at 3.7% p.a. Growth momentum peaks at 4.3% in the period 2022–2028, but the general growth trend is well maintained leading to an expansion rate of 3% in the last decade of the projection period. The growth trend in many countries is expected to be impacted by less favourable demographics, despite the improving prospects for productivity. Additionally, there is a need for improvements in institutions to support and enhance the growth potential effectively.

Russia is currently impacted by sanctions and a recent economic downturn. The country is expected to overcome these challenges and recover relatively well over the long-term. As already mentioned, however, the demographic trend is anticipated to be unfavourable, with a decline in the working-age population. Over the long-term, the country's declining population is set to be the main factor preventing growth from rising significantly above the modest long-term average of around 1.2%, especially if no further structural reforms are implemented. Nonetheless, labour productivity gains have the potential to offset this demographic development.

Economic growth in Russia is expected to rise by 1.4% p.a. in the period 2028–2035, after relatively tepid medium-term growth of 1%. Developments in commodity markets, especially oil and gas, will play an important role in Russia's growth trajectory. In this context, it is important to note that Russia is a country with a rich history of economic transformations. With benefits from vast resources, a skilled workforce, and a high potential for technological advancements, Russia has the opportunity to capitalize on these strengths and chart a new economic growth path through the implementation of structural reforms.

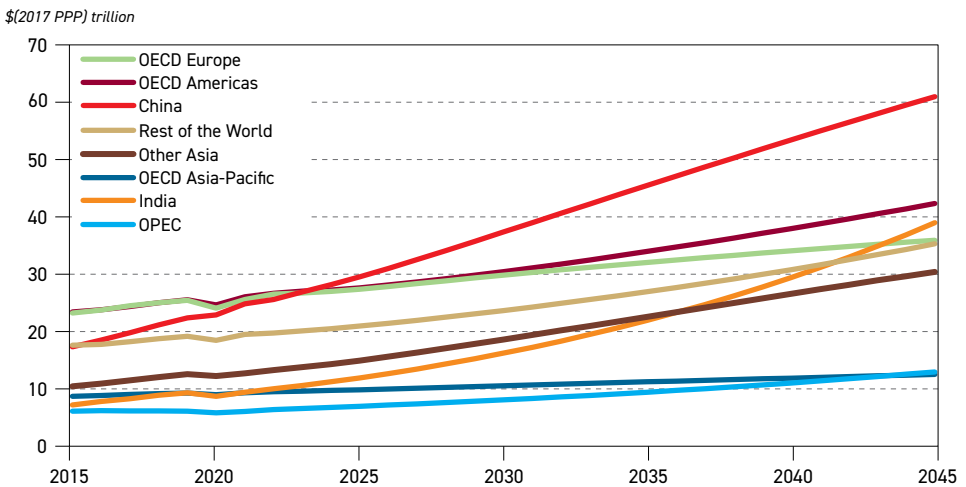
Long-term economic growth in **Other Eurasia** is expected to average 2.4% p.a., supported by a slight increase in the working-age population.

The expected increase in size of the world's major economies (Figure 1.5) means that global GDP is projected to almost double, from around $138 trillion in 2022 to $270 trillion in 2045, based on 2017 PPP.

Figure 1.6 indicates that significantly higher growth rates in non-OECD regions lead to a shift in the regional distribution of GDP over the forecast period. China and India are expected to increase their share of global GDP from 26% in 2022 to 37% in 2045. In contrast, the share of OECD countries will decline from 46% to 34%.

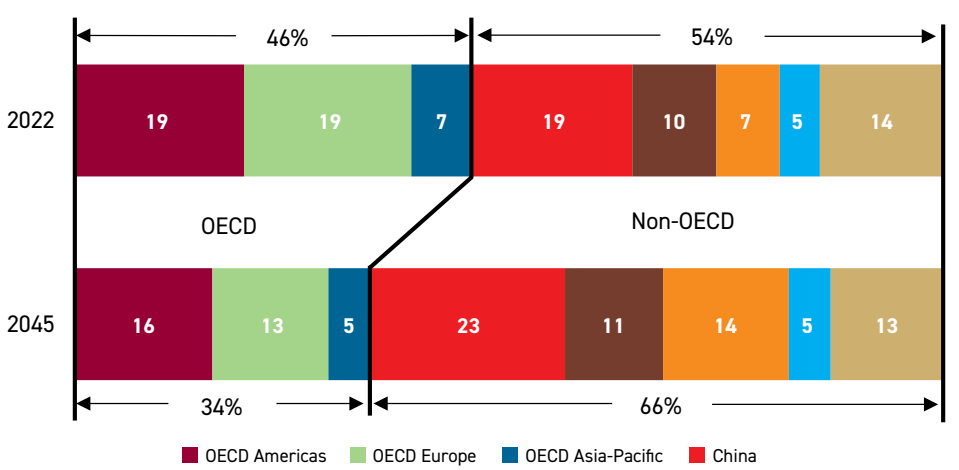
India is projected to nearly quadruple in size, adding about $29 trillion to its economy, while China is projected to grow by about 2.4 times, adding over $35 trillion to global GDP. By

Figure 1.5
Size of major economies, 2015–2045



Source: OPEC.

Figure 1.6
Distribution of the global economy, 2022 and 2045 %



Source: OPEC.

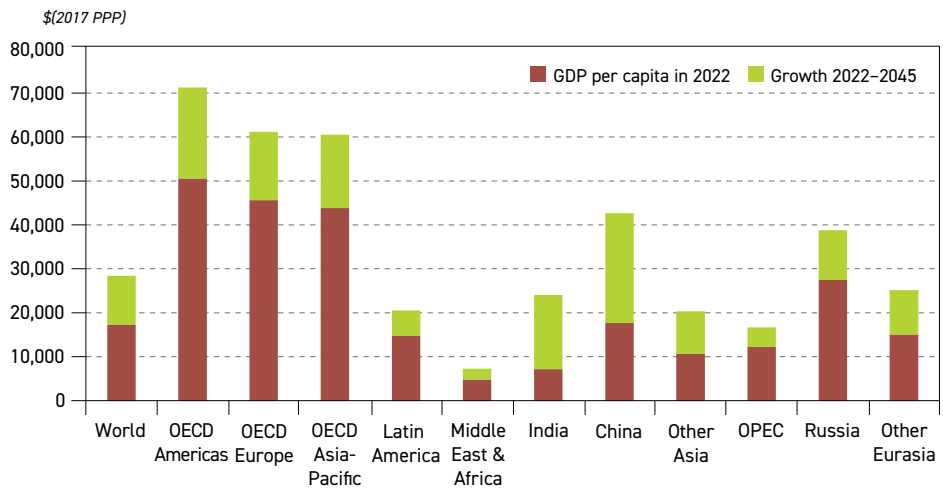
comparison, an addition of $28 trillion of GDP is anticipated for the OECD. The OPEC Member Country grouping is expected to double its economic size over the forecast period, adding $6.6 trillion to global GDP.

Although growth rates are uneven across regions, the global economic picture shows no significant changes in the ranking of average incomes (as measured by GDP per capita). OECD Americas is projected to continue to be the region with the highest GDP per capita, followed by OECD Europe and OECD Asia-Pacific.

The global average income is projected to rise from just over $17,000 (2017 PPP) in 2022 to over $28,000 (2017 PPP) in 2045.

The Middle East & Africa will still have the lowest GDP per capita, as shown in Figure 1.7, despite an increase in GDP per capita of more than 50%. With India forecast to exceed an average income of $20,000 (2017 PPP) in the long-term, the Middle East & Africa is set to be the only remaining region with an average income below $10,000 (2017 PPP) in 2045. India and China are expected to experience the largest changes, with average income China's narrowing the gap with OECD countries and overtaking Russia's GDP per capita levels.

Figure 1.7
Real GDP per capita in 2022 and 2045



Source: OPEC.

1.3 Energy policies

Developments in recent years have shown that the energy- and climate-related challenges the world faces are enormous and complex. This has been evidenced by the strains and conflicts related to energy affordability, energy security, and the need to reduce emissions playing out in regions across the world. There is now more talk of the energy sustainability trilemma, evidenced in many countries recently publically recognizing the need for more investments in oil and gas projects going forward.

The Reference Case used throughout the WOO assumes a gradual evolution of energy policy, targeting those areas described in this section. Therefore, a critical assessment of specific policy targets is performed based on available technology options, cost developments, trends in competition and levels of energy-related investment. As a result, the Reference Case adopts most of the specific targets already included in national legislation and Nationally Determined Contributions (NDCs) to the extent they are technically and financially viable.

However, and to be more realistic, it does not go as far as to include the achievement of net-zero policy targets within the forecast period. Similarly, the ambitious targets of switching sales of passenger vehicles to electric vehicles (EVs), are not expected to be fully realized.

Nonetheless, considerable improvements in energy efficiency are expected, as is a significant share of renewable energy sources in the future energy mix, and a substantial penetration of EVs, especially in Europe, China and the US. Furthermore, a temporary focus on energy security over the next few years is anticipated, before a general focus shift to emissions and climate change in the latter part of the forecast period.

Geopolitical tensions pose enormous challenges, particularly for developing countries, which have to contend with energy security and economic issues more than ever before, in addition to their vulnerability to climate change. For some countries, mitigation and adaptation measures may be of less immediate concern in the face of a global energy crisis and growing fears of economic recession. For others, the focus is on stronger energy efficiency measures and more stringent renewable energy support policies. This creates a complicated web of local, national and international energy policies.

In the **US**, energy policy has been characterized by interruptions, which is in contrast to the dynamism of EU climate and energy policy. Nevertheless, with the arrival of the Biden administration, ambition on climate change has increased. The US is now aiming to reduce its greenhouse gas (GHG) emissions by 50–52% below 2005 levels by 2030, and to achieve a 100% carbon-free electricity sector by 2035. The long-term ambition is to reach a net-zero emissions economy by 2050.

The IRA of 2022 included multiple provisions for both tax credits and incentives towards energy efficiency and to accelerate the energy transition. For instance, the Act aims to incentivize the utilization of energy efficiency technologies and the expansion of EV charging infrastructure. Other provisions aim to reduce renewable energy costs and to expedite the deployment of low GHG emissions power generation. Within the low GHG emission provisions, the IRA provides tax credits and incentives to fast track the deployment of emission reduction technologies, such as carbon capture utilization and storage (CCUS) and hydrogen. The IRA follows on from previous efforts under the Bipartisan Infrastructure Law to provide resources to improve public transit, upgrade the power grid, and invest in EVs and nationwide EV charging.

In the **EU**, sanctions related to the conflict in Eastern Europe have disrupted the EU's fossil fuel imports, on which it has been heavily dependent. It means that energy security has become an increasing concern, alongside the challenge of addressing the growing impacts of climate change and environmental degradation. The EU's climate targets, an emissions reductions of 55% by 2030 and net-zero by 2050, are enshrined in European Climate Law. Their implementation is supported by a series of legislative proposals called the 'Fit for 55' package.

One major area of policy development is the new Carbon Border Adjustment Mechanism (CBAM) and the EU has already adopted the proposal for the mechanism. The CBAM targets the import of goods from carbon dioxide ($CO_{2)}$-intensive industries. It is intended to work in parallel with the EU Emissions Trading Scheme (ETS) to replicate and complement its functioning with regard to imported goods. Member States' emission reduction targets under the Effort Sharing Regulation have also been strengthened and recent legislation sets stricter CO_2 emission performance standards for new cars and vans.

The EU has also adopted a revision of the EU ETS, making it more ambitious. The new revision includes an extension of the ETS to the maritime sector and a faster reduction of allowances, as well as a gradual phase-out of free allowances for some sectors. Moreover, it creates a new standalone ETS for buildings, road transport and fuels for additional sectors.

The EU's Net-Zero Industry Act aims to scale up the EU's manufacturing capacities for clean technologies to support the clean energy transition. It states that at least 40% of the annual deployment of net-zero technologies should be manufactured in the EU by 2030. The new act also supports CCS projects, by enhancing the availability of CO_2 storage sites to increase CO_2 injection capacity.

China has strengthened earlier targets and announced new ones, reflecting its updated NDC and contributing to its key goals of peaking CO_2 emissions by 2030, and becoming carbon neutral by 2060. Its 14th Five-Year Plan (FYP) on Modern Energy System Planning and 14th FYP on Renewable Energy Development will drive change up to 2025 and make progress towards the country's climate targets of reaching a 33% share of renewable electricity consumption in 2025.

In 2021 at COP26, **India** unveiled its major long-term target to become carbon neutral by 2070. India's National Electricity Plan 2023 (NEP2023) was released in May 2023, outlining the government's current projections for peak national electricity demand and potential required renewable and fossil-fuel based generation capacity within the forecast horizon of 2032, taking into consideration the country's climate change mitigation ambitions. According to the document, the share of nationwide non-fossil based generation capacity is projected to grow to 68.4% by the end of 2032.

Recent developments in climate change negotiations

Against a backdrop of multiple converging global challenges, developed and developing countries have reaffirmed their commitment to increased climate ambition in the context of just transitions. Since the 2022 edition of the WOO, policymakers continue to strive towards progress in the United Nations Framework Convention on Climate Change (UNFCCC) climate negotiations, the implementation of the Paris Agreement and the achievement of the sustainable development goals (SDGs) under the 2030 Agenda.

COP27 was held in Sharm El-Sheikh, Egypt, from 6–20 November 2022, in the midst of a rapidly changing global landscape, driven by high inflation, extreme weather events, geopolitical tensions and concerns about energy security, exacerbated by global underinvestment in the energy sector in recent years. It was labelled as an implementation COP, with UNFCCC Parties expected to move from climate change pledges to implementation. After intensive negotiations, the UNFCCC Parties adopted the 'Sharm el-Sheikh Implementation Plan' and took a historic decision to establish a Loss and Damage Fund.

Parties also agreed, inter alia, to update their NDCs or long-term strategies ahead of COP28, which will take place in Dubai, the United Arab Emirates from 30 November–12 December 2023. Developed countries were again urged to increase support to help developing countries mitigate and adapt to climate change.

On Loss and Damage, Parties agreed to establish new financing arrangements and a dedicated fund to assist developing countries in responding to losses and damage from the adverse effects of the unavoidable risks of climate change. At COP28, details will be negotiated on how to raise the necessary financial resources for this fund. The issue of Loss and Damage is likely to become a key pillar of UN climate change negotiations, alongside mitigation, adaptation and finance.

New partnerships and initiatives were revealed at COP27. These includes the 'Just Energy Transition Partnership', announced by the US and the EU, with Indonesia and Vietnam. More countries have joined the 'Methane Pledge', which was launched at the COP26 in Glasgow, bringing the total number of participants to around 150. The EU announced its readiness to update its NDC, indicating that the region's 2030 emissions reduction target could be 57% below 1990 levels, up from 55%. The US and China resumed formal cooperation to address climate change after their climate dialogue was put on hold in 2022.

The Intergovernmental Panel on Climate Change (IPCC) concluded its sixth cycle in March 2023, after eight years of work, providing policymakers with up-to-date information on climate science and the available scientific evidence on how to limit global warming. The AR6 Synthesis Report (SYR) is the last IPCC report under this cycle. This report was adopted on 19 March 2023. It is expected that the report will guide government' engagement in UNFCCC negotiations and the formulation of climate actions and policies.

The report highlights that total GHG emissions continue to rise, resulting in current global warming of 1.1°C above pre-industrial levels. It also notes that historical emission contributions have varied considerably between regions and this continues. Vulnerable communities that have historically contributed the least to current climate change are disproportionately affected. It states that global energy and carbon intensity has declined as a result of mitigation policies and increased ambition for climate action. It stresses that the pace and scale of climate action to date and existing plans are insufficient to limit global warming to well below 2°C.

The AR6 Synthesis Report emphasizes that many countries have announced a net-zero GHG or CO_2 emissions target by around mid-century. However, mitigation action could face challenges, including technology risks, scaling and cost. In addition, the adoption of low-emission technologies lags in developing countries, owing primarily to limited finance, technology development and transfer, and capacity. The report also highlights strategies, such as decommissioning existing infrastructure, retrofitting fossil-fuel power plants with CCS technologies, and scaling up renewable energy sources, such as solar and wind, which could help avoid the lock-in of associated emissions and stranded assets.

The IPCC stresses that CO_2 removal is critical to limiting the global temperature increase to 1.5°C. Pathways consistent with 1.5°C, with no or limited overshoot, require CO_2 removal, in addition to emission reductions across all sectors. This includes both natural (conventional) solutions – such as capturing and storing carbon in trees and soils – and new technologies that remove CO_2 directly from the air.

On the SDGs, the IPCC report concludes that climate-resilient development is consistent with reduced risk, lower GHG emissions and the achievement of these goals. This means that climate change adaptation and mitigation actions should be implemented in a more integrated, inclusive and equitable way towards sustainable development. At the mid-way point for SDGs to 2030, the goals remain in a critical state, including SDG 7, which calls for access to clean, reliable and affordable energy.

Looking ahead to COP28, the Presidency has announced it will make COP28 a practical COP, a COP of action and a COP for all, based on science-based, innovative solutions and built on the principles of pragmatism and inclusiveness, to unite the world around an agreement with bold, practical, science-based and ambitious solutions to the global climate change challenge.

In light of the above, as well as providing more detail on the latest energy policy developments, Chapter 7 of the Outlook incorporates more details on energy and climate related policies, which will also be taken into consideration for the scenario development and analysis incorporated in Chapter 8.

1.4 Technology and innovation

The mutually dependent relationship between technology and energy has allowed humankind to access enormous life improving resources. Given that the oil sector is the largest segment of the energy landscape, the WOO 2023 takes on board the role of both recent and future technology advancements in this sector.

Technology has established a solid foundation for the utilization of primary sources. For instance, photovoltaic (PV) technology has allowed humankind to use ample solar energy. At the same time, however, PV cells fall short in delivering continuous energy supply during sunless periods as this requires massive and complicated energy storage. Therefore, the Reference Case assumes a realistic approach to energy demand, as a whole, and oil demand, in particular, as it underlines that there is no single solution to meet growing global energy needs.

The WOO also assumes the continuous evolution of technology, especially in respect to improved energy efficiency and evolving cost. However, it does not assume any major technology breakthrough, although the potential for it exists, especially in the long-term.

1.4.1 Road transportation

Internal combustion engines (ICEs) have remained a pillar of road transportation ever since the introduction of the first passenger vehicle in 1885. Only recently have battery-electric vehicles (BEVs) started to be considered as potential substitutes despite the enduring range advantage of the ICE.

This Outlook assumes that ICEs remain the leading technology for both passenger and commercial road transport segments with continuously improving fuel efficiency.

Although the current share of powertrain electrification can be considered marginal, it is expected to play a larger role in the longer-term. However, powertrain electrification is an expansive concept, ranging from what the industry labels as 'mild hybrids' where the power of the electric motor is insufficient to propel the vehicle alone, even for short distances, to BEVs capable of travelling several hundred kilometres on a single charge.

Combining powertrain electrification with an ICE leads to the creation of hybrids (HEV) and plug-in hybrid electric vehicles (PHEV). Both forms enable the main engine to run with optimum fuel efficiency at all times with HEVs relying entirely on fuel with no need for external charging. This currently allows them to compete with diesel vehicles in terms of fuel economy, even though they are built almost exclusively for the passenger vehicle segment.

Since HEVs usually have gasoline engines, the added cost of including an additional powertrain is somewhat offset by simple and economic exhaust cleaning. The ability to be charged through external power sources makes PHEVs particularly popular in Europe. As for large

and heavy vehicles (mainly sport utility vehicles (SUVs)), both HEVs and PHEVs are currently, and will remain over the long-term, a solution that combines extended range with at least temporary zero emission capabilities that will assist in complying with tightening emission standards.

For BEVs, to some extent government incentives have contributed to their recent success. However, such widespread support in the form of various subsidies and privileges is expected to fade in the short- to medium term as electric mobility becomes more mainstream. Another factor contributing to rising BEV sales is their fast expanding model line-up. However, despite the considerable advancements in battery technologies (increased capacity with reduced weight and volume), batteries may fall short in matching the energy density of fossil fuels. Therefore, ICE-powered cars will retain a range-related competitive advantage that BEVs will struggle to match.

Software has become an essential component of modern vehicles, extending far beyond uses in navigation and entertainment systems. Today's intelligent battery management software, coupled with significant battery technology improvements, has resulted in incremental range increases. Today, nearly the full battery capacity of between around 10% and 95% is available for driving. Earlier BEVs could only use a range between approximately 20% and 85% without the risk of accelerated battery ageing. The end of the decade may be marked by the introduction of safer and more energy dense solid-state batteries, however, no major breakthroughs are projected.

Fuel cell electric vehicles (FCEVs) represent another alternative to ICEs in the passenger segment. FCEVs may become more viable in regions with large amounts of available hydrogen as more countries start lobbying for zero emissions at the tailpipe of passenger vehicles.

There is more potential for fuel cells, in combination with liquefied hydrogen, in the case of commercial vehicles. However, the Reference Case assumes that commercial vehicles will remain more dominated by ICEs, primarily diesel engines, than the passenger car segment. Additionally, the rise of fuel efficiency coupled with 1,000 litre tanks compromises a substantial range advantage, even when compared to fuel cells and liquefied hydrogen. Due to its ease of handling, liquid fuels are set to remain the preferred option for the notable expanding demand for commercial transportation in developing countries. Natural gas, either compressed (CNG) or liquefied (LNG), is expected to gain a larger share in markets with ample supply. As the required fuelling infrastructure is already in place, some Asian countries may opt for natural gas in the passenger segment too.

Due to a lack of sufficient range limits, batteries are only being utilized for either delivery or medium-sized day tour trucks. A noteworthy exception are battery-powered urban buses that are already widely operational in China.

1.4.2 Air transportation

This Outlook sees strong potential for growth in air transportation between now and the end of the forecast period. The expected fast-paced growth following the recovery from the COVID-19 pandemic, will allow for a stronger focus on technological advancements.

The IATA and ICAO recently adopted the LTAG for international aviation to achieve net-zero CO_2 emissions by 2050. One of the means to achieve this target will be aircraft with better

efficiency. The progressive and substantial development of aero-turbine fan blades, and the associated thrust enhancements, have contributed to noticeable efficiency improvements in recent years. Another major step forward in the past 20 years was the replacement of heavier aluminium in the fuselage and wings with lighter carbon fibre re-enforced composites (CFCs) to reduce the overall weight (e.g. Airbus A350 and Boeing 787), thus lowering the airplane's fuel consumption. However, the improvement in airplane efficiency alone will not be enough to achieve this ambitious CO_2 goal. Current improvements may already be reaching their efficiency limitations especially with the introduction of large geared fans and compression ratios of 40:1.

Continuous fuselage and wing design enhancements may lead to improved fuel efficiency as direct and induced drag is reduced. Redesigning the passenger cabin by reducing the weight and size of the seats to increase occupancy, galley and other cabin elements, may potentially reduce fuel consumption and with minor investments compared to the development and deployment of new generations of aircraft. For instance, adding two rows of seats in a medium-haul airplane, such as an Airbus 320 or Boeing 737, will increase occupancy by 6% to 8%, and reduce fuel consumption per passenger-kilometre almost to the same extent. Another option for reducing fuel consumption is to minimize excessive airtime through flight control modernization, especially in busy air space.

The ICAO has established the development and utilization of Sustainable Aviation Fuel (SAF) to limit and subsequently minimize the industry's emissions. SAFs are based on biofuels, or are synthetically produced from hydrogen. Although the use of liquid hydrogen has been discussed, it is only being considered as a potential solution for the distant future. SAFs appear to be the preferred option for medium- and long-haul flights in the longer-term.

In terms of electrification, smaller short-haul aircraft for commuter flights below 200 to 300 km are expected to benefit from battery electrification. Electric air taxis are not expected to play a significant role until the end of the outlook period.

The Reference Case takes the most recent and anticipated future developments in regards to airplane efficiency into consideration, along with the potential use of SAFs.

1.4.3 Marine transportation

Reducing emissions remains a target for marine transportation. In 2020, the International Maritime Organization (IMO) imposed a cap on the sulphur content of fuel and an industry-wide emissions reduction of 50% by 2050 is now envisioned. Against the backdrop of this development, LNG has gained strong momentum as a clean fuel with a significant emissions reduction potential. A considerable number of today's large propulsion engines used in marine transportation are duel-fuel and can switch from liquid fuel to LNG and back (even during operation). This is often advantageous, especially if a vessel is cruising through international waters with different pollution standards.

Taking into consideration the IMO ambition to reach net-zero GHG emissions from international shipping close to 2050, as well as the significant marine transportation demand growth projected over the next few decades, further measures will be crucial. With current fuel efficiency of almost 50%, the potential margin of improvement for marine engines is minimal. However, replacing liquid fuels with LNG has already lead to an impact on emissions reduction, with the potential to further limit emissions in the years to come.

Slow steaming as a rapid and simple strategy to reduce fuel use is already being employed. Hull and propeller design are also expected to slowly improve, but no significant breakthroughs are anticipated, as shipbuilding is a well-established and mature industry. The Reference Case reflects a rise in demand stemming primarily from the considerable industry expansion projected over the outlook period.

When compared to airplanes, both weight and size are not overwhelmingly important on a water-borne vessel. This leverages the likelihood to capture and store fuel combustion-generated CO_2 on-board and then safely dispose of it at ports. However, and with ammonia being seriously considered, the industry is inclined more towards the use of carbon-free fuel.

This is advantageous since there is substantial expertise in handling large amounts of ammonia on vessels, as indicated by the existing ammonia tanker fleet. In contrast with liquefied hydrogen, ammonia can be stored at a manageable pressure of around 10 bar without cooling and at around –34°C pressure-free. However, as the effect of using such zero-emission fuels would not be distinctly noticeable until around 2040 or so, it is not expected that such strategies would be widely implemented soon.

1.4.4 Conventional and renewable power generation

Both gas and coal have dominated power generation in multiple regions in recent decades. Coal-fired power plants are more efficient owing to more modern designed supercritical coal plants that place water under a high pressure exceeding 300 bar before heating. Today, a new generation of supercritical coal power plants exceed 45% efficiency. Regardless of the major success of such advancements, coal still has the highest CO_2 emissions any energy carrier. Although CCU may considerably reduce net emissions, adapting this technology requires massive additional investments and reduces conversion efficiency.

In recent years, gas has sharply increased its share in power generation as large combined-cycle power plants based on a combination of gas and steam turbines convert 60% and more of the gas into power. The WOO observes the importance of gas in this sector, especially in regions with abundant resources. Waste heat of the power plants can be utilized for space heating in urbanized areas during winter and that could leverage more widespread use of heat and power cogeneration.

With the exception of some oil producing countries, islands, and deserted areas relying on diesel generators, oil has not immensely contributed to power generation for many decades. However, emergency oil-fuelled power is expected to act as a future contingency option to compensate for blackouts from a lack of power from solar and wind.

In terms of nuclear power, the advancement of modular reactors, the use of thorium as a fuel source, and 'breeding' to yield more fissile material from non-fissile material that is present in the reactor aiding, is expected to set the scene towards the expanded proliferation of nuclear power. Nuclear power may regain its momentum especially in terms of helping address climate change and energy supply issues. However, the potential short-term effect is limited since the timeline from planning to commissioning a nuclear plant can take up to ten years or more.

Owing to noticeable governmental subsidies and support, both wind and solar have shifted to more competitive positions compared to 30 years ago. Generation costs have come down to

levels equivalent to fossil power generation in the most favourable locations. Within the overall power generation mix, wind and solar already have a significant share in regions where traditional power generation has been strong, for example, Europe, the US and China.

The penetration of renewables in power generation, especially wind and solar, is set to expand over the course of the forecast period and gradually displace coal, although in some regions coal may be used for an extended period of time given recent and future development plans.

1.4.5 Hydrogen

The Outlook also considers a gradual, yet steady, uptake in hydrogen use as a new emerging energy carrier. Perceived as a potential contributor to emissions reduction, and providing options for energy storage, hydrogen is attracting the attention of policymakers in both major consuming and producing countries.

There are several available technologies to produce hydrogen, each at a different stage of maturity. These depend on the range of available feedstocks and the impact of policy support for each technology.

Presently, around half of global hydrogen production is based on the steam naphtha reforming (SNR) process. The process mainly utilizes shorter-chain hydrocarbons as a feedstock, from natural gas to naphtha. Partial Oxidation (POX) is another widely deployed technology. It usually leverages the heavy part of the refined barrel that is decomposed into a mixture of hydrogen, CO_2 and carbon monoxide (CO) at temperatures ranging from 1,300 °C to 1,500 °C and in the presence of steam and oxygen. Both SNR and POX are also well suited to being combined with CCUS.

Ongoing developments to strip carbon from natural gas are also being carried out through methane pyrolysis, a process by which methane is thermally decomposed into hydrogen and carbon. The resultant product, aside from the sought after hydrogen, is primarily carbon that can be easily deposited either underground or on the surface.

Hygienic Earth Energy (HEE), developed by Proton Technologies, is another emerging technology to produce potentially massive quantities of blue hydrogen from oil-based feedstocks. The HEE process basically combines heating oil reservoirs through the injection of high purity oxygen deep into the reservoir, and harvesting pure hydrogen through a selective membrane that ensures all other gases are confined below the ground. However, its feasibility needs to be further monitored as this technology is in its early development stages.

Utilizing renewable energy sources, via electrolysis, is another method to produce fossil fuels-based hydrogen. This may be attainable in regions with abundant renewable power, either wind or solar. However, transporting massive quantities of hydrogen to consuming regions remains a challenge due to hydrogen's high energy density per mass, but a very low energy density per volume, even when liquefied. Moreover, transporting hydrogen produced in remote areas is challenging when compared to natural gas or oil, for both pipeline and maritime routes.

From the demand perspective, hydrogen as a gaseous energy carrier can be utilized almost everywhere natural gas is presently employed. It is expected that hydrogen will displace coal in steel production. Nonetheless, transitioning to hydrogen especially in industrial processes

requires additional investments. Commercial road transportation may also decarbonize its operations by capitalizing on hydrogen as indirect energy storage, or in combination with fuel cells. It is unlikely that heavy trucks for long-distance transportation will run on battery power, even in the more distant future.

Energy demand

Key takeaways

- Global primary energy demand is set to increase from 291 mboe/d in 2022 to 359 mboe/d in 2045, an increase of 23% over the outlook period.
- Energy demand growth slows gradually from the relatively high short-term rates to more modest expansion in the long-term, in line with slower population and economic growth.
- Energy demand growth is driven by non-OECD regions, which increase by 69 mboe/d over the outlook period. Almost 28% of the non-OECD growth comes from India alone. At the same time, energy demand in OECD countries drops slightly.
- In the Reference Case, demand for all primary fuels is set to increase in the long-term, with the exception of coal.
- The strongest incremental demand is expected for other renewables (notably wind and solar), which increases by 34.3 mboe/d over the outlook period, based on strong policy support and favourable economics in many regions. The share of other renewables in the energy mix rises from around 2.7% in 2022 to 11.7 % in 2045.
- Despite some short-term shortages, it is assumed that natural gas demand increases by almost 20 mboe/d over the outlook period, reaching 87 mboe/d in 2045.
- Oil demand is projected to increase by 15.4 mboe/d in the period to 2045 and reach 106.1 mboe/d. Oil's share in the energy mix is set to drop from 31.2% in 2022 to 29.5% in 2045. Despite this decline, oil will remain the fuel with the largest share in the energy mix by 2045.
- Coal is the only primary fuel expected to decline due to energy policy and climate commitments. It drops from around 76 mboe/d in 2022 to almost 54.4 mboe/d in 2045, mostly due to China and OECD countries.
- The share of fossil fuels in the energy mix drops from above 80% in 2022 to about 69% in 2045. This is mostly due to the decline of coal use. In the same period, the combined share of oil and gas in the energy mix still represents 54%.
- Energy intensity is projected to decline in all regions, leading to a global reduction rate of around 2% p.a. between 2022 and 2045. India and China are set to witness the largest reduction in energy intensity, with annual average rates of 3.4% and 2.8%, respectively.
- While progress has been made in reducing energy poverty and narrowing the disparity between OECD and non-OECD regions, there are still wide gaps and much work needs to be done. Energy poverty remains an urgent global issue that requires concerted efforts from policymakers to ensure affordable and sustainable energy access for all.

Chapter 2 provides an overview of the medium- and long-term primary energy demand trends by different fuels and major regions and/or countries in the Reference Case. Key assumptions provided in Chapter 1, such as demographic and economic developments, as well as long-term energy technology trends and evolution of energy policies, are taken into consideration in these projections. This chapter also focuses on the implications of energy demand trends on energy poverty and access in the Reference Case.

2.1 Major trends in energy demand

The global energy landscape has undergone significant changes during 2022. The start of the conflict in Eastern Europe in early 2022 led to an energy crisis that shifted energy flows and exacerbated the record-high prices for some energies. This was especially the case for spot natural gas and spot coal prices, as well as electricity prices in many regions.

Consequently, energy security and energy affordability moved back into a central focus for policy- makers across the globe. Governments in rich and developed regions helped their citizens with significant energy subsidies, such as for electricity and heating. While also reducing energy demand somewhat, most of these countries managed to secure sufficient energy supplies throughout the year. At the same time, in many developing countries, governments had significantly less manouvereing space. For instance, due to high prices, countries like Pakistan and Bangladesh had to reduce LNG imports, leading to electricity supply shortages.

The increased focus on energy security and energy affordability led to a variety of measures and strategies for both medium- and long-term. Many developed countries have already enhanced ambitious targets related to low-carbon energy and improvements in energy efficiency, which are also in line with climate change policies. Increasing the deployment of renewable energy and/or nuclear energy is seen as a means to address the dual challenge of energy security and sustainability. With this, several European countries, including Germany, reactivated mothballed coal-power plants to ensure stable electricity supply.

At the same time, many developing countries in their quest to improve energy security have turned increasingly to domestic energy supply, predominantly coal. China has approved a record high number of new coal power plants since early 2022, and Pakistan, for instance, intends to quadruple domestic coal-fired power capacity.

This clearly depicts the difference between developed and developing countries. In many developed countries, energy demand has increased marginally, or even declined in recent years. Unfavourable population growth trends in these countries, as well as rather modest economic growth, are expected to lead to negative energy demand expansion in some of these countries in the years to come. This allows for the faster penetration of alternative energy sources in the energy mix.

Additionally, developing countries, with fast growing populations, significant economic expansion and rising energy access are likely to see a strong increase in total energy demand. In addition, the deployment of renewables with respective ancillary services are as a rule capital intensive, while most developing countries do not have sufficient access to financing. This is why the increase of alternative energy sources in the mix is considerably slower, compared to developed countries.

Table 2.1 presents the global primary energy demand outlook in the medium- and long-term by fuel in the Reference Case. It is expected to increase from roughly 291 mboe/d in 2022 to almost 359 mboe/d in 2045. This represents an increase of 68 mboe/d, or around 23%, over the outlook period. The estimated average annual growth rate over the entire outlook period is 0.9% p.a. It is worth noting that the energy demand growth rate is not constant over these years. It slows gradually from relatively high short and medium-term rates to lower rates in the long-term. This is in line with slower population and economic growth. Furthermore, increasing energy efficiency, in combination with decreasing energy intensity, will also contribute to lower primary long-term energy demand growth.

Table 2.1
World primary energy demand by fuel type, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
Oil	90.7	96.4	102.0	104.3	105.3	106.1	15.4	0.7	31.2	29.5
Coal	75.9	74.6	71.1	65.9	60.0	54.4	–21.5	–1.4	26.1	15.1
Gas	67.1	69.6	75.0	80.2	84.4	87.0	20.0	1.1	23.1	24.2
Nuclear	15.0	15.9	17.4	19.4	21.7	23.8	8.8	2.0	5.2	6.6
Hydro	7.7	8.2	8.9	9.6	10.2	10.5	2.8	1.3	2.7	2.9
Biomass	26.6	27.9	30.2	32.3	34.1	35.2	8.6	1.2	9.1	9.8
Other renewables	7.9	11.2	18.5	26.7	35.8	42.2	34.3	7.5	2.7	11.7
Total	**290.9**	**303.9**	**322.9**	**338.3**	**351.6**	**359.2**	**68.3**	**0.9**	**100.0**	**100.0**

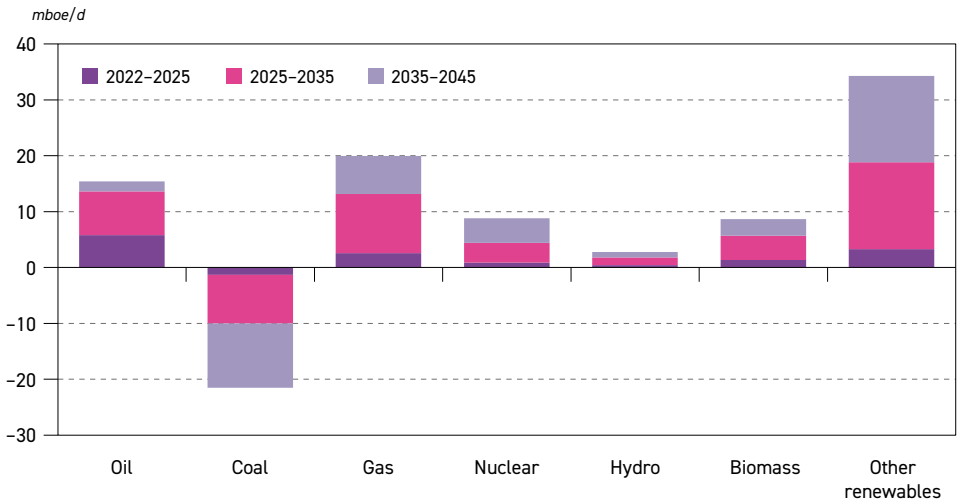
Source: OPEC.

At the same time, the expected drop in primary energy demand growth is much less pronounced in terms of final energy demand. This is due to the rising share of renewables, such as wind and solar, that have little or no transformation and/or transmission losses and given that they partially replace fossil fuels, where transformation losses are normally significant, coal, for example.

In the Reference Case, long-term demand for all primary fuels is expected to increase, with the exception of coal (Figure 2.1). The latter declines mostly due to more stringent climate change-related policies and announced coal phase out plans in most major consuming regions. The Reference Case shows that all energy sources will be needed to address future energy needs. At the same time, the primary energy mix will change in the years to come, with rising shares for renewables and nuclear energy, albeit in some regions more than others.

At the global level, the strongest incremental demand between 2022 and 2045 is expected for other renewables (notably wind and solar), which increases by 34.3 mboe/d over the outlook period. Strong policy support and favourable economics in many regions underpin this development with the share of other renewables increasing from around 2.7% in 2022 to 11.7% in 2045. This is equivalent to an annual average growth rate of 7.5% p.a., a significantly higher growth rate than any other primary fuel.

Figure 2.1
Growth in primary energy demand by fuel type, 2022–2045



Source: OPEC.

Natural gas demand is expected to increase by 20 mboe/d over the outlook period, reaching 87 mboe/d in 2045. Despite some short-term shortages, it is assumed that the availability of natural gas resources at competitive cost levels will help to increase long-term demand. Its relatively low CO_2 emissions, especially compared to coal, make gas the fuel of choice in many countries as they seek to reduce carbon emissions. Furthermore, due to the intermittent nature of new renewable electricity generation, natural gas is well suited to provide backup power supply. The share of natural gas in the primary energy mix is set to increase to 24.2% in 2045. Already in 2030, natural gas will become the second largest fuel in the mix, overtaking coal.

Oil demand is projected to increase by 15.4 mboe/d in the outlook period, rising from 90.7 mboe/d to 106.1 mboe/d in 2045. Oil's share in the energy mix is set to drop from 31.2% in 2022 to 29.5% in 2045. Despite this decline, oil is expected to remain the fuel with the highest share in the energy mix by 2045.

Demand for nuclear energy is set to increase from 15 mboe/d in 2022 to 23.8 mboe/d in 2045, an increase of nearly 9 mboe/d. Increasing support for nuclear energy as a low-carbon solution leads to an increasing number of new projects. This is not only in developing countries, but there is also a revival in developed countries.

A similar increase is expected for biomass with total demand reaching 35.2 mboe/d. The rise mostly reflects the advanced use of biomass. This relates to the production of biofuels, SAFs, bio-methane and bioplastics, as well as the use of biomass for electricity generation. The advanced use of biomass is projected to more than offset its traditional use, which declines in the outlook period, especially in developing countries.

Hydropower demand is set to grow by around 2.8 mboe/d and reach 10.5 mboe/d in 2045. The increase is likely to materialize mostly in developing countries (generally non-OECD Asia)

where hydro resources are still available. Minor additions can be expected in other regions, such as OECD Europe and OECD Americas.

As already mentioned, coal is the only primary fuel set to decline. Coal demand was estimated at around 76 mboe/d in 2022 and it is expected to drop to 54.4 mboe/d in 2045, a decline of 21.5 mboe/d. Energy policy and climate commitments, in combination with the increased availability of alternative energy sources, such as natural gas, nuclear and renewables, are the main reason for this development. Consequently, the share of coal in the global energy mix falls from 26.1% in 2022 to almost 15% in 2045.

The share of fossil fuels in the energy mix declines from above 80% in 2022 to 69% in 2045, which is due to the drop in coal use. In the same period, the combined share of oil and gas in the energy mix remains around 54%.

However, this global energy demand picture combines different long-term regional trends. Table 2.2 and Figure 2.2 show the energy demand outlook by region. It is evident that demand growth is driven by non-OECD countries.

Table 2.2
Total primary energy demand by region, 2022–2045

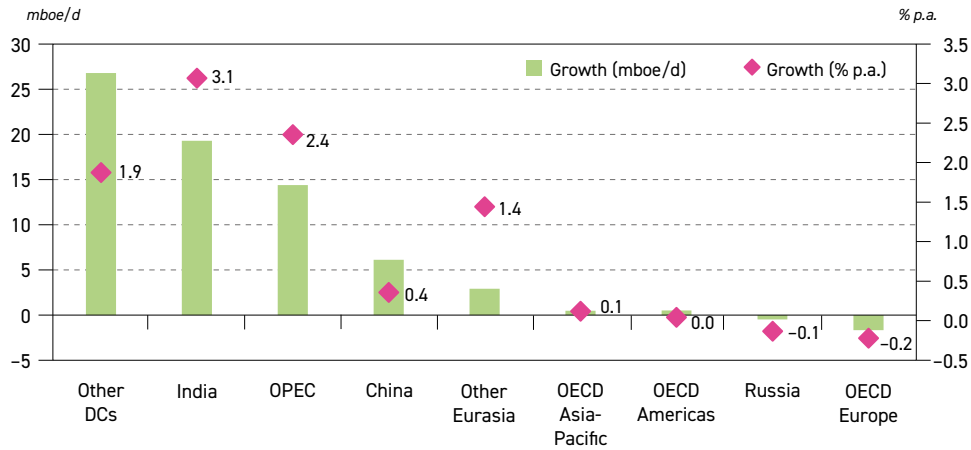
	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	55.4	55.4	56.4	56.6	56.4	55.9	0.5	0.0	19.0	15.6
OECD Europe	33.7	34.0	33.9	33.4	32.7	32.0	–1.7	–0.2	11.6	8.9
OECD Asia–Pacific	17.5	17.7	17.9	18.0	18.0	18.0	0.5	0.1	6.0	5.0
OECD	**106.6**	**107.1**	**108.2**	**108.0**	**107.1**	**105.9**	**–0.7**	**0.0**	**36.7**	**29.5**
China	71.3	75.2	78.1	78.7	78.1	77.4	6.1	0.4	24.5	21.6
India	19.2	21.3	25.4	29.7	34.1	38.5	19.3	3.1	6.6	10.7
OPEC	20.3	22.8	26.4	29.6	32.6	34.7	14.4	2.4	7.0	9.7
Other DCs	50.3	54.2	61.1	68.2	75.0	77.1	26.8	1.9	17.3	21.5
Russia	15.7	15.5	15.4	15.3	15.2	15.2	–0.5	–0.1	5.4	4.2
Other Eurasia	7.5	7.8	8.3	8.9	9.5	10.4	2.9	1.4	2.6	2.9
Non-OECD	**184.3**	**196.8**	**214.7**	**230.3**	**244.5**	**253.3**	**69.0**	**1.4**	**63.3**	**70.5**
World	**290.9**	**303.9**	**322.9**	**338.3**	**351.6**	**359.2**	**68.3**	**0.9**	**100.0**	**100.0**

Source: OPEC.

India is the single largest contributor to energy demand growth with incremental demand of 19.3 mboe/d over the outlook period, at a strong annual average growth rate of 3.1% p.a. In terms of the broader picture, India's energy demand growth accounts for around 28% of global energy demand growth by 2045.

Energy demand in Other Developing countries, consisting mostly of developing countries in Asia, Africa and Latin America, is expected to increase by almost 27 mboe/d, supported by

Figure 2.2
Growth in primary energy demand by region, 2022–2045



Source: OPEC.

strong population and economic growth, as well as rising energy access. Energy demand in the OPEC region is projected to increase by almost 14.4 mboe/d between 2022 and 2045, supported not only by growing populations and expanding economies, but by the ample availability of affordable energy resources. Energy demand in China is projected to rise by 6.1 mboe/d, with a strong decline in coal demand more than offset by a demand increase for other primary fuels, mostly other renewables, nuclear and natural gas.

Energy demand in the OECD is projected to increase slightly in the period to 2030 followed by a gradual decline thereafter. In total, energy demand is expected to drop by some 0.7 mboe/d over the outlook period. Relatively low population growth and modest economic development, in combination with increasing energy efficiency, are the main reasons for this trend. The decline is expected to materialize in OECD Europe (–1.7 mboe/d), while OECD Americas and OECD Asia-Pacific are each set to increase by 0.5 mboe/d.

2.2 Energy demand by major regions

This section discusses regional details in terms of primary energy demand. It explains developments in the energy mix related to economic development and major energy policies. The focus is on regions, such as OECD and non-OECD, as well as two major countries, China and India. Due to their size, some regions/countries have much higher significance for energy demand. For instance, OECD, China and India accounted for almost 70% of global energy demand in 2022, with changes in these regions affecting the global energy landscape as a whole.

Table 2.3 shows **OECD** primary energy demand by major fuel. Overall energy demand in OECD is projected to increase from 106.6 mboe/d in 2022 to 108.2 mboe/d in 2030, followed by a gradual decline towards 105.9 mboe/d in 2045. Consequently, overall energy demand is set to drop by a mere 0.7 mboe/d over the outlook period. OECD energy demand trends are dominated by slower population and modest economic growth, as well as strong policy measures that promote energy efficiency and the substitution of fossil fuels with renewables.

Table 2.3
OECD primary energy demand by fuel type, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
Oil	39.5	39.7	39.1	36.8	33.7	30.8	–8.7	–1.1	37.0	29.0
Coal	14.0	12.6	10.5	8.8	7.3	6.0	–7.9	–3.6	13.1	5.7
Gas	30.0	29.7	29.8	29.8	29.6	28.9	–1.1	–0.2	28.1	27.3
Nuclear	10.0	10.1	10.4	10.8	11.4	11.8	1.8	0.7	9.4	11.1
Hydro	2.5	2.6	2.7	2.8	2.9	3.0	0.4	0.7	2.4	2.8
Biomass	6.8	7.3	8.0	8.7	9.4	10.1	3.2	1.7	6.4	9.5
Other renewables	3.8	5.0	7.6	10.3	12.9	15.4	11.6	6.2	3.6	14.5
Total	**106.6**	**107.1**	**108.2**	**108.0**	**107.1**	**105.9**	**–0.7**	**0.0**	**100.0**	**100.0**

Source: OPEC.

In total, OECD fossil fuel demand is anticipated to decline by around 17.7 mboe/d over the outlook period, mostly oil, followed by coal and then gas. Oil demand is expected to drop by 8.7 mboe/d, mainly due to policies aiming at substituting oil with other energy sources. A large share of this substitution is expected to occur in the road transportation sector, which is in line with the higher penetration of alternative vehicles such, as EVs. Energy policies supporting this trend are already in place, some of which are legally binding. For instance, all new vehicle sales in the EU are expected to be zero-emission vehicles from 2035, while in the US, new tailpipe emissions limits are proposed. Even if not fully reached these measures are likely to lead to a significant increase in new EV sales in the coming decades.

Coal demand in the OECD is expected to decline by almost 8 mboe/d over the outlook period, reaching 6 mboe/d in 2045. Many coal plants are set to be closed in the coming years due to more stringent policies (including CO_2 pricing) and plants reaching the end of their life. Countries, such as Germany, were discussing shifting the phase-out of coal power plants to 2030, instead of 2038 as originally planned. In addition, the further expansion of renewable energy will limit the load hours of coal power plants. In OECD Americas, a large number of US coal power plants will be closed by 2030, due to ageing units, the increasing share of renewables and natural gas in the power generation mix. Despite ambitious policies, some countries may still leave limited coal capacities operational, some of which could be equipped with CCUS facilities.

OECD natural gas demand is set to remain stable in the period to 2040 at nearly 30 mboe/d, followed by a marginal decline to 28.9 mboe/d in 2045. This is due to OECD Europe, where the recent energy crisis related to gas supplies is expected to accelerate efforts to curtail gas usage and reduce overall gas imports. While gas is likely to remain an important part of the mix, many countries are increasing the production of biogas and/or synthetic gas, which could replace limited volumes of natural gas. Strong renewables growth will also reduce the need for gas-fired power generation.

In the Reference Case, gas demand in OECD Europe is set to drop by around 1 mboe/d in the period to 2045. At the same time, in OECD Americas, demand for natural gas is anticipated to remain stable at around 19 mboe/d. Demand is supported by the ample availability of domestic gas supply at competitive prices and natural gas replacing coal in the power generation sector. Similarly, in OECD Asia-Pacific, gas demand remains flat at around 3.6 mboe/d throughout the outlook period. Reduced coal usage will support demand, which will be offset by the higher deployment of renewables and nuclear energy.

Demand for other renewables in the OECD is set to increase by 11.6 mboe/d between 2022 and 2045 to reach almost 15.5 mboe/d. This development sees it climb to above 15% of the energy mix. Strong policy support is the main driver for the expansion of renewables, such as the IRA in the US, the EU Green Deal, RePowerEU and the EU Green Deal Industrial Plan.

Hydropower increases will be limited. In the case of biomass, OECD demand is anticipated to rise from 6.8 mboe/d in 2022 to 10.1 mboe/d in 2045. The large part of this increase is accounted for by the advanced use of biomass for biofuels, bioplastics and/or biogas production. Finally, OECD demand for nuclear power is set to increase by 1.8 mboe/d, reaching nearly 12 mboe/d in 2045. Many countries in this region have expressed an interest to further expand their nuclear capacity, including the US, France and Japan. It should be noted that 1.8 mboe/d is the net increase in total nuclear power demand in the OECD region, which also takes into account numerous closures of ageing capacity.

Due to these shifts in OECD energy demand, the mix is set-to change. The share of oil declines by 8 pp to 29% and the share of coal drops by almost 7.5 pp to below 6% during the outlook period. At the same time, the share of other renewables increases to 14.5% in 2045, from 3.6% in 2022.

Table 2.4 shows long-term energy demand in the **non-OECD.** Total energy is projected to increase from around 184 mboe/d in 2022 to more than 253 mboe/d in 2045, which is an increase of 69 mboe/d, or around 37%. India alone accounts for 19.5 mboe/d of this increase, which is almost 28% of the total.

Table 2.4
Non-OECD primary energy demand by fuel type, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
Oil	51.2	56.7	62.9	67.5	71.6	75.3	24.1	1.7	27.8	29.7
Coal	62.0	62.0	60.5	57.1	52.8	48.4	–13.6	–1.1	33.6	19.1
Gas	37.1	39.9	45.2	50.4	54.8	58.1	21.0	2.0	20.1	22.9
Nuclear	5.0	5.8	7.0	8.6	10.4	12.0	7.0	3.9	2.7	4.7
Hydro	5.2	5.5	6.2	6.8	7.4	7.6	2.4	1.6	2.8	3.0
Biomass	19.8	20.7	22.2	23.5	24.6	25.2	5.4	1.1	10.7	9.9
Other renewables	4.1	6.2	10.8	16.5	22.9	26.8	22.7	8.5	2.2	10.6
Total	**184.3**	**196.8**	**214.7**	**230.3**	**244.5**	**253.3**	**69.0**	**1.4**	**100.0**	**100.0**

Source: OPEC.

The largest increase comes from oil demand, which is projected to increase by almost 24.1 mboe/d to reach 75.3 mboe/d in 2045. This is in line with an expanding population and rising mobility needs. At the same time, gas demand is expected to increase from 37 mboe/d in 2022 to 58 mboe/d in 2045, an increment of 21 mboe/d. In many countries, rising natural gas supplies help to reduce energy poverty and increase energy access, while at the same time reduce the traditional use of biofuels for cooking and heating. Furthermore, rising gas usage is the consequence of policies to replace coal or oil in the power generation sector in some countries, including many countries in Asia and the Middle East. Finally, many developing countries (including OPEC Member Countries) have vast natural gas resources at competitive production costs at their disposal, which supports the increased usage of this fuel in the future.

Coal demand in the non-OECD is expected to decline by around 13.6 mboe/d in the outlook period. This is mostly due to policies to limit coal usage and limit CO_2 emissions in China. In addition, the replacement of old and inefficient coal units with new units is set to reduce the long-term need for this primary fuel. At the time, these reductions are partly offset by rising coal demand in South Asia.

Other renewables are forecast to grow strongly in the non-OECD, increasing from 4.1 mboe/d in 2022 to almost 27 mboe/d in 2045. This is an average annual growth rate of 8.5% p.a. China alone accounts for more than 40% of this increment, in line with policy backing, as well as China's continuous efforts to support and further develop its renewable industry. Nuclear energy will likely more than double between 2022 and 2045, reaching 12 mboe/d. A large number of projects under construction, especially in China, in combination with rising interest from several countries to develop this technology, are the main driver for this increase.

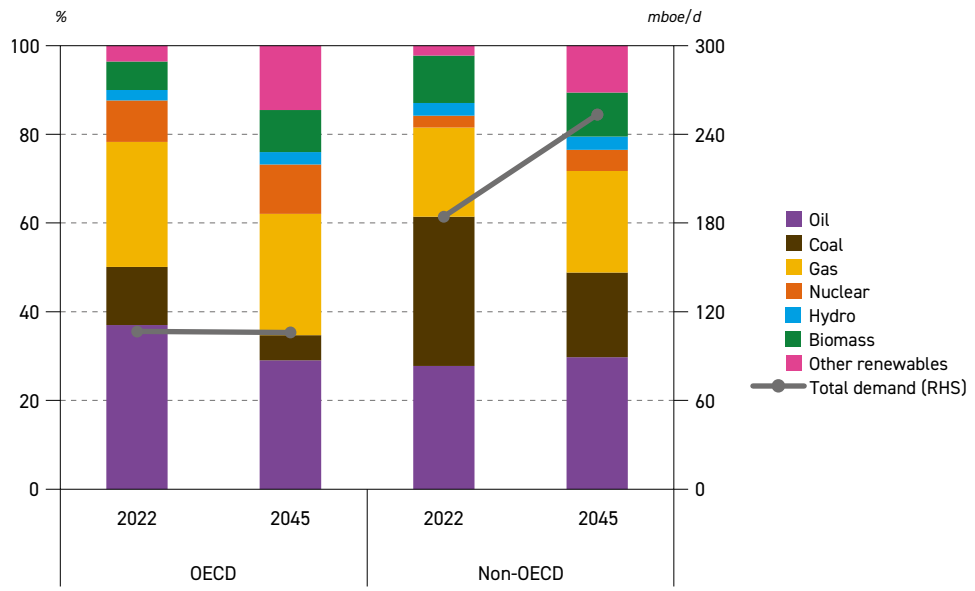
Demand for biomass is set to increase from just below 20 mboe/d in 2022 to 25.2 mboe/d in 2045. This increase is a combination of the reduction in the traditional use of biomass, especially in Africa, which is more than offset by its modern use. Finally, based on sufficient available resources, hydropower is expected to grow 1.6% p.a. over the outlook period, reaching 7.6 mboe/d in 2045. This expansion is expected to materialize mostly in the Asia-Pacific (including China) and, to some extent, Africa.

Figure 2.3 shows the changing energy mix in the OECD and non-OECD between 2022 and 2045. In both regions, the share of fossil fuels in the mix is expected to decline over the outlook period. However, the figure illustrates very different regional patterns.

The overall share of fossil fuels in the OECD declines from above 78% in 2022 to 62% in 2045. This is mostly due to the decline of oil's share in the mix, which drops from 37% in 2022 to 29% in 2045. Coal also declines, losing more than 7 pp to reach levels below 6% in 2045. The share of natural gas in the OECD energy mix is set to decline only slightly and settle at just above 27% in 2045. The gap will be filled by rising shares for other renewables (+10.9 pp), biomass (+3.1 pp), nuclear (+1.8 pp) and hydro (+0.4 pp).

In the non-OECD, the pattern in energy demand development is different. Based on strong population and economic growth, oil and gas increase their respective shares modestly by 1.9 and 2.8 pp in the outlook period, and the share of coal in the mix drops by a hefty 14.5 pp between 2022 and 2045. Consequently, the overall share of fossil fuels is set to decline by almost 10 pp between 2022 and 2045. The increase will come from other renewables (+8.4 pp) and nuclear (+2 pp).

Figure 2.3
Energy mix in OECD and non-OECD and primary energy demand, 2022–2045



Source: OPEC.

It is important to note that the overall level of energy demand is an important denominator for the final energy mix. In the OECD, primary energy demand is set to decline in the long-term, which helps to hasten the increase in the share of renewables. In the non-OECD, energy demand increases throughout the outlook period, which is why the share of non-OECD renewables in 2045 is lower compared to the OECD.

This section also provides more details about China and India, which, due to their size, have a decisive impact on the global energy landscape.

In China, primary energy demand is projected to increase in the initial years from 71.3 mboe/d in 2022 to 78.7 mboe/d in 2035. In the last decade of the outlook period, however, overall energy demand is set to decline slightly and reach 77.4 mboe/d in 2045. A declining population, as well as slower GDP growth and rising energy efficiency are the major drivers of this trend. The latter especially relates to the significant change in coal demand, which is set to decline from 41.6 mboe/d in 2022 to just under 24 mboe/d in 2045. This drop is in line with efforts to reach a CO_2 emissions peak by 2030 and carbon neutrality by 2060.

The more efficient use of coal also contributes to the decline in primary energy demand. China has recently approved a significant number of new coal-fired power plants, which totalled more than 100 Gigawatt (GW) in 2022. Some new coal plants will certainly replace old and inefficient coal units in the years to come, thus contributing to lowering primary coal demand in the country. The upshot of all this sees the share of coal in the primary mix falling from above 58% in 2022 to 30.7% in 2045.

China's oil demand is projected to increase over this decade, reaching levels close to 16.7 mboe/d in 2030. Towards the end of the outlook period, oil demand growth is expected to decelerate and reach 17.4 mboe/d in 2045. An expanding share of EVs in new vehicle sales

is set to put some pressure on oil demand growth, with heavy-duty transportation, aviation and marine sectors, as well as petrochemicals, driving future transportation demand growth. Natural gas demand is expected to increase from 5.8 mboe/d in 2022 to 10.2 mboe/d in 2045. Higher gas demand is anticipated to partly replace coal in power generation and help the country reach its CO_2 emissions targets. Rising gas demand in China is partly linked to the assumed increase in its domestic gas supply as laid out in the country's 14th FYP.

China is making huge investments into renewable energy, particularly wind and solar. In 2022, China commissioned around 140 GW of renewable capacity, which is almost 50% of the global additions. Strong growth is expected to continue in the years to come. Other renewables are projected to rise from 2.2 mboe/d in 2022 to almost 12 mboe/d in 2045, with its share in the energy mix reaching 15.5%. China's nuclear power is set to increase stepwise and more than double to reach 6.8 mboe/d in 2045, up from 2.5 mboe/d in 2022. China currently has 21 reactors under construction with a total capacity of around 21.5 GW. The official target is 70 GW of nuclear capacity by 2025, from the current level of 53.2 GW. The increase in nuclear power is part of the country's efforts to reduce the consumption of fossil fuels, especially coal. Hydropower and biomass demand are projected to increase modestly, inching up by 0.6 mboe/d and 1.6 mboe/d, respectively.

Table 2.5
China primary energy demand by fuel type, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
Oil	14.1	15.8	16.7	17.0	17.3	17.4	3.4	0.9	19.7	22.5
Coal	41.6	40.9	37.8	33.2	28.2	23.7	–17.9	–2.4	58.3	30.7
Gas	5.8	6.6	8.0	9.2	9.9	10.2	4.4	2.5	8.1	13.2
Nuclear	2.5	3.1	3.9	4.9	6.0	6.8	4.3	4.5	3.4	8.8
Hydro	2.4	2.5	2.6	2.8	2.9	3.0	0.6	1.1	3.3	3.9
Biomass	2.8	3.1	3.6	3.9	4.2	4.4	1.6	2.0	4.0	5.7
Other renewables	2.2	3.3	5.4	7.7	9.7	11.8	9.5	7.5	3.1	15.2
Total	**71.3**	**75.2**	**78.1**	**78.7**	**78.1**	**77.4**	**6.1**	**0.4**	**100.0**	**100.0**

Source: OPEC.

Table 2.6 shows the long-term energy demand outlook for India. Overall energy demand is projected to almost double and reach 38.5 mboe/d in 2045, driven by increasing population, an expanding middle class and economic development. India alone accounts for almost 28% of non-OECD primary energy demand growth to 2045 and all energy sources are expected to increase in the Reference Case. Oil demand is forecast to more than double from 5.1 mboe/d in 2022 to 11.6 mboe/d in 2045 with transportation, petrochemical and residential sectors the main drivers.

Table 2.6
India primary energy demand by fuel type, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
Oil	5.1	5.8	7.3	8.7	10.1	11.6	6.5	3.6	26.7	30.1
Coal	8.3	9.0	10.4	11.6	12.5	12.8	4.5	1.9	43.3	33.2
Gas	1.0	1.2	1.7	2.2	3.0	4.1	3.1	6.2	5.3	10.6
Nuclear	0.3	0.3	0.5	0.7	1.0	1.3	1.0	7.1	1.4	3.3
Hydro	0.3	0.3	0.4	0.5	0.6	0.6	0.3	3.3	1.6	1.7
Biomass	3.9	4.0	4.1	4.2	4.2	4.2	0.3	0.4	20.2	10.9
Other renewables	0.3	0.6	1.1	1.8	2.7	3.9	3.6	11.5	1.7	10.1
Total	**19.2**	**21.3**	**25.4**	**29.7**	**34.1**	**38.5**	**19.3**	**3.1**	**100.0**	**100.0**

Source: OPEC.

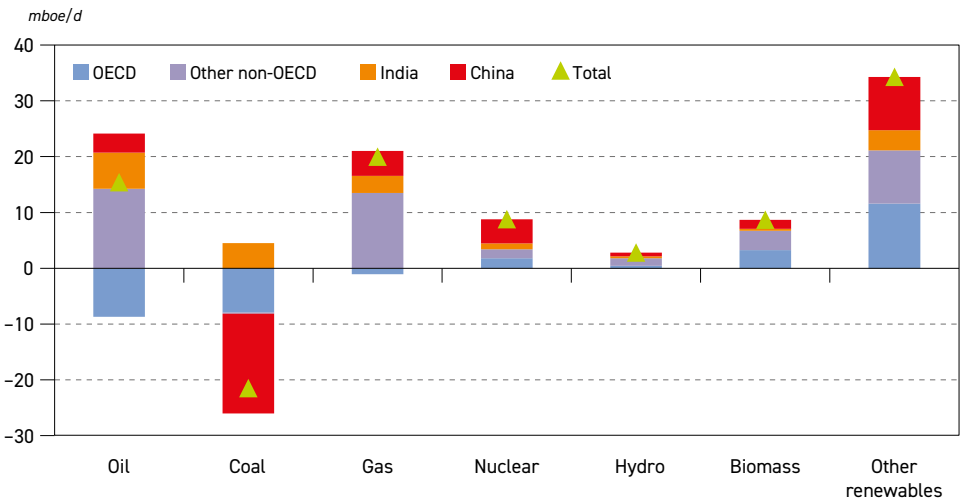
In line with expanding electricity consumption, India's coal demand is expected to increase, especially in the first part of the outlook period. From 8.3 mboe/d in 2022, coal demand is expected to increase to 11.6 mboe/d in 2035, and further, albeit at a slower pace, to 12.8 mboe/d in 2045. The reason for coal's slowing pace is the faster deployment of other energy resources, especially gas, nuclear and other renewables. Other renewables are projected to increase from 0.3 mboe/d in 2022 to almost 4 mboe/d in 2045. Consequently, the share of other renewables is set to increase to around 10.1% by 2045, from below 2% currently. The Indian government is supporting the expansion of renewables, including transmission and distribution networks. The official target is to reach 500 GW of renewables by 2030, which is an ambitious target, given current renewable capacity is around 160 GW.

Natural gas is also expected to expand strongly in the medium- and long-term. Increasing the share of gas in the mix will help to reduce coal usage, curb CO_2 emissions and support the deployment of intermittent renewables, such as wind and solar. Furthermore, the government supports the gasification of the country (City Gas distribution), which aims to reduce the usage of traditional cooking fuels in the residential sector. Although the government has a target for gas in the energy mix of 15% by 2030, the Reference Case sees a share of around 10.6% by 2045.

Nuclear power is likely to more than triple in the forecast period from 0.3 mboe/d to 1.3 mboe/d in 2045. Around 6 GW of nuclear capacity is under construction, which, once online, would almost double the country's current installed capacity. Finally, hydropower and biomass demand are each expected to increase by 0.3 mboe/d over the outlook period. The country is also set to reduce the traditional use of biomass, which will be more than offset by its modern use and the transformation into bio liquids and biogas.

Figure 2.4 illustrates regional demand changes in the outlook period by fuel and by region, which shows diverging trends. Renewable energy sources and nuclear power are forecast to increase in all major regions, driven by China and the OECD. Natural gas and, especially oil, are expected decline in the OECD, due to the overall stagnation of the energy market and the

Figure 2.4
Growth in energy demand by fuel type and region, 2022–2045



Source: OPEC.

active substitution of these fuels with renewables. At the same time, oil and gas demand are set to increase in the non-OECD. With a coal demand decline of nearly 18 mboe/d, China has the most significant impact on this fuel's demand, far ahead of OECD regions.

2.3 Energy demand by fuel

This section looks into energy demand trends by primary fuels. It discusses energy policies and provides the Reference Case outlook to 2045.

2.3.1 Oil

The global oil market experienced unprecedented turbulence in 2020 and 2021, as oil was the most affected energy source during the COVID-19 crisis. Indeed, oil demand declined by more than 7 mboe/d in 2020 (on an energy-content basis) and then increased by more than 5 mboe/d in 2021. These were the two largest swings in annual oil demand ever recorded. Recovery from the oil demand collapse in 2020 continued in 2022, when global demand increased by a significant 2.3 mboe/d, despite significantly increased geopolitical instability in Eastern Europe and higher energy prices.

The continuation of this conflict, combined with high inflationary pressures, rising interest rates and high-debt levels in many regions contributed to slower economic growth in 2023, estimated at 2.6% at the global level. Despite this, partly supported by the sustained demand recovery after COVID-19, as well as the continued demand re-alignment with levels of economic activity, oil demand is estimated to increase by 2.2 mboe/d in 2023. Moreover, this re-alignment (or catching-up for unrealized demand growth during 2020–2023) will likely continue in 2024 and 2025. Accordingly, global oil is projected to grow by another 2 mboe/d in 2024 and 1.7 mboe/d in 2025. The cumulative effect of these developments is that global oil demand will increase by 5.8 mboe/d between 2022 and 2025, reaching the level of 96.4 mboe/d in 2025 (Table 2.7).

Table 2.7
Oil demand by region, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	20.7	20.9	21.1	20.2	18.9	17.4	–3.3	–0.7	22.8	16.4
OECD Europe	11.9	11.9	11.5	10.5	9.4	8.5	–3.5	–1.5	13.2	8.0
OECD Asia–Pacific	6.9	6.9	6.6	6.0	5.4	4.9	–2.0	–1.5	7.6	4.6
OECD	**39.5**	**39.7**	**39.1**	**36.8**	**33.7**	**30.8**	**–8.7**	**–1.1**	**43.5**	**29.0**
China	14.1	15.8	16.7	17.0	17.3	17.4	3.4	0.9	15.5	16.4
India	5.1	5.8	7.3	8.7	10.1	11.6	6.5	3.6	5.6	10.9
OPEC	8.6	9.9	11.0	11.7	12.3	12.7	4.1	1.7	9.5	11.9
Other DCs	18.2	19.7	22.1	24.2	26.1	27.8	9.5	1.8	20.1	26.2
Russia	3.3	3.6	3.7	3.7	3.7	3.6	0.3	0.4	3.7	3.4
Other Eurasia	1.8	2.0	2.1	2.2	2.2	2.2	0.4	0.8	2.0	2.1
Non-OECD	**51.2**	**56.7**	**62.9**	**67.5**	**71.6**	**75.3**	**24.1**	**1.7**	**56.5**	**71.0**
World	**90.7**	**96.4**	**102.0**	**104.3**	**105.3**	**106.1**	**15.4**	**0.7**	**100.0**	**100.0**

Source: OPEC.

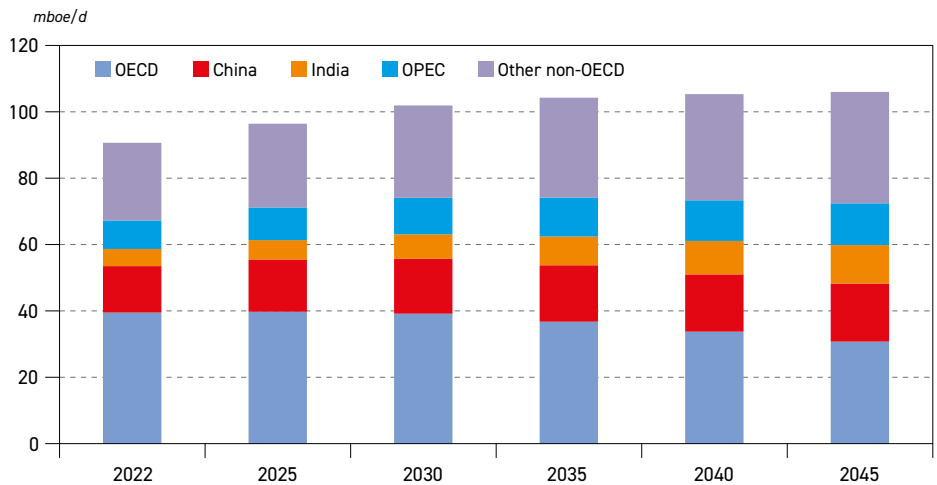
Significant demand growth is also set to continue beyond the initial years of the forecast period. The overall demand increase between 2025 and 2030 is 5.5 mboe/d. This incremental demand is set to decline somewhat in the second part of the forecast period, but it is still expected to be more than 2 mboe/d during the 2030–2035 period and remain in the range of 1 mboe/d during the last two five-year intervals.

There is a combination of factors that lead to some deceleration in long-term oil demand growth. The main ones include: oil substitution by biofuels, natural gas and electricity; the expanding penetration of EVs in the road transportation sector; efficiency improvements across all sectors of oil consumption; shifts towards less energy/oil intensive components in the composition of future GDP; and decelerating long-term population growth, among others. All these factors are discussed in more detail in Chapter 3.

The overall result of these developments is that primary oil demand increases from 90.7 mboe/d in 2022 to 102 mboe/d in 2030 and then further to 106.1 mboe/d in 2045. This represents an increase of 15.4 mboe/d. Even though this overall demand increase is somewhat lower than for solar, wind and natural gas combined, oil's already large demand base keeps it as the largest contributor to global energy requirements over the entire forecast period. Indeed, oil accounted for around 31% of global energy demand in 2022. Its share in the energy mix is set to increase slightly to almost 32% in 2035, before slowly declining to 29.5% in 2045. Nevertheless, this will still be the largest individual component of the global energy mix in 2045, more than 5 pp higher than the share of natural gas and almost three times higher than the contribution of solar and wind energy combined.

A breakdown of global oil demand by major regions is presented in Figure 2.5. It clearly shows that steady demand growth at the global level results from diverging trends at the regional level.

Figure 2.5
Oil demand by region, 2022–2045



Source: OPEC.

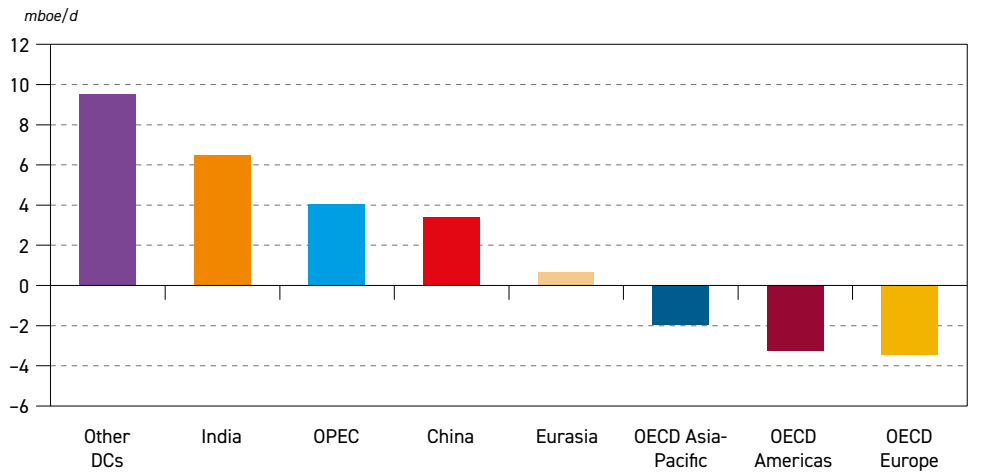
This is especially true when comparing OECD and non-OECD demand patterns. While demand for primary oil in non-OECD countries is projected to increase by 24.1 mboe/d between 2022 and 2045, a part of it will be offset by the demand decline in the OECD, which is expected to drop by 8.7 mboe/d.

Figure 2.6 provides some further details that re-emphasize this observation. Driven by high population growth and strong economic expansion in most developing countries, primary oil demand will see the largest increase in the group of 'Other Developing countries', followed by India. Oil demand in these two regions is set to increase by 9.5 mboe/d and 6.5 mboe/d, respectively.

The next largest contribution to future oil demand is expected from OPEC Member Countries. In this case, the demand increase is set to be stronger during the first part of the forecast period, growth expected to slow after 2035. Nevertheless, overall demand growth in OPEC Member Countries is forecast to be more than 4 mboe/d over the forecast period.

A similar pattern is envisaged for China, though this is even more concentrated in the first part of the forecast period. In this case, the strongest demand growth is projected in the period to 2025. Significant growth is also seen during the 2025–2030 period, but it then slows for the rest of the forecast period as oil substitution and the electrification of road transportation puts a cap on further demand growth. This will result in an overall demand increase of 3.4 mboe/d. Even lower incremental demand is expected from Eurasia, which witnesses a slight increase in the period to 2030, and then remains around this level thereafter. The overall increase in Eurasia (incl. Russia) is 0.7 mboe/d over the entire forecast period.

Figure 2.6
Incremental oil demand by region, 2022–2045



Source: OPEC.

Turning to the OECD, long-term primary oil demand is set to decline in all three sub-regions. The largest demand drop is projected for OECD Europe, where oil demand is anticipated to decline by 3.5 mboe/d between 2022 and 2045. This will be followed by OECD Americas, with a drop of 3.3 mboe/d. OECD Asia-Pacific is expected to add an additional 2 mboe/d to the OECD demand decline. The main factors leading to this demand drop, include the expanding penetration of EVs into the passenger fleet, policy driven oil displacement from industry and residential sectors, as well as technology driven efficiency improvements.

It is important to note that the figures shown in this chapter are not directly comparable with those shown in other chapters. There are two main reasons for this. Firstly, Chapter 2 uses energy equivalent units (mboe/d) to allow for a comparison between the different primary fuel types. In other chapters, however, oil is expressed in volumetric units of million barrels per day (mb/d). Secondly, the definition of oil in Chapter 2 is different from that used in Chapters 3 through 6. While Chapter 2 deals with primary energy sources, other chapters consider the outlooks for all liquid fuels. In that sense, in this chapter, biofuels is considered as biomass, coal-to-liquids (CTLs) as coal and gas-to-liquids (GTLs) as gas, but they are all part of the liquids outlook in Chapter 3 (and 4–6).

2.3.2 Coal

Coal demand increased slightly in 2022, driven by energy security concerns, the lack of available natural gas supplies and lower renewable and nuclear generation in some countries. Coal demand in 2022 was estimated at almost 76 mboe/d, which is close to the record high levels witnessed in 2015.

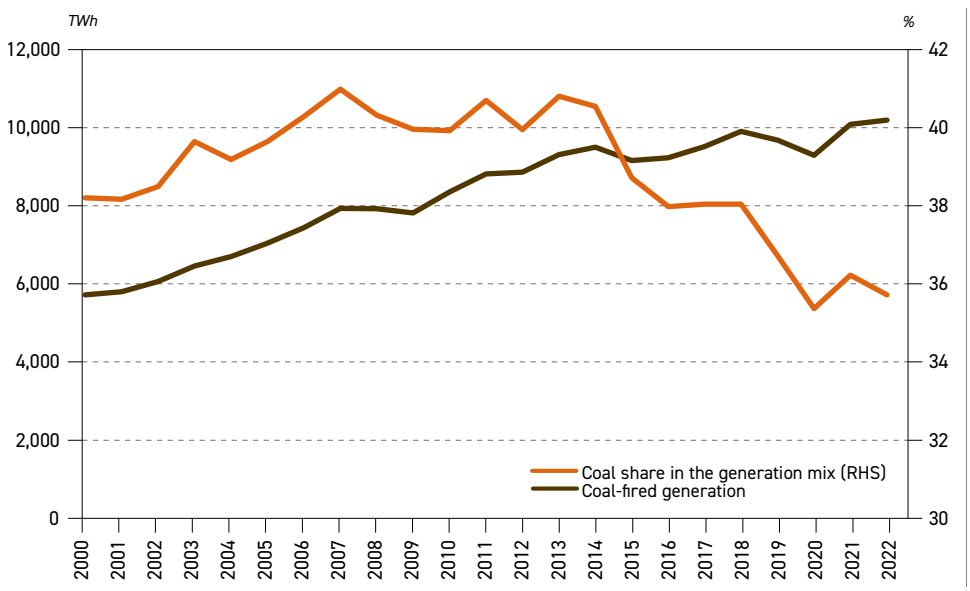
The energy crisis in 2022, insufficient gas supplies and extreme gas prices pushed many countries to reactivate their old, mothballed coal-fired plants (e.g. in Europe), in order to provide security of supply. In addition, the consequence of inadequate gas supplies led to the announcement of a large number of new coal-fired projects, especially in Asian developing countries with

domestic coal supplies. China alone has approved more than 100 GW of new coal-fired projects since early 2022. Pakistan, which suffered blackouts during 2022 due to insufficient gas supplies, plans to quadruple its coal-fired capacity to roughly 10 GW, from a current capacity of just below 2.5 GW. A similar strategy could be followed by Bangladesh and others. Countries like India, still rely heavily on coal power and are expected to expand its use in the years to come. All this could lead to increasing coal usage in the medium-term.

At the same time, energy and climate-change policies are putting pressure on coal usage in developed and developing countries, as many countries are committed to phase-out coal power. The rising share of renewables, natural gas and nuclear power are also expected to limit the load hours of coal plants.

However, it is important not to obfuscate the size and importance of coal-fired generation in today's power supply. Looking back, rising generation from renewables and gas in recent years has led to declining share for coal in the generation mix. From almost 41% in 2013, the share of coal in the mix declined to 36% in 2022 (Figure 2.7), mostly driven by energy policies. Nonetheless, in absolute terms, coal-fired generation has been on the rise since 2000 and reached almost 10,200 TWh in 2022, an all-time high. This occurred despite all the measures aimed at limiting coal use for power generation.

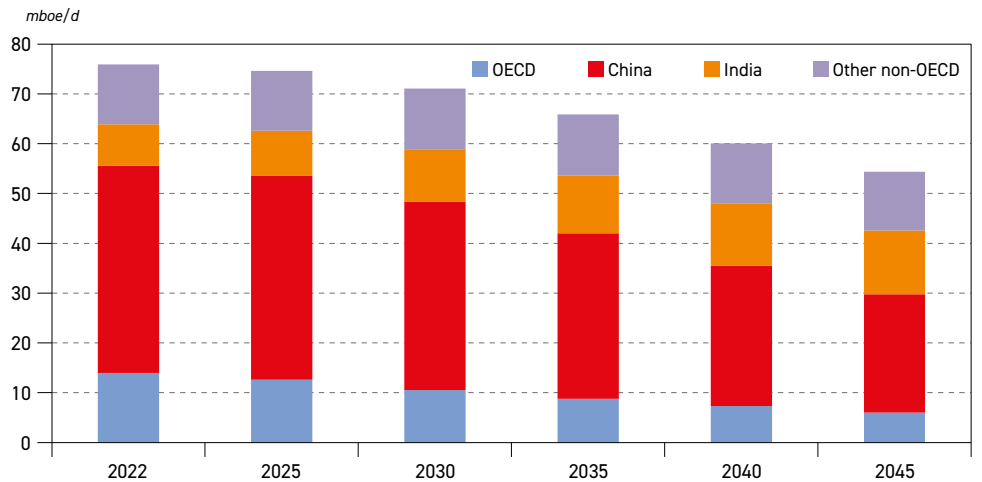
Figure 2.7
Coal-fired generation and share in the global generation mix



Source: Ember.

As shown in Figure 2.8 and Table 2.8, rising coal use in developing countries, in combination with downward pressure from substitution and coal plant decommissioning in the OECD, will likely lead to relatively stable medium-term demand. From almost 76 mboe/d in 2022, demand is set inch down to around 74.5 mboe/d in 2025. A larger impact from policies and substitution is expected after 2025, with global coal demand set to drop to

Figure 2.8
Coal demand by major region, 2022–2045



Source: OPEC

Table 2.8
Coal demand by region, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	5.4	4.8	3.9	3.2	2.5	1.9	–3.5	–4.4	7.1	3.5
OECD Europe	4.1	3.6	2.6	1.9	1.3	0.9	–3.2	–6.3	5.4	1.7
OECD Asia–Pacific	4.5	4.3	4.0	3.7	3.5	3.2	–1.3	–1.4	5.9	5.9
OECD	**14.0**	**12.6**	**10.5**	**8.8**	**7.3**	**6.0**	**–7.9**	**–3.6**	**18.4**	**11.1**
China	41.6	40.9	37.8	33.2	28.2	23.7	–17.9	–2.4	54.8	43.7
India	8.3	9.0	10.4	11.6	12.5	12.8	4.5	1.9	10.9	23.5
OPEC	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1
Other DCs	8.0	8.2	8.7	8.9	9.0	9.0	1.0	0.5	10.6	16.6
Russia	2.3	2.2	2.0	1.8	1.6	1.4	–0.9	–2.1	3.1	2.6
Other Eurasia	1.6	1.6	1.5	1.5	1.4	1.3	–0.3	–1.0	2.1	2.4
Non-OECD	**62.0**	**62.0**	**60.5**	**57.1**	**52.8**	**48.4**	**–13.6**	**–1.1**	**81.6**	**88.9**
World	**75.9**	**74.6**	**71.1**	**65.9**	**60.0**	**54.4**	**-21.5**	**-1.4**	**100.0**	**100.0**

Source: OPEC.

just below 66 mboe/d in 2035 and then further to 54.4 mboe/d in 2045. This represents a total decline of 21.5 mboe/d. Coal is the only primary fuel that declines throughout the outlook period.

There are two major contributors to the long-term decline in coal demand – China and OECD countries. China is expected to reduce its coal demand by almost 18 mboe/d between 2022

and 2045. This is likely the result of the country's policy to increase the supply of alternative energy sources and substitute coal with other renewables, hydro, nuclear and natural gas, especially in power generation.

As already mentioned, China has approved the construction of a hefty 120 GW of new coal power plants during 2022 and early 2023. In comparison, approved coal-fired capacities in 2021 were just below 20 GW. It is likely, however, that many of these new projects will be highly efficient and, once online, will replace old and inefficient units and thus reduce coal use. Ultra supercritical and supercritical coal plants can reach efficiencies of around 45% or even higher, which is significantly higher compared to the efficiencies of older plants at around 30%, with some even lower.

Finally, although currently uncertain, some coal plants could include CCUS facilities, which could prolong their lifetime and align them with environmental targets for 2030 and 2060. While the 14th FYP recognizes the importance of coal for domestic energy security, it also seeks to 'strictly control' coal consumption. The proclaimed target to reach a CO_2 emissions peak by 2030 will require cuts in coal demand from the middle of this decade onwards.

In OECD, coal demand is expected to decline from 14 mboe/d in 2022 to 6 mboe/d in 2045. As in China, coal in power generation will be largely substituted by additional renewables and nuclear power. Many OECD countries have committed themselves to the phase-out of coal power plants. Earlier in 2023, G7 countries agreed to speed up the phase-out of coal plants, without specifying a precise date. Germany, one of the largest coal consumers, failed to shift the phase-out date to 2030 from the earlier agreed 2038, partly because of energy security concerns.

In the US, coal-fired generation has been on a steady decline for around ten years, mainly substituted by natural gas and, to some extent, renewables. This has had an effect on numerous existing coal power plants, affecting their load factors and, consequently, their profitability. As a result, many coal plants are expected to close in the coming years. Almost 50 GW of coal-fired capacity (roughly 25% of the current operating capacity) could be closed by the end of this decade. Japan and Australia are also expected to reduce coal use. Japan sees a decline of coal in power generation to 19% by 2030, down from current levels of above 30%.

The only regions where coal demand is expected to increase are India and Other Developing countries. As already mentioned, rising energy demand, in combination with security of supply concerns and the local availability of coal, are set to be the major drivers of this increase. Coal demand in India is expected to increase by 4.5 mboe/d to reach 12.8 mboe/d in 2045. It is important to note that demand increases significantly to 2040, after which the growth is expected to slow down. In Other Developing countries, demand increases from 8 mboe/d in 2022 to 9 mboe/d by 2045, mostly in Asia.

2.3.3 Natural gas

The year 2022 was an extraordinary one for gas markets. It included the start of the conflict in Eastern Europe and the reduction of gas supplies from Russia to Europe, with a then reshuffling of LNG trade flows and Europe buying additional volumes. At the same time, the LNG market lacked the spare capacity to match soaring demand, which led to record high LNG spot

prices. TTF spot gas prices at the Title Transfer Facility in the Netherlands (TTF) increased briefly to levels above $95 per million British thermal units (MBtu) in late summer 2022. It averaged around 37 US$/Mbtu in 2022. This compares with average levels of around 15.5 US$/Mbtu in 2021 and only 3.1 US$/Mbtu in 2020. Similar spot price anomalies during 2022 were recorded in other hubs.

Due to record high prices, OECD Europe's overall gas demand declined by more than 12% in 2022. At the same time, and due to lower pipeline imports from Russia, Europe imported almost 175 billion cubic metres (bcm) of LNG in 2022, an all-time high. This was 32% of the global LNG market, significantly higher than a share of between 20% and 25% in the years prior. While Europe managed to secure sufficient gas supplies, many developing countries had to abstain from the LNG market, especially in the 2H22 due to high prices. Countries like Bangladesh, Pakistan and Brazil had to reduce LNG imports, which led to a lack of energy supplies and repeated electricity shortages. At the same time, gas demand in China was subdued due to COVID-19 restrictions, as well as high prices, leading to lower LNG imports there.

The overall net effect of the gas market distortions was negative global gas demand growth, with a drop of some 0.5% y-o-y. Regions, which registered gas demand drops, were OECD Europe, China, India and numerous countries in the developing world.

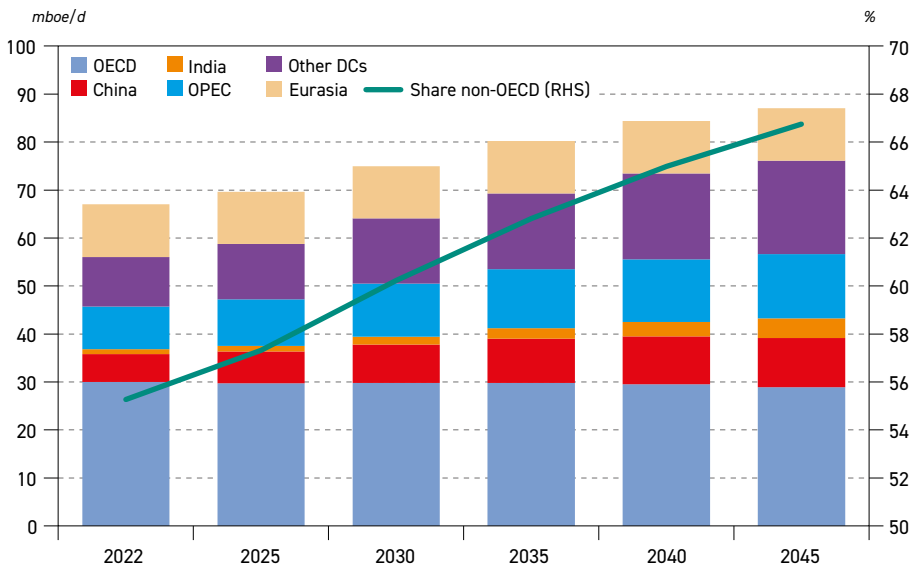
During 2023, the gas market stabilized partly due to the relatively warm winter in the Northern Hemisphere, which resulted in ample storage levels at the end of the heating season, relative to previous years. In addition, several new LNG terminals were commissioned, thus increasing the potential for LNG supply. Consequently, spot gas prices dropped to around 10 US$/Mbtu (Dutch TTF) in mid-2023. Nevertheless, the market has still been erratic, and could continue to be depending on weather-related demand during the upcoming winter season and possible disruptions of the remaining pipeline gas flows from Russia to Europe.

Uncertainties related to the security of gas supplies were the main reason for many countries reconsidering their long-term reliance on gas. Some countries have announced plans for the increased use of coal (e.g. in developing Asia), as well as the faster deployment of alternatives to natural gas, such as bio-methane, hydrogen and batteries. This is the main reason why the long-term gas outlook in the Reference Case has been revised down relative to the WOO 2022. Nevertheless, natural gas is expected to remain the backbone of energy and electricity systems in many countries due to ample availability, competitive cost levels, as well a relatively low carbon footprint and lower toxic particle emissions.

Figure 2.9 and Table 2.9 show the long-term demand outlook for natural gas in the Reference Case. Demand growth comes from the non-OECD, which increases by 21 mboe/d over the outlook period to reach 58.1 mboe/d. This growth is only partly offset by the expected small decline of 1.1 mboe/d in the OECD region. Consequently, global gas demand growth is set to reach 20 mboe/d, expanding from 67.1 mboe/d in 2022 to 87 mboe/d in 2045.

The largest individual drivers of this are China and India. China's gas demand is expected to increase from 5.8 mboe/d in 2022 to 10.2 mboe/d in 2045. Additional gas use will partly substitute coal in electricity generation and thus, help CO_2 emissions peak by 2030. Furthermore, natural gas will aid the balancing of the rising share of intermittent renewables in the power system. As mentioned earlier, China also links the prospects of strong natural gas demand growth to a potential increase in domestic supply.

Figure 2.9
Natural gas demand by region, 2022–2045



Source: OPEC.

Table 2.9
Natural gas demand by region, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	18.9	18.7	18.9	19.1	19.1	18.9	0.0	0.0	28.2	21.7
OECD Europe	7.4	7.4	7.3	7.1	6.8	6.4	–1.0	–0.6	11.1	7.4
OECD Asia–Pacific	3.7	3.6	3.6	3.6	3.6	3.6	0.0	–0.1	5.5	4.2
OECD	**30.0**	**29.7**	**29.8**	**29.8**	**29.6**	**28.9**	**–1.1**	**–0.2**	**44.7**	**33.3**
China	5.8	6.6	8.0	9.2	9.9	10.2	4.4	2.5	8.7	11.8
India	1.0	1.2	1.7	2.2	3.0	4.1	3.1	6.2	1.5	4.7
OPEC	8.9	9.7	11.0	12.2	13.0	13.4	4.5	1.8	13.3	15.4
Other DCs	10.3	11.5	13.6	15.8	17.9	19.5	9.2	2.8	15.4	22.4
Russia	8.1	7.9	7.6	7.4	7.2	6.9	–1.2	–0.7	12.1	7.9
Other Eurasia	2.9	3.0	3.2	3.5	3.7	4.0	1.1	1.4	4.3	4.6
Non-OECD	**37.1**	**39.9**	**45.2**	**50.4**	**54.8**	**58.1**	**21.0**	**2.0**	**55.3**	**66.7**
World	**67.1**	**69.6**	**75.0**	**80.2**	**84.4**	**87.0**	**20.0**	**1.1**	**100.0**	**100.0**

Source: OPEC.

India is active in the continued gasification of its energy system. Expanding city gas distribution systems are set to increase gas usage in the residential and commercial sectors. Gas can help reduce the traditional use of biomass, as well as potentially substitute some

liquefied petroleum gas (LPG) demand. Furthermore, initiatives that encourage natural gas vehicles may bring additional support. Assuming its strong long-term competitiveness, gas is expected to play a more important role in power generation. Currently, India's gas-powered power plants are used sub-optimally due to a lack of (domestic) gas supplies and have the potential to be ramped up in the future. In the Reference Case, India's gas demand more than triples in the outlook period, reaching levels of 4.1 mboe/d in 2045.

The OPEC region is another strong driver of gas demand, which is based on strong energy and electricity demand growth, combined with ample domestic supplies at competitive cost levels. OPEC's gas demand is expected to increase from just under 9 mboe/d in 2022 to 13.4 mboe/d in 2045. OPEC Member Countries are projected to increase the share of gas in their power generation mix, which will help to reduce more expensive oil-fired generation. This is why several countries are investing in gas projects, including Saudi Arabia, the United Arab Emirates, IR Iran and Iraq.

Finally, growth is expected in a number of developing countries in Asia, Africa and Latin America. Natural gas will help to reduce energy poverty and increase energy access, especially in African countries. Furthermore, natural gas is likely to help reduce the reliance on coal and support the expansion of renewables. Natural gas demand in Other Developing countries is forecast to increase from 10.3 mboe/d in 2022 to 19.5 mboe/d in 2045.

In the OECD, natural gas demand is expected to level off this decade, followed by a moderate decline thereafter. In the period to 2045, natural gas demand in OECD Europe is set to decline by 1 mboe/d. Due to the uncertainty of natural gas supplies from Russia, European countries are putting efforts into not only diversifying gas supplies, but also reducing gas demand. The RePowerEU programme aims to reduce gas usage for heating, increasing the share of renewables in the mix, decarbonizing industry and increasing its electrification. All these measures lead to negative gas demand growth in OECD Europe.

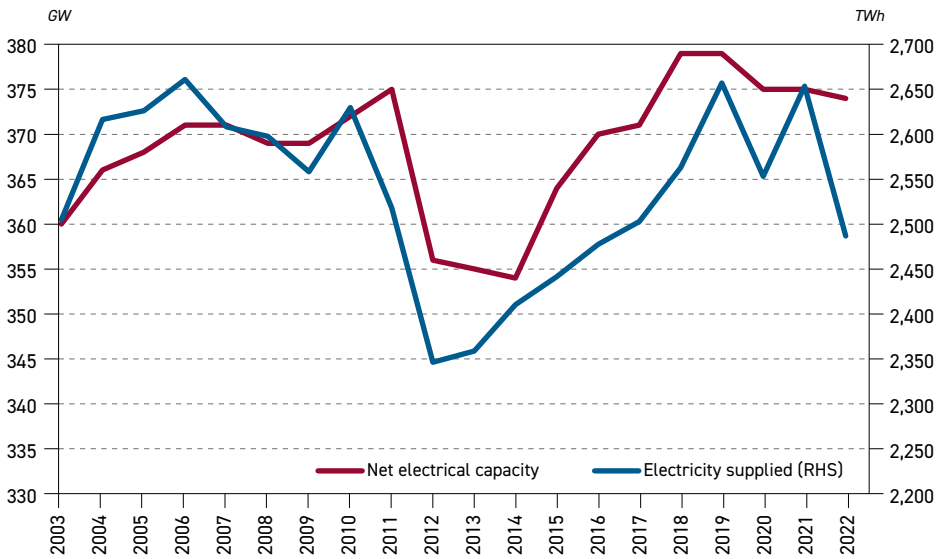
In OECD Americas, gas demand is expected to remain stable at around 19 mboe/d throughout the outlook period, supported by ample domestic supply at competitive prices, thus replacing coal in the electricity generation. OECD Asia-Pacific also sees relatively stable gas demand over the forecast period.

2.3.4 Nuclear

Nuclear power represented around 5.2% of global primary energy demand in 2022. Despite this relatively small share, nuclear power is extremely important for the power generation mix in several countries, especially OECD regions. Low variable costs, combined with a stable base and a low carbon footprint make it an important part of the overall energy mix.

According to the International Atomic Energy (IAEA), there are currently 410 nuclear power reactors in operation with total capacity of roughly 370 GW. There are 57 reactors (almost 60 GW) currently under construction, most of which are in Asia and Europe. Despite significant additions in recent years, the total nuclear net electrical capacity has not increased since 2019, as shown in Figure 2.10. Total net nuclear electrical capacity is now hovering around 375 GW down from a peak of almost 380 GW in 2018/19. Produced electricity dropped in 2022 because of lower capacity, as well as due to lower availability in some countries (e.g. France).

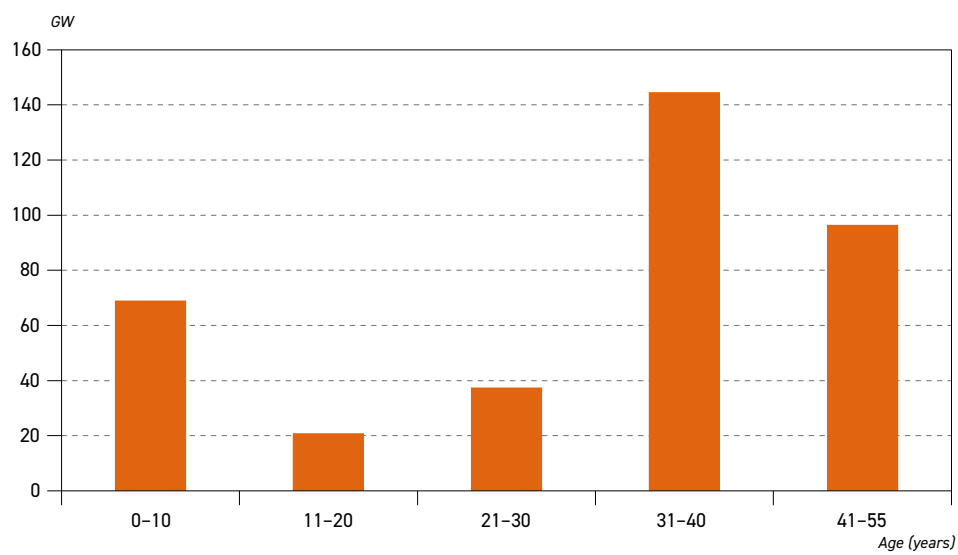
Figure 2.10
Nuclear net electrical capacity and electricity supplied



Source: IAEA.

It is important to note that much of the added new capacity in recent years was offset by the permanent shutdowns of ageing plants. For instance, from 2020 to today, a total of 22 GW of new capacity was connected to the grid, while at the same time 23 GW was permanently shut. Looking ahead, around 25% of nuclear power capacity is more than 40 years old and potentially approaching the end of its lifetime. Moreover, around 40% of nuclear power capacity is between 30 and 40 years old. This could be a challenge when looking to expand the role of nuclear power in the long-term.

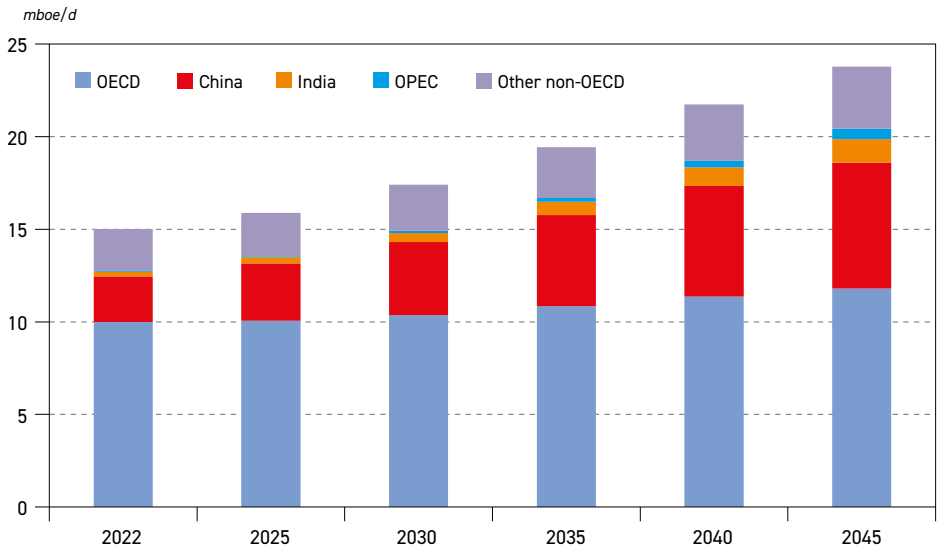
Figure 2.11
Nuclear net electrical capacity by age



Source: IAEA.

Despite the noted challenges, given the strong policy push the outlook assumes a robust increase in nuclear power in the Reference Case (Figure 2.12 and Table 2.10). Nuclear energy has gained much attention in recent years due its low carbon footprint and its ability to provide baseload power supply. Furthermore, security of supply concerns have also helped nuclear power attract

Figure 2.12
Nuclear energy demand by region, 2022–2045



Source: OPEC.

Table 2.10
Nuclear demand by region, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	4.9	4.8	4.9	5.0	5.1	5.2	0.3	0.2	32.7	21.7
OECD Europe	3.9	3.9	3.9	3.9	4.0	4.1	0.2	0.3	26.0	17.4
OECD Asia-Pacific	1.2	1.4	1.6	1.9	2.3	2.5	1.3	3.3	7.9	10.5
OECD	**10.0**	**10.1**	**10.4**	**10.8**	**11.4**	**11.8**	**1.8**	**0.7**	**66.6**	**49.6**
China	2.5	3.1	3.9	4.9	6.0	6.8	4.3	4.5	16.3	28.6
India	0.3	0.3	0.5	0.7	1.0	1.3	1.0	7.1	1.8	5.4
OPEC	0.0	0.1	0.1	0.2	0.3	0.6	0.5	12.2	0.3	2.4
Other DCs	0.4	0.4	0.5	0.5	0.6	0.6	0.2	1.8	2.8	2.6
Russia	1.3	1.3	1.3	1.4	1.6	1.7	0.5	1.4	8.3	7.3
Other Eurasia	0.6	0.6	0.7	0.8	0.9	1.0	0.4	2.3	3.9	4.1
Non-OECD	**5.0**	**5.8**	**7.0**	**8.6**	**10.4**	**12.0**	**7.0**	**3.9**	**33.4**	**50.4**
World	**15.0**	**15.9**	**17.4**	**19.4**	**21.7**	**23.8**	**8.8**	**2.0**	**100.0**	**100.0**

Source: OPEC.

additional interest. This is why many countries have intensified interest to invest in new nuclear power plants, such as OECD regions, but also several developing countries too. Global nuclear demand is projected to increase by nearly 9 mboe/d and reach almost 24 mboe/d in 2045.

Almost half of the global increase in nuclear demand is projected to materialize in China. Nuclear power is set to become an increasingly important energy source for China if it is to reach a peak in CO_2 emissions. Furthermore, as an important provider of base load power, nuclear power will be a substitute for coal power plants in the generation mix. This will help to provide balance to the power generation system. According to the 14th FYP, China is expected to reach 70 GW of installed nuclear capacity by 2025. There is almost 22 GW of nuclear capacity currently under construction in China.

Nuclear demand in India is expected to increase by 1 mboe/d to 2045, from around 0.3 mboe/d in 2022. The Indian government has ambitious plans to more than triple installed nuclear capacity to 22.5 GW by 2031. In OPEC countries, nuclear power is expected to reach 0.5 mboe/d in 2045, as several Member Countries have started investing in nuclear energy. Additional nuclear energy is expected in Russia and Other Eurasia, totalling almost 1 mboe/d.

In the OECD, the largest increase in nuclear power is projected for OECD Asia-Pacific. This is in line with the restart of nuclear power plants in Japan, which has also adopted a plan to extend the lifetime of some nuclear reactors beyond 60 years. In addition, several new plants in Japan and South Korea are under construction. In the long-term, nuclear power demand in OECD Americas and OECD Europe is expected to increase by 0.3 mboe/d and 0.2 mboe/d, respectively. Several countries are planning to renew their nuclear power plant fleets, including France and the UK. Poland plans an expansion of nuclear power through both small and large reactors.

2.3.5 Hydro

Around 34 GW of new hydropower capacity (including pumped hydro) was installed in 2022, the highest level since 2016. With around 4,400 terawatt hours (TWh) of generated electricity in 2022, hydropower accounted for around 15% of the global electricity generation. The expansion of hydropower is set to continue in the future with large resources available particularly in the developing regions of Asia, Africa and Latin America. Globally, around 130 GW of hydro capacity is under construction and 160 GW is planned. However, due to high capital costs and long lead times for many hydro projects, the build-up of hydropower is rather a slow process. Nevertheless, hydropower remains an important part of the mix as a large number of hydro plants (accumulation and pumped storage) can be used for balancing purposes.

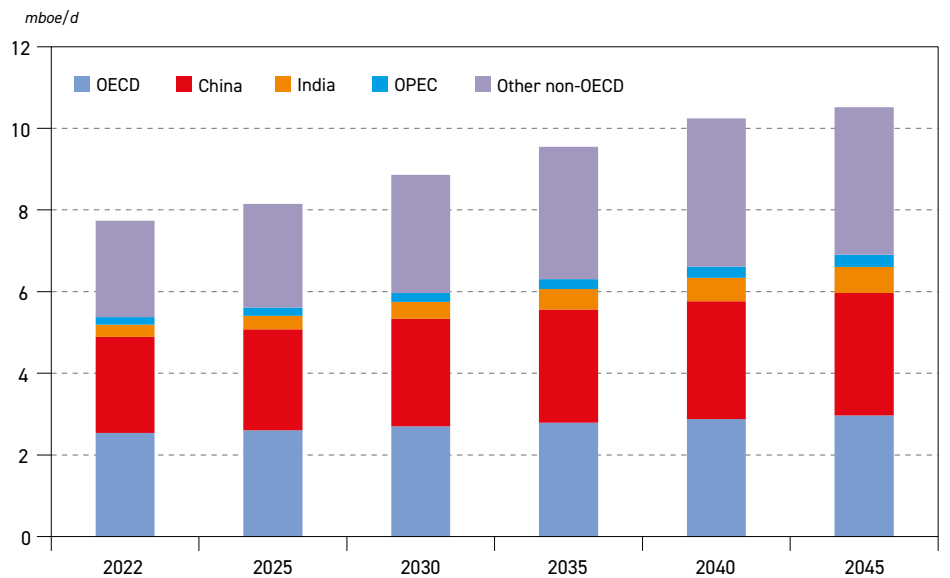
The Reference Case sees hydropower demand increasing from 7.7 mboe/d in 2022 to 10.5 mboe/d in 2045 (Table 2.11 and Figure 2.13), representing an increase of 2.8 mboe/d. The largest increment in the outlook period is expected in China with 0.6 mboe/d. During 2022, China commissioned almost 24 GW of hydropower capacity of which 8.7 GW was pumped hydro. This included the finals stages of its large Baihetan hydropower plant with total installed capacity of 16 GW of installed capacity. The trend is projected to continue with the large unutilized resources and with a significant number of hydropower projects in the pipeline. Hydropower demand is forecast to increase in Other Developing Countries, as well as India. The incremental cumulative demand for these regions to 2045 is projected at 1.4 mboe/d, to reach 3.5 mboe/d in 2045.

Table 2.11
Hydro demand by region, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	1.3	1.3	1.4	1.4	1.5	1.6	0.3	0.9	16.4	14.9
OECD Europe	1.0	1.1	1.1	1.1	1.1	1.2	0.1	0.4	13.6	11.0
OECD Asia-Pacific	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.6	2.8	2.3
OECD	**2.5**	**2.6**	**2.7**	**2.8**	**2.9**	**3.0**	**0.4**	**0.7**	**32.8**	**28.2**
China	2.4	2.5	2.6	2.8	2.9	3.0	0.6	1.1	30.5	28.5
India	0.3	0.3	0.4	0.5	0.6	0.6	0.3	3.3	3.9	6.1
OPEC	0.2	0.2	0.2	0.2	0.3	0.3	0.1	2.0	2.4	2.8
Other DCs	1.8	2.0	2.3	2.6	3.0	2.9	1.1	2.1	23.3	27.5
Russia	0.4	0.4	0.4	0.4	0.5	0.5	0.1	1.0	4.9	4.5
Other Eurasia	0.2	0.2	0.2	0.2	0.2	0.2	0.1	1.5	2.3	2.3
Non-OECD	**5.2**	**5.5**	**6.2**	**6.8**	**7.4**	**7.6**	**2.4**	**1.6**	**67.2**	**71.8**
World	**7.7**	**8.2**	**8.9**	**9.6**	**10.2**	**10.5**	**2.8**	**1.3**	**100.0**	**100.0**

Source: OPEC.

Figure 2.13
Hydro demand by region, 2022–2045



Source: OPEC.

In OECD Americas, hydro demand is set to increase by roughly 0.3 mboe/d to 1.6 mboe/d in 2045. North America still has sufficient hydro resources to support this growth. In addition, hydro projects are likely to benefit from the IRA in the US, adopted in 2022, as well as Canada's

2023 budget that has supportive tax schemes. In OECD Europe, the expansion of hydropower is limited as the available resources are mostly utilized. Total hydropower demand in this region is anticipated to reach 1.2 mboe/d in 2045, inching up from 2022 levels.

2.3.6 Biomass

With a share of around 9% in 2022, biomass is currently the largest non-fossil fuel energy source in the global primary energy mix. A large part of biomass is currently consumed in developing countries and regions, such as South Asia and sub-Saharan Africa in the form of traditional applications for residential heating and cooking. Through the alleviation of energy poverty and increasing access to more modern energy sources, it can be assumed that demand for traditional biomass will drop further in the future.

At the same time, demand for advanced biomass and its derivatives is likely to increase, particularly in developed countries, as they seek to meet ambitious climate change targets. Advanced applications of biomass include producing biofuels and biogas, providing residential and industrial heat, and generating electricity. The drivers of this trend are energy market regulations and continuous subsidies.

The growth potential of biomass as an energy source is limited by resource availability. This includes the conflict over the use of agricultural land for food or biomass production, but also the increasing demand for land for nature-based solutions, which are considered as a measure to ensure healthy ecosystems. In addition, the emergence of bio-refining concepts, which envisage the use of biomass to produce fibres, proteins and basic chemicals, could put further pressure on the availability of biomass for energy applications.

In this outlook (Table 2.12 and Figure 2.14), the average growth of global biomass energy demand is projected at 1.2% p.a. for the forecast period, resulting in global demand of 35.2 mboe/d by 2045. This represents roughly a 10% share of global primary energy demand at the

Table 2.12
Biomass demand by region, 2022–2045

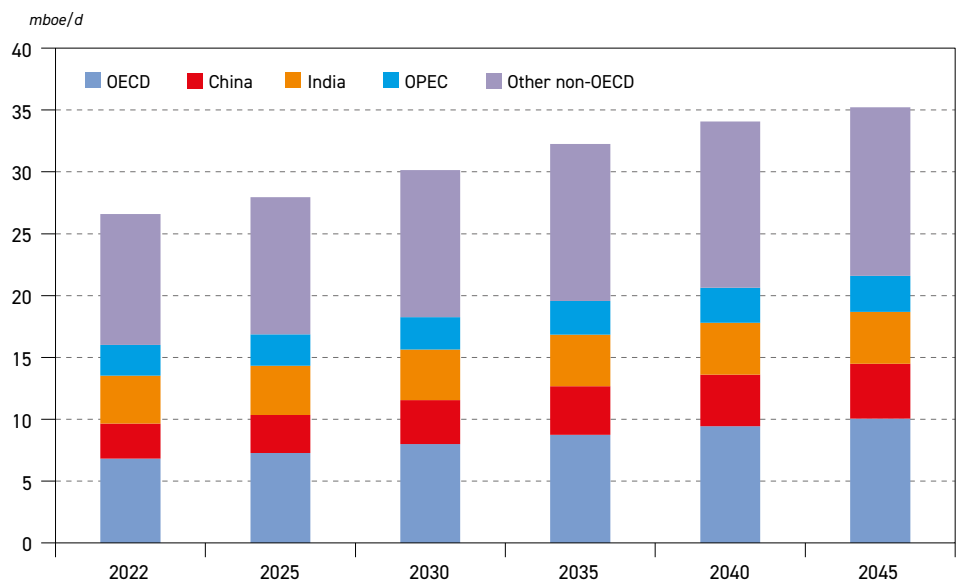
	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	2.8	3.0	3.2	3.5	3.7	4.0	1.2	1.6	10.6	11.4
OECD Europe	3.4	3.7	4.1	4.5	4.9	5.2	1.8	1.9	12.9	14.8
OECD Asia-Pacific	0.6	0.6	0.7	0.7	0.8	0.8	0.2	1.5	2.1	2.3
OECD	**6.8**	**7.3**	**8.0**	**8.7**	**9.4**	**10.1**	**3.2**	**1.7**	**25.6**	**28.5**
China	2.8	3.1	3.6	3.9	4.2	4.4	1.6	2.0	10.6	12.6
India	3.9	4.0	4.1	4.2	4.2	4.2	0.3	0.4	14.6	11.9
OPEC	2.5	2.5	2.6	2.7	2.8	2.9	0.4	0.7	9.4	8.2
Other DCs	10.0	10.5	11.3	12.0	12.6	12.7	2.7	1.0	37.8	36.0
Russia	0.2	0.2	0.3	0.3	0.4	0.4	0.2	3.0	0.8	1.2
Other Eurasia	0.3	0.3	0.4	0.4	0.5	0.5	0.2	2.2	1.2	1.5
Non-OECD	**19.8**	**20.7**	**22.2**	**23.5**	**24.6**	**25.2**	**5.4**	**1.1**	**74.4**	**71.5**
World	**26.6**	**27.9**	**30.2**	**32.3**	**34.1**	**35.2**	**8.6**	**1.2**	**100.0**	**100.0**

Source: OPEC.

end of the forecast period. The increased use of biomass is anticipated in both OECD and non-OECD countries to meet low-carbon energy initiatives. The intensified policy focus on energy security also supports growing demand for biomass.

Figure 2.14 shows the projected development of biomass demand and its regional distribution. In the OECD, biomass is used mainly for heating, electricity generation and the production of liquid and/or gaseous biofuels. However, the demand for biomass will need to increase to meet future policy targets. This is particularly the case in the aviation and shipping sectors.

Figure 2.14
Biomass demand by region, 2022–2045



Source: OPEC.

In OECD Europe, biomass demand is expected to increase from 3.4 mboe/d in 2022 to 5.2 mboe/d in 2045. This growth is being driven by policies that require increasing levels of biofuels in the transport sector, including SAF for aviation, as well as increasing demand for biogas production, which is expected to partly replace natural gas in the future. As the sustainability of biomass has come under increasing scrutiny, the EU has sought to improve the sustainability criteria for bioenergy by banning the use of biomass from primary and highly biodiverse forests and implementing a cascading principle for biomass. Under the cascade principle, woody biomass has priority for use in wood-based products before it can be burned for energy purposes.

In OECD Americas, biomass demand is projected to increase by about 1.2 mboe/d, reaching 4 mboe/d in 2045. In addition to ethanol production, the US is supporting efforts to increase the production of SAF from biomass to meet 100% of aviation fuel demand by 2050. Canada's Clean Fuel Regulations, which require fuel suppliers to gradually reduce the carbon content of their fuels, are also expected to increase demand for biofuels in the country.

In non-OECD, the largest rise in biomass use is expected in China, which increases by 1.6 mboe/d over the outlook period. It will be supported by the replacement of coal with solid biomass in existing plants, an increase in biofuels for transport, and the advanced use of biomass for biogas and electricity and/or heat generation. Traditional biomass use for residential heating is projected to decline as biomass is replaced by oil and gas. The share of biomass in China's energy mix increases from 4% in 2022 to almost 6% by 2045.

In India, biomass use is expected to increase by some 0.3 mboe/d in the period to 2045. The share of biomass in primary energy demand is expected to decline from 14.6% to 12%. This mirrors the expected decline in the traditional use of biomass and its replacement by more modern energy sources. The modern use of biomass for power generation and biofuels is growing, resulting in a modest net-growth. The recent amendment to India's National Policy on Biofuels is focused on reducing the import of petroleum products and advancing the deadline to reach a blending target of 20% biofuel from 2030 to 2025/2026. Biofuels play an important role in India's strategy as it also supports the ambitious targets of doubling farmers' income and reducing air pollution.

2.3.7 Other renewables

Other renewables (predominantly wind and solar, but also geothermal and tidal) have witnessed strong growth in recent years. According to the International Renewable Energy Agency, the installed capacity increased by around 265 GW, of which 75 GW was wind capacity and 190 GW solar capacity. The largest addition was recorded in China, which added almost 125 GW of combined solar and wind capacity in 2022, far higher than any other country.

In the ranking of countries, China is the number one country in terms of installed solar and wind capacity. According to the International Renewable Energy Agency (IRENA), China's total installed solar and wind capacities in 2022 were 393 GW and 366 GW, respectively. China's share in total installed wind and solar capacity is around 41% and 37%, respectively.

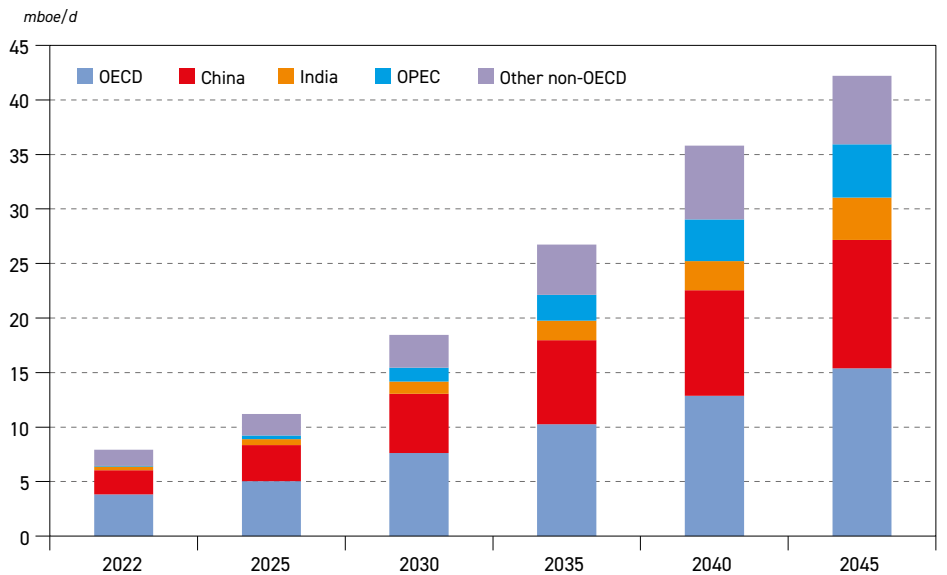
In 2023, many countries have scaled up their commitments and targets related to wind and solar capacities. This should help to not only substitute coal and/or gas in power generation and thus reduce CO_2 emissions, but also facilitate a higher degree of energy security. Despite recent problems with supply chains and inflationary trends, which pushed wind and solar costs higher during 2022, it is expected that levelized generation costs will continue to decline in the long-term, albeit at rates not seen in the past. This is due to continuous technological and efficiency improvements, as well as economies of scale.

Nevertheless, while levelized generation costs are an important factor in the competitiveness of renewables, they ignore the costs of system integration. The rising share of intermittent energy sources in the generation mix requires significantly higher levels of balancing and ancillary services provided by dispatchable power plants and demand side measures, as well as storage (e.g. batteries and/or hydrogen). Additional renewable capacities require significant additional investments in transmission and distribution capacities, which have to provide sufficient capacity during peak load hours from wind and solar plants. Insufficient investment in balancing options and grids may lead to negative electricity prices and production curtailments, thus hindering further investments into power generation capacities. This is why the real cost of production of wind and solar plants can be significantly higher than the levelized costs of production. It will often depend on local power market circumstances.

The Reference Case projects strong medium- and long-term growth of other renewables across all regions. Demand is expected to increase from nearly 8 mboe/d in 2022 to above 42 mboe/d in 2045. This represents growth of 34.3 mboe/d, or average growth of 7.5% p.a. over the outlook period. Other renewables show the largest incremental demand additions, as well as the fastest growth due to its low 2022 base.

Figure 2.15 and Table 2.13 show the long-term outlook for other renewables by region. China is expected to see the highest incremental demand for other renewables of around 9.5 mboe/d. China's efforts to reach a CO_2 emissions peak by 2030 and carbon neutrality by 2060 are the major driver of this increase. In addition, China has become the major producer of solar panels, wind turbines, batteries and other related equipment, lowering costs through economies of scale and continuous innovation.

Figure 2.15
'Other renewables' demand by region, 2022–2045



Source: OPEC.

India is projected to increase its other renewables demand by 3.6 mboe/d from only 0.3 mboe/d in 2022. The official target of 500 GW of installed renewable capacity (mostly wind and solar) by 2030 requires a much faster deployment of renewables compared to recent years.

In OPEC Member Countries, other renewables demand is projected at almost 5 mboe/d in 2045, up from only 0.1 mboe/d in 2022. This represents average annual growth of around 21.5%. Many countries in the Middle East, including Saudi Arabia and the United Arab Emirates have announced ambitious medium- and long-term targets related to renewables, especially solar. Renewables should help to diversify electricity supply and reduce the consumption of oil in electricity generation.

Table 2.13
'Other renewables' demand by region, 2022–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2022	2025	2030	2035	2040	2045	2022–2045	2022–2045	2022	2045
OECD Americas	1.4	1.9	3.1	4.3	5.6	6.9	5.5	7.1	18.0	16.4
OECD Europe	1.9	2.4	3.4	4.3	5.0	5.7	3.8	5.0	23.6	13.5
OECD Asia-Pacific	0.5	0.8	1.2	1.7	2.2	2.8	2.2	7.4	6.7	6.5
OECD	**3.8**	**5.0**	**7.6**	**10.3**	**12.9**	**15.4**	**11.6**	**6.2**	**48.3**	**36.5**
China	2.2	3.3	5.4	7.7	9.7	11.8	9.5	7.5	28.0	27.9
India	0.3	0.6	1.1	1.8	2.7	3.9	3.6	11.5	4.0	9.2
OPEC	0.1	0.3	1.3	2.4	3.8	4.9	4.8	21.6	0.7	11.5
Other DCs	1.4	1.9	2.7	4.1	5.7	4.5	3.1	5.2	17.9	10.8
Russia	0.0	0.0	0.1	0.2	0.4	0.6	0.6	17.8	0.2	1.3
Other Eurasia	0.1	0.1	0.2	0.4	0.7	1.2	1.1	13.6	0.8	2.8
Non-OECD	**4.1**	**6.2**	**10.8**	**16.5**	**22.9**	**26.8**	**22.7**	**8.5**	**51.7**	**63.5**
World	**7.9**	**11.2**	**18.5**	**26.7**	**35.8**	**42.2**	**34.3**	**7.5**	**100.0**	**100.0**

Source: OPEC.

Other Developing countries (mostly Asia and Africa) are expected to increase demand for other renewables from 1.4 mboe/d in 2022 to 4.5 mboe/d in 2045. The expansion of other renewables will help to address issues related energy access and energy poverty through more distributed generation.

In the OECD, other renewables are projected to increase by 11.6 mboe/d, based on strong policy support and energy security concerns. In OECD Americas, demand is seen increasing by 5.5 mboe/d to almost 7 mboe/d in 2045. The IRA with generous tax credits, supports the expansion of wind and solar power. In addition, the vast available resources also help to increase wind and solar capacity at a much faster rate than in OECD Europe or OECD Asia-Pacific.

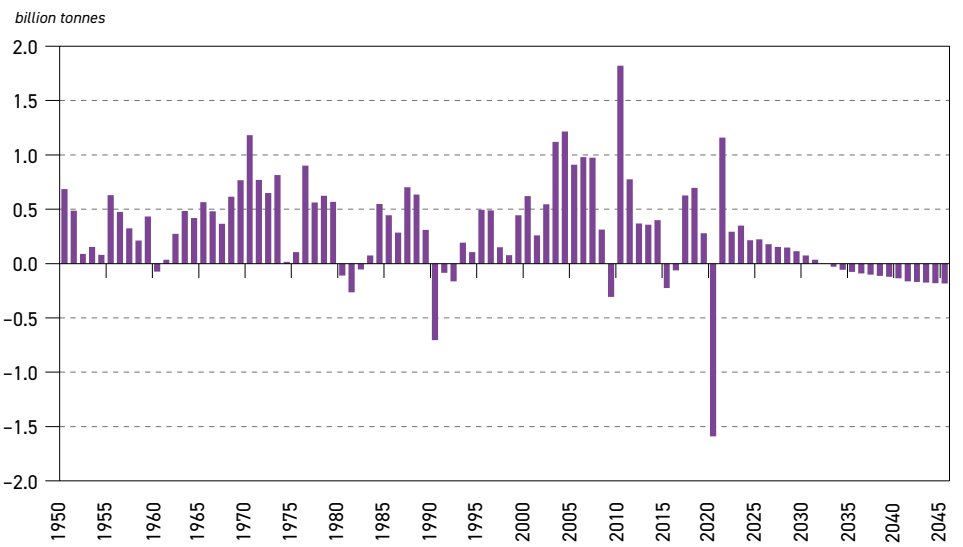
In OECD Europe, other renewables are forecast to increase to 5.7 mboe/d in 2045, up from just below 2 mboe/d. The EU Green Deal, as well as the RePowerEU programme, seek to strongly increase the share of renewables in the medium- and long-term. A rising number of projects in the North Sea will support this development. Earlier this year a number of North Sea countries signed an agreement to add 120 GW of offshore wind by 2030 and to reach at least 300 GW by 2050. In OECD Asia-Pacific, other renewables is set to reach 2.8 mboe/d in 2045, up from 0.5 mboe/d in 2022. Japan aims to reach a renewables share of 36–38% in the electricity mix by 2030 with more optimistic prospects for the long-term. Similarly, South Korea plans to boost the share of renewables in its electricity mix to 30.6% in 2036, up from 7.5% in 2021.

2.4 Energy related CO_2 emissions

Following the wide swings in annual energy-related CO_2 emissions in 2020 and 2021, when COVID-19 induced lockdowns resulted in the largest ever annual emissions decline of more

than 1.5 billion tonnes (bt) in 2020, recent data indicates that CO_2 emissions growth has stabilized at significantly lower levels, when compared to the average growth over the past 20 years. This is presented in Figure 2.16. Looking forward, the figure also shows that global CO_2 emissions will likely continue to grow during the current decade, albeit at decelerating rates, and approach a peak sometime around 2030.

Figure 2.16
Annual change in energy related CO_2 emissions, 1950–2045



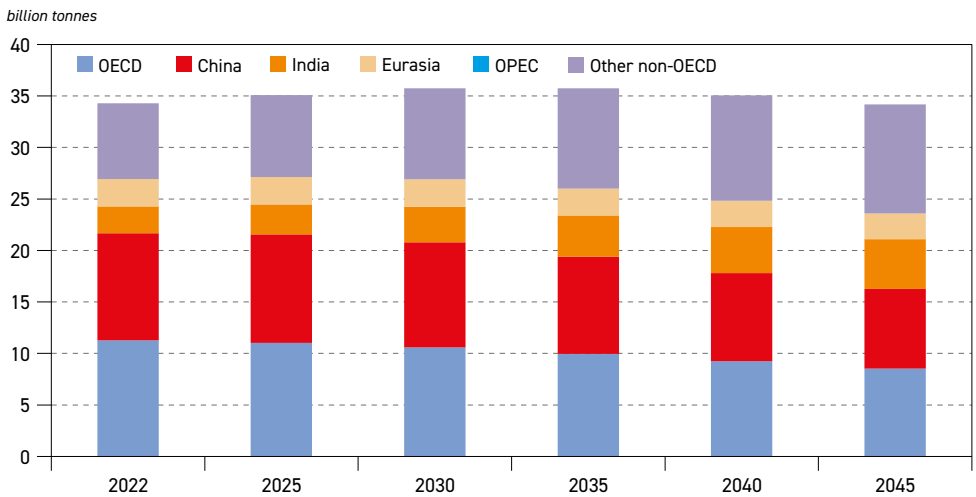
Source: OPEC.

In absolute terms, annual energy-related CO_2 emissions reached around 34.3 bt in 2022 and are projected to reach 35.7 bt by 2035. Afterwards, they are set to slowly decline for the rest of the forecast period to 34 bt by 2045. This projected reversal to declining global annual emissions is a welcome development, although more efforts are required to accelerate the decline to rates consistent with the goals of the Paris Agreement.

The regional perspective in terms of energy-related emissions are presented in Figure 2.17. Reflecting the projections for future energy demand, this figure shows a distinct pattern for OECD and China compared to other developing countries, including India. Driven by population growth, economic development, efforts to improve the level of energy access and eradicate energy poverty, as discussed in detail in the previous parts of this chapter, CO_2 emissions in 'Other non-OECD' and India will continue growing. The largest emissions increase over the forecast period is projected for 'Other non-OECD', which includes all African countries, as well as several large developing economies in Latin America. Therefore, annual energy-related CO_2 emissions in this region are projected to increase by more than 3 bt between 2022 and 2045. Similarly, the expanding energy needs of India will result in an annual increase in CO_2 emissions of 2.2 bt during the same period, despite significant growth in renewables, nuclear and hydropower.

Emissions growth in these regions will be more than offset by declines in the other two regions, OECD and China. In fact, with the exception of a few years (mainly after the

Figure 2.17
Energy-related annual CO_2 emissions by region, 2022–2045



Source: OPEC.

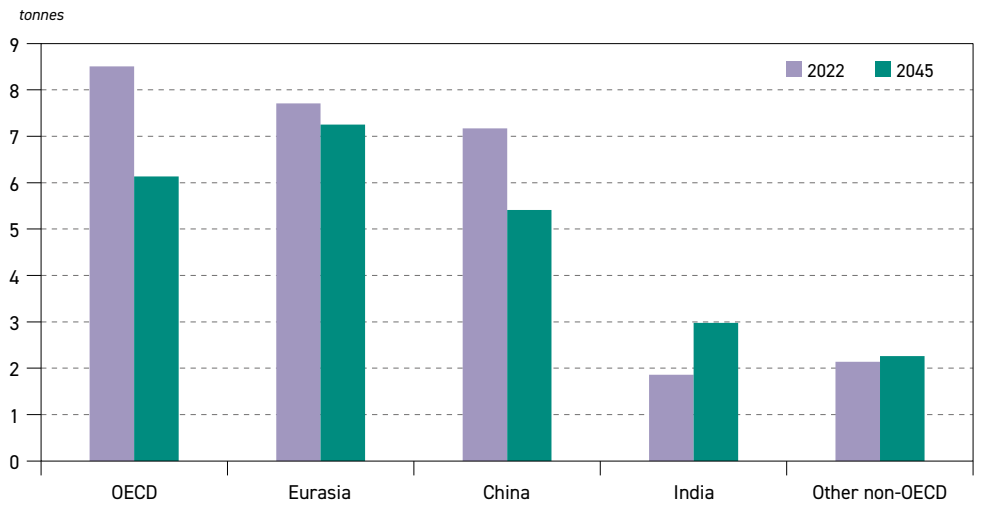
COVID-19 pandemic), OECD emissions have been on a declining trend since the recovery from the financial crisis in 2008. This pattern is expected to continue for the entire forecast period on the back of declining demand for all fossil fuels and strong growth in renewable energy.

Energy-related emissions in China are projected to increase marginally in the next few years, but are then set to peak sometime around 2025 and then decline for the rest of the forecast period. The overall change is comparable to the OECD, since 2045 annual CO_2 emissions in China are projected to be lower by 2.7 bt, compared to 2022 levels. However, the contributing elements to this decline are different when compared to the OECD. In the case of China, oil and gas demand are set to increase over the forecast period. Therefore, related CO_2 emissions will also increase. This rise however, will be more than compensated by declining CO_2 emissions from coal, which are estimated to drop by 3.5 bt between 2022 and 2045.

A marginal decline in future CO_2 emissions is also expected for the Eurasia region, at 0.2 bt between 2022 and 2045. This decline is primarily driven by falling coal and gas demand in Russia, while other countries in the region will likely see a minor increase in CO_2 emissions over the forecast period.

It is important to note, however, that the contrasting picture between declining emissions in OECD and China and rising emissions in other developing countries, when expressed in absolute terms, tells only half of the story. It is equally important to look at emissions on a per capita basis. From this perspective, as presented in Figure 2.18, the pattern changes dramatically. It shows that, despite rising emissions in developing countries, per capita CO_2 emissions hardly change in 'Other non-OECD' and only slightly increase in the case of India. Moreover, this figure shows that per capita emissions in OECD will remain 2–3 times higher than those in 'Other non-OECD' and India. This ratio would even increase if compared to per capita emissions in Eurasia.

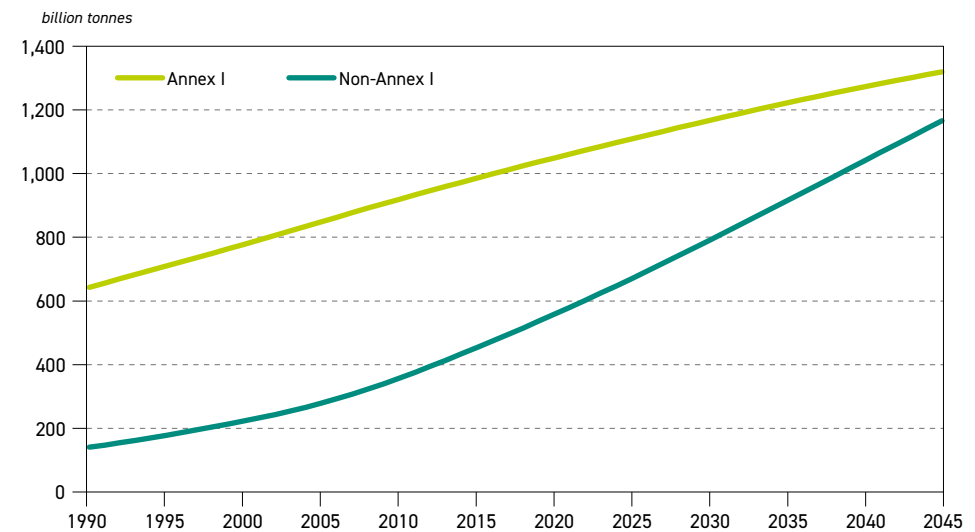
Figure 2.18
Per capita CO_2 emissions by region, 2022 and 2045



Source: OPEC.

This disproportional share in the contribution of global CO_2 emissions between developed and developing countries is also demonstrated in Figure 2.19. It shows that cumulative CO_2 emissions of Annex I countries since 1900 increased from around 640 bt in 1990 to more than 1 gigatonnes (Gt) in 2022 and are projected to further increase to 1.3 Gt in 2045. Moreover, since 1900, they have been consistently at significantly higher levels than those from non-Annex I.

Figure 2.19
Cumulative CO_2 emissions since 1900, 1990–2045



Source: OPEC.

Although this difference will narrow in the future on the back of rapid energy demand growth in many developing countries, cumulative energy-related CO_2 emissions of Annex I countries will consistently remain above those generated by non-Annex I countries. This underscores the historic responsibility of Annex I countries.

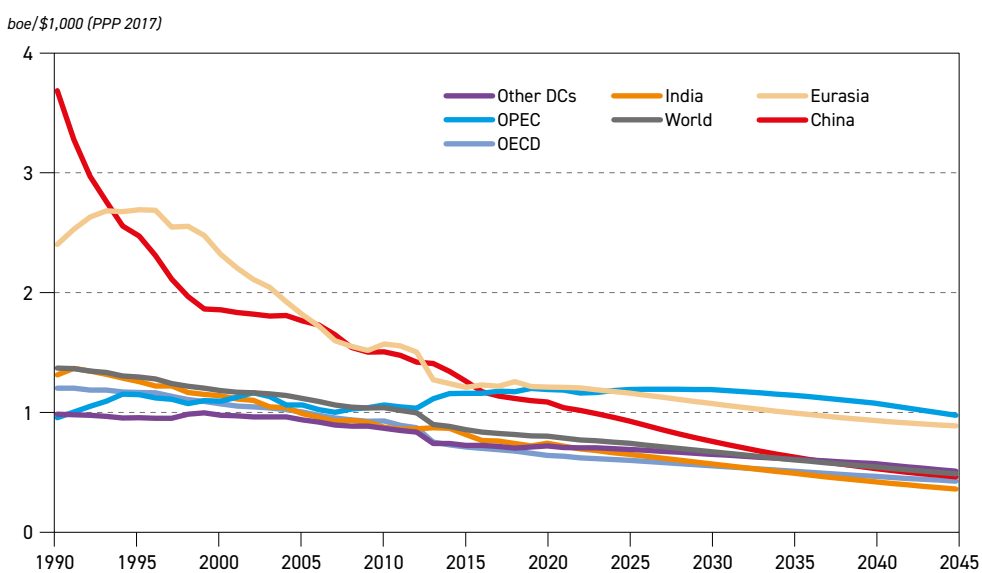
2.5 Energy intensity and consumption per capita

This subsection highlights the evolution and projections of energy intensity globally and in selected regions. Energy intensity is defined as the ratio of energy used per unit of GDP and is a measure commonly used to assess the energy efficiency of an economy. When energy efficiency increases, energy intensity decreases, indicating that more economic value is obtained from each unit of energy consumed.

However, energy intensity figures and trends vary across regions and countries due to several factors. These include economic structure, level of economic development, demographics, climate, and urbanization levels. These factors introduce complexities that need to be considered to gain a comprehensive understanding of the energy efficiency landscape.

Global energy intensity trends (Figure 2.20) indicate that despite the global economy being approximately three times larger in 2022, compared to 1990, energy demand only increased by a factor of 1.7. This demonstrates the positive impact energy efficiency improvements achieved over this period. Those improvements can be largely attributed to technological advancements, policy involvements and renewable energy deployment, such as wind and solar, which have played a crucial role in improving energy efficiency and reducing the amount of energy required to produce a unit of GDP.

Figure 2.20
Evolution and projections of energy intensity in major world regions, 1990–2045



Source: OPEC.

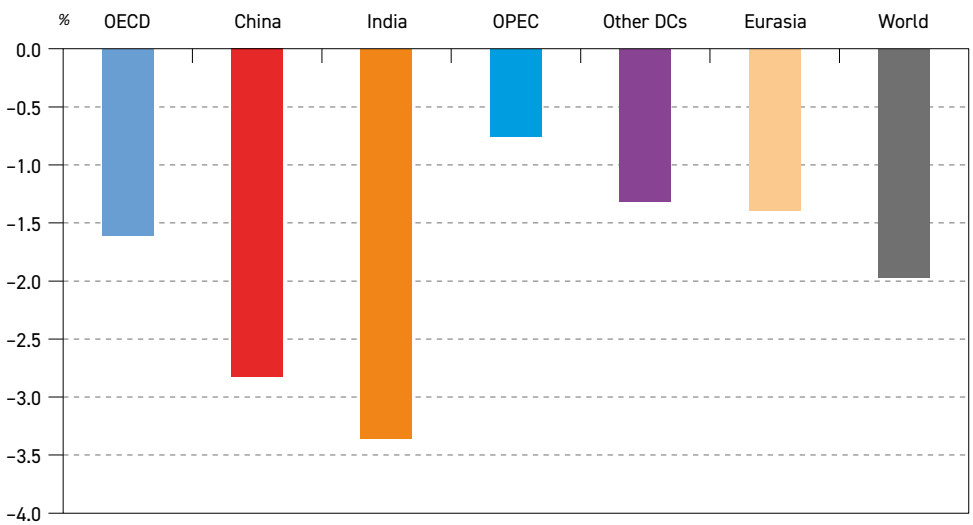
At a country level, China and India have made significant improvements in terms of energy efficiency throughout the period 1990–2022. This is due to some key initiatives and strategies undertaken by their respective governments.

The Chinese government, for instance, has put energy intensity reduction as one of the country's top priorities and has made significant progress in energy conservation over the past three decades. It has implemented several programmes, such as the Top 1,000 Enterprises Energy Conservation Program, Energy Efficiency Standards and Labels and fostering energy service companies (ESCOs) that deliver energy efficiency projects that are financed through the resulting energy cost savings.

OECD countries have already recorded substantial improvements in energy intensity, whereby technological progress and the growing number of energy efficiency policies have played a key role. These countries continue to prioritize energy efficiency as a critical aspect of their sustainable development goals.

Over the long-term, energy efficiency improvements are expected to continue at a similar pace and converge in most regions. This suggests that ongoing technological developments and supportive policies will contribute to further reductions in energy intensity. Figure 2.21 illustrates the energy intensity performance across the selected regions. Energy intensity is expected to decline in all regions, leading to a global reduction rate of around 2% p.a. between 2022 and 2045. However, it should be noted that reduction rates fluctuate from one region to another.

Figure 2.21
Average annual rate of improvement in global and regional energy intensity, 2022–2045



Source: OPEC.

For example, India and China are expected to witness the largest reduction in energy intensity, with annual average reduction rates of 3.4% and 2.8%, respectively, in the same period. The main contributors are the continuing decline in coal use, which is expected to be halved by the end of the forecast period and replaced by natural gas and partly renewables, as well as the more efficient use of energy.

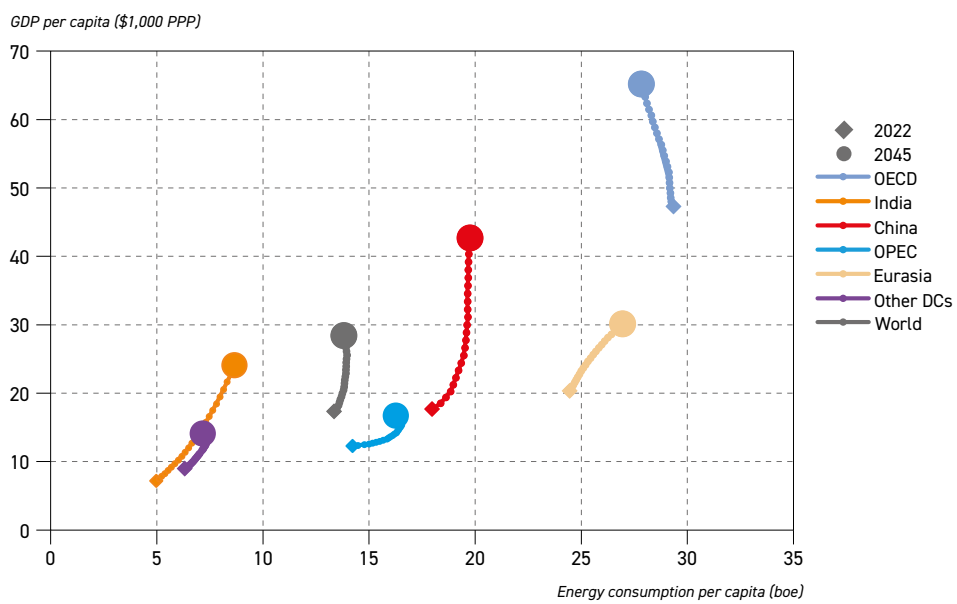
OECD countries have made a lot of progress thus far, and are using energy more efficiently than any other region. Energy efficiency improvements in this region are expected to continue at a steady rate of 1.6% p.a. throughout the forecast period. Others regions are likely to achieve an estimated reduction in the range of 0.75% p.a. to 1.4% p.a. between 2022 and 2045.

Another crucial issue at the global level is energy poverty and access to clean and affordable energy. It is important to note that energy poverty has seen significant improvements in the years prior to COVID-19 and the recent energy crisis. The two events had a negative impact on the access to energy in developing countries, as well as energy affordability. Historically, there has been a substantial disparity in energy consumption per capita between the OECD and non-OECD regions. In the 1970s, the OECD's average energy consumption was almost 27 boe per capita, while developing countries lagged far behind with only around 5 boe per capita. In India, where energy consumption levels were even lower, the figure was below 1.6 boe per capita.

Since the 1970s, the gap between the OECD and non-OECD regions has not narrowed significantly. However, the rapid economic expansion, especially in Asian developing countries, has had a positive impact. This growth has lifted millions of people out of poverty, expanded the middle classes, and consequently increased access to energy. However, it is crucial to recognize that energy poverty remains a significant concern.

In the long-term, the non-OECD region is projected to experience continued economic growth, which will be accompanied by increasing electrification, rising income levels, urbanization, and an expanding middle class. This growth trajectory is particularly evident in China and India, the two largest economies in the region. Figure 2.22 presents the relationship between energy demand per capita and GDP (income) per capita for the selected regions.

Figure 2.22
Energy consumption per capita *versus* GDP at PPP per capita, 2022–2045



Source: OPEC.

In China, average per capita energy consumption is expected to rise, from around 18 boe in 2022 to approximately 20 boe in 2045. In India, average consumption is anticipated to increase significantly from 5 boe in 2022 to roughly 8.7 boe by 2045. India is also set to have the highest long-term energy growth rate among developing countries.

Other Developing Countries are expected to witness a moderate improvement in energy consumption per capita, from 6.3 boe in 2022 to just above 7 boe in 2045, which is only a quarter of the energy consumption per capita in the OECD region.

In contrast, the OECD region, characterized by service-oriented economies, is projected to witness a continued decline in energy consumption per capita, a trend that has been ongoing since 2004. This decline indicates a decoupling of GDP growth and energy demand, primarily driven by advancements in technology and policy-driven energy efficiency improvements. The rising share of renewables is also contributing to this trend. The projected outlook suggests that energy consumption per capita in the OECD will drop from approximately 29 boe in 2022 to 27.8 boe in 2045.

While progress has been made in reducing energy poverty and narrowing the gap between the OECD and non-OECD regions, there is still a long way to go. Energy poverty remains an urgent global issue that requires concerted efforts from policymakers to ensure affordable and sustainable energy access for all.

Oil demand

Key takeaways

- Global oil demand is set to reach the level of 110.2 mb/d in 2028, representing a strong increase of 10.6 mb/d compared to 2022.
- Non-OECD oil demand is projected to increase by a robust 10.1 mb/d between 2022 and 2028, reaching a level of 63.7 mb/d by 2028. OECD demand increases by 0.5 mb/d over the same period.
- Beyond the medium-term, non-OECD demand continues to grow strongly, adding another 15.6 mb/d between 2028 and 2045.
- In the long-term, global oil demand is forecast to increase by 16.4 mb/d between 2022 and 2045, rising from 99.6 mb/d in 2022 to 116 mb/d in 2045.
- The largest contributions to the non-OECD demand increase are set to come from India, Other Asia, China and Africa. India itself will add 6.6 mb/d to its oil demand over the forecast period.
- China's oil demand is projected to increase by 4 mb/d over the forecast period. This demand increase, however, is front-loaded with around 2.9 mb/d materializing over the current decade.
- Long-term OECD demand prospects see a continued decline to slightly below 37 mb/d by 2045. This is around 9 mb/d lower than demand in 2022.
- The largest incremental demand during the forecast period is projected for the road transportation, petrochemical and aviation sectors. Oil demand in these sectors is set to increase by 4.6 mb/d, 4.3 mb/d and 4.1 mb/d, respectively.
- Oil demand in road transportation will continue to expand this decade, increasing by 4.3 mb/d by 2030, before it stabilizes at levels above 49 mb/d for the rest of the forecast period. This pattern will result in an overall demand increase of 4.6 mb/d between 2022 and 2045.
- The global vehicle fleet is set to increase from 1.6 billion in 2022 to 2.6 billion in 2045 with the fastest growth expected in the segment of EVs. Nevertheless, ICE-based vehicles will continue to dominate the global fleet over the forecast period and still account for more than 72% in 2045.
- With respect to refined products, major long-term demand growth is expected for jet/kerosene (+4 mb/d) followed by ethane/liquefied petroleum gas (+3.6 mb/d), diesel/gasoil (+3.1 mb/d), naphtha (+2.5 mb/d) and gasoline (+2.5 mb/d).

Following the turbulent years of 2020, 2021 and 2022, when oil demand first declined by 9.1 mb/d in 2020 and subsequently recovered part of these losses by 5.9 mb/d in 2021 and 2.5 mb/d in 2022, the oil market experienced another eventful year since the Outlook was last published in October 2022. The last quarter of 2022 and beginning of 2023 were marked by high inflation and continued geopolitical tensions, with the conflict in Eastern Europe at the centre.

High energy prices that prevailed during most of 2022 started declining towards the end of the year as it became clearer that the energy supply crises in Europe would ease, supported by a relatively mild winter. Adding to this was Russia's ability to redirect its oil exports, mainly to Asia, after the new set of EU sanctions come into force, which, with a few minor exemptions, banned oil imports to the EU from Russia.

On the economic side, major central banks have increased key interest rates in an effort to tame inflation. Combined with high debt levels in several regions, this lowered the prospects for economic growth during 2023 and the following few years. Subsequently, global GDP growth projections for 2023 is estimated at 2.6%, while global annual growth is expected to stay at around 3% until 2025.

Despite this outlook, oil demand proved to be resilient in 2023. It remains to be seen, however, how the relationship between oil demand and the level of economic activity will develop in the years to come as mixed signals are emerging on factors that have the potential to steer this link in the future.

On the one hand, energy security is still top of the agenda for policymakers as many of them have learned lessons from developments in recent years. Moreover, calls for more equitable growth have come from developing nations where people need more energy, not less, and where countries need to be able to utilize their resources to the full. For the billions in certain regions without access to electricity or clean cooking fuels, energy transitions have a very different meaning to the net zero goals often espoused by some in the developed world. Finally, several major energy companies signaled a shift in their investment strategy towards more investments in oil projects.

On the other hand, there are new policy initiatives focused on emission reductions, such as the adoption of the 'Fit for 55' package by the European parliament in April 2023 and the IRA in the US adopted in August 2022. Additionally, there is the LTAG for international aviation to achieve net-zero CO_2 emissions by 2050, adopted by the ICAO and the IATA in October 2022. These policy initiatives, and many others adopted earlier, include ambitious targets associated with huge investment requirements that are often lagging. This leads to an obvious implementation gap, as well as increasing scepticism about the viability of adopted policies and their eroding public acceptance and support.

Another important area relates to recent investments by car manufacturers to shift production lines towards electric mobility, especially in China and Europe. This needs to be closely monitored as the evolving composition of the car fleet could have a significant impact on future oil demand. It is clear that the electrification of road transportation will continue over the forecast period. However, the question is how fast and to what extent, given there are many challenges ahead that could potentially limit this growth. This includes sufficient electricity generation and grid expansion, the development of a larger charging network and the availability and cost of critical minerals. Bearing in mind the potential impact of these

factors, as well as the high level of uncertainties related to each of them, this chapter looks to provide insights into the evolving oil demand outlook in the period to 2045.

3.1 Oil demand outlook by region

As already mentioned, due to COVID-19 oil demand declined by 9.1 mb/d in 2020. Following the subsequent partial recovery of 5.9 mb/d in 2021, demand grew by another 2.5 mb/d in 2022. Initial expectations for demand growth in 2022, however, were significantly higher. At the beginning of 2022, most institutions expected a full demand recovery already during the year, with demand increasing by 3 to 4 mb/d. These expectations were gradually revised downward on the back of re-emerging COVID-19 related regional lockdowns, higher energy prices, high inflationary pressure and conflict in Eastern Europe. All these factors resulted in moderate economic momentum with global GDP at 3.2%.

As discussed in detail in Chapter 1, most of these factors continued to affect economic growth in 2023, with GDP levels for this year estimated at 2.7%. Global oil demand, however, especially in developing countries, has shown a resilience to moderating economic growth and is expected to increase by another 2.4 mb/d compared to 2022.

One main reason for this relatively strong demand growth is the ongoing recovery from the COVID-19 induced decline, for example, in the road transportation and aviation sectors. Another reason relates to the 'demand catch-up process' across several sectors and regions. Due to the imposed regulations and lockdowns, oil demand was misaligned with the level of economic activity during 2020–2022. These regulations largely disappeared in 2023, hence, there is an additional potential for higher demand growth. It is very likely that this factor will play a role in the next few years too.

It should be noted that a large part of the 2023 demand growth is expected to come from developing Asia and the Middle East. Combined together, these two regions account for 1.9 mb/d of incremental demand in 2023. Contrary to these regions, oil demand in the OECD is already showing some signs of weakening the link between economic growth and oil demand.

As presented in Table 3.1, demand trends from 2023 are expected to continue in 2024. At the global level, oil demand is set to increase by 2.2 mb/d in 2024 of which 1.6 mb/d is projected for developing Asia and the Middle East. Other non-OECD regions are anticipated to grow by 0.4 mb/d. A positive demand change is also projected for the OECD during 2024.

The rest of the medium-term period is expected to be marked by a gradual deceleration in demand growth for the OECD, where growth turns negative towards the end of medium-term. This shift will start in OECD Asia-Pacific and OECD Europe, in 2026 and 2027, respectively, while demand growth in OECD Americas is set to remain positive during the medium-term period.

Oil demand increments are projected to continue to be strong for non-OECD countries in the second half of the medium-term. Demand growth in this region is estimated at 1.7 mb/d in 2025 and 1.3 mb/d in 2028. During these years, demand recovery from the 2020 collapse, as well as its re-alignment with the level of economic activity, will be largely completed in both the OECD and non-OECD. Global annual GDP growth will gradually recover and is projected to remain in a fairly narrow range of 2.9% to 3.3%, while GDP growth in OECD will be below 2%.

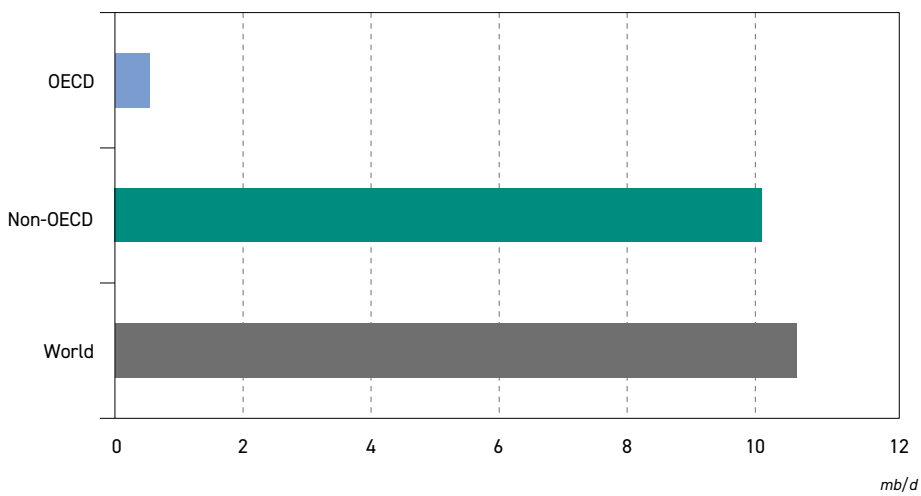
Table 3.1
Medium-term oil demand in the Reference Case *mb/d*

	2022	2023	2024	2025	2026	2027	2028	Growth 2022–2028
OECD Americas	25.0	25.1	25.3	25.5	25.6	25.7	25.8	0.8
OECD Europe	13.5	13.4	13.5	13.5	13.5	13.5	13.4	–0.1
OECD Asia-Pacific	7.4	7.5	7.5	7.5	7.5	7.4	7.3	–0.1
OECD	**45.9**	**46.0**	**46.3**	**46.5**	**46.6**	**46.6**	**46.5**	**0.5**
China	14.9	15.8	16.4	16.8	17.1	17.3	17.5	2.7
India	5.1	5.4	5.6	5.9	6.2	6.5	6.8	1.6
Other Asia	9.0	9.3	9.6	9.9	10.2	10.4	10.6	1.6
Latin America	6.4	6.6	6.8	6.9	7.1	7.3	7.4	1.0
Middle East	8.3	8.7	9.1	9.4	9.5	9.7	9.8	1.5
Africa	4.4	4.6	4.7	4.9	5.1	5.3	5.5	1.1
Russia	3.6	3.7	3.8	3.8	3.9	3.9	3.9	0.4
Other Eurasia	1.2	1.2	1.2	1.2	1.3	1.3	1.3	0.1
Other Europe	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.1
Non-OECD	**53.6**	**56.0**	**58.0**	**59.6**	**61.1**	**62.5**	**63.7**	**10.1**
World	**99.6**	**102.0**	**104.3**	**106.1**	**107.7**	**109.0**	**110.2**	**10.6**

Source: OPEC.

The overall impact of these trends is that global oil demand is set to reach 110.2 mb/d in 2028, representing a strong increase of 10.6 mb/d compared to 2022. Figure 3.1 summarizes these projections from the perspective of major regions. It shows a contrasting picture between continued non-OECD demand growth and stagnating demand in the OECD during the medium-term. Indeed, non-OECD oil demand is projected to increase by a robust 10.1 mb/d between 2022 and 2028 to reach a level of 63.7 mb/d.

Figure 3.1
Incremental oil demand by region, 2022–2028



Source: OPEC.

Long-term demand prospects are summarized in Table 3.2. Recent projections show that global oil demand is set to increase by 16.4 mb/d between 2022 and 2045, rising from 99.6 mb/d in 2022 to 116 mb/d in 2045. This table also shows an extension of the trends set out in the second part of the medium-term period in respect to the divergent regional oil demand pathways of OECD and non-OECD countries. Indeed, with the exception of the initial few years of the forecast period when OECD demand is set to expand, the long-term prospects for this region is a continued demand decline to below 37 mb/d by 2045. This will be 9.3 mb/d lower than the observed demand in 2022.

Table 3.2
Long-term oil demand by region

mb/d

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	25.0	25.5	25.8	24.8	23.2	21.5	–3.5
OECD Europe	13.5	13.5	13.1	12.0	10.8	9.8	–3.7
OECD Asia-Pacific	7.4	7.5	7.2	6.6	6.0	5.4	–2.0
OECD	**45.9**	**46.5**	**46.0**	**43.4**	**40.0**	**36.7**	**–9.3**
China	14.9	16.8	17.8	18.2	18.5	18.8	4.0
India	5.1	5.9	7.3	8.8	10.2	11.7	6.6
Other Asia	9.0	9.9	11.1	12.1	12.9	13.6	4.6
Latin America	6.4	6.9	7.8	8.4	8.7	9.0	2.5
Middle East	8.3	9.4	10.0	10.7	11.4	11.9	3.6
Africa	4.4	4.9	5.9	6.6	7.4	8.2	3.8
Russia	3.6	3.8	4.0	4.0	3.9	3.9	0.3
Other Eurasia	1.2	1.2	1.3	1.4	1.5	1.5	0.3
Other Europe	0.8	0.8	0.9	0.9	0.8	0.8	0.0
Non-OECD	**53.6**	**59.6**	**66.0**	**71.0**	**75.4**	**79.4**	**25.7**
World	**99.6**	**106.1**	**112.0**	**114.4**	**115.4**	**116.0**	**16.4**

Source: OPEC.

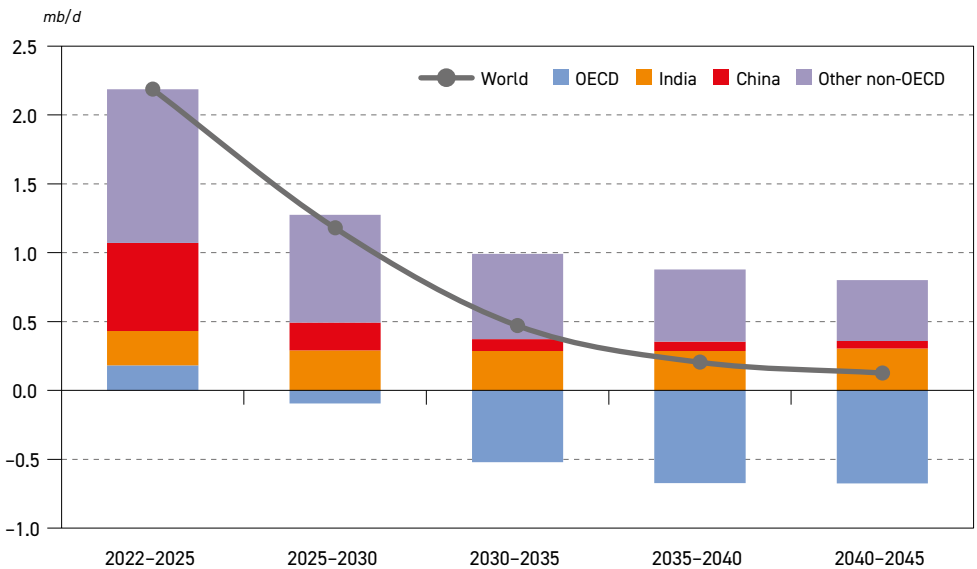
This projected demand decline will be the result of a variety of factors, primarily driven by the policy set-up in this region. In efforts to reduce energy-related emissions, policies are set to foster technology development, provide incentives for their implementation, to use energy more efficiently across all sectors of consumption and to substitute oil by electricity and gas as much as possible. Important elements in these efforts will be the gradual penetration of EVs in the road transportation sector, the displacement of oil-based heating systems in residential and industrial sectors, a further reduction of oil demand in the electricity sector and the penetration of alternative fuels in the marine and aviation sectors. Moreover, this region's demand decline will be supported by a rather static, but ageing total population, and low long-term economic growth. While none of these factors separately will drastically change the picture in related sectors, the combined effect of them will be significant.

The strong non-OECD oil demand growth will be driven by a completely different set of factors. Rising population and urbanization, the strong expansion of the middle-class, robust economic growth potential, the shift from traditional use of biomass to cleaner oil products,

strong vehicle fleet growth, including commercial vehicles with a higher share of heavy-duty vehicles, and agriculture sector shifts will all result in strong regional oil demand growth over the forecast period. This is expected to increase by 25.7 mb/d between 2022 and 2045.

Figure 3.2 provides some details about the evolution of this demand growth in respect to major regions. In the period 2022–2025, it is China that is the source of the largest incremental demand, expanding by more than 0.6 mb/d p.a. on average. Demand in Other Asia, the Middle East and India are each projected to grow by around 0.3 mb/d annually during the same period. However, demand growth in China, Other Asia and the Middle East gradually decelerate as time progresses, while India keeps the same pace. It becomes the region with the largest incremental demand in the long-term. Moreover, steady demand growth in Africa will make this region the third largest source of long-term incremental demand.

Figure 3.2
Average annual oil demand increments by region, 2022–2045



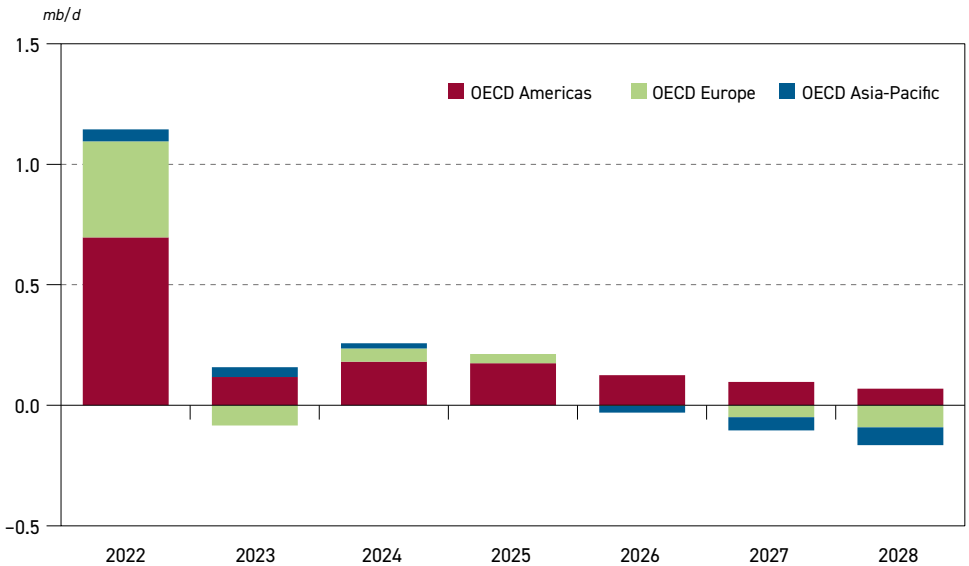
Source: OPEC.

Another important observation included in Figure 3.2 is an evolving profile of global annual demand increments over the forecast period. Driven mainly by the recovery process from the 2020 demand collapse, average annual demand growth is forecast at 2.2 mb/d over the 2022-2025 period. Growth is then expected to slow to 1.2 mb/d over the next five years and even more to 0.5 mb/d during the 2030–2035 period. Nevertheless, oil demand will continue growing over the entire forecast period as incremental demand in non-OECD more than offsets declining OECD demand.

3.1.1 OECD

The medium-term prospects for OECD oil demand are presented in Figure 3.3. It clearly shows that OECD incremental demand in 2022 stands out compared to all other medium-term years. This is because this region's demand was still on a recovery path from the COVID-19 pandemic, especially in the 2H22 when most restrictions were removed and life returned

Figure 3.3
Annual oil demand growth in the OECD, 2022–2028



Source: OPEC.

(almost) back to normal. At the same time, however, this was also a period when economic prospects began to deteriorate, leading to slower GDP growth prospects in the years to come.

With OECD GDP growth estimated at around 1% for 2023 and 2024, and only slightly higher growth for the remaining part of the medium-term, oil demand in this region turns to lower increments in 2023 and 2024 and, with the exception of the last year of the medium-term, is expected to remain positive.

For OECD Europe, only minor incremental demand increases are projected to 2025. Annual demand in 2026 is then set to be stagnant, before declining thereafter on the back of weak economic growth, strong EV sales and the impact of policy measures that increasingly affect oil demand. The overall effect of these developments will be slightly lower oil demand for this region in 2028, compared to 2022. A similar trend, including a comparable overall contraction of around 0.1 mb/d, is also projected for OECD Asia-Pacific.

In the case of OECD Americas, oil demand will likely continue growing during the medium-term. This will result in the region's oil demand expanding by 0.8 mb/d, reaching 25.8 mb/d in 2028.

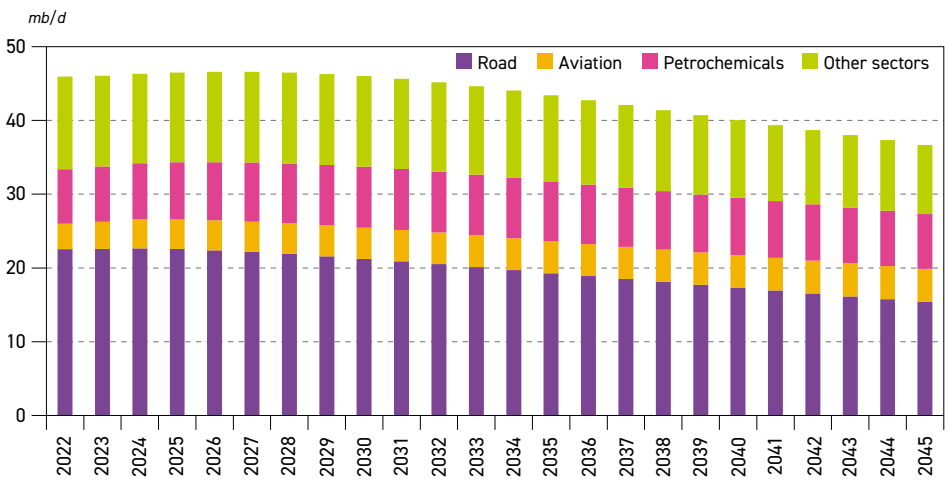
In total, OECD oil demand is forecast to increase by 0.5 mb/d between 2022 and 2028, reaching 46.5 mb/d by the end of the medium-term.

In the long-term, OECD oil demand is set to be on a declining trajectory, dropping below 37 mb/d by 2045. This represents an overall demand decline of 9.3 mb/d over the forecast period. The largest part of this decline is projected for OECD Europe. The overall demand decline of 3.7 mb/d in this region represents around 27% of the base demand in 2022. Demand decline in the other two regions, OECD Americas and OECD Asia-Pacific, will be lower in absolute terms,

at 3.5 mb/d and 2 mb/d, respectively. In relative terms, however, while the OECD Asia-Pacific is comparable to OECD Europe, it represents only 14% of OECD Americas demand in 2022.

Figure 3.4 provides details about future OECD oil demand from the perspective of major sectors. Clearly, the largest change in future oil demand is forecast to take place in the road transportation sector, which is projected to decline by 7.2 mb/d between 2022 and 2045. This represents around 77% of this region's overall demand contraction.

Figure 3.4
OECD oil demand by sector, 2022–2045



Source: OPEC.

The main reason for the road transportation demand drop relates to a gradual penetration of EVs into the future car fleet in OECD countries. Europe's policy set-up is for a ban of new ICE personal car registrations as of 2035, which will significantly impact oil demand in this region. In the US, the IRA also includes incentives supporting new EV sales. Considering these policies and following strong new EV growth sales in recent years, this Outlook assumes that close to 300 million EVs will be registered in OECD countries by 2045. These cars will reduce future OECD demand by more than 5 mb/d by the end of the forecast period. A more detailed review of recent EV sales and projections for future penetration rates is provided in section 3.2.1.

Significant demand reduction will also result from efficiency improvements in future ICEs. Recent emissions standards in the EU require average emissions of 95g CO_2/km for newly registered cars at the manufacturer level. The equivalent norm for vans is 147 g CO_2/km. These standards will be reduced by 15% during the period of 2025–2029 and further by 55%/50% for cars and vans during the 2030–2034 period. Clearly, a large part of this reduction will be achieved by a higher EV share in new registrations. Nevertheless, efficiency improvements must also be achieved in ICE-based cars and vans.

Similar standards, though generally less ambitious, exist in other OECD countries too. In the US, these are set by Corporate Average Fuel Economy (CAFE) standards. The current regulation for passenger cars requires a fuel economy of 50.5 miles per gallon (mpg). This is

supposed to increase to 54.5 mpg in 2025, while a further tightening of these standards for all vehicle categories is expected.

Besides road transportation, a significant demand decline is also projected for 'Other sectors'. This aggregates industry, residential, agriculture, commercial, marine transport and the electricity generation sectors. In total, OECD oil demand in these sectors is set to decline by 3.2 mb/d over the forecast period. The largest potential for long-term demand reduction exists in the residential (–1 mb/d) and industry (–0.6 mb/d) sectors. The primary means to achieve this reduction in the residential and commercial sectors, include tighter building codes for newly constructed houses, the replacement of oil-based heating systems in older buildings and better insulation. Demand in the industry sector will mainly be affected by efficiency improvements and fuel substitution when oil-based technologies are replaced by electricity, natural gas and, at a later stage, by hydrogen.

OECD oil demand in the petrochemical sector by 2045 is projected to be at a similar level as that observed in 2022. This fact, however, masks rather complex developments in this sector with changing dynamics over time and with regional specifics. Oil demand in this sector is set to increase slightly in all OECD sub-regions during the current decade and then start declining sometime after 2030. The most affected region will be OECD Europe where oil demand in this sector will be rather stagnant over the medium-term and see the most pronounced decline over the long-term. Due to strict emission standards and the lack of access to cheaper feedstock, Europe is expected to lose its competitiveness in this sector and related oil demand is forecast to drop by 0.3 mb/d between 2022 and 2045.

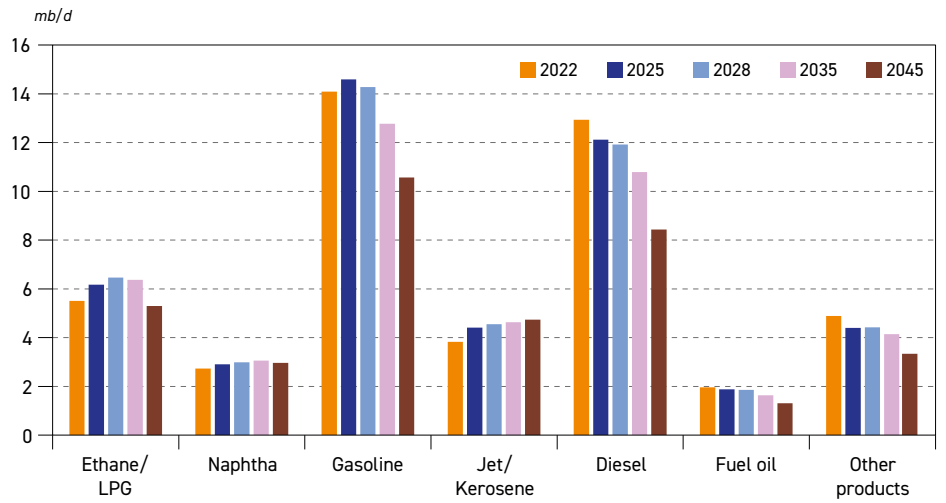
The other two regions, however, OECD Americas and OECD Asia-Pacific will be much less affected. The first one will benefit from much stronger growth during the current decade due to the availability of cheaper feedstock, while the latter will be supported by strong demand for petrochemical products in its wider region. Therefore, 2045 oil demand in the petrochemical sector in these two regions will be slightly higher than levels observed in 2022.

The aviation sector is the only one where OECD oil demand is projected to increase over the forecast period. The overall increase is not large, projected at 1.1 mb/d between 2022 and 2045. Moreover, part of this increase is related to the remaining demand recovery from the COVID-19 pandemic, especially in 2023 and partly in 2024.

Figure 3.5 translates developments in specific sectors to demand for refined products in OECD countries. It shows that diesel will be the hardest hit product in the future OECD demand mix. Diesel oil is projected to drop by 4.5 mb/d over the forecast period, driven by declining demand in the road transport, industry, residential and marine transport sectors. A similar demand pattern is also projected for gasoline, which is expected to drop below 11 mb/d in 2045, from more than 14 mb/d in 2022. The demand decline for this product is almost entirely linked to the OECD's changing vehicle park, including the penetration of EVs and more efficient vehicles.

OECD demand for ethane/liquefied petroleum gas (LPG) and naphtha broadly mirrors developments in the petrochemical sector. Naphtha provides a baseload for petrochemicals, hence, its demand is projected to remain relatively stable over the forecast period. In contrast, demand for ethane/LPG will be driven by its availability that, especially in the case of OECD Americas, is linked to this region's tight oil production. This is projected to continue

Figure 3.5
OECD oil demand by product, 2022–2045



Source: OPEC.

expanding over the current decade and provide additional feedstock to the petrochemical industry. However, tight oil production is set to peak around 2030, meaning that ethane availability will drop in the second part of the forecast period.

Fuel oil and 'other products' will be affected by declining demand in industry (including lower refinery own use), power generation and marine bunkers. The overall decline for 'other products' is anticipated to be around 1.6 mb/d, while demand for residual fuel is projected to drop by 0.7 mb/d between 2022 and 2045. The only product with increasing demand over this period will be jet kerosene, reflecting the increased traffic in the aviation sector.

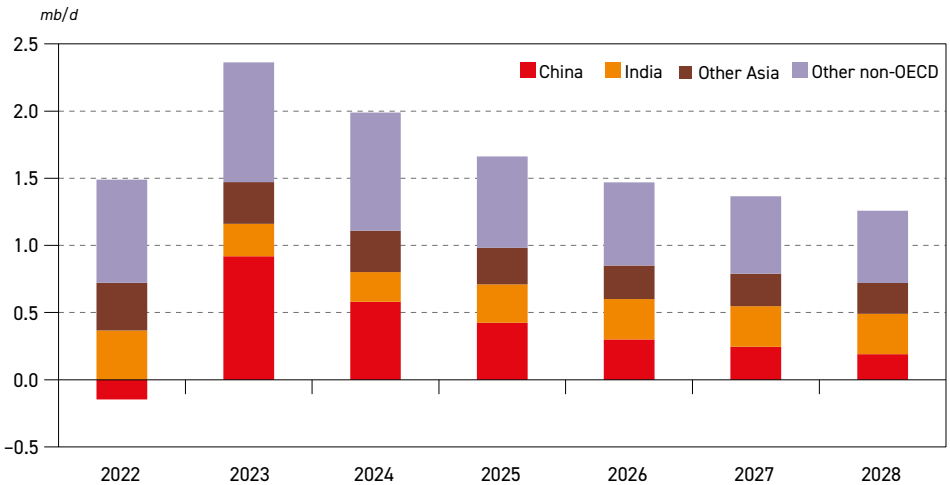
3.1.2 Non-OECD

Following a strong demand increase in 2021, the expectation was that a demand recovery from the COVID-19 related 2020 decline would continue in 2022. However, sustained lockdowns in China, demand drops in Russia and Other Eurasia, and slower economic growth compared to 2021, limited demand expansion to only 1.3 mb/d. The main factor for this was the demand contraction in China, estimated at 0.1 mb/d.

This, however, is expected to change in 2023 as Chinese demand is projected to rebound by 0.9 mb/d, while demand growth in other non-OECD regions is set to continue broadly at the same level as 2022. As a result, as presented in Figure 3.6, total non-OECD demand is forecast to increase by 2.4 mb/d in 2023. Strong incremental demand in this region is also projected for 2024, with demand supported by a 'catch up process' and a recovery from the last scars of COVID-19. During this year and 2025, all regions are expected to gradually revert to normal growth that is aligned with, and justified by, market fundamentals.

As a result, annual non-OECD oil demand is expected to continue growing in the period 2025–2028, with average annual increments of around 1.4 mb/d and despite some growth

Figure 3.6
Annual oil demand growth in non-OECD countries, 2022–2028

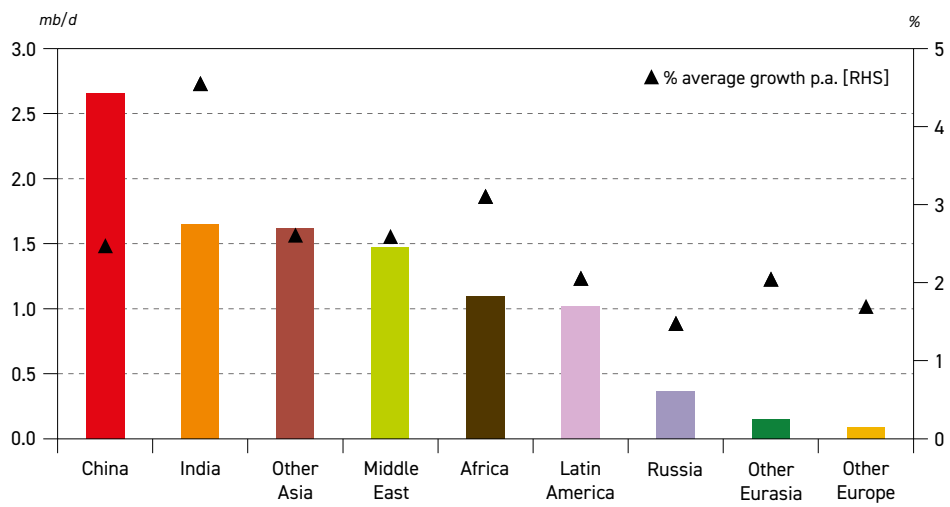


Source: OPEC.

deceleration in China. This will be on the back of continued strong demand growth in India and Other Asia, while more moderate increases are seen in Africa and Latin America.

The overall effect is that non-OECD demand is set to grow by 10.1 mb/d between 2022 and 2028, which is a reflection of progressing industrialization, enhanced mobility and improved living standards for millions in these countries. As presented in Figure 3.7, the largest incremental

Figure 3.7
Non-OECD regional oil demand growth, 2022–2028

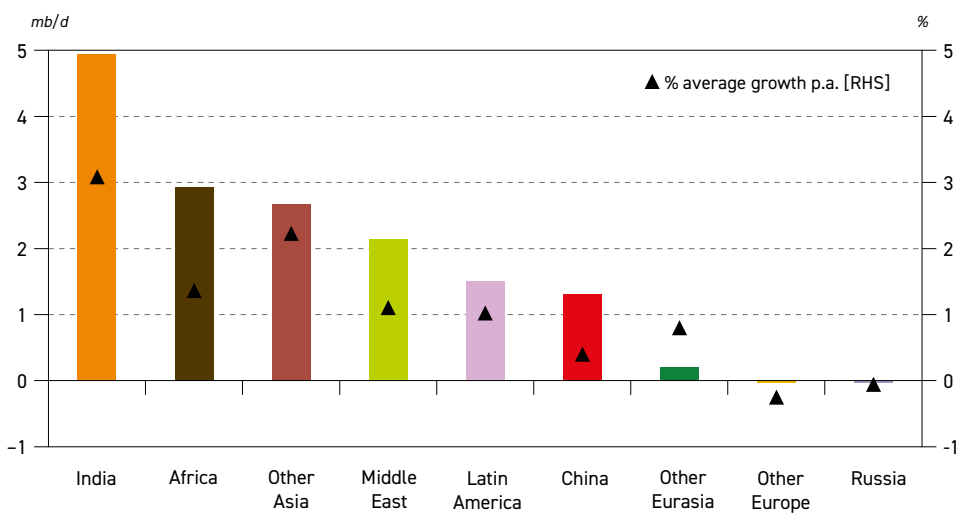


Source: OPEC.

demand during this period is projected for China, at 2.7 mb/d, reaching a level of 17.5 mb/d in 2028. It will be followed by India, Other Asia and the Middle East, with each contributing to medium-term non-OECD incremental demand around 1.5 mb/d to 1.6 mb/d. Demand additions in Africa and Latin America will be in the range of 1 mb/d to 1.1 mb/d, while only minor increments are estimated for other regions. It is important to note, however, that this order changes when a comparison in relative terms is considered. In this case, India and Africa are the two regions with the fastest average annual growth, which if sustained, will have important implications for long-term oil demand.

Beyond the medium-term, non-OECD demand is forecast to continue growing, adding another 15.6 mb/d between 2028 and 2045. This will help contribute to improving energy access, reducing energy poverty, fostering industrial growth and expanding all transportation options. During this period, the rate of growth is set to slow from around 1.3 mb/d p.a. in 2028 to 0.8 mb/d p.a. during the last five years of the forecast period. The largest contributions to this demand increase will come from India, Other Asia and Africa. Driven by economic growth, urbanization, industrialization and the expansion of the vehicle fleet, combined demand in these three regions is set to increase by 10.6 mb/d between 2028 and 2045 (Figure 3.8). India itself will add 4.9 mb/d to its oil demand during this period, expanding by 3.1% p.a. on average.

Figure 3.8
Non-OECD regional oil demand growth, 2028–2045

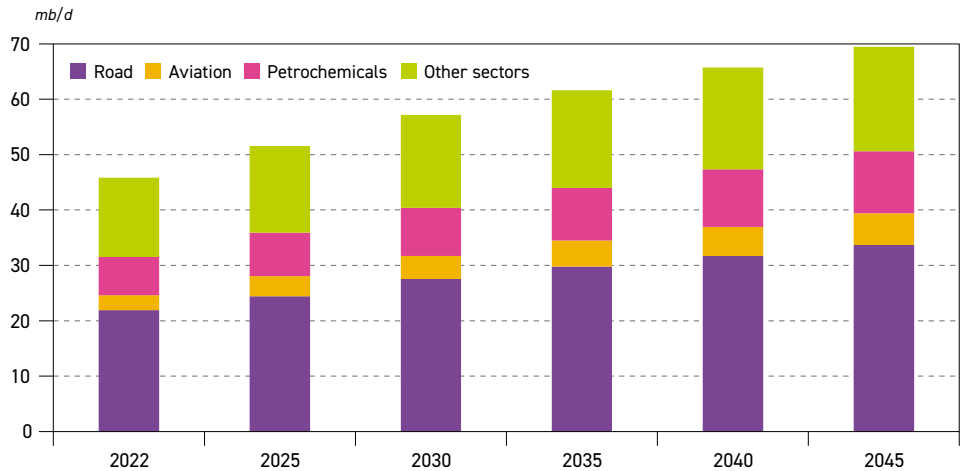


Source: OPEC.

Important demand additions are also projected for the Middle East (+2.1 mb/d), Latin America (+1.5 mb/d) and China, with incremental demand of 1.3 mb/d. Oil demand in the remaining non-OECD regions will plateau over the next decade as demand in Russia and Other Europe will move in a fairly narrow range of 0.1 mb/d to 0.2 mb/d after 2028.

Major changes in non-OECD countries are also projected in respect to sectoral demand. The trends from this perspective are presented in Figure 3.9. This figure amplifies the importance of the road transportation sector for future non-OECD demand. Driven by a rising number of

Figure 3.9
Non-OECD oil demand by sector, 2022–2045



Source: OPEC.

both passenger cars and commercial vehicles, oil demand in this sector is set to increase by almost 12 mb/d over the forecast period, much more than any other sector.

Significant demand increases are also projected in the petrochemical sector, mainly in Asia and the Middle East, on the back of a number of large petrochemical projects in these regions and rising demand for petrochemical products (more details are included in section 3.2). As a result, oil demand in this sector is set to rise from 6.9 mb/d in 2022 to 11.2 mb/d by 2045, adding 4.3 mb/d of incremental demand over this period. While the figure is somewhat lower, there is also a large demand increase in the non-OECD aviation sector driven by an expanding middle class with a propensity for air travel. Therefore, aviation oil demand is projected to increase by 3.1 mb/d over the forecast period.

Demand additions in other sectors will likely be smaller. Nonetheless, combining demand together for industry, residential, agriculture, other transport and power sectors adds another 6.6 mb/d of incremental demand in this region between 2022 and 2045.

India

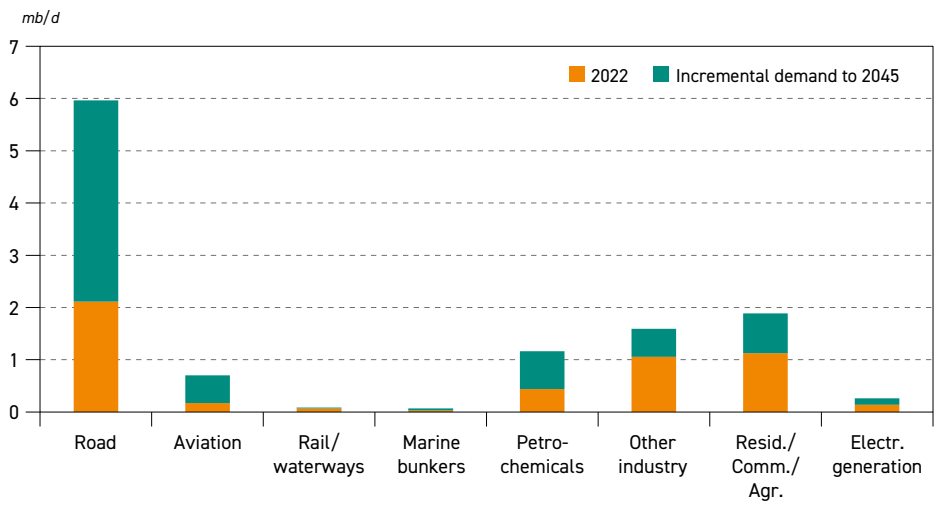
According to the latest estimates from UNDESA, India reached a population of 1.43 billion during 2023, surpassing the population of mainland China. Moreover, projections made by UNDESA show that India's population will continue growing over the next two decades and reach 1.62 billion by 2045. Besides this significant increase in its population, around half of India's population is below the age of 25, providing an additional boost to economic activity. As a result, India's working population is expected to expand to around 1.1 billion by 2045. This favourable demographic growth will drive economic expansion too. This outlook is based on the assumption that India's GDP will grow by 6.1% p.a. on average between 2022 and 2045, remaining robust even towards the end of the forecast period.

Another important aspect of India's demographics that will have a significant impact on future oil demand is the urbanization rate. Despite the fact that India is home to several of the most

populous cities in the world, its current urbanization rate is only around 34%. This is much lower compared to developed countries, as well as many developing countries. With many policy interventions in recent years, such as the 'Smart Cities Mission' initiative, the construction of affordable rental housing complexes and adapting rapid transport metro systems in larger cities, India's urbanization is set to increase considerably during the forecast period. In turn, this will support demand growth for modern energy sources, including oil.

An assessment of the potential impact of these factors on India's future oil demand is presented in Figure 3.10. By far the largest expected demand growth is for transport fuels. Strong economic growth will drive demand for freight transport leading to incremental demand for diesel in the road transportation sector. It will also lead to a fast expansion of the middle class which, in combination with urbanization and improved road infrastructure, results in a more than quadrupling of the number of passenger vehicles between 2022 and 2045. As discussed in section 3.2.1, the size of the passenger vehicle fleet in India is set to expand from around 46 million in 2022 to almost 200 million in 2045 (excluding two-wheelers). In contrast to China and OECD Europe, the penetration of EVs will likely remain subdued in India, with the large majority of vehicles using ICE. This is forecast to increase India's gasoline demand by around 1.6 mb/d over the forecast period, and further support diesel demand in road transportation.

Figure 3.10
Oil demand in India by sector, 2022 and 2045



Source: OPEC.

Significant demand growth is also projected in other sectors, especially the petrochemical and residential sectors. Oil demand in the petrochemicals sector is set to expand by 4.3% p.a. on average between 2022 and 2045, driven by demand for a variety of petrochemical products. This is on the back of growing construction and industrial production, an expanding agriculture sector and demand for plastics. This also manifests itself in the list of petrochemical projects that are expected to be constructed and become operational over the next few years, as the country is forecast to account for around one third of new

projects in Asia. As a result, India oil demand in this sector is set to increase by 0.3 mb/d already by 2030. It is then anticipated to further extend this incremental demand to 0.7 mb/d by 2045, compared to 2022.

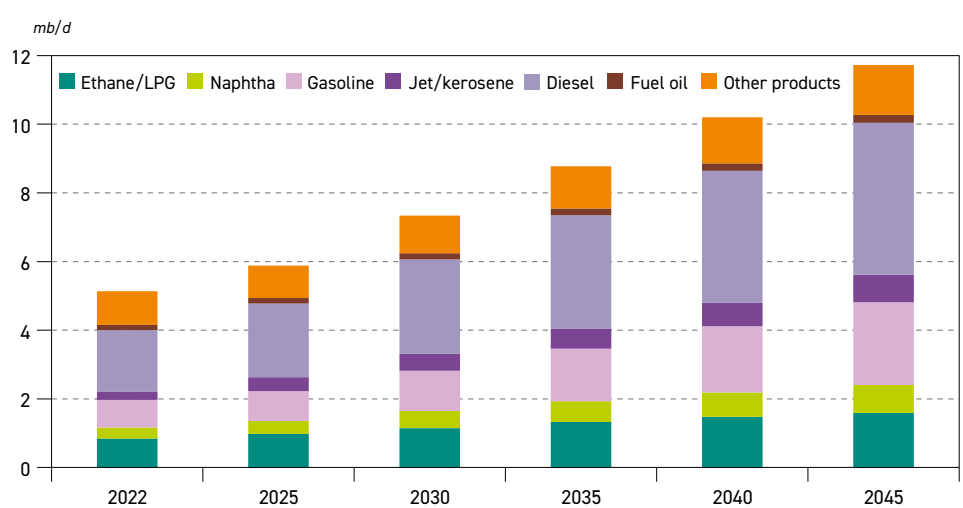
A similar level of incremental demand, 0.8 mb/d over the forecast period, is projected in the combined residential, commercial and agricultural sectors, expanding from 1.1 mb/d in 2022 to 1.9 mb/d in 2045. Reflecting the strong population growth and increases in the urbanization rate, there remains the potential for additional oil demand in this sector. However, part of this potential will likely be met by other energy sources, such as electricity and natural gas. In particular, residential oil demand will face competition in areas where natural gas access is improved as part of the City Gas Distribution programme.

The most dynamic changes are expected in the aviation sector. Oil demand in this sector is projected to expand by more than 6% p.a. on average during the forecast period. The current demand base is relatively low, as observed oil demand for aviation was below 0.2 mb/d in 2022. This, however, will gradually change on the back of governmental initiatives that support the construction of new regional airports and provide schemes to make air transport affordable to common citizens, such as the UDAN scheme and the Regional Connectivity Scheme (RCS). Alongside the expected growth of the middle class, both domestic and international air traffic will increase significantly over the forecast period. Accordingly, India oil demand in this sector is set to increase to 0.7 mb/d in 2045.

Accounting for a comparable demand addition in the industry sector, as well as minor increments in the remaining sectors, total oil demand in India is set to increase by 6.6 mb/d, rising from 5.1 mb/d in 2022 to 11.7 mb/d by 2045.

Figure 3.11 translates these sectoral trends into demand for specific refined products. India's current oil demand composition is characterized by a relatively high share of diesel/gasoil, which accounts for around 35% of total demand. In fact, the share of diesel/gasoil is set to

Figure 3.11
Oil demand in India by product, 2022–2045



Source: OPEC.

expand to 38%, mainly on the back of growing freight transport and industrial production. Some demand growth for this product will also come from the petrochemical industry, as well as the commercial and agriculture sectors. Therefore, the projected diesel demand level for India in 2045 is 4.4 mb/d.

As discussed earlier, India's incremental gasoline demand will result from the growing number of passenger vehicles, with the range of the increase around 1.6 mb/d between 2022 and 2045. In a similar way, jet kerosene demand growth, which is anticipated to increase by 0.6 mb/d, is directly link to aviation sector developments.

Significant incremental demand is also projected for ethane/LPG. Combined demand for these two products is set to increase by 0.7 mb/d over the forecast period. The larger part of this increase relates to LPG demand in the residential sector. This will be supported by ethane growth in the petrochemical sector. However, demand in this sector in India is dominated by naphtha. Therefore, naphtha demand is set to increase by 0.5 mb/d, from 0.3 mb/d in 2022 to 0.8 mb/d in 2045.

Another specific of the Indian oil market is the relatively high demand for the group of 'other products', such as bitumen, pet coke, lubes and waxes. Most of these products are used to expand the road network, as refinery fuels and to produce energy-intensive goods such as cement, aluminium and steel. Since all these sectors are set to expand in India, related oil demand is also set to grow from 1 mb/d in 2022 to 1.5 mb/d in 2045.

The only refined product projected to remain in a narrow range of 0.1 mb/d to 0.2 mb/d during the entire forecast period is residual fuel oil. This is due to the fact that India has no major international bunkering hubs, and given that the electricity sector is dominated by the use of coal, renewables and natural gas.

China

As stated earlier, China's oil demand is projected to grow from 14.9 mb/d in 2022 to 18.8 mb/d in 2045, representing an overall demand increase of 4 mb/d. This demand increase, however, is front-loaded with around 2.9 mb/d materializing during the current decade. This means that China's oil demand will continue growing, albeit at lower rates.

This overall demand pattern for China will result from a combination of several factors. Firstly, the country's economic growth is projected to stay at around 5% p.a. for the next few years, and will then likely be below this mark by the end of the medium-term. Moreover, growth is expected to slow further to around 4% p.a. sometime after 2030. The average GDP growth is set to be at 3% p.a. over the last ten years of the forecast period. This represents a significant deceleration from annual rates in the range of 7% to 10%, that were typically observed between during the 1990–2015 period. Part of this slowdown is attributed to a peaking and, consequently, a declining population with unfavourable demographics due to an ageing population and shrinking labour force.

At the same time, it needs to be emphasized that China's long period of high economic growth created a populous middle class, which will continue to support the strong sales of new vehicles, the private consumption of retail products and demand for travel services, including international flights. This provides a solid basis for sustained demand in related sectors, even though the growth will slow.

Secondly, the composition of China's economy is already shifting towards a higher share of services, with less energy and oil intensive industries that have a higher value-added. Examples of this are the shift to the fast growing car manufacturing sector, the production of electronic devices and tourism services. On the other hand, this will likely provide an additional impulse to the petrochemical industry, residential and agriculture sectors, as well as to oil demand in road transportation, until the expanding penetration of EVs further curbs growth in this sector.

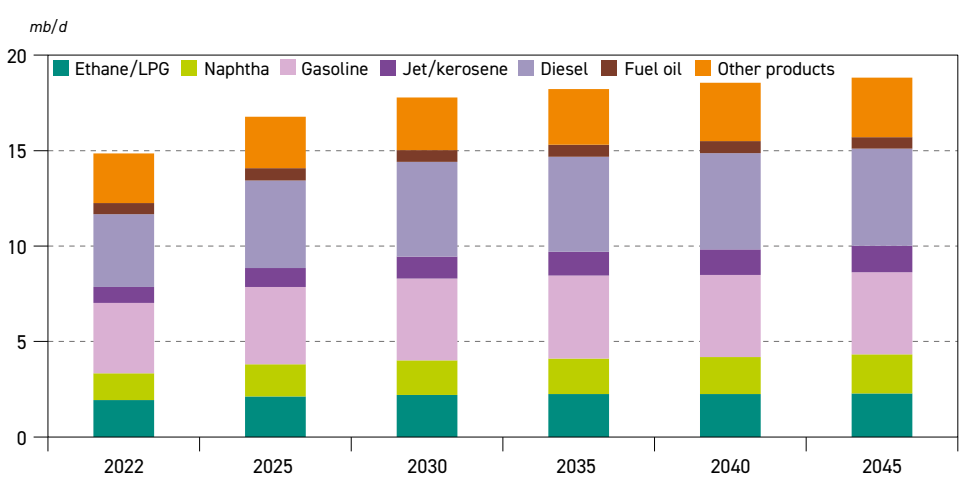
The penetration of EVs is evidently an issue to be considered. Recent data on new car registrations show the rapid decline in sales of ICEs in China, from 28.5 million in 2017 to 17.3 million in 2022. This represents an average annual decline of 10%. During the same period, the sales of EVs increased, reaching a level of 6.6 million in 2022 and a market share of 26%. Moreover, HEVs are also becoming popular in China adding to efficiency improvements in road transportation.

As a result of these developments, the structure of the vehicle fleet in China is changing as EVs reached a share of almost 5% of the vehicle in 2022. This share still seems to be relatively small, but the rate of penetration is growing. Naturally, this growth could slow when it reaches higher penetration levels as it will require much longer sales numbers in future years to sustain the significant growth. Nevertheless, even a decelerating rate in penetrating the vehicle fleet will potentially have an impact on future oil demand in China.

The impact of these future oil demand trends in China is presented in Figure 3.12 and Figure 3.13. The first one breaks down China's oil demand into major refining products. The second one complements this picture by looking at oil demand from the perspective of major sectors.

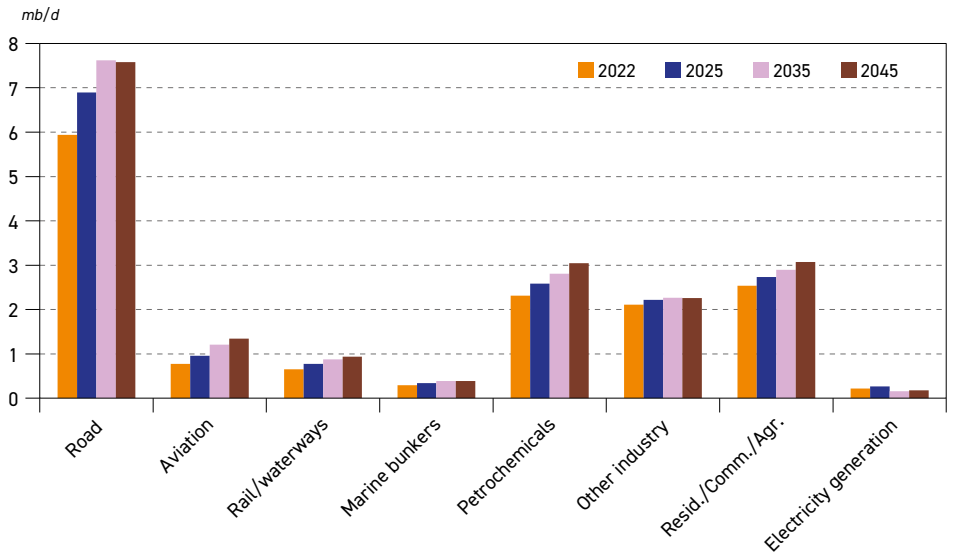
Oil demand in the road transportation sector accounted for 40% of China's total demand in 2022. Therefore, changes in the size and structure of the vehicle fleet in China will have large implications on its future oil demand. The size of the passenger vehicle fleet in China is

Figure 3.12
Oil demand in China by product, 2022–2045



Source: OPEC.

Figure 3.13
Oil demand in China by sector, 2022–2045



Source: OPEC.

projected to increase from around 300 million cars in 2022 to more than 540 million in 2045 (excluding two-wheelers). However, a significant part of the potential demand growth resulting from this impressive fleet size increase will be offset by improved average efficiencies, as well as fuel substitution through electricity and natural gas. The EVs expansion will play a major role in this respect as the number of EVs is expected to expand from 15 million in 2022 to almost 190 million in 2045. This would represent almost 35% of the passenger vehicle fleet in China.

In addition to passenger cars, the size of the commercial fleet will also expand. It is set to more than double over the forecast period, from around 30 million in 2022 to 72 million in 2045. However, the share of EVs in this category will be much lower compared to passenger cars. Moreover, commercial vehicles have much higher average oil consumption per vehicle, thus supporting the base oil demand in this sector as especially heavy-duty vehicles are hard to replace.

The combined effect of these changes is that China's oil demand in road transportation continues to grow until around 2035 and reaches 7.6 mb/d, around 1.7 mb/d higher than in 2022. It is then set to plateau, before declining marginally during the last ten years of the forecast period, hence, contributing to the overall deceleration of China's oil demand growth.

Primarily driven by domestic demand for petrochemical products, this industry will be the second largest contributor to China's incremental demand. In this sector, oil demand is set to grow by 0.7 mb/d over the forecast period, from 2.3 mb/d in 2022 to 3 mb/d in 2045. In contrast to road transportation, oil demand in this sector is anticipated to continue growing throughout the forecast period, though annual increments will be rather minimal towards the end of the forecast period. From the feedstock perspective, China's petrochemical industry is traditionally based on naphtha and, this will continue to be the major feedstock in the future.

A similar demand pattern is also projected for China's aviation sector. Oil demand in this sector is expected to expand by 0.6 mb/d between 2022 and 2045. This overall increase, however, is front-loaded with arounnd 60% of it (0.3 mb/d) materializing in the period to 2030. In other words, robust medium-term demand growth will gradually change to modest growth until around 2035. It will then be followed by plateauing oil demand towards the end of the forecast period.

Modest, but steady demand increases are projected in the residential and agriculture sectors. This is largely supported by steady demand growth in agriculture. Overall incremental demand is just 0.5 mb/d between 2022 and 2045. Nevertheless, a demand level of between 2 mb/d and 3 mb/d in this sector contributes to the 'base load' of future oil demand in China. A minor demand increase is also projected for the rail and domestic waterways sector. Additional oil demand of 0.3 mb/d in this sector over the forecast period is primarily linked to increased traffic and an expansion of the country's waterways network, the longest in the world, consisting of more than 200,000 km.

Oil demand in electricity generation in China is minimal, at just around 0.2 mb/d. Its use is confined to fuelling diesel aggregates for special purposes and to electricity production from the heavy bottom of the refined barrel. This will not significantly change in the years to come, hence, keeping oil demand in this sector fairly stable and growth limited during the forecast period. It should be noted that the situation will change quite soon in the industry sector, where oil demand is projected to start to already see a slow decline sometime after 2025. This will happen on the back of a shifting structure in Chinese industry and by a gradual substitution of oil by natural gas and electricity.

From the perspective of major refined products, the largest demand increase in China is projected for diesel/gasoil. Demand for this product is set to increase by 1.3 mb/d between 2022 and 2045. A large part of this increase is related to the growing number of commercial vehicles, supported by demand in agriculture and domestic waterways.

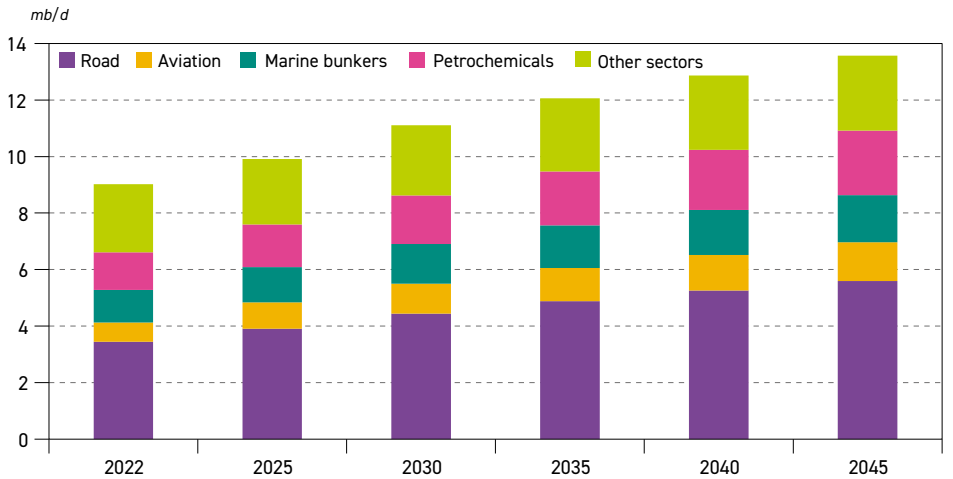
Driven entirely by the expanding fleet of passenger vehicles, demand for gasoline is set to increase by 0.6 mb/d over the forecast period. In a similar way, naphtha demand is forecast to almost entirely match demand growth in the petrochemical industry, expanding by 0.6 mb/d over the long-term. However, demand for jet/kerosene of 0.5 mb/d is lower than the projected increase for the aviation industry. This is because part of the jet/kerosene growth will be offset by the declining use of kerosene in the industry and residential sectors.

Other non-OECD Regions

Other Asia is home to more than 1.1 billion people. The five most populous countries of the region, Indonesia, Pakistan, Bangladesh, Philippines and Vietnam have a combined population of almost 900 million. Moreover, this region has a very dynamic population and strong urbanization growth, as well as significant differences in the stages of development between the countries. This is also reflected in the projected GDP growth of Other Asia, which is at a robust 4.3% p.a. on average during the medium-term. GDP growth then slows somewhat, but it remains in the range of 4% p.a. until 2035 and 3% p.a. for the rest of the forecast period.

This solid economic growth will provide strong support for oil demand, especially in the first half of the forecast period. As presented in Figure 3.14, Other Asia oil demand in the road transportation sector is set to increase by 2.2 mb/d between 2022 and 2045. This is on the

Figure 3.14
Oil demand in 'Other Asia' by sector, 2022–2045



Source: OPEC.

back of expanding numbers of both passenger cars and commercial vehicles (more details are available in 3.2.1). Significant demand increases are also expected in the petrochemical and aviation sectors, at 0.9 mb/d and 0.7 mb/d, respectively.

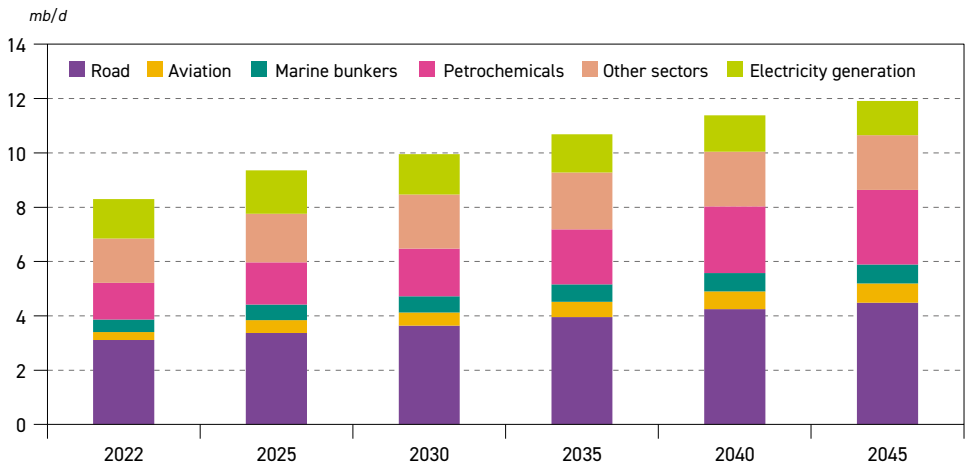
This region is also home to several large bunkering ports, including Singapore, the largest bunkering port in the world. Therefore, demand for marine bunkers has a share of 13% in the overall demand slate for this region. This share will likely be maintained in the years to come as expected growth in this region's maritime trade will likely offset efficiency improvements and the increased share of LNG as a bunkering fuel. The net result is that demand for marine bunkers in Other Asia is set to grow by 0.5 mb/d over the long-term.

Similar to Other Asia, **Africa** also represents a region with very dynamic demographic developments, a young population, a growing labour force, abundant natural resources and a strong potential for industrial expansion and urbanization. With these attributes, oil demand in Africa is projected to increase by 3.8 mb/d between 2022 and 2045. The largest potential for incremental oil demand in this region exists in the road transportation sector. This is due to the relatively low vehicle ownership in Africa, although this is expected to improve over the forecast period. The vehicle fleet in the region is set to grow by an estimated 120 million. In turn, this will give a boost to oil demand in this sector, which is forecast to expand by around 1.7 mb/d over the forecast period.

The remaining part of incremental oil demand in Africa will be split between the residential/agriculture (0.6 mb/d, mainly LPG and domestic kerosene), electricity generation (0.5 mb/d), aviation (0.3 mb/d) and industry (0.3 mb/d) sectors. In contrast to other regions, where oil use for electricity generation is typically declining, it is set to continue to expand in Africa due to the need for decentralized power generation in many places, including those still lacking access to electricity. Another interesting observation for Africa relates to the limited use of oil in the petrochemical industry, currently at around 0.2 mb/d. This is anticipated to marginally increase to 0.3 mb/d in 2045, much lower than in other high growth regions.

Oil demand in the **Middle East** countries is projected to increase by 3.6 mb/d between 2022 and 2045. As presented in Figure 3.15, the bulk of this increase will likely materialize in two sectors, road transportation and petrochemicals, adding about 1.4 mb/d each to the region's oil demand over the forecast period. Demand growth in road transportation will be more pronounced during the current decade and will then decelerate gradually towards the end of the forecast period.

Figure 3.15
Oil demand in the Middle East by sector, 2022–2045



Source: OPEC.

In contrast, demand growth in the petrochemical sector will be more equally spread over the forecast period, increasing broadly by 0.3 mb/d in five-year intervals. This will be due to the availability of feedstock, primarily ethane and LPG, and supplemented by naphtha. This gives this region a comparative advantage to its neighbouring regions. Significant demand growth is also projected in the aviation and industry sectors, each adding another 0.4 mb/d to future oil demand. Small, but still positive, oil demand growth is also expected from maritime shipping on the back of expanding trade between the Middle East and other regions. Besides imports of retail goods and various materials, higher oil exports from this region will result in growing demand for marine bunkers. By 2045, this is estimated to be 0.2 mb/d higher than in 2022.

However, part of the demand growth in the above sectors is expected to be offset by declining oil demand in electricity generation, as efforts are made to replace oil by natural gas and renewables. This will make higher volumes of oil available, either for refining, or direct exports.

Changes in future oil demand in the remaining non-OECD regions will likely be rather constrained. In **Latin America**, population growth is expected to be limited. Add to this, the relatively low labour productivity and high debt levels in several countries, and GDP growth is set to be rather moderate, confined to the range of 1.3% to 2.3% p.a. over the forecast period. This economic activity is reflected in the region's expected overall demand increase

of around 2.5 mb/d, expanding from 6.4 mb/d in 2022 to 9 mb/d by 2045. As is the case in most regions, incremental demand is primarily driven by road transportation, which is set to increase by 0.7 mb/d. The continued shift to cleaner fuels in the residential sector and the growing need for agricultural products results in a combined demand increase of 0.5 mb/d over the forecast period. A similar level of demand increase is also projected in the aviation and industrial sectors, adding around 0.4 mb/d and 0.3 mb/d, respectively, between 2022 and 2045.

Demand growth will be even more constrained in the remaining three non-OECD regions. Oil demand in **Other Eurasian** countries is projected to increase by 0.3 mb/d, expanding steadily from 1.2 mb/d in 2022 to 1.5 mb/d in 2045. Diesel/gasoil will account for almost 50% of this growth, mainly in the road transportation and industry sectors. The remaining part of the demand increase will be for gasoline, jet kerosene and 'other products', mainly associated with bitumen used for the expansion of the road network.

Demand in **Russia** and **Other Europe** will expand only slightly to around 2035 before it plateaus and marginally declines for the rest of the period. Oil demand in Russia will peak at levels slightly below 4 mb/d, while demand in Other Europe will likely not surpass the 1 mb/d mark. This trajectory will result from offsetting effects of some growth in petrochemicals (especially in Russia), aviation and road transportation and stagnating to declining demand in other sectors.

3.2 Oil demand outlook by sector

Table 3.3 provides an overview of oil demand trends from the perspective of major consumption sectors. It underscores that oil use in various transportation modes constitutes the backbone of current, as well as future oil demand. Indeed, the transportation sector accounted for around 57% of global oil demand in 2022 and, with minor variations, is projected to retain this share over the entire forecast period.

Table 3.3
Sectoral oil demand, 2022–2045

mb/d

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
Road	44.5	47.0	48.8	49.1	49.1	49.1	4.6
Aviation	6.1	7.6	8.4	9.0	9.6	10.2	4.1
Rail/waterways	1.9	2.0	2.2	2.2	2.3	2.2	0.3
Marine bunkers	4.1	4.4	4.8	4.9	4.9	4.9	0.8
Transportation	**56.6**	**61.1**	**64.1**	**65.2**	**65.9**	**66.4**	**9.8**
Petrochemicals	14.3	15.6	17.0	17.6	18.2	18.6	4.3
Other industry	12.8	13.2	14.0	14.5	14.3	14.2	1.5
Industry	**27.1**	**28.8**	**31.0**	**32.1**	**32.4**	**32.9**	**5.8**
Resid./Comm./Agr.	11.2	11.5	12.5	12.8	12.9	12.8	1.6
Electricity generation	4.7	4.7	4.5	4.3	4.2	4.0	–0.8
Other uses	**15.9**	**16.2**	**16.9**	**17.1**	**17.1**	**16.7**	**0.9**
World	**99.6**	**106.1**	**112.0**	**114.4**	**115.4**	**116.0**	**16.4**

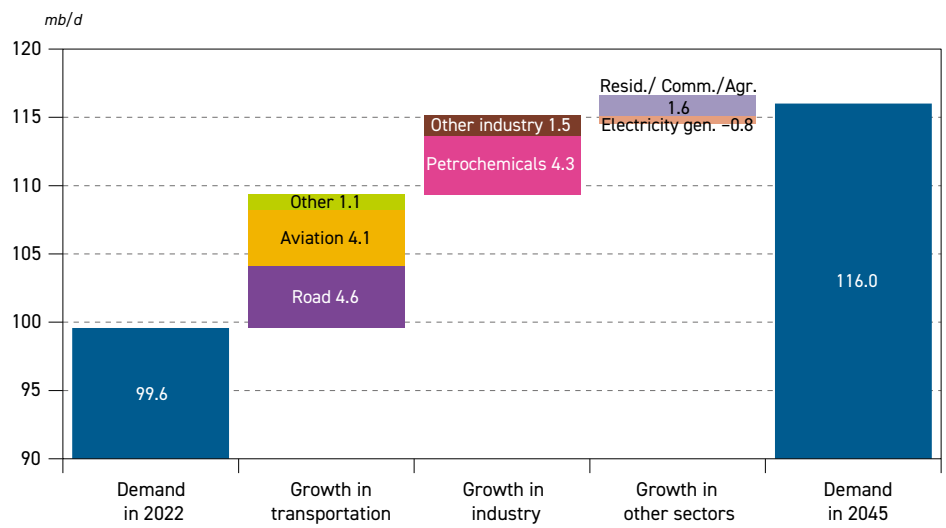
Source: OPEC.

The second largest source of oil demand is the industry sector. This sector consumed around 27% of global demand in 2022. The large part of this consumption relates to the use of oil as a feedstock to the petrochemical industry. While oil combustion in the industry sector is projected to remain relatively stable in the long-term, strong future demand for petrochemical products will pull demand for oil as a feedstock significantly higher.

The remaining part of oil demand is spread across a variety of sectors, including residential, commercial, agriculture and electricity generation. After initial growth during the current decade, projections show that the combined long-term oil demand of these sectors will be relatively stable, at levels around 17 mb/d. It should be noted, however, that this stable demand at the global level is a result of often diverging trends at the regional and products level.

Figure 3.16 summarizes sectoral oil demand trends in terms of incremental demand between 2022 and 2045. It clearly shows that various transportation modes are not only the main source of current demand, they also provide the largest source of future incremental demand. Combined together, the transportation sector will increase by almost 10 mb/d between 2022 and 2045.

Figure 3.16
Oil demand growth by sector, 2022–2045



Source: OPEC.

The largest incremental demand during the forecast period is projected for the road transportation sector. This sector will be exposed to the impact of the offsetting effects of various factors. Oil demand in this sector depends on the size and composition of the vehicle fleet, consumer driving habits, vehicle fuel economies that are often subject to policy measures, regional scrappage rates, as well as consumer choices when buying new vehicles, often giving preference to larger vehicles, such as SUVs. Moreover, there is a distinct pattern between personal cars and commercial vehicles, which adds to the complexity of demand modelling in this sector.

The key parameters affecting oil demand in the passenger car segment are efficiency improvements and the penetration of alternative vehicles into regional fleets, mainly EVs. Passenger EVs are projected to expand to more than 190 million by 2030 and further to 560 million by 2045, hence, gradually offsetting a portion of oil demand. The net effect is that oil demand in this segment is set to peak sometime after 2030 and then slowly decline for the rest of the forecast period.

These changes, however, will be less present in the segment of commercial vehicles. Some light-duty vehicles will likely be replaced by EVs, but the level of penetration is expected to be relatively low. Some fuel substitution will also likely be achieved via natural gas, but this will be constrained in respect to both regional coverage and the level of penetration. Given the size of the commercial vehicle fleet is set to double, or increase by 270 million vehicles, oil demand in this segment will continue growing during the forecast period. Therefore, oil demand in the road transportation sector is forecast to expand from 44.5 mb/d in 2022 to above 49 mb/d in 2045.

Large demand additions are also projected for the aviation sector. Driven by the propensity to travel and a rise in the middle class, especially in developing Asia and the Middle East, oil demand in this sector is set to increase by 4.1 mb/d between 2022 and 2045. This increase could potentially be even higher given the projected rise of air traffic in terms of passenger kilometres. However, improved energy efficiency and the gradual penetration of alternative fuels will likely offset part of this potential.

Demand additions in the other transportation sub-sectors – marine bunkers, rail and domestic waterways – are set to be relatively low. Expanding maritime trade will drive demand for marine bunkers, especially in Asia and the Middle East. The related demand change will be around 0.8 mb/d over the forecast period. Another 0.3 mb/d is also expected from the combined rail and domestic waterways sector, which is primarily linked to waterways traffic in China.

Important demand growth is also projected in the industry sector. The larger part of it, estimated at 4.3 mb/d to 2045, relates to the strong demand for petrochemical products. In fact, after road transportation, this industry will be the second largest source of incremental demand. In contrast, the overall demand change in the 'other industry' will be limited to 1.5 mb/d, mainly due to declining demand in OECD regions where natural gas and electricity will increasingly play an important role in industry.

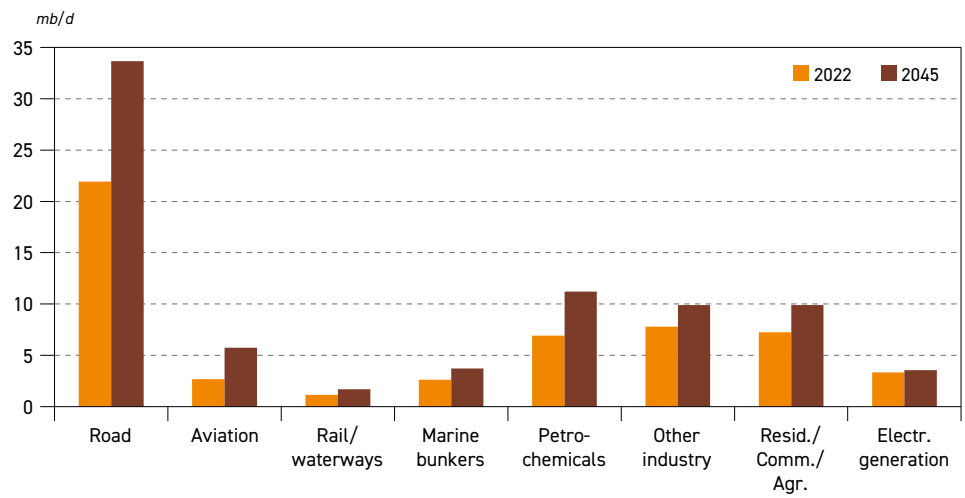
Oil substitution will also be present in non-OECD countries, albeit to a lesser extent. Moreover, strong industrialization in many non-OECD countries is set to more than compensate for any oil replacement so that 'other industry' demand in this region increases by 2.1 mb/d over the forecast period. The overall demand change in the industry sector, at the global level, is forecast to be 5.8 mb/d. It reaches almost 33 mb/d in 2045, from 27.1 mb/d in 2022.

Finally, combined oil demand in the remaining sectors will be the result of diverging trends in specific areas. For example, oil consumed for electricity generation in the OECD is set to be almost completely eliminated during the forecast period. It is expected to decline by around 1 mb/d, with the remaining volumes serving rather as a back-up solution, or utilized in remote areas. In contrast, oil used for the same purpose in Africa is anticipated to increase by 0.4 mb/d over the forecast period. Similar pathways are projected for oil demand in the residential and agriculture sectors, where significant growth in LPG and diesel demand in the

non-OECD more than offset declining demand for these products in the OECD. The net effect will be that combined oil demand in these sectors, after some growth during the current decade, fluctuates around 17 mb/d over the period to 2045.

The main trends in the sectoral oil demand of OECD countries were presented in Figure 3.5. Figure 3.17 provides the summary sectoral demand changes in the non-OECD. As mentioned in 3.1.1, OECD oil demand is set to decline in all major sectors except for aviation. In contrast, non-OECD demand is forecast to grow in all major sectors, albeit only a marginal change is projected for electricity generation. The largest demand increase is projected in the road transportation sector (+11.7 mb/d between 2022 and 2045). This will be followed by the petrochemical industry, where demand is set to expand by 4.3 mb/d. Incremental demand in the aviation sector is estimated at 3.1 mb/d. Smaller, but still important demand increments are projected in residential (+2.5 mb/d), 'other industry' (+2.1 mb/d) and other transport (+1.6 mb/d) sectors.

Figure 3.17
Sectoral oil demand in non-OECD countries, 2022 and 2045



Source: OPEC.

3.2.1 Road transportation

The road transportation sector accounts for the largest part of oil demand in most countries and regions. This sector has accounted for 43–46% of global oil demand over the past ten years, with its share mostly above 55% in the case of OECD Americas, around 47% in OECD Europe and about 40% in China. It underlines that developments in this sector could potentially have large implications on regional and global oil demand in the years to come.

From the global perspective, there are several critical factors steering demand in this sector. The first is the size of the vehicle park. This Outlook assumes that the global fleet will significantly increase during the forecast period. Population growth and improving economic and social conditions, especially in developing countries, will drive the sales of new vehicles and lead to much higher car ownership compared to the current situation. Moreover, a higher level of economic activity will require a higher number of commercial vehicles too.

The second factor is the changing composition of the vehicle park. It is clear that the electrification of road transportation will be the most important component in this respect. The big unknown is how fast it will progress, and to what extent it will affect commercial vehicles. At the same time, we must not lose sight of other alternatives, such as natural gas and hydrogen-based vehicles.

The third factor relates to the potential efficiency improvements of vehicles. Clearly, there is scope to achieve better fuel economies in ICE-based vehicles. However, it remains to be seen how far this will impact overall fuel economies, or whether it will be (at least partially) offset by consumers' preference for larger vehicles.

Last but not least, the potential impact of autonomous mobility needs to be considered. This has the potential to change the travel patterns of passengers and make commercial transportation far more efficient in the longer-term. This sub-section will try to capture the combined impact of these factors and make an assessment about future oil demand in this very dynamic sector.

Vehicle stock

The future vehicle stock is a function of existing stocks, new sales and the scrappage of older vehicles. Therefore, it is important to look at recent trends in new vehicle sales, both at the global and regional levels. Global vehicle sales declined from around 100 million vehicles annually during 2016–2019 to a range of 85–90 million in the past three years (excluding two-wheelers). More specifically, total new sales were at 86.1 million vehicles in 2022 of which passenger cars accounted for slightly more than 73 million and commercial vehicles for almost 13 million.

China had the largest share of new sales in 2022 with a market of almost 25 million. This level of new sales represents close to 30% of worldwide vehicle registrations during the year. This was despite a decline in new sales of around two million units compared to 2021, on the back of the continued lockdowns. Out of the 2022 figure, personal cars accounted for more than 22 million units. An important feature of the Chinese car market is the high share of EVs in new sales, much higher than in any other region considered in this Outlook.

New vehicle sales in the second largest market, OECD Americas, also declined slightly to 18.2 million in 2022 compared to 19.7 million in 2021. This market is dominated by ICE-based vehicles, as EVs accounted for only one million of new sales in 2022. Initial sales figures for 2023 indicate that the share of EVs will rise during the year, supported by additional incentives including the IRA, the effect of which will only be fully seen this year.

The other two OECD regions, OECD Europe and OECD Asia-Pacific, follow the same path as OECD Americas. New vehicle sales in these regions declined by around 5% each in 2022, reaching an annual market size of 14.2 million and 7.6 million, respectively.

OECD Europe represents the second largest market for EVs, after China, with annual sales of 2.7 million in 2022. Another specific of this region is the large share of PHEVs in new sales on the back of significant subsidies in several countries. However, the phase-out of PHEV subsidies in some major countries, such as Germany, may change this in the near future. Sales figures for the initial months of 2023 support this view, although more time is needed to fully assess the real impact. Moreover, recent sales figures also confirm a declining trend for diesel-based passenger cars in OECD Europe.

It is important to note that the OECD and China combined account for more than 80% of global vehicle sales. The largest car markets among other non-OECD regions exist in India, Other Asia and Latin America, each with annual sales of around five million vehicles. It is expected, however, that these regions will gradually gain share in both new sales, as well in the size of the vehicle park over the forecast period. This is clearly visible in Table 3.4, which presents the projected size of the passenger car fleet at the regional and global level. It shows that the number of passenger cars is set to increase from around 1.4 billion in 2022 to 2.1 billion in 2045.

Table 3.4
Number of passenger cars, 2022–2045

millions

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	282.2	286.3	295.7	307.2	314.9	317.4	35.2
OECD Europe	259.4	261.9	264.7	267.2	269.4	271.2	11.8
OECD Asia-Pacific	112.0	111.0	106.9	101.7	95.4	88.5	–23.5
OECD	**653.5**	**659.2**	**667.3**	**676.1**	**679.6**	**677.1**	**23.5**
China	301.3	341.3	411.5	477.4	523.0	541.6	240.3
India	45.7	56.2	80.0	112.9	153.0	197.3	151.7
Other Asia	88.1	95.8	117.9	147.6	181.7	219.9	131.8
Russia	38.0	37.9	37.7	37.1	36.1	35.0	–3.0
Other non-OECD	242.2	259.7	294.9	336.5	381.7	431.9	189.7
Non-OECD	**715.2**	**790.9**	**942.1**	**1,111.5**	**1,275.5**	**1,425.7**	**710.5**
World	**1,368.8**	**1,450.0**	**1,609.4**	**1,787.5**	**1,955.2**	**2,102.8**	**734.0**

Source: OPEC.

Most of this growth is forecast to take place in non-OECD regions. China itself is projected to add 240 million passenger cars to its fleet, surpassing the 540 million mark by 2045. Even more impressive growth, in relative terms, is projected for India. The number of passenger cars in this country is set to quadruple during the forecast period, from 45.7 million in 2022 to almost 200 million in 2045. This will be possible on the back of sustained economic growth in the range of 6% p.a., which will generate a larger middle class in this country. At the same time, it needs to be highlighted that these new vehicles will partly offset the number of two-wheelers (excluded from this analysis).

Larger groups of countries included in 'Other Asia' and 'Other non-OECD' will also contribute to the substantial increase in the number of passenger cars. Other Asia is set to more than double the number of passenger cars on its roads while 'Other non-OECD', which covers Africa, Middle East and Latin America, is expected to increase this number by 190 million between 2022 and 2045.

In contrast to non-OECD regions, car parks in the OECD are already fairly saturated leaving little room for further expansion. Consequently, the number of passenger cars in the OECD is set to witness marginal growth over the next decade before it stabilizes and even slightly declines towards the end of the forecast period. Some potential for growth still exists in OECD

Americas and OECD Europe. This, however, will be largely offset by declines in OECD Asia-Pacific where population levels are already on a declining trajectory. Moreover, this region's ageing population will also contribute to a declining passenger car park.

Turning to the commercial fleet, Table 3.5 shows that this is projected to increase from 267 million in 2022 to almost 540 million in 2045. As expected, a large part of this increase is for non-OECD, where the commercial fleet is set to expand by more than 220 million vehicles between 2022 and 2045.

Table 3.5
Number of commercial vehicles, 2022–2045 *millions*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	41.1	41.7	46.1	52.0	57.7	63.2	22.1
OECD Europe	45.2	46.5	51.7	57.8	63.9	69.7	24.5
OECD Asia-Pacific	25.6	25.6	26.2	26.8	27.5	28.2	2.6
OECD	**111.9**	**113.7**	**124.0**	**136.6**	**149.1**	**161.2**	**49.2**
China	30.9	34.5	42.7	52.5	62.7	72.1	41.2
India	20.1	23.6	31.9	42.7	57.0	73.0	52.9
Other Asia	31.0	33.8	42.5	51.9	61.6	71.2	40.2
Russia	6.0	6.1	6.0	6.0	6.1	6.2	0.2
Other non-OECD	66.7	72.1	86.2	104.5	127.9	154.2	87.5
Non-OECD	**154.7**	**170.2**	**209.3**	**257.6**	**315.3**	**376.7**	**222.0**
World	**266.6**	**283.9**	**333.3**	**394.2**	**464.4**	**537.9**	**271.2**

Source: OPEC.

India's expected economic growth will require a tripling of the number of commercial vehicles, making its fleet comparable to that of China by 2045. Significant growth is also projected for China and Other Asia, each enlarging their commercial fleet by around 40 million vehicles. The largest fleet increase is projected for 'Other non-OECD', which includes a large group of rapidly expanding countries, with the fleet expanding by almost 90 million vehicles, from 66.7 million in 2022 to 154 million in 2045. This rapid growth of the commercial vehicle fleet in developing countries follows strong economic growth in most of the countries. In turn, this requires an expansion of freight services at all levels, from the transport of raw materials, the exchange of components and product delivery to final consumers.

The commercial fleet in the OECD region is also projected to increase, however, at a much slower rate compared to the non-OECD. In this case, the largest increase is set to come from OECD Europe (+25 million vehicles), followed by OECD Americas with an additional 22 million commercial vehicles by 2045.

Vehicle fleet composition

Besides the size of the global vehicle fleet, the composition of it also matters. Until recently, the overwhelming majority of vehicles was based on ICE, with oil products as the energy

source. These powertrains were supplemented by natural gas in some markets, such as India, China, Pakistan, IR Iran, Argentina and others. The share of natural gas vehicles (NGVs) at the global level was in the range of just 2%, while other alternative powertrains, such as EVs and FCEVs, accounted for a negligible fraction.

This has started to change in recent years, however, with the uptake of EVs. Seen as a way to comply with tighter emissions regulations and supported by purchase subsidies and additional policy measures (e.g. for research and infrastructure development), EVs have gradually penetrated both new sales and the vehicle fleet, especially in China and Europe. The EU, in particular, considers electrification as a silver bullet to decarbonize its road transportation sector and, consequently, has adopted the strategy to ban the sales of ICEs by 2035 (with an exception if it uses synthetic fuels).

These trends are clearly present in the composition of new vehicle sales. As mentioned in the previous sub-section, global vehicle sales declined significantly at the start of the COVID-19 pandemic in 2020. However, new sales of EVs, consisting of BEVs and plug- PHEVs, continued to grow. The sales of EVs have increased strongly from around 1 million in 2015 to 11.3 million in 2022, largely at the expense of ICE vehicles. While EVs accounted for just 1% of new sales in 2015, this share increased to above 4% in 2020 and further to more than 13% in 2022.

These global trends in new vehicle sales are even more pronounced in the case of China. EVs sales in the country have increased more than seven-fold over the past five years, from 860,000 in 2017 to 6.6 million in 2022. This was largely driven by BEV sales (five million in 2022), but also supported by PHEV (1.5 million in 2022). In relative terms, EVs in China reached a market share of 26% in 2022, if sales of all vehicles are considered. This number increases to 28% in the segment of passenger cars. Moreover, sales of HEVs approached 1 million in 2022, from less than 200,000 in 2017, thus further reducing potential oil demand as these vehicles typically have better fuel economies compared to conventional ICEs.

As a result of these developments, the structure of China's vehicle fleet is changing as EVs gradually penetrate. The share of EVs in China's vehicle fleet approached 5% in 2022, from almost zero in 2015. Naturally, this growth is set to slow after reaching higher penetration levels as it will require much higher sales numbers in future years to sustain significant growth. Nevertheless, even a growth deceleration in the penetration of the vehicle fleet will potentially have an impact on future oil demand.

Developments in other regions lag behind China, but the rising penetration of EVs is noticeable in almost all regions. Europe has followed a similar path to China in recent years, with EVs surpassing a 3% share in OECD Europe's vehicle fleet. Moreover, this share would approach 4% if only passenger cars were considered. There has been a somewhat slower penetration of EVs in OECD Americas so far, with a share just slightly above 1% in 2022. Even lower penetration rates can be viewed in other regions, including Japan, where EVs are still well below a 1% share. However, Japan has the largest penetration of HEVs, approaching a 20% share, which results in a very fuel-efficient fleet.

Looking forward, there are several uncertainties on how fast EVs will penetrate the global fleet. New sales of EVs will likely continue growing in China and the OECD. However, it remains to be seen how the rate of growth will change once subsidies are removed. Other question marks relate to price and range issue. Some progress has been reported on the development of solid-state batteries, which could potentially increase the range of EVs and

reduce the price if production proves to be scalable. On the other hand, the rise in the price of critical minerals could keep EVs more expensive, particularly if the industry needs to rely on lithium-ion batteries for a longer time.

A large uncertainty also relates to the speed of EV penetration in developing countries, where very little progress has been achieved to significantly increase sales so far. This is one of the reasons why the global penetration of EVs was still below 2% in 2022, despite the impressive growth in China and Europe.

Last but not least, there is the question as to what extent electrification will impact commercial vehicles, for which cost effectiveness, range and the recharging network are key issues. The penetration of EVs in the commercial sector is currently generally restricted to urban buses and last-mile delivery solutions. Smaller electric trucks are used for short-distance vehicles and mandatory daily return to a (recharging) base.

Considering the recent changes in the composition of new sales, the policy setup in key countries, the investment plans of car manufacturers, as well as related implementation challenges, Table 3.6 presents the summary of projections on the number of EVs at the regional level in the period to 2045. Moreover, Figure 3.18 shows the projected composition of the global vehicle fleet over the same period. It shows that EVs will be the fastest growing powertrain during this period. The number of EVs is set to increase from around 30 million in 2022 to 600 million in 2045. OECD countries and China will play a major role in this expansion, accounting for close to 500 million EVs in 2045. Making a comparison on a single country basis, sees China leading the way with almost 190 million of EVs by the end of the forecast period. In all cases, EVs will grow much faster in the passenger car segment compared to commercial vehicles.

NGVs are also expected to expand, but at a far lower rate than EVs. The size of the NGV fleet is set to rise from 34 million vehicles in 2022 to 113 million in 2045. However, the

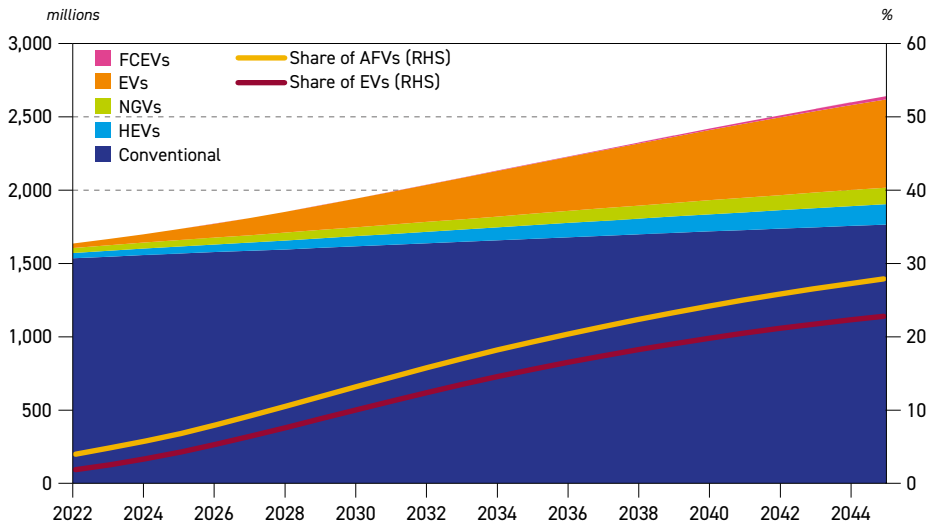
Table 3.6
Number of electric vehicles, 2022–2045

millions

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	4.1	9.7	29.3	58.2	90.3	126.9	122.9
OECD Europe	9.3	23.0	60.0	95.0	119.5	141.0	131.7
OECD Asia-Pacific	0.6	1.4	5.6	14.0	23.9	32.3	31.7
OECD	**13.9**	**34.1**	**94.9**	**167.3**	**233.7**	**300.2**	**286.3**
China	15.7	37.8	88.6	135.7	171.4	188.5	172.8
India	0.2	0.6	2.7	7.6	14.7	22.3	22.1
Other Asia	0.3	1.0	5.5	16.7	31.4	46.6	46.3
Russia	0.0	0.1	0.5	1.6	3.2	4.9	4.9
Other non-OECD	0.2	0.6	3.0	10.3	23.7	39.0	38.8
Non-OECD	**16.4**	**40.1**	**100.3**	**171.9**	**244.4**	**301.3**	**284.9**
World	**30.3**	**74.2**	**195.2**	**339.2**	**478.1**	**601.5**	**571.2**

Source: OPEC.

Figure 3.18
Global fleet composition, 2022–2045



Source: OPEC.

expansion of this type of vehicle is likely limited to Asian and Latin American countries, and is expected to almost disappear from European roads. The advantage of NGVs is that they can also partly penetrate the commercial segment as ICE-based vehicles can be adapted to natural gas.

The smallest expansion over the forecast period is projected for hydrogen-based fuel cell vehicles. This technology has a great potential to offer an alternative pathway to road transportation electrification in efforts to reduce emissions. However, due to higher costs, technology readiness and the availability of hydrogen, this Outlook does not assume the mass expansion of FCEVs. The number of these vehicles might reach some 20 million. It means that compared to other vehicle types, the market will remain rather niche.

An important implication of these trends is that the number of ICE-based vehicles is set to rise from 1.6 billion in 2022 to 1.9 billion in 2045, hence retaining their leading role in the global fleet with a share of 72% in 2045. Moreover, this share is even more dominant in the category of commercial vehicles, at 92% at the end of the forecast period. Needless to say, this large number of ICE-based vehicles will provide a solid base for the sustained use of oil in this sector. Another important conclusion from this analysis is that, due to the large existing base of ICEs in the global fleet, the transition to alternative powertrains will likely take decades, not years.

Outlook for oil demand in road transportation

Table 3.7 presents the combined effect of various factors on oil demand in the road transportation sector in major regions. At the global level, oil demand in this sector will continue to expand this decade, increasing by 4.3 mb/d by 2030, before it stabilizes at levels above 49 mb/d for the rest of the forecast period. This pattern will result in an overall demand increase of 4.6 mb/d between 2022 and 2045.

Table 3.7
Oil demand in the road transportation sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	13.7	13.8	13.1	12.2	11.4	10.6	–3.1
OECD Europe	6.3	6.2	5.8	5.1	4.4	3.6	–2.7
OECD Asia-Pacific	2.6	2.6	2.3	1.9	1.6	1.2	–1.4
OECD	**22.6**	**22.6**	**21.2**	**19.3**	**17.3**	**15.4**	**–7.2**
China	5.9	6.9	7.5	7.6	7.6	7.6	1.6
India	2.1	2.5	3.3	4.1	5.0	6.0	3.9
Other Asia	3.4	3.9	4.4	4.9	5.3	5.6	2.2
Latin America	3.3	3.3	3.6	3.8	3.9	4.0	0.7
Middle East	3.1	3.4	3.6	4.0	4.2	4.5	1.4
Africa	2.0	2.3	2.7	3.0	3.4	3.8	1.7
Russia	1.1	1.2	1.2	1.2	1.2	1.1	0.0
Other Eurasia	0.6	0.6	0.7	0.7	0.7	0.7	0.2
Other Europe	0.4	0.4	0.4	0.4	0.4	0.4	0.0
Non-OECD	**21.9**	**24.4**	**27.5**	**29.8**	**31.7**	**33.7**	**11.7**
World	**44.5**	**47.0**	**48.8**	**49.1**	**49.1**	**49.1**	**4.6**

Source: OPEC.

While the figures show a relatively stable long-term global demand path, specific regions will see much wider variations over the forecast period. In the OECD, the gradual increase in the EV fleet to 300 million and with the efficiency improvements in ICEs is set to reduce oil demand by 7.2 mb/d over the forecast period. The largest part of this decline is projected for OECD Americas, at 3.1 mb/d, mainly due to it being the region's largest demand base (hence, it sees the largest impact of efficiency improvements). Demand declines in OECD Europe and OECD Asia-Pacific are also expected to be significant, projected at 2.7 mb/d and 1.4 mb/d, respectively. In fact, in relative terms, the demand drop in these two regions will be even more dramatic than in OECD Americas.

The developing world will see a different oil demand pattern in the road transportation sector. Driven by a fast expanding vehicle fleet, in combination with a relatively slow penetration of alternative vehicles (the exception being China), means that oil demand in these countries is set to increase. In particular, this will be the case in India, where oil demand increases by a staggering 3.9 mb/d, from just 2.1 mb/d in 2022 to 6 mb/d in 2045. Somewhat lower incremental demand, but still significant, is projected for Other Asia and Africa, expanding by 2.2 mb/d and 1.7 mb/d, respectively. An important feature of road transportation oil demand in these three regions is that growth shows almost no signs of deceleration over the entire forecast period.

However, this is not the case for China. Road transportation oil demand in this country is set to expand strongly during the current decade. In fact, China's demand in this sector is expected to increase by 1.6 mb/d between 2022 and 2030, which is the largest incremental demand among all regions during this period. Around that time, however, the penetration of EVs is anticipated to be large enough to curtail further demand growth. Despite this, China's road transportation

will be by far the most important oil consumer in Asia, even by the end of the forecast period. It will also be the second largest consumer globally, behind OECD Americas.

Finally, only minor demand changes are expected in the remaining part of the non-OECD. While a moderate demand increase is projected for Other Eurasia, road transportation demand in Russia and Other Europe is set to remain in a very narrow range around current consumption levels.

Summing up all the changes for non-OECD, road transportation demand in this region is set to increase by 11.7 mb/d between 2022 and 2045.

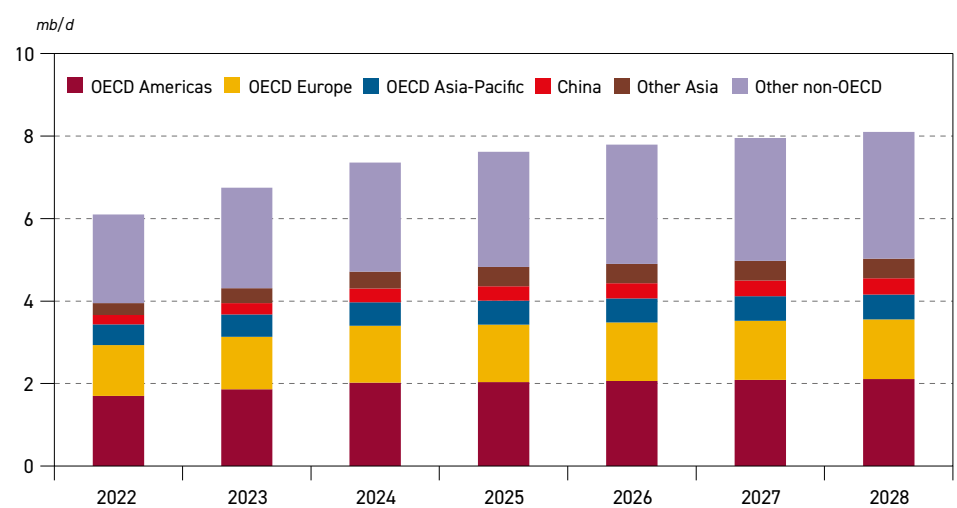
3.2.2 Aviation

Aviation was one of the most affected sectors during the COVID-19 pandemic and the scars are still being felt today. Aviation oil demand almost halved in 2020, falling to around 4 mb/d from 7.3 mb/d in 2019. A partial demand recovery began in 2021, but re-emerging regional lockdowns at that time prevented any significant rise in aviation oil demand. The recovery process continued in 2022 on the back of an increased propensity to travel, but this was also hampered by travel restrictions that still remained in place, causing travellers to be more cautious and to limit the number of flights.

The situation improved further during 2023, but many obstacles to a full recovery remain. These include high inflation, slower economic growth and conflicts in several parts of the world. Accordingly, the IATA Global Outlook for Air Transport estimated that the "industry-wide revenue passenger-kilometres (RPKs) are likely to be at 87.8% of the 2019 level for 2023 as a whole". A positive sign is that many airlines have returned to profitability again, which is a good basis for further growth.

These developments are also reflected in the related oil demand in this sector. As presented in Figure 3.19, aviation oil demand increased to 6.1 mb/d in 2022 and is expected to grow to 6.7 mb/d in 2023 and then 7.4 mb/d in 2024. By then, oil demand will be above 2019 levels,

Figure 3.19
Oil demand in the aviation sector, 2022–2028



Source: OPEC.

and its annual growth will then decelerate to reflect undistorted market fundamentals. As a result, oil demand is projected to reach 8.1 mb/d by the end of the medium-term period.

It is worth mentioning that demand growth during this period will be much faster in non-OECD countries, compared to the OECD. The overall medium-term demand increase in the non-OECD will be almost 1.3 mb/d, compared to 0.7 mb/d in the OECD. This will lead to a shrinking gap in aviation oil demand between these two regions over the period. While the difference was around 1 mb/d in 2019, it will be around 0.2 mb/d in 2028.

Turning to the long-term prospects, these will be affected by a number of additional factors. Driven by economic growth in developing countries, a rising share of the middle class – a source of potential travellers – demand is set to increase significantly. The IATA estimates that demand for air travel will double by 2040. Moreover, economic growth will also support the expansion of freight transport, which, in turn, will result in incremental oil demand. However, part of the potential demand increase will be offset by expected higher fuel economies in modern aircraft, higher load factors and route optimization.

While the impact of these measures on future oil demand can be reasonably quantified, a large uncertainty relates to recent initiatives from the ICAO and the IATA. In October 2022, ICAO member states adopted the LTAG for international aviation to achieve net-zero CO_2 emissions by 2050. It is worth noting that this target is far more ambitious than the previous one that envisaged a reduction in net aviation CO_2 emissions of 50% by 2050 (compared to 2005 levels). Moreover, while the previous target was primarily based on offsetting emissions, the new agreement focuses on a substantial reduction of direct CO_2 emissions from aircrafts, either by much better efficiency or by the use of alternative fuels.

This vision is outlined in 'The Net Zero Roadmaps' by the IATA. It foresees that the required emission reduction will be achieved via three main means: reducing aircraft energy use (through more efficient aircraft that use less energy); changing the fuel and reducing its carbon footprint (using net-zero and true-zero fuel alternatives, with SAF expected to be the main alternative); and re-capturing all the CO_2 that could not be avoided.

It remains to be seen to what extent the aviation industry will be able to implement this vision. While it is expected that small electric aircraft could start entering the market in the current decade, it is unlikely that this type of aircraft will play a significant role in displacing future oil demand over this Outlook's forecast period. In respect to SAF, this has the potential to play a more prominent role, subject to reducing production costs and resolving some technical obstacles. However, it is unlikely that the expansion of SAF will progress fast enough to replace a significant part of oil demand until 2045.

Bearing in mind the related uncertainties, current projections indicate that aviation oil demand is projected to increase from 6.1 mb/d in 2022 to 10.2 mb/d in 2045. This represents an increase of 4.1 mb/d over the forecast period. Moreover, unlike many other sectors of consumption, demand in this sector is set to continue to steadily rise over the entire forecast period. The annual increments, even in the long-term, will be in the range of more than 0.1 mb/d.

Table 3.8 presents a regional breakdown of oil demand in the aviation sector. It shows that the global trends set out in the medium-term will extend to the long-term too, as a major part of future incremental demand will take place in non-OECD countries. Aviation demand in this

Table 3.8
Oil demand in the aviation sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	1.7	2.0	2.1	2.2	2.2	2.3	0.6
OECD Europe	1.2	1.4	1.5	1.5	1.5	1.5	0.3
OECD Asia-Pacific	0.5	0.6	0.6	0.6	0.7	0.7	0.2
OECD	**3.4**	**4.0**	**4.2**	**4.3**	**4.4**	**4.5**	**1.1**
China	0.8	1.0	1.1	1.2	1.3	1.3	0.6
India	0.2	0.3	0.3	0.4	0.6	0.7	0.5
Other Asia	0.7	0.9	1.1	1.2	1.3	1.4	0.7
Latin America	0.2	0.3	0.4	0.5	0.6	0.6	0.4
Middle East	0.3	0.5	0.5	0.6	0.6	0.7	0.4
Africa	0.2	0.3	0.4	0.5	0.5	0.6	0.4
Russia	0.2	0.2	0.2	0.2	0.3	0.3	0.0
Other Eurasia	0.0	0.1	0.1	0.1	0.1	0.1	0.0
Other Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-OECD	**2.7**	**3.6**	**4.2**	**4.7**	**5.2**	**5.7**	**3.1**
World	**6.1**	**7.6**	**8.4**	**9.0**	**9.6**	**10.2**	**4.1**

Source: OPEC.

region is set to increase by 3.1 mb/d between 2022 and 2045, while OECD will add another 1.1 mb/d over the same period.

At the regional level, the largest incremental demand is expected to come from Other Asia. Demand in this region is set to increase by 0.7 mb/d over the forecast period. China and India will add around 0.5 mb/d to 0.6 mb/d each. Noticeable additions are also projected for the Middle East, Latin America and Africa, which are forecast to contribute 0.4 mb/d each. Contrary to these regions, only marginal demand additions are foreseen for Eurasia and Other Europe (+0.1 mb/d combined).

Aviation demand in the OECD is expected to expand from 3.4 mb/d in 2022 to 4.5 mb/d in 2045. Around half of this incremental demand comes from OECD Americas. Of the overall growth of more than 1 mb/d, 0.8 mb/d is projected during the current decade. This leaves just 0.3 mb/d, indicating a plateauing of aviation demand in this region in the last 15 years of the forecast period. During this period, the OECD will represent a mature market where growth is constrained by infrastructure capacity and only a minor population increase.

3.2.3 Petrochemicals

The petrochemical sector is projected to be the second largest source of oil demand growth over the forecast period. Growth will be driven by a wide range of petrochemical products, the largest share being polymers, which in turn are linked to growth in GDP, population and income levels. However, correlation between end-use product demand and oil demand is expected to weaken on the back of increasing oil substitution by secondary material and bio-based feedstock. Recycled plastics currently represent around 7% of global plastic use and this share is expected to increase to more than 10% by 2045.

Demand uncertainties in this sector remain high, particularly related to environmental concerns and regulations, such as efforts to reduce emissions, the push to increase recycling, the ban on single-use plastics and moves to foster plastic substitutions. There is also an ongoing multilateral process to develop an International Legally Binding Instrument (ILBI) to end plastic pollution, led by the Intergovernmental Negotiating Committee that expects to reach an agreement by 2024.

While the majority of participants in the negotiations agreed on the need to reduce plastic pollution, there were diverging opinions during the first and second sessions on whether to limit the scope of the instrument on the environmental footprint of plastics or widen it to reduce plastic production, which could significantly affect the petrochemical sector.

However, technological developments and innovative approaches could enable the use of oil-based feedstocks in this sector for a long time. Technologies include CCUS and electrically heated steam crackers, such as the project developed by BASF, Sabic and Linde, which could significantly reduce CO_2 emissions from petrochemical operations.

Furthermore, even recycling has limitations that are difficult to overcome today, such as, the complexity of the supply chain (collection, sorting, cleaning and treatment are complex processes that involve the cooperation of multiple actors), high cost, low quality of resulting feedstock and limited recycling technologies. In addition, the substitution of plastics by other materials remains constrained due to a lack of materials that can provide comparable functionalities without any disadvantages.

Considering the uncertainties surrounding petrochemicals, Table 3.9 presents an assessment of oil demand in this sector. At the global level, oil demand is projected to increase by

Table 3.9
Oil demand in the petrochemical sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	3.6	3.8	4.3	4.3	4.1	3.9	0.3
OECD Europe	1.8	1.8	1.8	1.7	1.6	1.5	–0.3
OECD Asia-Pacific	2.0	2.1	2.1	2.1	2.1	2.1	0.1
OECD	**7.4**	**7.7**	**8.3**	**8.1**	**7.8**	**7.4**	**0.0**
China	2.3	2.6	2.7	2.8	2.9	3.0	0.7
India	0.4	0.6	0.7	0.9	1.0	1.2	0.7
Other Asia	1.3	1.5	1.7	1.9	2.1	2.3	0.9
Latin America	0.3	0.4	0.4	0.5	0.5	0.5	0.2
Middle East	1.3	1.5	1.8	2.0	2.4	2.7	1.4
Africa	0.2	0.2	0.2	0.2	0.3	0.3	0.1
Russia	0.9	1.1	1.1	1.1	1.1	1.1	0.2
Other Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-OECD	**6.9**	**7.9**	**8.7**	**9.5**	**10.4**	**11.2**	**4.3**
World	**14.3**	**15.6**	**17.0**	**17.6**	**18.2**	**18.6**	**4.3**

Source: OPEC.

4.3 mb/d throughout the forecast period, rising from 14.3 mb/d in 2022 to 18.6 mb/d in 2045. This significant and steady growth at the global level hides a stark contrast between regions. In fact, oil use in petrochemicals is set to increase strongly in the non-OECD region, growing by 4.3 mb/d between 2022 and 2045. On the other hand, OECD oil demand in this sector in 2045 is expected to be at the same level observed in 2022.

Non-OECD Asia is set to witness the largest incremental demand rise throughout the forecast period, estimated at 2.4 mb/d. Demand additions of 0.9 mb/d, 0.7 mb/d and 0.7 mb/d are anticipated in Other Asia, India and China, respectively. Combined, these three regions are set to account for 55% of this sector's global incremental demand. This growth will be driven by economic and population expansion, as well by well-established processing/manufacturing industries in the region.

Moreover, many projects are under construction in non-OECD Asia, particularly in China, India and some countries in the South East region. China is reshaping its downstream sector by building several mega-refineries with integrated petrochemical units (mostly naphtha crackers) and is phasing out smaller ones. India sees partnerships with Middle Eastern national oil companies (NOCs) as an opportunity to develop a modern petrochemical industry, mainly based on integrated projects to capture higher margins. Indonesia and Malaysia are following a similar path.

The Middle East is expected to witness strong demand growth too, estimated at 1.4 mb/d over the forecast period. In fact, it is the Middle East that is set to witness the largest growth as a standalone region due to the local availability of feedstocks at a competitive cost.

A large number of petrochemical projects at a world scale in different stages of development have been listed within this region, such as the large mixed-feed steam cracking project under development by OQ, Sabic and KPI in Duqm, Oman. In Saudi Arabia, Saudi Aramco has made progress on two petrochemical projects worth $18 billion in development with Sabic and TotalEnergies, respectively. Saudi Aramco and TotalEnergies also awarded EPC contracts of $11 billion to seven different firms for a giant petrochemical complex in Jubail, Saudi Arabia, in June 2023. This project is expected to be operational by 2027. Saudi Aramco and Sabic are also proceeding with the first crude oil-to-chemicals (COTC) petrochemical plant in Yanbu, Saudi Arabia, which will be integrated with the existing refinery.

Other projects are currently under development in IR Iran, the United Arab Emirates and Qatar. These projects will support the region's oil demand for petrochemicals over the medium-term. Moreover, a continuation of this trend is expected over the long-term too.

In Russia, oil consumption in the petrochemical sector is expected to increase sharply during the next three-to-four years. In the long-term, however, demand is anticipated to stabilize at a level of 1.1 mb/d. This development is reflected in the updated petrochemical industry development roadmap approved by the Russian government in May 2023, which aims to accelerate production of polymers by 34% by 2025. It is worth noting that the new roadmap intends to increase the feedstock share for petrochemical needs from 26.7% in 2022 to 35.2% in 2025, while the 2030 Energy Strategy aimed to increase this share from 23.1% in 2018 to 35% in 2035. In reality, it means the deadline to reach the previous target was shifted by a decade. Oil demand for petrochemicals in other non-OECD regions – Africa and Latin America – are expected to witness only a slight demand increase in the range of 0.1 mb/d to 0.2 mb/d each.

In the OECD region, oil demand in this sector is expected to peak at around 8.1 mb/d at the end of this decade before dropping to 7.4 mb/d in 2045, the same level as observed in 2022. OECD Europe is the only region where oil demand for petrochemicals drops over the forecast period. Sluggish economic growth, rising production costs, as well as stricter recycling rules and emission policies are likely to prompt sectoral rationalization in Europe, leading to a demand decline of 0.3 mb/d between 2022 and 2045.

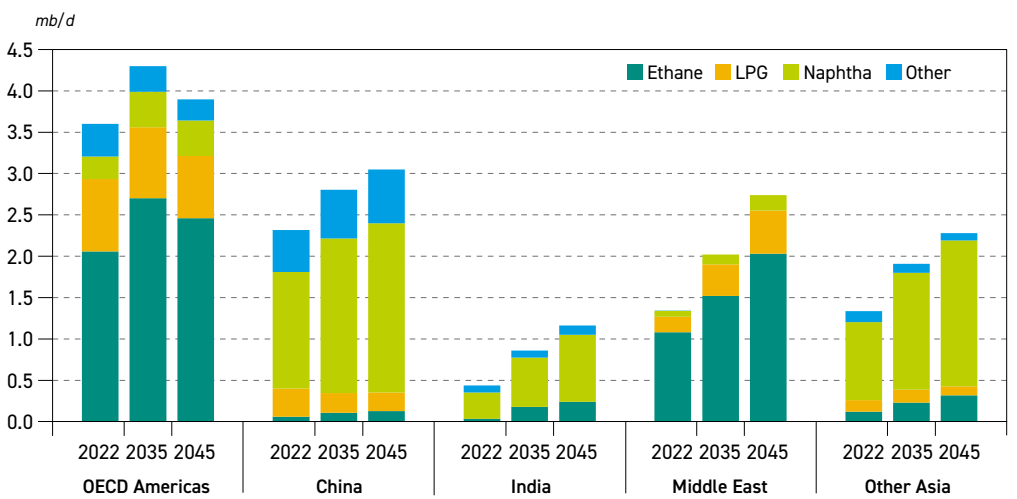
The trend in OECD Asia-Pacific is expected to follow a similar pattern as OECD Europe. An exception to this is South Korea, where some projects, including the S-Oil Shaheen naphtha cracker in Ulsan, are expected to become operational in the medium-term. These projects will support oil demand above 2 mb/d for the rest of the forecast period by offsetting demand declines elsewhere in the region.

Contrary to the other two OECD regions, OECD Americas is anticipated to experience a notable increase in oil demand in this sector during the current decade, expanding by 0.7 mb/d between 2022 and 2030. This rise can be attributed to the additional capacity that will be brought online to benefit from the availability of cheap ethane supplies. Notable projects contributing to this increase include the joint venture project between Chevron Phillips Chemical and Qatar Petrochemical, which is expected to create the largest cracker in the world, with a capacity of 1.9 million tonnes a year (mt/y).

However, this US demand growth is projected to peak sometime after 2030 and revert to a decline due to falling ethane supply. This, in turn, will likely enable the comeback of more competitive naphtha cracking. Consequently, oil demand in the petrochemical sector of OECD Americas is forecast to drop by 0.4 mb/d between 2030 and 2045.

Looking at these trends from the perspective of major refined products, Figure 3.20 presents a summary of product demand in key petrochemical regions. At the global level, naphtha accounts for the largest share of total demand in this industry (6.2 mb/d out of total demand

Figure 3.20
Regional demand in the petrochemical sector by product, 2022–2045



Source: OPEC.

of 14.3 mb/d in 2022), followed by ethane (3.7 mb/d) and LPG (2.5 mb/d). At the same, naphtha is expected to also provide the largest incremental demand (2.6 mb/d) during the forecast period given large increases in Asian countries. As a result, naphtha is set to see its share increase from 44% in 2022 to 47% in 2045.

Driven by developments in the Middle East and OECD Americas, where the majority of petrochemical feedstock is ethane, demand for this product is set to increase by 2 mb/d. The share of ethane is anticipated to increase from 26% in 2022 to 30% in 2045. This will be at the expense of LPG and other products, with shares for these gradually declining.

3.2.4 Other sectors

The overall demand change in the combined **residential, commercial and agricultural** sectors is relatively small, just 1.5 mb/d between 2022 and 2045. To a large extent, this is the result of diverging trends between its sub-sectors, as well as between regions. Typically, oil demand in the agriculture sector is expected to grow in most regions during the forecast period. However, demand trends in the residential and commercial sectors differ between regions as they are affected by regional policy setup, such as building codes, the level of economic development and regional specifics (e.g. heating *versus* cooling).

The impact of these factors on future oil demand is presented in Table 3.10. It shows that global oil demand in this sector is set to continue growing for a large part of the forecast period. It is only in the last few years that demand drops, when OECD declines more than offset growth in developing countries. OECD oil demand in this sector is set to remain relatively stable over the current decade, at around 4 mb/d. After 2030, however, stricter policy measures, such as those included in the EU's 'Fit for 55' package, are expected to gradually accelerate oil displacement in this sector.

The residential sector, in particular, is considered a 'low hanging fruit' in reducing future emissions. Specific regulations aimed to reduce energy and oil consumption in both new buildings via stricter codes, as well in older inefficient buildings through revamps and retrofits, constitute an essential part of the 'Fit for 55' package.

Clearly, these types of regulations are not limited to Europe. Building codes that promote energy efficiency, incentives to install heat pumps and PV technology, incentives to purchase more efficient appliances and preferences to district heating are common measures not only in OECD countries, but increasingly in a number of developing countries. However, the impact of population growth, urbanization and a rising middle class in the non-OECD will more than offset energy savings resulting from these regulations.

This is especially the case in India and Africa where oil demand in this sector is projected to increase by 0.8 mb/d over the forecast period. In the case of India, the largest part of this demand growth is for LPG and kerosene for cooking and lighting and diesel used in the agriculture sector. Obviously, there is even higher potential for demand growth in India. Part of this potential, however, will likely be eliminated by the expanding use of natural gas with City Gas Distribution (CGD) networks gradually extended. The aim of this plan is to provide natural gas access to more than 70% of the population.

Large potential for oil demand growth in this sector also exists in Africa. In particular, sub-Saharan Africa will benefit from switching from solid biomass to oil-based products such as

Table 3.10
Oil demand in the residential/commercial/agricultural sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	1.6	1.6	1.8	1.9	1.7	1.3	–0.3
OECD Europe	1.5	1.6	1.5	1.3	1.2	1.1	–0.4
OECD Asia-Pacific	0.8	0.8	0.8	0.7	0.6	0.5	–0.3
OECD	**3.9**	**3.9**	**4.1**	**3.9**	**3.5**	**2.9**	**–1.0**
China	2.5	2.7	2.8	2.9	3.0	3.1	0.5
India	1.1	1.3	1.4	1.6	1.8	1.9	0.8
Other Asia	0.9	0.8	0.8	0.9	0.9	0.9	0.0
Latin America	0.8	0.9	1.1	1.2	1.3	1.3	0.5
Middle East	0.5	0.5	0.6	0.6	0.5	0.5	0.1
Africa	0.6	0.7	0.9	1.0	1.2	1.4	0.8
Russia	0.4	0.4	0.4	0.4	0.4	0.4	0.0
Other Eurasia	0.2	0.2	0.2	0.2	0.2	0.2	0.0
Other Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Non-OECD	**7.2**	**7.6**	**8.4**	**8.9**	**9.4**	**9.9**	**2.6**
World	**11.2**	**11.5**	**12.5**	**12.8**	**12.9**	**12.8**	**1.6**

Source: OPEC.

LPG. Moreover, oil can also be used for off-grid electricity generation in remote rural settlements for household lighting, heating and cooling. An important part of the demand growth in this region is related to agriculture. Similar factors will also drive Latin America oil demand in this sector, which is set to expand by 0.5 mb/d.

With some minor growth in other regions, non-OECD oil demand in the combined residential, commercial and agricultural sector is expected to grow by 2.6 mb/d, rising from 7.2 mb/d in 2022 to 9.9 mb/d in 2045. The most important component of this growth is set to be LPG for use in the residential sector, which is projected to increase by 1.4 mb/d over the forecast period. It is followed by diesel (+0.5 mb/d) used in agriculture and for off-grid electricity generation.

The **shipping industry** was long considered as generally conservative, one where it took a long time to implement any change. This, however, has changed in recent years on the back of increasing competition to oil from alternative fuels and stricter industry regulations primarily targeting emissions reduction.

The most likely alternative seems to be LNG. The orderbook for new vessels shows that close to 50% of new ships will have pure LNG or dual-fuelled engines. Moreover, methanol-fuelled ships are attracting attention and their share in the orderbook is increasing. Engine manufacturers also work on developing ammonia fuelled engines that could offer another alternative to oil, especially for deep-sea shipping. Other alternatives include the use of hydrogen and electricity as energy sources in this industry.

Prototype vessels for each of these alternative powertrains already exist, demonstrating their advantages, but also their disadvantages. However, given the long lifetime of most vessels, it is unlikely that a significant penetration of these engines would be reached before 2045.

Nevertheless, their gradual penetration will likely put a cap on potential oil demand growth, and provide a further delinking from the rate of expanding maritime trade.

On the regulation side, maritime trade is governed by the IMO, which has the responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. In efforts to reduce emissions from shipping, IMO member states adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships in July 2023. This strategy includes a common ambition to reach net-zero GHG emissions from international shipping close to 2050, a commitment to ensure an uptake of alternative zero and near-zero GHG fuels by 2030, as well as indicative check-points for 2030 and 2040. These goals are much more ambitious than the previous one to achieve a 50% reduction in overall GHG emissions from marine transport by 2050, compared with 2008 levels.

Part of the strategy, already implemented as of 2023, is the introduction of two new indexes: the Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII) Rating Scheme. Based on these indexes, every ship will be assessed for its energy performance in respect to its design, as well as the carbon intensity of its operations. Consequently, underperforming ships will be either subject to penalties or corrective measures that need to be implemented. It is expected that adoption of these tools will lead to improved efficiency of existing vessels, lower emissions and, in turn, to slower oil demand growth in this sector. However, it remains to be seen how successful this scheme will be as there are many uncertainties and open questions related to it.

Bearing in mind these uncertainties and the impact of regional GDP developments on maritime trade, Table 3.11 presents projections for oil-based marine bunker demand to 2045. The overall change between 2022 and 2045 is limited to only 0.8 mb/d. Moreover, the bulk of incremental demand in this sector is projected during the current decade, with growth from

Table 3.11
Oil demand in the marine bunkers sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	0.5	0.5	0.5	0.5	0.5	0.4	0.0
OECD Europe	0.8	0.8	0.8	0.7	0.7	0.6	-0.2
OECD Asia-Pacific	0.2	0.2	0.2	0.2	0.2	0.2	-0.1
OECD	**1.5**	**1.5**	**1.5**	**1.4**	**1.3**	**1.2**	**-0.3**
China	0.3	0.3	0.4	0.4	0.4	0.4	0.1
India	0.0	0.0	0.0	0.1	0.1	0.1	0.0
Other Asia	1.1	1.3	1.4	1.5	1.6	1.7	0.5
Latin America	0.3	0.3	0.4	0.4	0.4	0.4	0.2
Middle East	0.4	0.5	0.5	0.6	0.6	0.6	0.2
Africa	0.1	0.2	0.2	0.2	0.2	0.2	0.1
Russia	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other Eurasia	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other Europe	0.1	0.0	0.1	0.1	0.1	0.1	0.0
Non-OECD	**2.6**	**2.9**	**3.2**	**3.4**	**3.6**	**3.7**	**1.1**
World	**4.1**	**4.4**	**4.8**	**4.9**	**4.9**	**4.9**	**0.8**

Source: OPEC.

4.1 mb/d in 2022 to 4.8 mb/d in 2030. After 2030, demand for marine bunkers will continue to grow, albeit in a narrow range of 4.8 mb/d to 4.9 mb/d. This will be on the back of the growing penetration of LNG vessels and the increased efficiency of oil-based vessels that counterbalance the still-expanding maritime trade.

With future economic growth driven by Asian countries, the centre of gravity of international maritime trade is set to further shift towards Asia. Moreover, several large bunkering ports are located in this region, as well as in the Middle East. These factors are forecast to drive demand for marine bunkers in the non-OECD over the entire forecast period, with regional demand increasing by 1.1 mb/d. The largest demand increases are projected in Other Asia (+0.5 mb/d) and the Middle East (+0.2 mb/d), whereas other non-OECD regions add another 0.4 mb/d to incremental demand.

Shifting trade towards non-OECD regions will also have implications for OECD demand in this sector. This is expected to remain relatively stable, at around 1.5 mb/d during the current decade, before the penetration of non-oil-based vessels, efficiency improvements and environmental regulations start biting into oil demand. The demand decline is not anticipated to be large, but steady across all OECD regions.

A similar set of measures in OECD countries will drive down oil demand in '**other industry**' too. A large part of OECD oil demand in this sector has been displaced in recent decades and this trend is set to continue over the forecast period. For example, the industrial use of oil in OECD Europe was in the range of 3.5 mb/d during the 1970s. However, it declined to a range of 2.2 mb/d in the 1990s and further to around 1.8 mb/d in the 2010s.

Given the availability of natural gas at competitive prices for US domestic use and the policy push to reduce emissions, it is expected that efficiency improvements and oil substitution will continue in this sector. OECD oil demand is set to steadily decline over the forecast period to reach a level of 4.3 mb/d by 2045 from 5 mb/d in 2022 (Table 3.12). This demand decline will also be supported by a falling share of heavy industry in the region's economic activity.

The demand outlook for this sector in non-OECD countries has a somewhat different narrative. Naturally, the electrification of industry, the increased use of natural gas and policy measures to reduce emissions will be present and impact non-OECD industrial oil demand too. However, expanding industrialization and the available choice of fuels to be used in many of these countries will more than offset the impact of potential fuel substitution and efficiency gains.

Therefore, the largest incremental demand is projected in regions with the gratest industrialization potential. This is particularly the case in India where demand growth in this sector is set to be in the range of 0.5 mb/d over the forecast period. Other Asia, Latin America, the Middle East and Africa are also forecast to expand, each growing by around 0.3 mb/d.

Somewhat lower demand changes are also projected in the remaining non-OECD regions, namely China, Other Eurasia, Russia and Other Europe, which combined add another 0.3 mb/d. From the perspective of refined products, changing demand in this sector typically affects demand for diesel, residual fuel and LPG.

Observed global oil demand in **rail and domestic waterways** was just 1.9 mb/d in 2022, making it the sector with the lowest oil demand. Moreover, as presented in Table 3.13, more

Table 3.12
Oil demand in the 'other industry' sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	2.8	2.9	3.1	3.1	2.7	2.5	–0.3
OECD Europe	1.4	1.4	1.4	1.4	1.3	1.3	–0.1
OECD Asia-Pacific	0.8	0.8	0.7	0.7	0.6	0.6	–0.2
OECD	**5.0**	**5.1**	**5.2**	**5.1**	**4.6**	**4.3**	**–0.6**
China	2.1	2.2	2.2	2.3	2.3	2.3	0.1
India	1.1	1.1	1.2	1.4	1.5	1.6	0.5
Other Asia	0.9	1.0	1.1	1.1	1.2	1.2	0.3
Latin America	1.0	1.0	1.1	1.2	1.3	1.3	0.3
Middle East	1.2	1.3	1.4	1.5	1.5	1.5	0.3
Africa	0.7	0.6	0.7	0.8	0.9	1.0	0.3
Russia	0.6	0.5	0.6	0.6	0.6	0.6	0.0
Other Eurasia	0.2	0.2	0.3	0.3	0.3	0.3	0.1
Other Europe	0.1	0.2	0.2	0.2	0.2	0.2	0.0
Non-OECD	**7.8**	**8.1**	**8.8**	**9.4**	**9.6**	**9.9**	**2.1**
World	**12.8**	**13.2**	**14.0**	**14.5**	**14.3**	**14.2**	**1.5**

Source: OPEC.

than 60% of this demand is concentrated in only two regions. The largest consumer in this sector is China with a demand level of 0.7 mb/d in 2022, of which around 0.6 mb/d was linked to domestic waterways and less than 0.1 mb/d to diesel consumption in rail transport. It is

Table 3.13
Oil demand in the rail and domestic waterways sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	0.5	0.5	0.5	0.5	0.5	0.4	–0.2
OECD Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.0
OECD Asia-Pacific	0.1	0.1	0.1	0.1	0.0	0.1	0.0
OECD	**0.7**	**0.7**	**0.7**	**0.7**	**0.6**	**0.5**	**–0.2**
China	0.7	0.8	0.8	0.9	0.9	0.9	0.3
India	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other Asia	0.1	0.1	0.2	0.2	0.2	0.2	0.1
Latin America	0.1	0.1	0.2	0.2	0.2	0.2	0.1
Middle East	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Africa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Russia	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-OECD	**1.1**	**1.3**	**1.4**	**1.6**	**1.6**	**1.7**	**0.6**
World	**1.9**	**2.0**	**2.2**	**2.2**	**2.3**	**2.2**	**0.3**

Source: OPEC.

very likely that the share of domestic navigation will rise even further in the future as China's waterway network is set expand, but oil will likely be further replaced by electricity in the rail sector. The assessed net effect is that the country's combined rail and waterways demand is expected to grow by 0.3 mb/d between 2022 and 2045.

The second largest consumer in this sector is OECD Americas, accounting for around 0.5 mb/d in 2022. However, the demand pattern in this region differs from the one in China. In this case, around 0.3 mb/d is used in rail transportation and some 0.2 mb/d in domestic waterways. Moreover, there are no great plans for an expansion of either of these transportation modes.

Therefore, it is expected that any potential demand increase related to some minor expansions will be more than offset by improved engine efficiencies, as well as oil's replacement by electricity, especially in the rail sector. Consequently, OECD Americas oil demand in this sector is set to decline by around 0.2 mb/d between 2022 and 2045. For the same reasons, demand in other OECD regions will also marginally decline, while no significant changes are expected in the remaining non-OECD regions.

With the exception of a few recovery years after the financial crisis in 2008–2009 and COVID-19 in 2020–2021, global oil demand for **electricity generation** has been on a declining trajectory since the early 1990s. However, the demand pattern and changes have not been uniform across regions. The main reason for the declining trend was oil displacement from this sector in the OECD, China and Russia, while other regions have kept demand broadly stable, or in some cases increased it, such as most countries in the Middle East. In very broad terms, aside from a demand increase in Africa, these trends are set to continue over the forecast period.

As presented in Table 3.14, global oil demand in this sector is set to drop by 0.8 mb/d, falling to 4 mb/d in 2045, from 4.7 mb/d in 2022. The primary reason for this decline will

Table 3.14
Oil demand in the electricity generation sector by region, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
OECD Americas	0.6	0.3	0.2	0.1	0.1	0.1	–0.5
OECD Europe	0.3	0.2	0.1	0.1	0.2	0.1	–0.2
OECD Asia-Pacific	0.5	0.4	0.4	0.3	0.2	0.2	–0.3
OECD	**1.4**	**0.9**	**0.7**	**0.6**	**0.5**	**0.4**	**–1.0**
China	0.2	0.2	0.2	0.2	0.2	0.2	0.0
India	0.1	0.1	0.2	0.2	0.2	0.3	0.1
Other Asia	0.5	0.4	0.4	0.4	0.3	0.3	–0.1
Latin America	0.4	0.6	0.6	0.6	0.6	0.6	0.1
Middle East	1.4	1.6	1.5	1.4	1.3	1.3	–0.2
Africa	0.4	0.6	0.8	0.8	0.8	0.8	0.4
Russia	0.1	0.2	0.2	0.2	0.1	0.1	0.0
Other Eurasia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Europe	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-OECD	**3.3**	**3.8**	**3.7**	**3.7**	**3.7**	**3.6**	**0.2**
World	**4.7**	**4.7**	**4.5**	**4.3**	**4.2**	**4.0**	**–0.8**

Source: OPEC.

be the almost complete elimination of oil used for electricity generation in the OECD. This is projected to decline by 1 mb/d over the forecast period and reach a level of just 0.4 mb/d by 2045. By then, virtually no oil will be used in large power plants. The use of oil will basically be restricted to electricity generation within the refinery gates, the use of diesel aggregates in remote places and for emergency back-up purposes.

Part of this OECD demand decline in the OECD will be offset by growing demand in several non-OECD regions. In this respect, the largest contribution (0.4 mb/d) is projected for Africa, followed by India and Latin America each adding 0.1 mb/d between 2022 and 2045. In these regions, especially in Africa, additional oil demand is set to help improve access to electricity and provide a back-up to shortages and disruptions from on-grid electricity.

Finally, some demand decline, especially in the long-term, is projected for the remaining non-OECD regions, including the Middle East, Other Asia, China, and Eurasia. Consequently, oil demand for electricity generation in non-OECD regions is set to remain at a fairly stable level of around 3.7 mb/d during the forecast period.

3.3 Oil demand outlook by product

Demand for specific refined products is largely determined by major trends at the regional and sectoral levels as there are direct links between demand for several products and sectors. For example, gasoline demand mirrors developments in road transportation, naphtha is tightly linked to petrochemicals and jet kerosene to the aviation sector. However, other products, such as diesel/gasoil, ethane/LPG and residual fuel oil are consumed in a variety of sectors, often with divergent demand patterns.

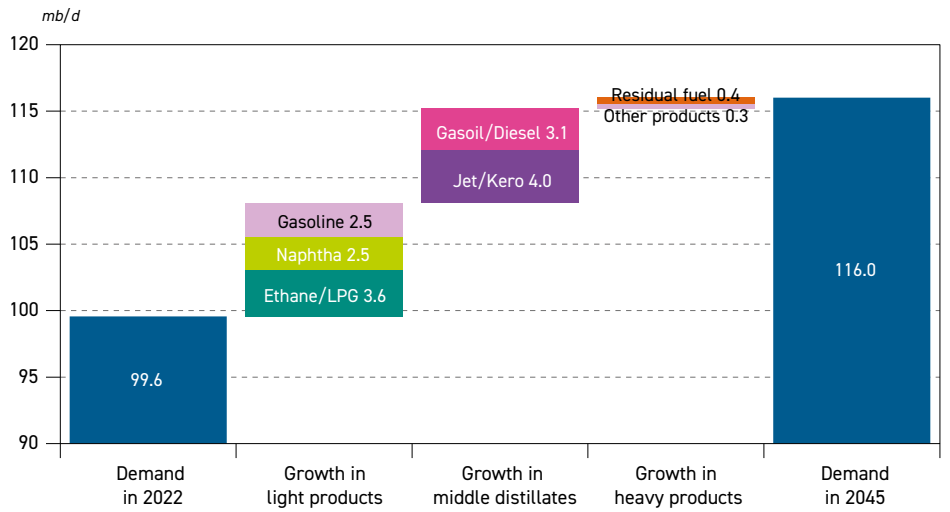
Global demand for the main categories of oil products is presented in Table 3.15. Figure 3.21provides a summary from the perspective of incremental demand between 2022 and 2045. Light products, composed of ethane, LPG, naphtha, gasoline and ethanol, accounted

Table 3.15
Global oil demand by product, 2022–2045 *mb/d*

	2022	2025	2030	2035	2040	2045	Growth 2022–2045
Ethane/LPG	12.9	14.1	15.5	16.0	16.4	16.5	3.6
Naphtha	6.3	7.0	7.7	8.1	8.5	8.8	2.5
Gasoline	26.3	28.1	28.9	29.0	29.0	28.8	2.5
Light products	**45.6**	**49.2**	**52.1**	**53.1**	**53.8**	**54.2**	**8.6**
Jet/kero	6.8	8.4	9.2	9.8	10.3	10.9	4.0
Gasoil/diesel	28.6	29.5	31.1	31.6	31.6	31.7	3.1
Middle distillates	**35.4**	**38.0**	**40.3**	**41.4**	**41.9**	**42.6**	**7.1**
Residual fuel	6.7	7.3	7.6	7.5	7.4	7.2	0.4
Other products	11.8	11.6	12.1	12.4	12.2	12.1	0.3
Heavy products	**18.5**	**18.9**	**19.7**	**19.9**	**19.6**	**19.3**	**0.7**
World	**99.6**	**106.1**	**112.0**	**114.4**	**115.4**	**116.0**	**16.4**

Source: OPEC.

Figure 3.21
Demand growth by product category between 2022 and 2045



Source: OPEC.

for 46% of global demand in 2022. Combined demand for these products is set to increase by 8.6 mb/d to 2045. This means that they will broadly retain the same share during the entire forecast period.

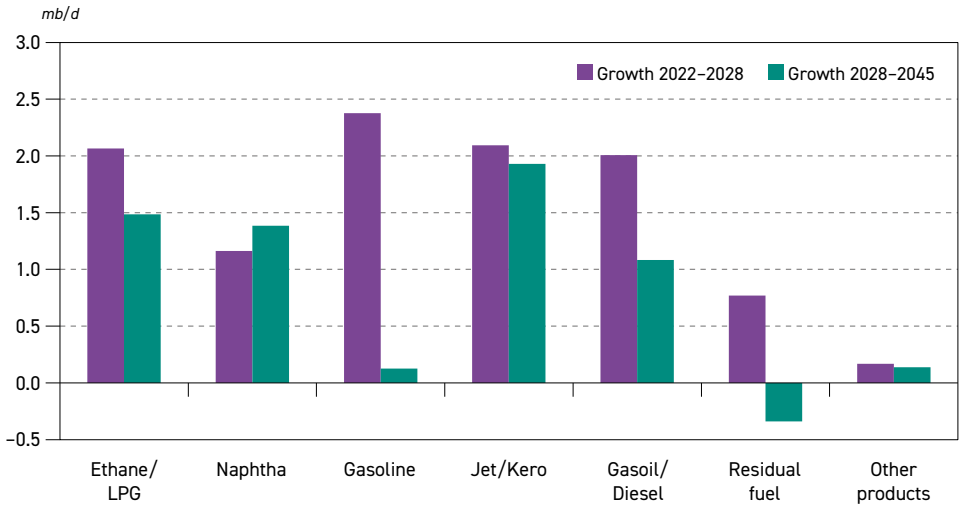
The largest demand increase in this category is expected to come from ethane/LPG with combined incremental demand of 3.6 mb/d. Of this, 2.1 mb/d is linked to ethane consumption, primarily in the petrochemical industry, and the remainder, close to 1.5 mb/d, is for LPG. This product is mostly consumed in the residential, industry and petrochemical sectors.

Another important observation relates to a distinct consumption pattern over time. While ethane is projected to grow continuously over the entire forecast period, LPG demand is set to peak sometime around 2035 (at around 10.8 mb/d) and then start to decline.

Besides ethane, demand for naphtha is also determined by developments in the petrochemical sector, especially in Asia, OECD Europe and Latin America where the petrochemical industry is based on naphtha feedstock. As discussed in section 3.2, this industry is set to grow over the forecast period, with the exception of Europe. Accordingly, demand for naphtha is set to rise by 2.5 mb/d with the largest increments projected for Other Asia (0.8 mb/d), China (0.6 mb/d) and India (0.5 mb/d). In contrast, naphtha demand in OECD Europe is expected to decline by 0.1 mb/d.

The demand pattern for gasoline, the largest component of light products with a current consumption of more than 26 mb/d, witnesses the largest changes over the forecast period. As presented in Figure 3.22, which splits the total demand change into 2022–2028 and 2028–2045 periods, gasoline demand is set to increase by 2.5 mb/d during the medium-term. The main reason for this increase is the continued expansion of the passenger car fleet, the majority of which is set to be gasoline based.

Figure 3.22
Growth in global oil demand by product



Source: OPEC.

Gasoline demand will continue growing over the next decade, albeit at a slower rate. During this period, the number of passenger cars is still expected to expand, but the growth of EVs, as well as ICE efficiency improvements, will be sufficient to limit gasoline demand growth that stabilizes at around 29 mb/d for the rest of the forecast period.

The second largest group of products is middle distillates. This consists mainly of diesel/gasoil (including biodiesel), jet kerosene and domestic kerosene. The overall demand growth for these products is somewhat lower than light products, at 7.1 mb/d during the forecast period. Almost 60%, or 4 mb/d of this incremental demand relates to kerosene. Virtually all this demand is set to come in the form of jet fuel on the back of strong growth in the aviation sector. In fact, the overall increase in kerosene demand is slightly lower than incremental demand in the aviation sector. This is because demand for domestic kerosene is set to slightly decline, hence part of the kerosene volume will 'shift' from the residential sector to aviation.

The demand pattern for diesel/gasoil is forecast to be different. Around 60% of this product is consumed in the road transportation sector, mainly by commercial vehicles, except for Europe where a significant share of passenger cars still use diesel. With the number of commercial vehicles set to expand, diesel demand in this segment will also grow. Part of this incremental demand will, however, be offset by declines in other sectors, such as marine bunkers, residential and commercial sectors. As a result, demand for diesel/gasoil is projected to increase by 3.1 mb/d over the forecast period. The majority of this growth is expected to materialize over the medium-term, at almost 2 mb/d, meaning that demand growth for this product will slow in the longer-term.

In terms of the heavy part of the refined barrel, consisting mainly of residual fuel oil, bitumen, petroleum coke, waxes, lubes, still gas and crude oil used for direct burning, projections indicate virtually no growth for the combined demand of these products. Some demand increase is projected for residual fuel, particularly during the medium-term period. Part of

this incremental demand will, however, likely be offset by declines in the long-term so the net demand increase for residual fuel is around 0.4 mb/d between 2022 and 2045.

Demand for the last group of 'other products' is expected to increase from 11.8 mb/d in 2022 to 12.4 mb/d by 2035, then slowly decline over the period 2035–2045. Within this group, demand for bitumen, lubes and waxes is expected to increase, especially in developing countries. This, however, will be more than offset by the declining use of crude oil to generate electricity. Moreover, the increasing complexity of the future refining sector will reduce the availability of petroleum coke as refiners strive to produce a higher share of 'better value' products. Overall, demand for 'other products' is expected to increase by 0.3 mb/d between 2022 and 2045.

Liquids supply

Key takeaways

- A degree of uncertainty continues to surround the medium- and long-term outlook for non-OPEC liquids supply given recent market volatility, with the global economy still emerging post-pandemic, record-high inflation and corresponding interest rate hikes, as well as geopolitical tensions.

- Nevertheless, recent liquids production remains robust, with non-OPEC supply healthy and OPEC+ maintaining a pre-emptive and cautious stance in order to keep markets well supplied, balanced and stable.

- Non-OPEC liquids supply is projected to grow by 7 mb/d, from 65.8 mb/d in 2022 to 72.7 mb/d in 2028. Incremental supply in the US makes up nearly half of this, at 3.4 mb/d, with other major drivers being Brazil, Guyana, Canada, Qatar and Norway.

- US tight oil supply is set to continue to grow, albeit not as rapidly as in the boom years of 2018 and 2019. From 12.7 mb/d in 2022, it is expected to rise to 16.6 mb/d in 2028, where it will essentially plateau before declining again from the early 2030s. US barrels will continue to make up the bulk of global tight oil supply, but Argentinean tight oil – largely from Vaca Muerta – is finally poised to take off and triple national output to 1 mb/d in the long-term.

- With US liquids supply peaking towards the end of the current decade, overall non-OPEC production will also start declining from the early 2030s, eventually falling to 69.9 mb/d by 2045. Guyana, Canada, Argentina, Brazil and Kazakhstan are some of the few non-OPEC producers set to continue growth beyond the medium-term, but non-crude liquids including biofuels and other unconventionals will also keep increasing.

- OPEC liquids will rise steadily from 34.2 mb/d in 2022 to 37.7 mb/d in the medium-term, and further to 46.1 mb/d by 2045. Thus, OPEC's share of global liquids supply will rise from 34% in 2022 to 40% in 2045.

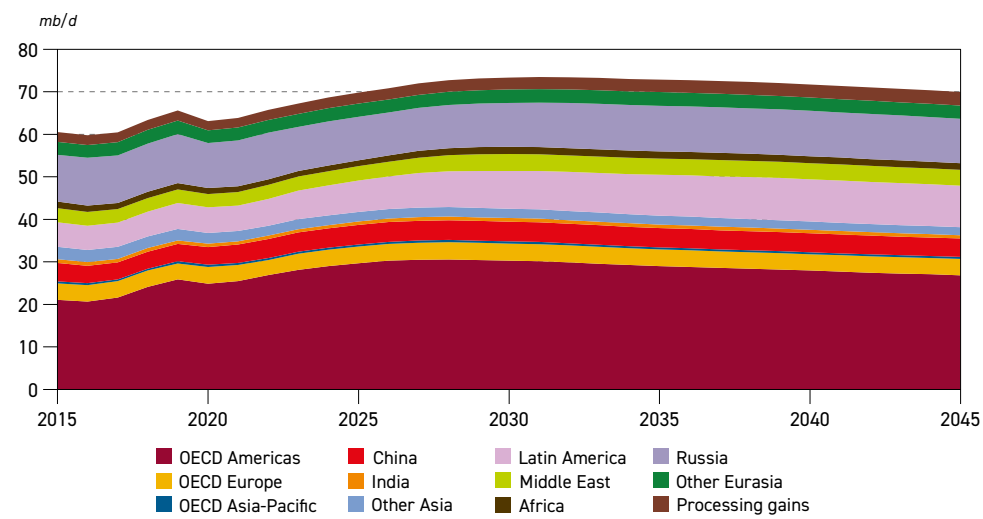
- Long-term investment requirements for the overall oil sector are estimated at a cumulative $14 trillion (in 2023 $US), or around $610 billion p.a. on average. Of this, $11.1 trillion is expected to be required in the upstream sector, or an average of $480 billion p.a. This will represent a considerable challenge and potential risk to market stability and energy security if it does not materialize. Downstream and midstream requirements are estimated at $1.7 and $1.2 trillion, respectively.

This chapter describes the outlook for liquids supply from 2022–2045. As in previous WOOs, the medium-term projections for 2022–2028 and the longer-term outlook are discussed separately, due to the different methodologies employed. The medium-term view relies on a bottom-up approach, identifying upstream project start-ups, their progress and the underlying decline in mature fields, while the long-term outlook is based on an assessment of the available resource base and other factors. US and other tight oil is also modelled and discussed separately, as are non-crude liquids.

4.1 Global liquids supply outlook

A degree of uncertainty continues to surround the medium- and long-term outlook for non-OPEC liquids supply given recent market volatility, a global economy still emerging post-pandemic, record-high inflation and corresponding interest rate hikes, as well as increasing political polarization and geopolitical tensions.

Figure 4.1
Long-term non-OPEC liquids supply outlook



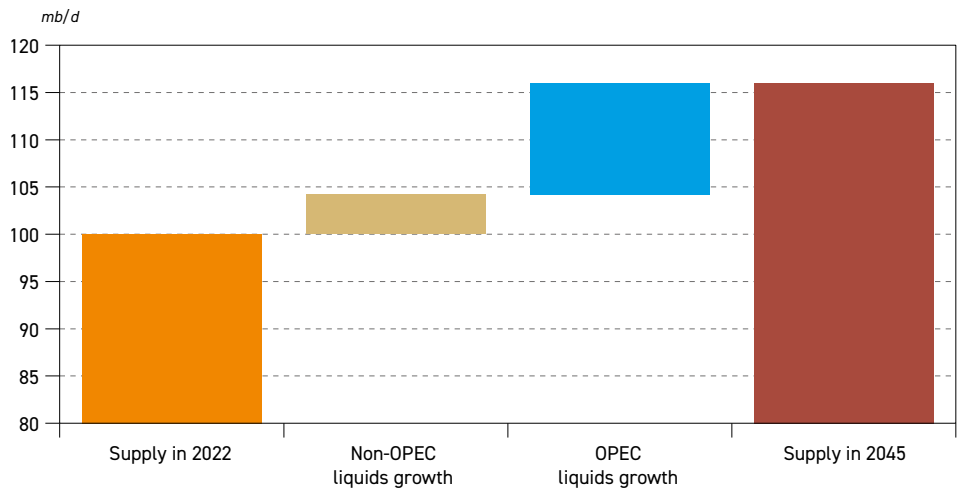
Source: OPEC.

Against the backdrop of calls to transition towards a lower-emissions future, persistent long-term concerns remain around oil and gas sector investment, especially given concerns related to financing, shareholder pressure, and ESG interests. Nevertheless, recent liquids production remains robust, with non-OPEC supply healthy and OPEC+ continuing to act proactively to maintain well-supplied, balanced and stable markets.

4.2 Drivers of medium-term and long-term liquids supply

The outlook for non-OPEC liquids supply retains the pattern described in recent Outlooks – healthy growth in the medium-term, followed by a peak in the early 2030s, after which output gradually declines again. Combined with oil demand projected to grow in the long-term, this implies steadily rising requirements for OPEC liquids, and hence an increasing market share for OPEC Member Countries.

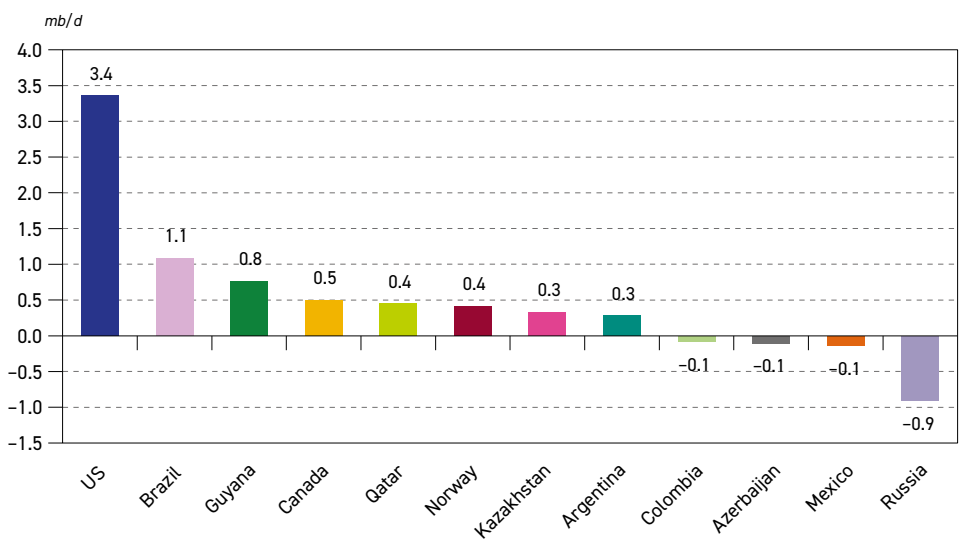
Figure 4.2
Composition of global liquids supply growth



Source: OPEC.

Sustained by projections of robust fundamentals, non-OPEC liquids supply is expected to grow by 7 mb/d, from 65.8 mb/d in 2022 to 72.7 mb/d in 2028. While concerns remain about whether upstream investments will remain sufficient, a sizable list of upstream projects is in the pipeline, many of which were set in place in recent years and due to come online in the medium-term. Moreover, US tight oil will remain a major driver of medium-term supply increases, even as growth slows. Brazil, Guyana and – to a lesser extent – Canada, Qatar,

Figure 4.3
Select contributors to non-OPEC total liquids change, 2022–2028

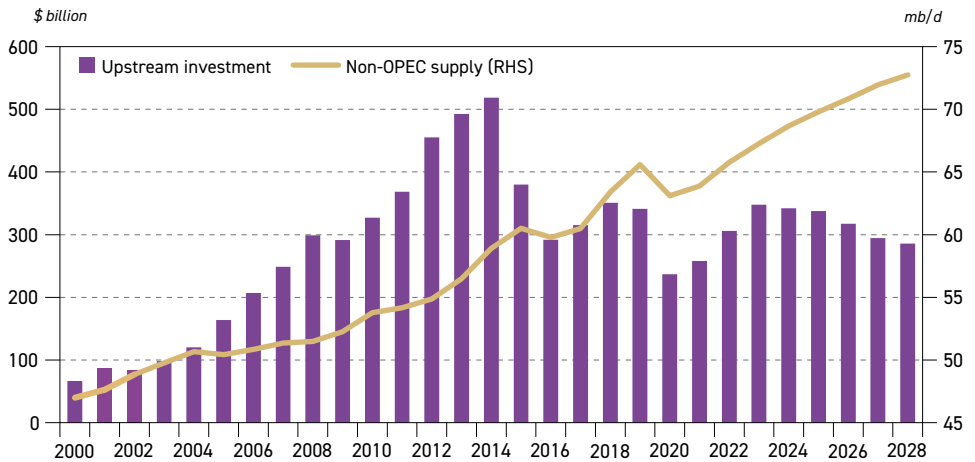


Source: OPEC.

Norway, Kazakhstan and Argentina will contribute most other barrels. By contrast, Russian liquids supply is expected to decline in the medium-term, while mature producers such as Mexico, Azerbaijan and Colombia are also set to see lower output.

Recent data show that after a massive, pandemic-related downturn in 2020, upstream investment grew by 22% in 2022. This is set to increase by another 13% in 2023. At the same time, there has been considerable cost inflation related to such issues as labour, raw materials,

Figure 4.4
Global upstream (oil only) capital expenditure



Source: OPEC.

and energy used in upstream activities. According to the US Bureau of Labor Statistics, US upstream costs have risen by 23% since early 2021, reaching levels last seen in 2014. Nevertheless, the list of firm projects that are under development is sufficient to see average non-OPEC supply growth of 1.2 mb/d p.a. in the medium-term.

US tight oil, meanwhile, is also set to grow, albeit not at rates seen in the 'shale revolution' years of the last decade. Drilling and completion rates, key indicators of near-term supply, are weaker but somewhat offset by efficiency gains, technology, and the growing significance of unconventional natural gas liquids (NGLs) in the overall picture.

After US tight oil peaks around 2030, and as a result US liquids supply, total non-OPEC liquids will also likely peak shortly thereafter at 73.5 mb/d. By 2045, supply is projected to drop to 69.9 mb/d again, as a decline in the US and other mature producers – including Norway, Mexico, Colombia, the UK and China, among others – fails to offset continued growth in Canada, Guyana, Argentina, Brazil and Kazakhstan. Non-crude liquids, including NGLs, biofuels and others, will also continue to grow in the long-term after crude oil from non-OPEC producers peaks. Meanwhile, total OPEC liquids supply is projected to increase from 34.2 mb/d in 2022 to 46.1 mb/d in 2045, thereby raising the group's market share from 34% to 40% in the long-term.

4.3 Breakdown of liquids supply outlook by main regions

Regionally, medium-term non-OPEC liquids supply growth remains heavily centred on the Americas. Collectively, OECD Americas and Latin America contribute over 90% of incremental supply in the 2022–2028 period, adding around two-thirds and one-third, respectively. The Middle East, Africa, OECD Europe and China see smaller increases in the medium-term, while Russia and Other Asia see a decline.

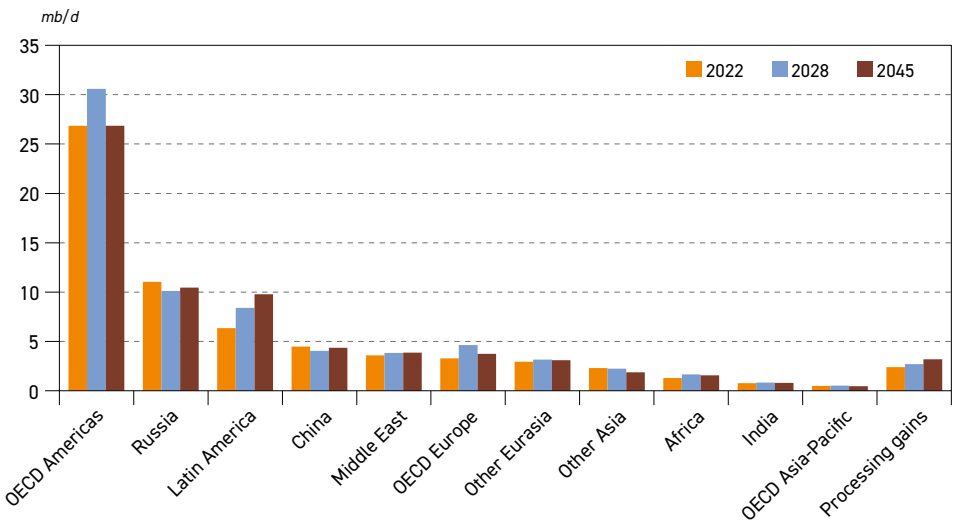
In the long-term, the supply increase is even more skewed towards Latin America, which makes up the bulk of non-OPEC liquids supply growth to 2045, contributing 3.4 mb/d to overall growth of 4.2 mb/d. The Middle East, led by Qatar, along with Africa and OECD Europe, are also set to make smaller contributions in this period. All other regions are expected to see flat or lower supply in the long-term.

Table 4.1
Long-term global liquids supply outlook *mb/d*

	2022	2025	2030	2035	2040	2045	Change 2022–2045
US	19.2	21.7	22.4	21.0	19.7	18.3	–0.9
of which: tight oil	*12.7*	*15.4*	*16.7*	*16.0*	*15.2*	*14.1*	*1.4*
Canada	5.6	6.0	6.1	6.2	6.5	6.9	1.3
of which: oil sands	*3.2*	*3.4*	*3.5*	*3.7*	*4.1*	*4.5*	*1.4*
Mexico & Chile	2.0	2.0	1.9	1.8	1.7	1.6	–0.5
OECD Americas	26.9	29.7	30.3	29.0	27.9	26.8	0.0
OECD Europe	3.6	3.9	4.0	3.9	3.9	3.8	0.3
OECD Asia-Pacific	0.5	0.5	0.5	0.5	0.5	0.5	0.0
OECD	**30.9**	**34.1**	**34.8**	**33.4**	**32.3**	**31.1**	**0.2**
Latin America	6.3	7.4	8.9	9.6	9.9	9.8	3.4
Middle East	3.3	3.3	3.9	3.8	3.8	3.7	0.5
Africa	1.3	1.4	1.7	1.7	1.6	1.6	0.3
China	4.5	4.6	4.6	4.5	4.4	4.3	–0.1
India	0.8	0.8	0.8	0.9	0.8	0.8	0.0
Other Asia	2.3	2.3	2.2	2.1	2.0	1.9	–0.4
Russia	11.0	10.2	10.3	10.7	10.7	10.5	–0.6
Other Eurasia	2.9	3.1	3.2	3.2	3.1	3.1	0.1
Non-OECD	**32.4**	**33.2**	**35.7**	**36.5**	**36.4**	**35.6**	**3.2**
Processing gains	2.4	2.6	2.8	3.0	3.1	3.2	0.8
Non-OPEC	**65.8**	**69.8**	**73.3**	**72.9**	**71.7**	**69.9**	**4.2**
Crude	43.9	46.1	47.4	45.9	43.8	41.4	–2.5
of which: tight crude	*8.9*	*10.9*	*11.7*	*11.3*	*10.6*	*9.8*	*0.9*
NGLs	12.5	13.6	15.0	15.1	15.1	14.8	2.3
of which: unconventional NGLs	*5.4*	*6.4*	*7.2*	*7.2*	*7.2*	*7.1*	*1.7*
Global biofuels	2.8	3.1	3.6	4.0	4.5	4.7	1.9
of which: fuel ethanol	*1.8*	*2.0*	*2.2*	*2.4*	*2.6*	*2.7*	*0.9*
of which: biodiesel	*1.0*	*1.1*	*1.4*	*1.6*	*1.9*	*2.0*	*1.0*
Other liquids	4.1	4.4	4.6	4.9	5.3	5.9	1.8
of which: GTLs	*0.2*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.0*
of which: CTLs	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*	*0.4*	*0.1*
of which: others incl. Canadian oil sands	*3.6*	*3.9*	*4.0*	*4.3*	*4.6*	*5.2*	*1.6*
Total OPEC liquids	**34.2**	**36.5**	**38.9**	**41.6**	**43.7**	**46.1**	**11.9**
World	**100.0**	**106.3**	**112.2**	**114.4**	**115.4**	**116.0**	**16.0**

Source: OPEC.

Figure 4.5
Non-OPEC liquids supply outlook by region



Source: OPEC.

US

As in previous Outlooks, the US remains by far the largest source of non-OPEC liquids supply growth in the medium-term, with production growing by 3.4 mb/d through 2028, out of a total projected non-OPEC liquids supply increase of 7 mb/d. This in turn is overwhelmingly driven by tight oil, which increases by 3.9 mb/d in this period (tight crude and unconventional NGLs combined), and which will more than offset modest declines in conventional Lower-48 crude and conventional NGLs. Biofuels supply will also increase marginally.

US tight crude is projected to grow from 7.9 mb/d in 2022 to 10.4 mb/d in 2028, or by a solid 2.5 mb/d. The bulk of this, a full 2.1 mb/d, is projected to be realized in the Permian Basin, with the Eagle Ford and Bakken adding another 0.2 mb/d and 0.1 mb/d, respectively, and the other basins essentially flat.

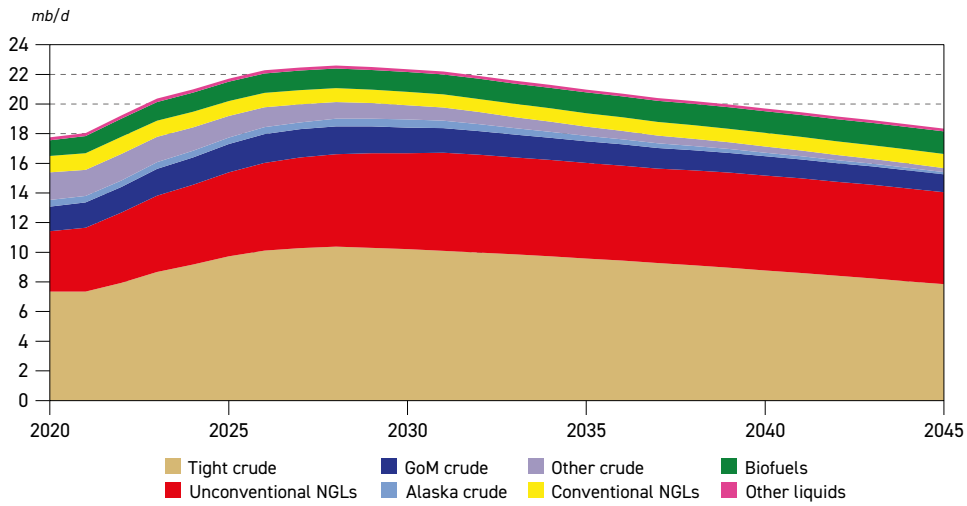
US unconventional NGLs are projected to grow another 1.5 mb/d, easily offsetting the decline in conventional NGLs of 0.2 mb/d. Unconventional NGLs output largely remains a side-effect of continued strong growth in natural gas, which in turn has benefited from strong global demand for LNG amid the recent energy crisis.

Crude production in the offshore Gulf of Mexico is also expected to increase; production in the region is projected to outstrip pre-pandemic levels and achieve a new record level of around 2 mb/d by 2026, the result of a slew of medium-term projects coming on-stream. These include a further ramp-up at Phase 2 of the 120 kb/d Mad Dog, with the start-up of the Argos platform in April 2023. The Shell-operated Vito field also started production in early 2023 and is set to add 80 kb/d.

Other sizeable projects in the next few years include Anchor and Whale (each with 80 kb/d, with first production in 2024), Shenandoah and Shenzi North, adding 40 kb/d and 25 kb/d, respectively, in 2025, and Ballymore and Sparta, each with around 75 kb/d capacity, expected

to start-up in 2026. However, after reaching a 2026 peak of 2 mb/d, Gulf of Mexico crude production is projected to then decline gradually due to a dearth of new projects.

Figure 4.6
US total liquids supply outlook



Source: OPEC.

Alaska is expected to experience somewhat of a renaissance after several years of stagnation. From average production of 440 kb/d in 2022, output is projected to rise to 510 kb/d by 2028. The 80 kb/d Pikka field is due to come online in 2026, followed by the large Willow field, with a capacity of 180 kb/d, set to see first oil in 2028.

Table 4.2
US total liquids supply in the long-term

mb/d

	2022	2025	2030	2035	2040	2045	Change 2022–2045
US tight oil	12.7	15.4	16.7	16.0	15.2	14.1	1.4
of which: tight crude	*7.9*	*9.7*	*10.2*	*9.6*	*8.8*	*7.8*	*–0.1*
of which: unconventional NGLs	*4.7*	*5.7*	*6.5*	*6.4*	*6.4*	*6.2*	*1.5*
US Gulf of Mexico crude	1.7	1.9	1.7	1.5	1.3	1.2	–0.5
US Alaska crude	0.4	0.4	0.6	0.4	0.2	0.2	–0.3
US other crude	1.8	1.5	1.0	0.6	0.4	0.3	–1.5
US other NGLs	1.2	1.0	0.9	0.9	0.9	0.9	–0.2
US biofuels	1.2	1.3	1.3	1.4	1.5	1.5	0.3
US other liquids	0.2	0.2	0.2	0.2	0.2	0.2	0.0
Memo item: US total crude	*11.9*	*13.5*	*13.4*	*12.0*	*10.7*	*9.5*	*–2.4*
Memo item: US total NGLs	*5.9*	*6.7*	*7.4*	*7.3*	*7.3*	*7.1*	*1.2*
Total US liquids production	**19.2**	**21.7**	**22.4**	**21.0**	**19.7**	**18.3**	**–0.9**

Source: OPEC.

The fact that the large Willow field will be developed raises the prospect of extended stabilization or even further recovery in Alaskan crude production. First developed in the late 1970s, oil production in the northern state hit a peak of around 2 mb/d in the late 1980s, and was still as high as 1 mb/d in the early 2000s.

Willow was only given the go-ahead by the Biden administration in March 2023, after much deliberation and some modifications, amid worries about its environmental impact and procedural concerns about the permitting process. With a view towards – in the government's own words – balancing energy security and environmental needs, the project saw drilling pads reduced from 5 to 3, and operator ConocoPhillips forced to relinquish some existing acreage.

More generally, the bipartisan IRA signed into law in August 2022 crucially links incentives to increase renewable energy capacity with offering upstream acreage in regular lease sales of a minimum of 60 million acres offshore and 2 million acres onshore each year. This along with revived lease sales held by the US Bureau of Land Management (BLM) in early 2023 – the first to be held in over a year, which attracted significant bidding interest – suggest that the current US administration remains cognizant of the importance of continued investment in domestic oil and gas production.

US biofuels are projected to increase to 1.3 mb/d in the medium-term, with the increase split evenly between fuel ethanol and biodiesel. 'Other liquids', including refinery additives, kerogen and synthetic fuels, are expected to stay flat at 0.2 mb/d over the medium-term.

After peaking in the late 2020s, US total liquids then decline modestly in the long-term to 18.3 mb/d in 2045. Conventional crude and NGLs will decline the most, while tight crude will end up at 7.8 mb/d, marginally lower than in 2022. Unconventional NGLs will keep growing, rising to 6.2 mb/d, as will biofuels – driven by mandates – that increase to 1.5 mb/d. Still, over the entire 2022–2045 period, US total liquids are projected to fall modestly, by 0.9 mb/d.

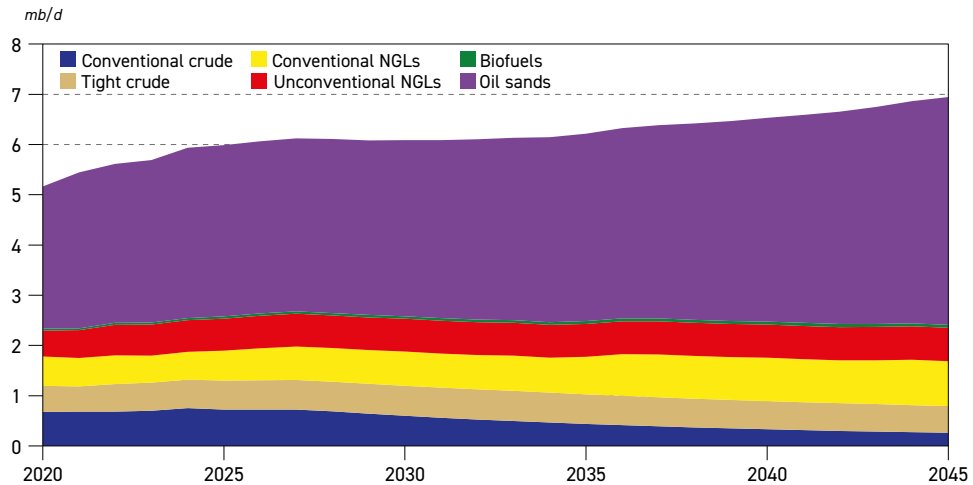
Canada

The outlook for Canadian liquids supply remains steady growth, both in the medium- and long-term. Projections are for total supply to rise from 5.6 mb/d in 2022 to 6.1 mb/d in 2028. This increment will be driven by growth in oil sands production from 3.2 mb/d in 2022 to 3.5 mb/d in 2028 – with modest capacity expansions at existing plants, debottlenecking and efficiency gains rather than wholly new greenfield projects. In the long-term, expectations are for further increases in oil sands capacity, as the national Pathways CO_2 capture project is already well advanced, with investment funding plans in place. The plan is to start injecting CO_2 in 2026–2028, thus allowing for a significant extension of the life expectancy of relatively high-emissions oil sands production.

Canada is also set to see modest increases in tight crude, rising to 0.6 mb/d in 2028, while medium-term conventional crude oil output stays flat at 0.7 mb/d. The country's crude production off its east coast is set to receive a minor boost in the latter part of the medium-term when the 75 kb/d West White Rose expansion project starts up. The smaller Terra Nova field is also expected to restart production, having been offline since 2019. However, the major Bay du Nord project – with a planned capacity of 150 kb/d – was discontinued in mid-2023 after operator Equinor questioned its economics, at least *vis-à-vis* less challenging upstream developments elsewhere.

In the long-term, total Canadian liquids are set to keep expanding, rising to 6.9 mb/d in 2045, predominantly due to higher oil sands output. This makes Canada one of the most important drivers of post-peak non-OPEC liquids supply growth.

Figure 4.7
Canada total liquids supply outlook

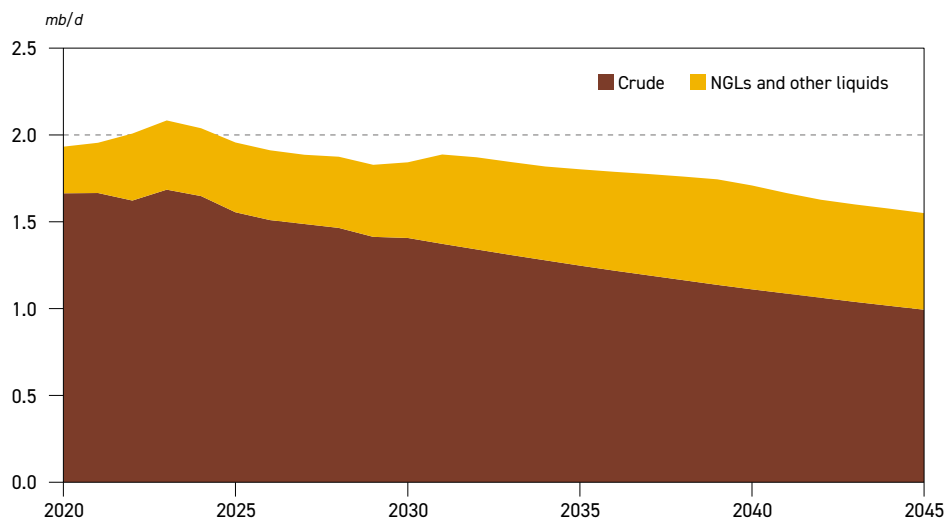


Source: OPEC.

Mexico

In Mexico, the investment decisions following the country's 2013 energy reforms are increasingly visible, with the long-running decline since peak production in the mid-2000s now halted and output stabilized. In the medium-term, total new (gross) capacity of 500 kb/d is expected

Figure 4.8
Mexico total liquids supply outlook



Source: OPEC.

to come online, including the 85 kb/d heavy crude Pit field from 2025, the 150 kb/d Zama field from 2026, and the 80 kb/d Trion project from 2028, among others. Trion is notable because it will be the first deepwater oil field developed in Mexico, in the Perdido Basin, adjacent to existing producing acreage in US waters. This is still a largely underexplored area, with much of Mexico's legacy production closer to shore in shallow waters.

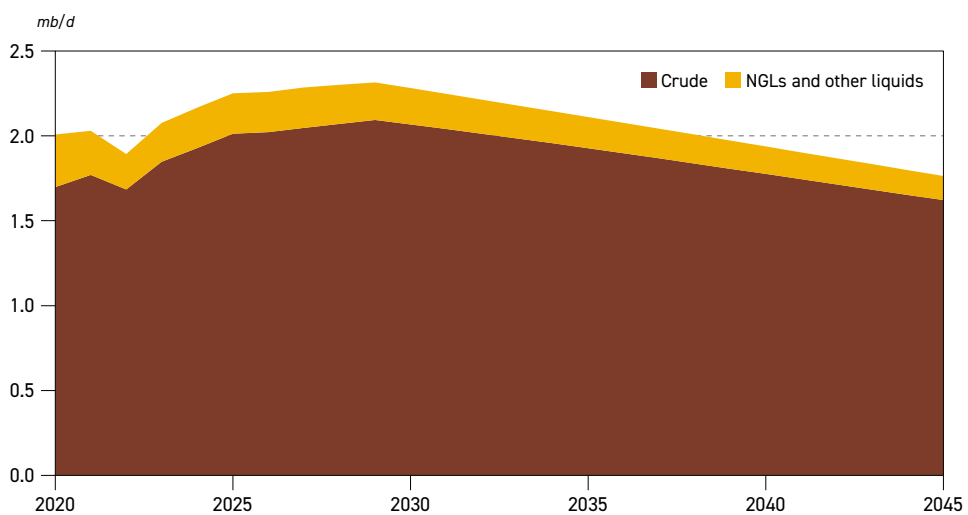
National oil company Pemex is investing heavily, setting upstream capital expenditure at $13.4 billion for 2023, up by a hefty 48% from the previous year. Much of this is set to be invested in existing fields, including $2.5 billion allocated for the Ku-Maloob-Zaap (KMZ) field, the country's largest and mainstay of national oil production, albeit declining, with capacity of around 550 kb/d.

However, stabilized production around 2 mb/d is not expected to last, despite the new start-ups, due to pronounced decline rates at existing, mature fields. Thus, projections are for Mexico's liquids supply to dip from 2 mb/d in 2022 to 1.9 mb/d in 2028, unless declines can be stemmed, and/or additional new projects brought online. Nonetheless, even in the long-term, the decline is expected to be quite modest, with production slipping to 1.5 mb/d by 2045 on crude's decline, despite some offset from higher NGLs production.

Norway

Norway is one of a handful of non-OPEC contributors to medium-term liquids supply growth. With several fields continuing to ramp-up output, or starting up in the next couple of years, production is projected to grow from 1.9 mb/d in 2022 to 2.3 mb/d in 2028. Notably, the giant Johan Sverdrup is set to reach capacity of around 750 kb/d and the 200 kb/d Johan Castberg field in the Barents Sea should come online in 2024. Fenja, Balder X, the Grane expansion and other developments should add to this too. In late June 2023, the Norwegian government gave the go-ahead to another flurry of developments, ensuring further investment in its upstream sector, notably including the 80 kb/d Yggdrasil development. Previously, in 2022,

Figure 4.9
Norway total liquids supply outlook



Source: OPEC.

the looming expiry of a pandemic-induced tax break had already led to a high number of new projects being sanctioned.

Thus, Norway's liquids supply is projected to remain at an average of 2.2 mb/d until the mid-2030s, when, in the absence of further major developments, such as the two Johans, output will begin to slide. By 2045, liquids supply is estimated to average 1.8 mb/d.

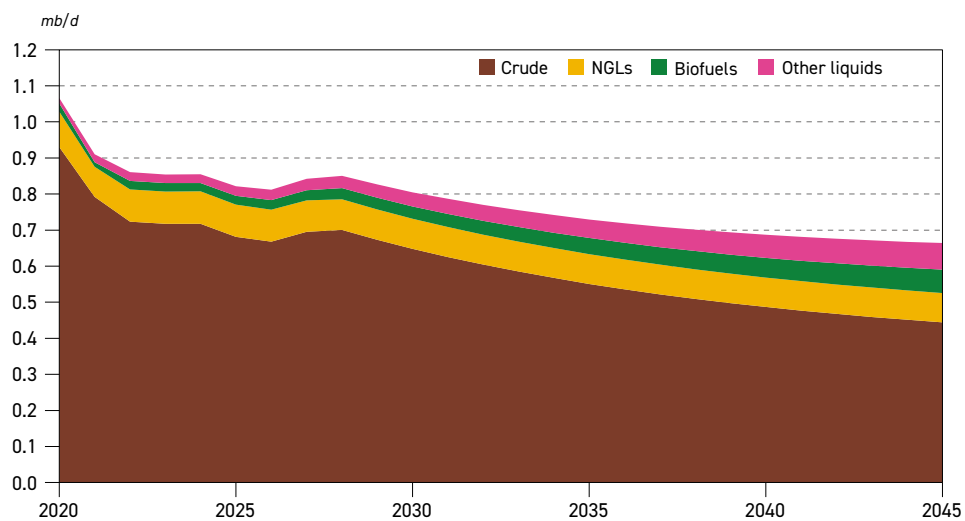
UK

By contrast, fellow North Sea producer the UK is projected to see its medium-term liquids supply remain relatively flat, at around 0.9 mb/d, albeit with a brief dip in 2025-2027. In the medium-term, notable new upstream additions include the 35 kb/d Penguins redevelopment in 2023, Galapagos, with a similar capacity, in 2025, and new capacity of around 40 kb/d, in the Greater Buchan Area, from 2026. In general, however, the UK suffers from a shorter and slimmer list of upstream development projects, reflecting its smaller remaining resource base compared to Norway, and thus fewer attractive larger-scale projects.

In addition, industry bodies and some operators present in the UK have complained of unattractive economics, after the UK government in May 2022 introduced the 'Energy Profits Levy', in effect a windfall tax on production. The tax, which was hiked in early 2023 and is supposed to remain in place until 2028, was introduced in the wake of high energy prices. According to industry association Offshore Energies UK, a large majority of its members are considering scaling down investments in the UK or even pulling out as a result. The tax remains in place for the time being, but the government introduced a price floor in mid-2023, which would eliminate the tax if the prices of oil and gas fall below a certain threshold.

In late July 2023, Prime Minister Sunak announced that 100+ new licences to drill oil and gas in the North Sea would be granted, in an attempt to shore up domestic production.

Figure 4.10
UK total liquids supply outlook



Source: OPEC.

Nonetheless, with a degree of uncertainty surrounding UK investment conditions, expectations are for a further gradual slide in output beyond the medium-term, while projections indicate that total liquids supply will inch down to 0.7 mb/d by 2045. This total masks the fact that expected growth in biofuels and synthetic aviation fuel will somewhat offset the decline in crude supply in this period.

Brazil

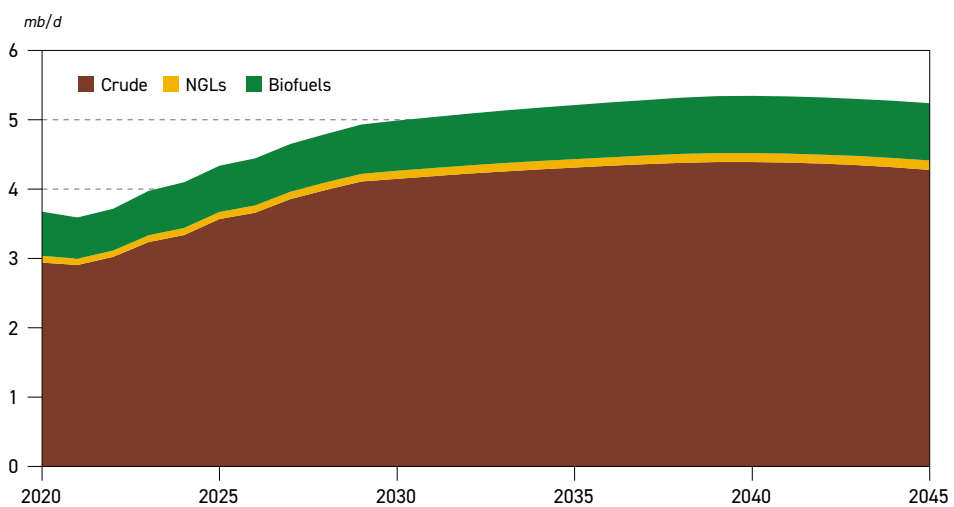
Brazil remains one of the key contributors to non-OPEC liquids supply growth, especially in the medium-term. Output is projected to rise from 3.7 mb/d in 2022 to 4.8 mb/d in 2028, as a steady stream of large-scale developments in the country's deepwater 'pre-salt' producing areas comes online. In this period, the country is expected to see a gross nameplate capacity of 2.5 mb/d start producing, albeit not all of this capacity will be fully utilized or ramp-up fully within this timeframe. In part, new capacity will be offset by natural decline in older offshore and onshore oil fields.

In the coming years, however, Brazil will see the start-up of stages 5 to 10 of the super-giant Buzios field, already one of the country's most prolific, with each stage adding 150-225 kb/d of capacity, based around large floating production, storage and offloading (FPSO) units. In addition, stages 1, 2 and 3 of the Mero field will start up in 2023, 2024 and 2025, respectively, each with 180 kb/d capacity. Other large new developments include the 220 kb/d Bacalhau field, due to come online in 2025, and phase 1 of the 120 kb/d Sergipe-Alagoas project, due to see first oil flow in 2026.

In the longer-term, Brazil's liquids supply is also expected to grow, albeit less rapidly. Output is set to peak at 5.3 mb/d in the mid-2030s and still average 5.2 mb/d by 2045.

While the pre-salt area in the Santos Basin is likely to continue to prove an attractive investment proposition, the government has also set in place a new programme, entitled,

Figure 4.11
Brazil total liquids supply outlook



Source: OPEC.

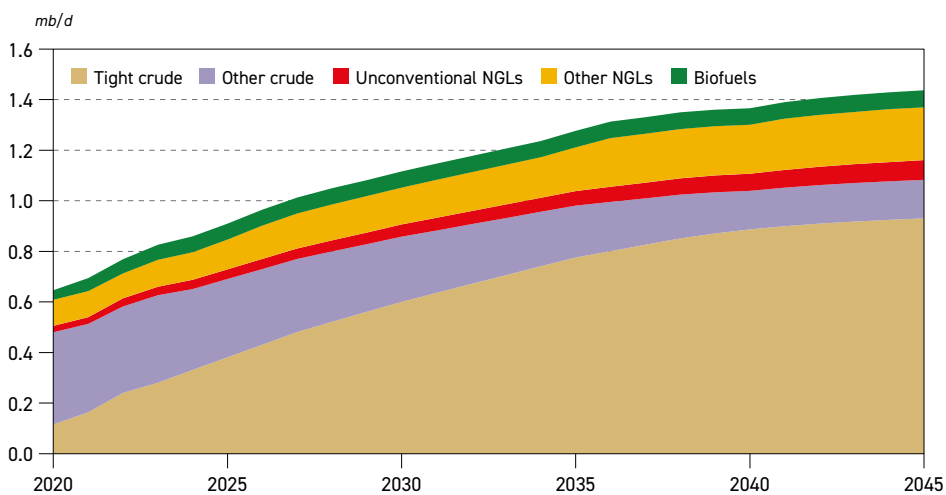
'Potencializa E&P'. This is designed to set incentives to expand exploration activity in under-explored areas, including Brazil's 'equatorial margin', south of areas that have proven rich in hydrocarbon resources within Guyana and Suriname's maritime territories. National oil company Petrobras's 2023–2027 strategic investment plan foresees that around half of its $6 billion exploration budget is directed towards this area, or some 16 of 42 planned exploration wells. Of note, activity in the area – effectively offshore of the mouth of the Amazon river – is being disputed for ecological reasons.

Nonetheless, Brazil is expected to remain one of the key sources of non-OPEC liquids supply growth due to its ample resources, stable policy framework and well-established infrastructure, ensuring continued investment.

Argentina

Argentina too is projected to see a meaningful liquids supply increase, both in the medium- and long-term. With output having averaged 750 kb/d for the past 20 years, total liquids supply is expected to rise from 0.8 mb/d in 2022 to 1 mb/d in 2028, largely as a result of tight crude in the Vaca Muerta formation of Neuquén province finally taking off, with production expected to double in this period. With export bottlenecks gradually easing, further long-term growth is anticipated, with total liquids projected to reach 1.4 mb/d by 2045.

Figure 4.12
Argentina total liquids supply outlook



Source: OPEC.

In addition, there is potential for even further growth. New areas are attracting exploration, including the offshore Argentine Basin in the south of the country. Geologically, this area is allegedly akin to its counterpart in southern Africa, Namibia, where recent large discoveries have been made, including the large Venus field, with potentially 5 billion boe of recoverable oil and gas. The Argentine Basin is considered one of the least-explored remaining areas in the world.

The Argentine government is planning a new round of offshore oil and gas exploration blocks. The last round was in 2019, but plans for a follow-up were stymied by COVID-19.

YPF estimates there are 31 billion boe of potential offshore hydrocarbon resources, which is even more than its estimate for the onshore Vaca Muerta that has estimated resources of 29 billion boe.

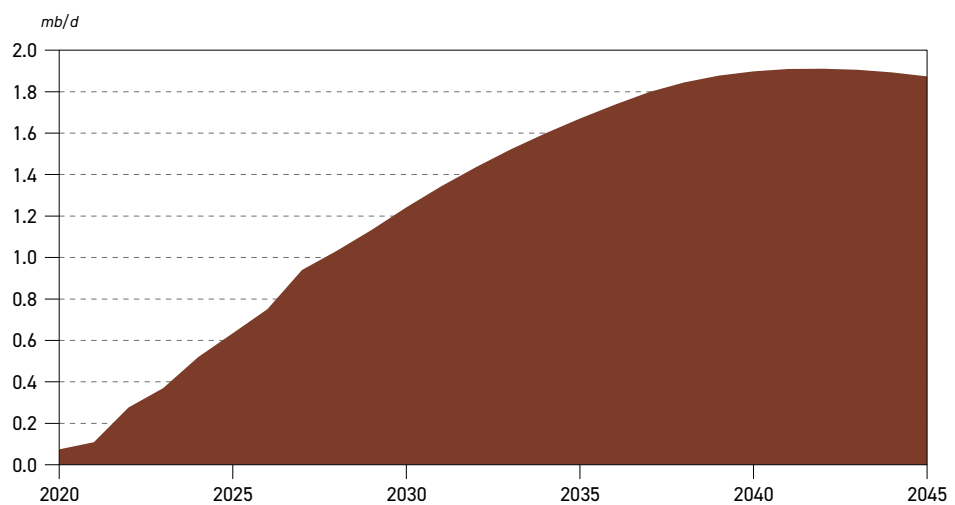
Guyana

Guyana's liquids supply is projected to maintain its recent strong ramp up, as the world's major emerging oil producer continues to bring on-stream new FPSOs. From 0.3 mb/d in 2022, with Liza Phase 1 operating since 2019, and Liza Phase 2 increasing output since start-up in 2022, total output is projected to rise to 1 mb/d by 2028. Incremental supply capacity is well documented, with four new FPSOs likely to commence production in the medium-term, including the Payara, Yellowtail, Uaru and Whiptail projects. Each comprise several sub-fields and utilize large 220–250 kb/d FPSOs.

Highly productive wells have led to existing production facilities exceeding nameplate capacity after debottlenecking, Moreover, new projects are being sanctioned at a rapid pace and more are expected. In March 2023, the country announced a new offshore round, with 14 blocks available, after 2022 saw 1.8 billion boe discovered. Of these finds, ten were in the Stabroek block, while another discovery was made in the Corentyne Block.

According to the partners developing the major Stabroek block, ExxonMobil, Hess Corporation and CNOOC, the first six FPSOs are largely on track and the plan may eventually to be have as many as ten operating in the country. This Outlook's projections are for a further rise in liquids supply, from 1 mb/d in 2028 to a peak of around 1.9 mb/d that is sustained from the late 2030s. As such, Guyana is the single largest contributor to long-term non-OPEC liquids supply growth, as although the US will add more in the medium-term, output there is expected to peak and decline thereafter.

Figure 4.13
Guyana total liquids supply outlook

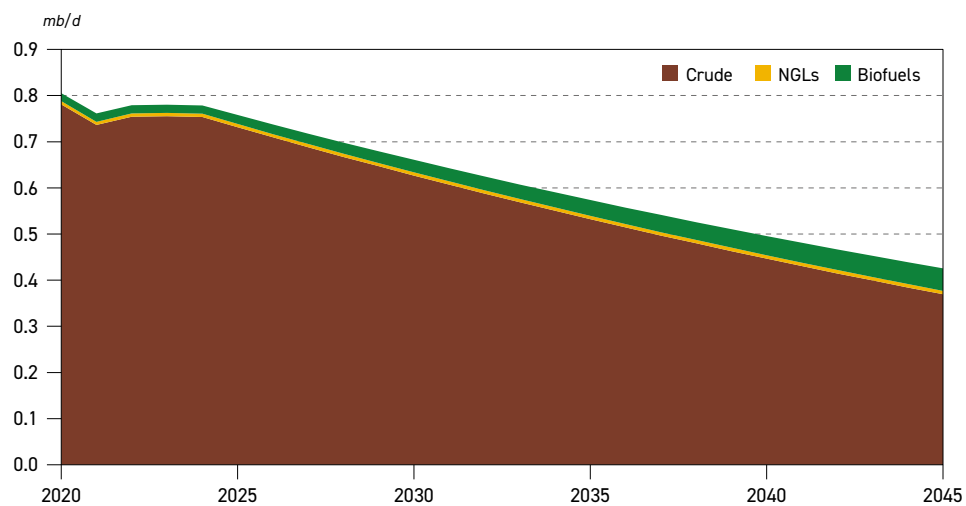


Source: OPEC.

Colombia

The outlook for liquids supply in Colombia is facing a degree of uncertainty after the election of President Gustavo Petro. Essentially elected upon a platform to wind down the country's oil and gas production, while diversifying the country's economy, the fact remains that Colombia remains hugely dependent on export revenues from the hydrocarbons sector. With no new exploration licences being issued, no acreage sales, and a ban on fracking, despite Colombia's vast shale potential, projections indicate a gradual decline in supply from 0.8 mb/d in 2022 to 0.7 mb/d in 2028. Thereafter, assuming no major change in policy, and with a relatively high maturity in existing fields, output is expected to slide further to around 0.5 mb/d in the mid-2030s, and to as low as 0.4 mb/d in 2045.

Figure 4.14
Colombia total liquids supply outlook



Source: OPEC.

Qatar

Qatari liquids supply is projected to increase from 1.9 mb/d in 2022 to 2.4 mb/d in 2028, as the next large stage in the development of the super-giant offshore North Field starts to come online from around mid-decade. Primarily a project to increase gas production and thus LNG exports, the field is also expected to ultimately add around 0.5 mb/d of NGLs once fully on-stream. With relatively steady crude output of around 0.6 mb/d, Qatar's total liquids is thus projected to remain around 2.5 mb/d from 2030.

Africa

Liquids supply from non-OPEC African producers is projected to rise from 1.3 mb/d in 2022 to 1.6 mb/d in 2028, as newcomers Senegal, Uganda and Mozambique all see projects start up.

Senegal is expected to produce first oil at Phase 1 of its Sangomar development in late 2023/early 2024, with nameplate capacity of 100 kb/d. Uganda is projected to see its Lake Albert project come on-stream in 2026, with the Tilenga field contributing 190 kb/d in a first phase.

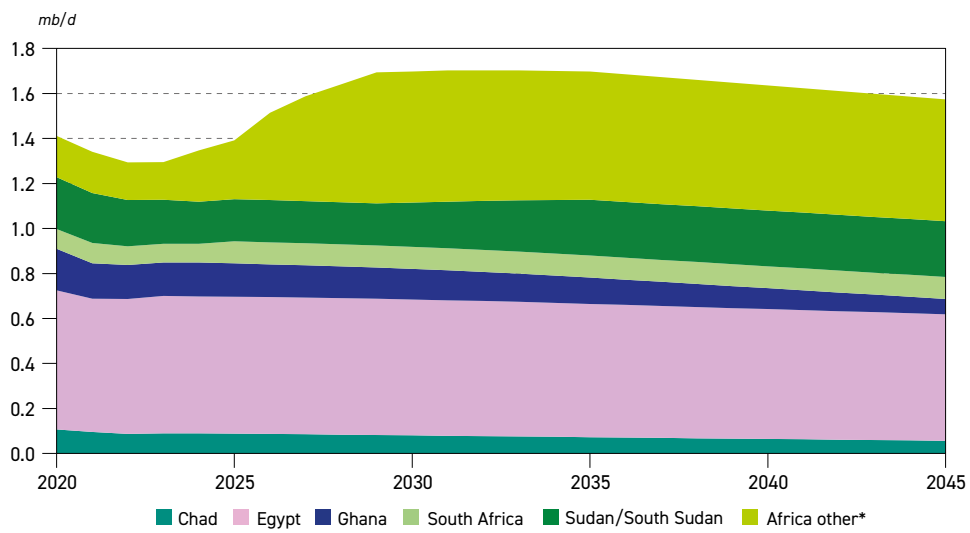
This is set to be followed by the 40 kb/d Kingfisher field, likely to come online in 2027. Lastly, Mozambique is set to add modest volumes of condensate related to its Mozambique LNG project, due to start up in 2026. Moreover, some growth will come from the fast-tracked Baleine in Ivory Coast, which is projected to add 15 kb/d later in 2023 as the FPSO commences operations. Later stages should see a further 55 kb/d added.

A lot of excitement has surrounded further discoveries offshore Namibia, adding to the giant Venus field that is expected to hold an estimated 5 billion boe of recoverable oil and gas. The new discoveries, including Jonker, Graff and La Rona, raise the likelihood of Venus being developed and Namibia joining the club of oil producers. First oil from Venus could come onstream in the latter half of the 2020s.

Elsewhere, development of the South Lokichar complex in Kenya still looks uncertain, after TotalEnergies and Africa Oil Corp seem likely to depart the consortium, leaving Tullow as the sole operator. And in Ghana, development of the Pecan field is on hold given part-ownership by Lukoil and associated legal complications.

With production somewhat flat in legacy producers, including Egypt, Chad and South Africa, total non-OPEC African liquids production is expected to remain fairly stable at 1.7 mb/d for most of the 2030s, before declining slightly to average 1.6 mb/d by 2045.

Figure 4.15
Africa total liquids supply outlook



** Africa other includes Cameroon, Senegal, Tunisia, Uganda and smaller producers, but excludes African OPEC producers*

Source: OPEC.

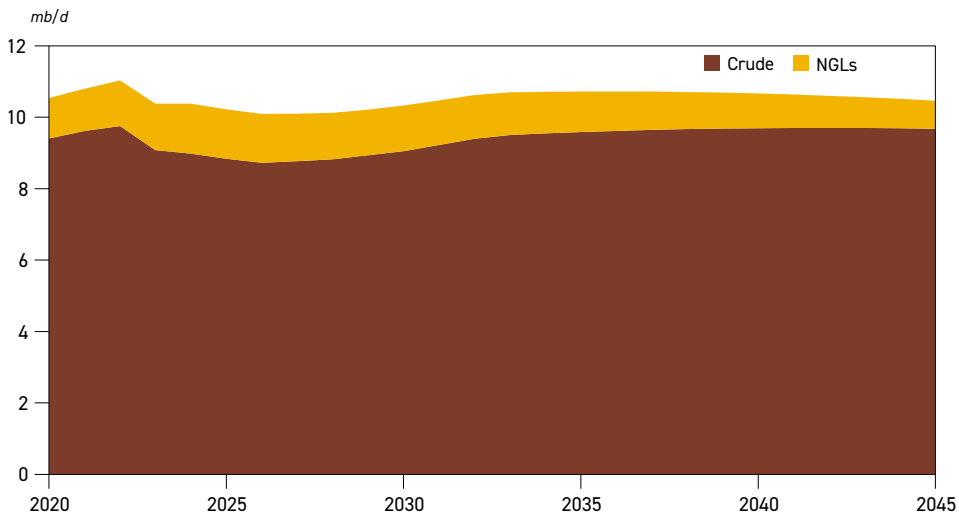
Russia

Russia's liquids supply is projected to decline from 11 mb/d in 2022 to 10.1 mb/d in 2028. After declining to 10.4 mb/d in 2023/24, Russian supply is set to creep lower to 10.1 mb/d due to a lack of investment in new capacity, but it is expected to pick up again in the 2030s.

The government and state-owned major Rosneft say that the Vostok mega-project will still go ahead, with Rosneft, for example, starting work on the Ichemminskoye field. This field would become part of the Vankor cluster, with crude oil to be delivered to the nearby Lodochnoye field. According to the government, crude exports from the Vostok project will be 600 kb/d, starting from 2024, rising to 2 mb/d by 2030, mostly using the Northern Sea Route.

This Outlook projects that, having recovered to around 10.7 mb/d by the mid-2030s, total liquids supply will slide to around 10.5 mb/d by 2045, with strong declines at increasingly mature fields more than offsetting growth in new fields.

Figure 4.16
Russia total liquids supply outlook



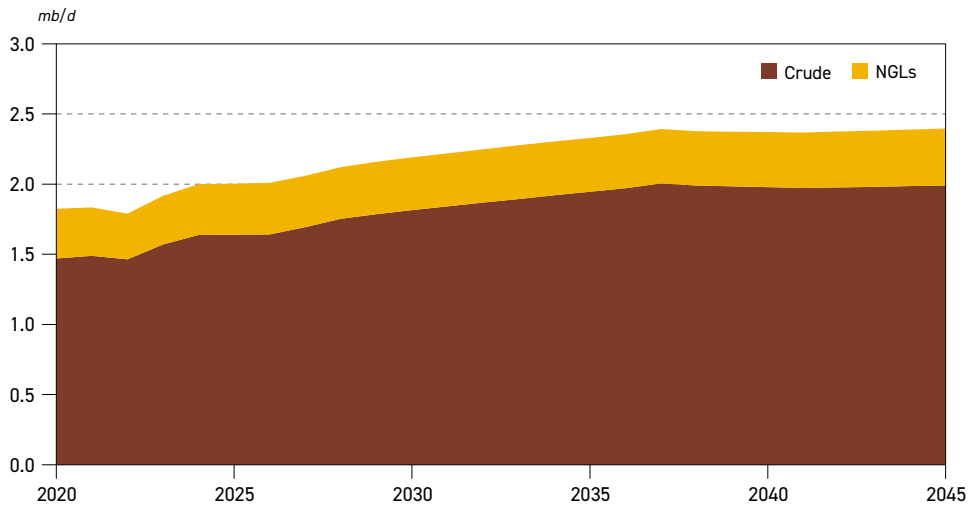
Source: OPEC.

Kazakhstan

Kazakhstan's liquids supply is expected to continue to grow, rising from 1.8 mb/d in 2022 to 2.1 mb/d in 2028. New barrels from the continued ramp-up of the Tengiz Future Growth Project drive expansion in the early part of the medium-term period, with the total increment from this redevelopment adding 260 kb/d capacity. Later on, a gas re-injection project at the Kashagan field and modest expansion at the Karachaganak field will add more barrels.

In the longer-term, further incremental supply at all three of Kazakhstan's aforementioned giant fields is likely to sustain supply growth, projected to reach and be sustained at around 2.4 mb/d from the mid-2030s. Export routes would likely need to be re-examined to ensure future expansions. While the bulk of the country's crude exports to date travel through the Caspian Pipeline Consortium (CPC) line, which traverses southern Russia and loads from the Black Sea terminal at Novorossiysk, Kazakhstan is reportedly also considering expanding a smaller line that currently carries some 200–400 kb/d to China (a share of which is typically Russian crude oil). In addition, the country is examining shipping more crude across the Caspian to Azerbaijan, from where it could be loaded onto the underutilized Baku-Tbilisi-Ceyhan (BTC) pipeline, which terminates on Turkiye's Mediterranean coast.

Figure 4.17
Kazakhstan total liquids supply outlook

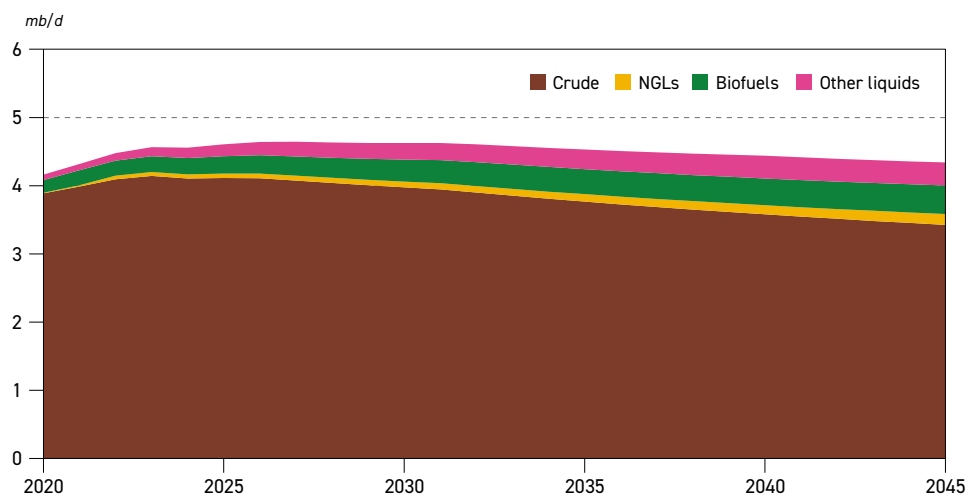


Source: OPEC.

China

Despite a large mature base, China has managed to increase production in recent years, and is projected to see a small increase in total liquids supply from 4.5 mb/d in 2022 to 4.6 mb/d in 2028. A relatively modest string of start-ups, mostly offshore, will serve to offset natural decline at the country's large onshore legacy fields, including Daqing, Shengli and others. New start-ups in the medium-term include Luda 21–2, a cluster of Qinhuangdao fields, Huizhou 26-6 and Jinhuazhen, all with capacities in the 30–50 kb/d range.

Figure 4.18
China total liquids supply outlook



Source: OPEC.

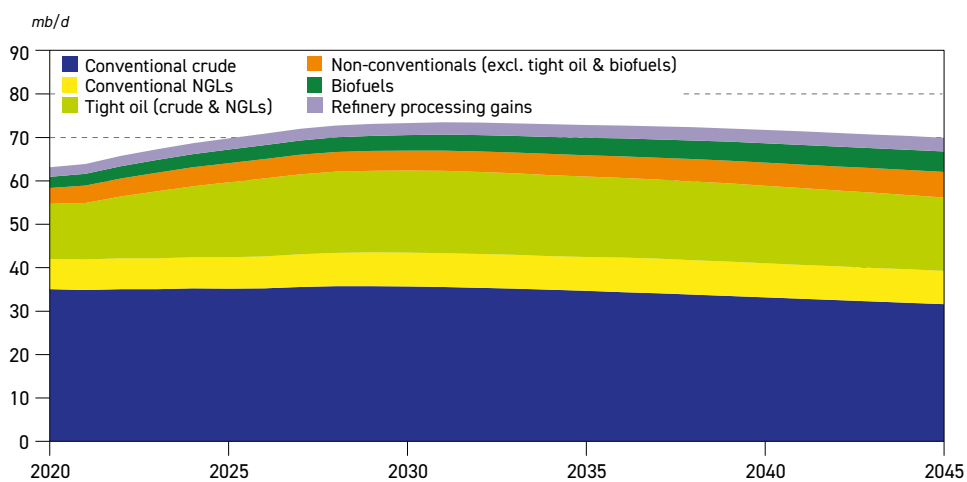
With an eye on energy security amid geopolitical tensions, the Chinese majors are under pressure to increase capital expenditure and maintain, or even boost the upstream supply of oil and increasingly, natural gas. To some extent, this will be visible throughout the 2030s, when China is projected to maintain relatively stable production levels until the late part of the decade, with only a modest decline in the long-term, to average 4.3 mb/d in 2045.

The aforementioned decline in conventional crude will be partially offset by modest growth in tight oil, which is set to rise from 130 kb/d in 2022 to 170 kb/d in 2028, and further to 320 kb/d in the long-term. Biofuels supply is projected to grow from 0.1 mb/d in 2022 to 0.3 mb/d in 2045, with a modest increase in CTLs from 0.2 mb/d to 0.3 mb/d, and an estimated 0.1 mb/d of synthetic aviation fuel.

4.4 Breakdown of liquids supply by type of liquids

As in previous Outlooks, crude oil will drive growth in the medium-term, adding around half of the non-OPEC liquids supply increment of 7 mb/d. NGLs will make up another 2.1 mb/d of growth, while global biofuels, other liquids and refinery processing gains combined add another 1.3 mb/d in this period. In the long-term, the crude oil trend is reversed. From 2022 to 2045, non-OPEC crude oil supply declines by 2.5 mb/d, but this will be offset by strong NGLs growth of 2.3 mb/d, global biofuels and other liquids at 1.9 mb/d and 1.8 mb/d, respectively, and incremental refinery processing gains of 0.6 mb/d.

Figure 4.19
Non-OPEC liquids supply outlook by type



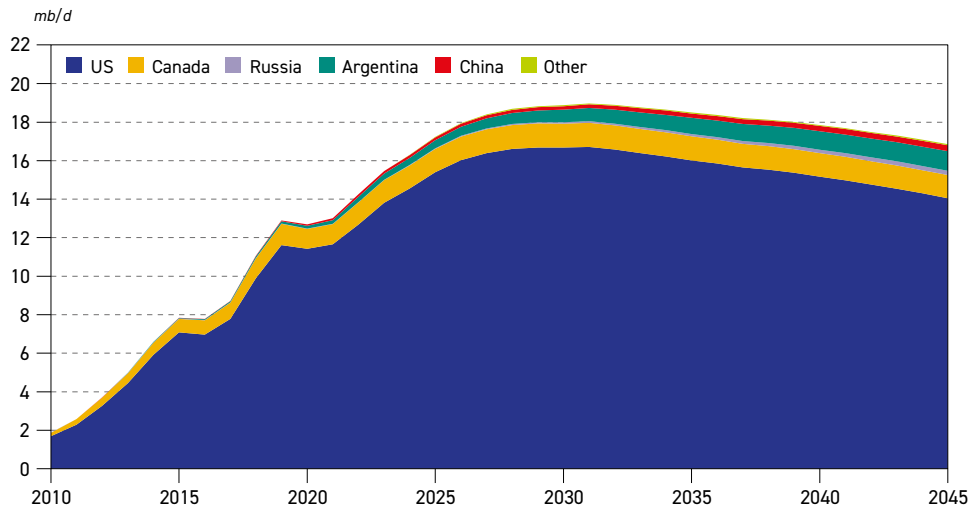
Source: OPEC.

4.4.1 Tight oil: US and other developments

Global tight oil supply is projected to grow strongly in the medium-term, rising from 14.3 mb/d in 2022 to 18.7 mb/d by 2028. The bulk of these barrels is in the US, which makes up 90% of global supply and drives the increase in output. However, Canada and Argentina are already sizeable producers, with 2022 levels of 1.2 mb/d and 0.3 mb/d. Russia, China and others are set to remain much smaller producers of tight oil for the time being. In the

long-term, besides the US, which sees total tight oil output peak in the early 2030s albeit with long-term growth relative to 2022, the other main driver is Argentina, where total output grows to around 1 mb/d by 2045, as supply from Neuquén Province finally starts to ramp up.

Figure 4.20
Tight oil supply breakdown



Source: OPEC.

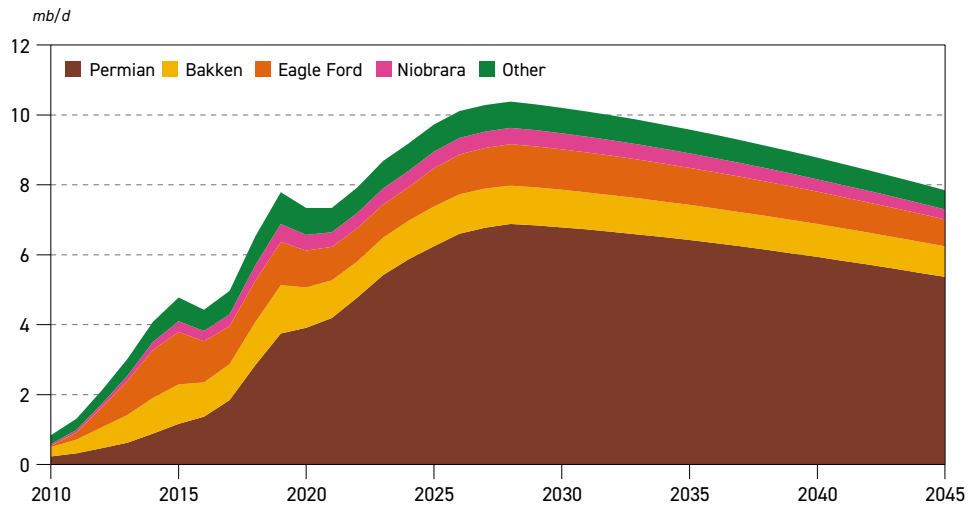
US

Tight oil producers in the US remain under pressure to return more profits to shareholders, concentrate on cutting costs and improve the bottom line over investing in new production. Upstream cost inflation has become a concern, with respondents to a regular Dallas Fed survey in early 2023, for instance, highlighting widespread concerns about costs, supply chain challenges and worries about access to capital.

Nevertheless, US tight oil supply has held up well despite numerous warnings of imminent decline. Essentially, tight crude production levels have returned to pre-pandemic volumes on an annual basis when comparing 2022 with 2019 output. Moreover, output has continued to grow month-on-month, despite drilling rig counts stagnating and even declining slightly since late 2022, and measures of well completion, fracking and other activity also slowing.

The bottom line is that productivity in the wider sense is still increasing, with output rising despite fewer rigs, lower investment and cost inflation. A key driver of this state of affairs is advances in relevant technology. As companies have consolidated acreage through acquisitions, the larger producers have benefited from contiguous land, maximizing the spacing and timing of drilling, completion, logistics and takeaway for a larger patch of land, thereby essentially benefiting from economies of scale. On this basis, for example, ExxonMobil claims that its Permian drilling efficiency has quadrupled in recent years, only needing one-quarter of the rig count to generate the same output.

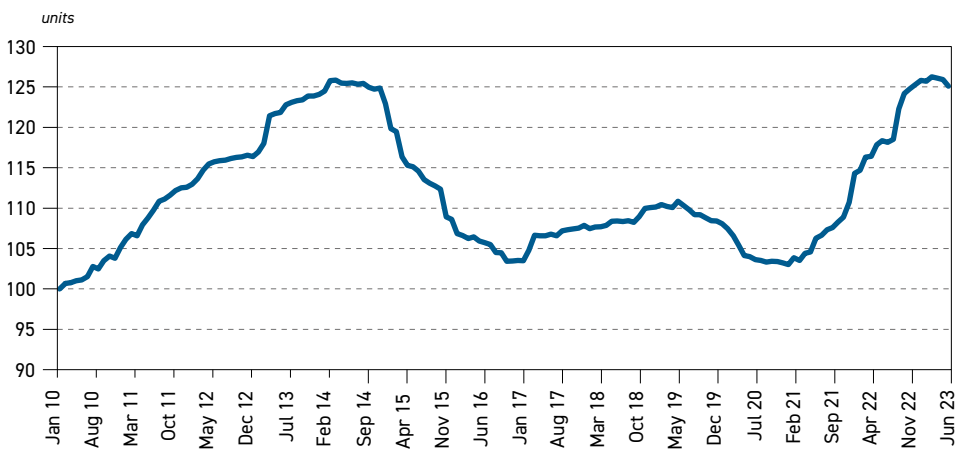
Figure 4.21
US tight crude oil supply by major producing basin



Source: OPEC.

Other technology advances also remain important in determining tight oil's long-term future. ExxonMobil, for example, quotes current extraction rates of around 10% per well compared to rates in a range of 20–40% for conventional fields. Raising extraction rates, by improving fracking techniques, or fracking multiple times, so-called 'refracking' and experimenting with proppants, could in theory all raise the productivity of individual wells hugely. Refracking in particular, including older wells, appears to be a relatively simple and low-cost means to extract more oil from the ground.

Figure 4.22
US producer cost composite index (January 2010 = 100)



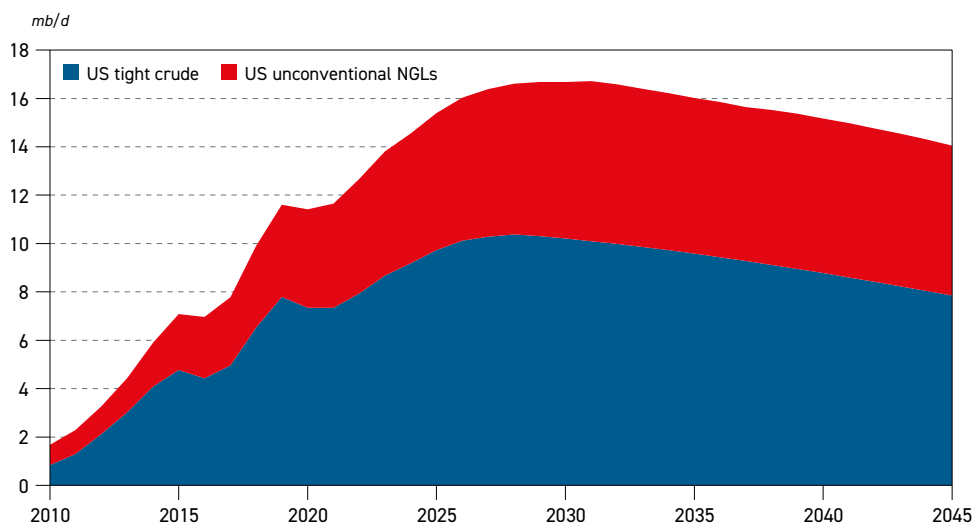
Source: US Bureau of Labor Statistics.

The role of the super-majors and larger producers in terms of growing US tight oil supply could increase, with ExxonMobil looking to expand output by 10% in 2023, raising it to 1 mboe/d by 2027. Chevron is also looking to increase output by 9% in 2023, to 770 kboe/d, after increasing output by 16% in 2021.

Another crucial, but often forgotten reason for overall US liquids supply growth is the continued success story of unconventional NGLs. Unlike tight and other crude in the US, NGLs supply never stopped growing, even against the background of the enormous demand shock resulting from COVID-19 in 2020. The US retains a significant cost advantage over other producers in terms of developing new gas supplies, coupled with a long list of new LNG exporting capacity coming online.

Thus, overall, US tight oil production is still holding up well. Its recovery from the pandemic-induced crisis and recent performance are impressive, and its short- and medium-term growth potential is significant. Even though growth has slowed and will most likely remain lower than in the boom years, US tight oil is nonetheless projected to make up 56% of medium-term non-OPEC supply growth. In the long-term, even after US tight oil has long peaked, it is still expected to make up a sizeable 20% of non-OPEC supply in 2045, or 12% of global liquids supply.

Figure 4.23
US tight oil breakdown



Source: OPEC.

Argentina

Argentinian tight oil prospects are brightening, with interest and investment in the Vaca Muerta formation in the Neuquén Province increasing, as long-standing infrastructure constraints gradually begin to ease. The Trans-Andean pipeline from Neuquén Province to Chile, a 100 kb/d capacity line, is being revived after years of inactivity. It will allow for supply of crude to a refinery in Concepcion on Chile's coast, or potentially crude exports. At the same time, Oleoductos de Valle is planning to double its 225 kb/d crude pipeline out of Vaca Muerta by the end of 2024.

National oil and gas company YPF is also considering another pipeline to the country's Atlantic Coast, with a potential capacity of 380 kb/d. The latter would include a crude export terminal capable of loading Very Large Crude Carriers (VLCCs). YPF itself has noted that with plans to double its current domestic production of 225 kb/d by 2027, it will exceed domestic refining capacity, and thus need export outlets to allow for further growth.

Years of experience in tight oil formations in the US are also helping to unlock barrels, with techniques increasingly applied in Argentina. These include optimized well spacing, longer laterals being drilled, better completion efficiencies, and other gains, all resulting in higher initial production volumes.

As a result of the improved outlook, Argentinean tight oil prospects have been raised. Projections are for total volumes to double from 270 kb/d in 2022 to 560 kb/d in 2028, and keep growing beyond, eventually averaging an estimated 1 mb/d by 2045.

4.4.2 Other non-crude liquids supply

The supply of other non-crude liquids are set to continue to make a modest, but meaningful contribution to long-term non-OPEC liquids supply growth. Global biofuels, including fuel ethanol, biodiesel, and eventually some small volumes of biojet, are projected to grow from 2.8 mb/d in 2022 to 4.7 mb/d in 2045. A desire to reduce emissions, while recycling biological wastes, means that rules mandating percentage shares of biofuels in petroleum-based fuels continue to tighten.

Recently, given the greater difficulty of fitting aircraft with either electric or hydrogen propulsion, there has been a widespread discussion of so-called sustainable aviation fuels being developed. For instance, the EU is considering mandating substantial blending rules of up to 70% by 2050, which could be covered by biological-origin jet fuel (biojet), recycled carbon-based fuels, or entirely synthetic fuels using captured CO_2 and hydrogen. The IATA, the aviation industry body, has calculated that the production of such fuels would have to rise to 7.75 mb/d by 2050 for the sector to reach net-zero targets. This compares to estimated aviation demand of 10.2 mb/d in

Table 4.3
Long-term global non-crude liquids supply outlook

	2022	2025	2030	2035	2040	2045	Change 2022–2045
Fuel ethanol	1.8	2.0	2.2	2.4	2.6	2.7	0.9
Biodiesel	1.0	1.1	1.4	1.6	1.9	2.0	1.0
Global biofuels	**2.8**	**3.1**	**3.6**	**4.0**	**4.5**	**4.7**	**1.9**
Canadian oil sands	3.2	3.4	3.5	3.7	4.1	4.5	1.4
Gas-to-liquids (GTL)	0.2	0.3	0.3	0.3	0.3	0.3	0.0
Coal-to-liquids (CTL)	0.3	0.3	0.4	0.4	0.4	0.4	0.1
Synthetic aviation fuel	0.0	0.0	0.1	0.2	0.2	0.4	0.4
Other*	0.4	0.4	0.4	0.4	0.3	0.3	–0.1
Total 'Other liquids'	**4.1**	**4.4**	**4.6**	**4.9**	**5.3**	**5.9**	**1.8**
Non-OPEC total	**7.0**	**7.6**	**8.2**	**8.9**	**9.8**	**10.6**	**3.7**

** Including kerogen, extra-heavy crude, MTBE and other refinery additives.*

Source: OPEC.

2045. However, this must be seen against estimated production in 2022 of only 5 kb/d, or 0.1% of last year's aviation demand, indicating the size of the challenge ahead.

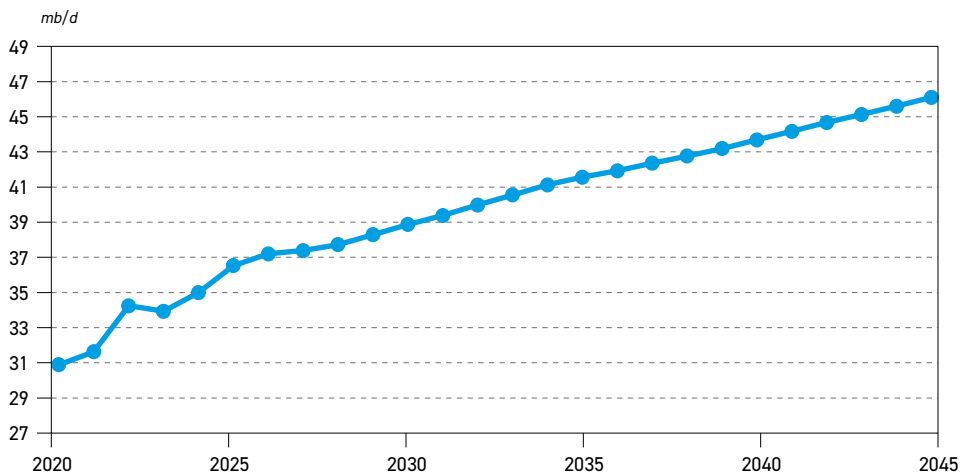
This Outlook estimates that biojet production (included in 'biodiesel') will rise to 0.3 mb/d by 2045, and synthetic aviation fuel (included in 'other liquids') to 0.4 mb/d, on the premise that currently floated ambitious mandates will not all be implemented, nor attained. However, if this were the case, higher production profiles would be possible.

Meanwhile, supply growth in 'other liquids', besides synthetic aviation fuel, is dominated by Canadian oil sands, which are expected to see steady growth from 3.2 mb/d in 2022 to 4.5 mb/d in 2045. CTLs and GTLs will grow very modestly, to a combined 0.7 mb/d by 2045.

4.5 OPEC liquids

OPEC liquids supply is projected to grow by 3.5 mb/d in the medium-term, from 34.2 mb/d in 2022 to 37.7 mb/d in 2028, as demand continues its post-pandemic recovery, especially in the 2023–2025 period. After US liquids supply, and thus non-OPEC liquids, peak in the early 2030s, OPEC liquids will continue to grow, eventually rising to 46.1 mb/d in 2045. In terms of market share, this means that OPEC liquids will rise from 34% of global liquids supply in 2022 to 40% by 2045.

Figure 4.24
OPEC total liquids supply outlook

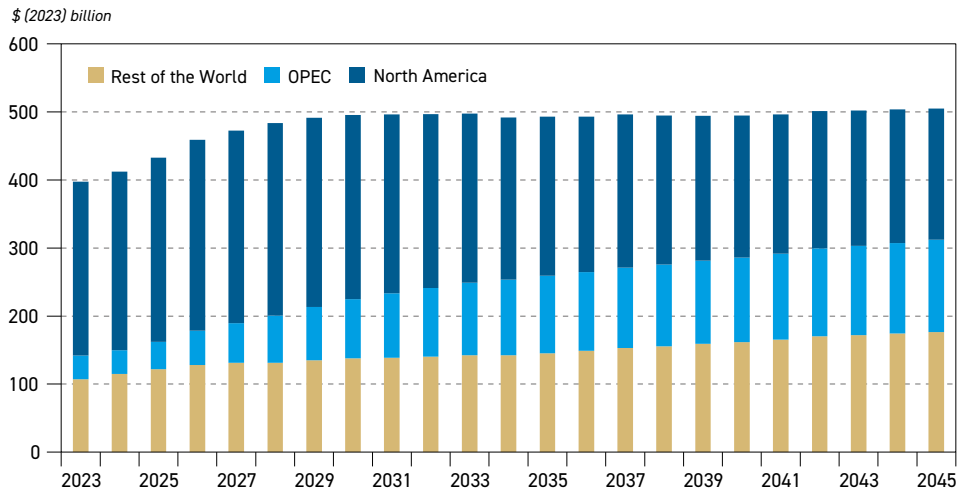


Source: OPEC.

4.6 Upstream investment requirements

Cumulative oil-related investment requirements remain substantial, in order to guarantee that growing oil demand needs are met, even while accounting for the natural underlying decline in existing fields. The upstream sector, which accounts for the bulk of investment needs, is projected to require $11.1 trillion in the 2023–2045 outlook period, or $480 billion p.a. (all values expressed in 2023 US dollars).

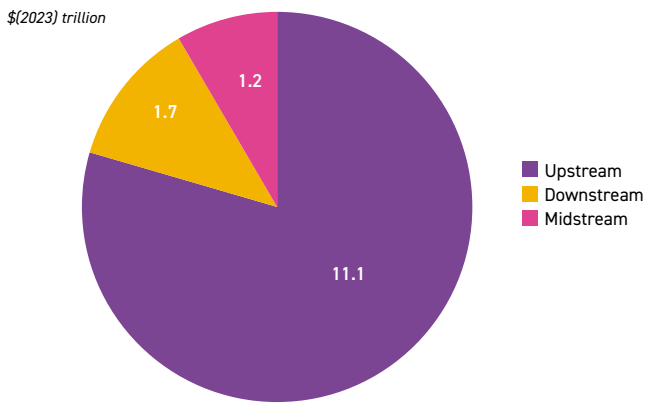
Figure 4.25
Annual upstream investment requirements, 2023–2045



Source: OPEC.

Regionally, the bulk of this, or 65%, will initially be required in North America, both due to its relative size and importance in medium-term supply growth, but also due to the relatively high cost of developing Canadian oil sands, deepwater and tight oil in the US. Over time, this share is reduced, as the relative significance of developing resources elsewhere increases. Upstream investment needs in the rest of non-OPEC, excluding North America, are set to rise from $107 billion p.a. in 2022 to $177 billion p.a. in 2045. Investment requirements in OPEC Member Countries are set to quadruple, from $35 billion p.a. in 2022, to $136 billion p.a. in 2045.

Figure 4.26
Cumulative oil-related investment requirements by segment, 2023–2045



Source: OPEC.

Ensuring that these investments are made and sustained is a key challenge and of utmost importance to the stability of oil markets and security of supply. Even as upstream investment is set to pick up in 2023, rising by 13%, to $360 billion, this only just brings capital expenditure back to pre-pandemic levels. Hurdles to upstream investment, or even calls to

curtail investment, are not helpful in this regard, and raise the risk of supply shortfalls and market volatility.

Besides the upstream sector, estimated investment requirements in the downstream and midstream sectors are calculated to be $1.7 trillion and $1.2 trillion, respectively, for 2023–2045. Thus, in sum, global investment requirements for the overall oil sector are assessed at $14 trillion in the long-term, or nearly $610 billion p.a.

Refining outlook

Key takeaways

- During 2022, the downstream market witnessed major stress tests amid strong demand growth in the post-pandemic recovery and geopolitical tensions. The market stabilized somewhat in late 2022 and early 2023.
- A large source of uncertainty over the past year has been Russian product exports in light of sanctions and price caps. Nevertheless, Russian crude oil producers and refiners have been able to reroute large portions of their product exports to other destinations, which has contributed to less market volatility.
- During the medium-term, around 6.6 mb/d of refining capacity additions are projected. Most of the new additions are in the Asia-Pacific (3.1 mb/d), the Middle East (1.6 mb/d) and Africa (1.2 mb/d). Additions in other regions are minor and mostly limited to the expansion of existing refineries.
- In the long-term (2023–2045), global refining additions are at 19.2 mb/d (including creep capacity). Similar to oil demand growth, additions are front-loaded, with a significant slowdown in the rate towards 2045.
- Almost 85% of long-term additions are located in the Asia-Pacific, the Middle East and Africa. This continues the trend of refining capacity migration from developed to developing countries.
- The medium-term balance shows a tightening market due to strong demand growth. The estimated deficit of potential refining capacity relative to required refining capacity is set to increase from 0.7 mb/d in 2023 to 1.7 mb/d in 2028, with the largest deficits in the Asia-Pacific.
- Global utilization rates are set to rise above 80% in 2023, similar to 2019 levels. The utilization rate is then set to increase to 83% in 2028 due to strong demand growth and refinery closures.
- Refinery runs are expected to increase to almost 90 mb/d in 2035. The growth continues beyond 2035 with global runs reaching almost 92 mb/d in 2045. US & Canada and Europe, as well as developed Asia-Pacific, are set to decline from 2030 onwards. This is more than offset by strong increases in developing regions.
- Around 1.2 mb/d of refinery shutdowns are expected between 2023 and 2028. This is considerably lower compared to closures in the period 2020-2022.
- Secondary capacity additions to 2045 are significant, with 19.5 mb/d of desulphurization, 10.7 mb/d of conversion capacities and 6.1 mb/d of octane units.
- Total required downstream sector investments are projected at almost $1.7 trillion. More than $550 billion is required for refinery capacity expansions, while $1.1 trillion is for continuous maintenance and replacement.

This chapter presents the oil downstream outlook for the period 2023-2045. It is fully consistent with the Reference Case assumptions, including projections on oil demand (Chapter 3) and supply (Chapter 4). The chapter examines various market drivers and factors that may influence the future global refining sector, highlighting challenges, uncertainties and opportunities. Similar to Chapter 3 and 4, the analysis is conducted in two different timeframes – the medium-term (2023–2028) and long-term (2023–2045).

The chapter initially focuses on recent downstream developments, followed by an updated assessment of current 'base' capacity by region that is the basis for medium- and long-term projections. These projections are conducted according to different methodologies. First, new medium-term refining capacity additions are assessed based on a thorough review of refinery projects and their progress. Second, based on global and regional oil demand and supply trends, long-term refining capacity additions (i.e. requirements for additions) are projected. Moreover, the analysis in this chapter shows how the downstream market balance is anticipated to evolve in the medium- and long-term. This provides insights into regional market balances and utilization rates.

There are also discussions and forecasts for recent and near-term refinery closures. In the medium-term, projections are based on announcements (firm closures) and an assessment of potential closures by 2028. Beyond 2028, the Reference Case makes no explicit forecasts on closures, but provides an indication on the required refinery closures.

This chapter also examines medium- and long-term secondary capacity additions. This includes projections for fluid catalytic cracking (FCC), coking and hydrocracking, desulphurization capacity, and octane units. Based on these secondary capacity additions and the projected demand by product, the potential medium-term market balance is highlighted.

Finally, this outlook forecasts global and regional investment requirements related to medium-term additions and those beyond this timeframe, as well as investments for continuous maintenance and replacement.

5.1 Existing refinery capacity

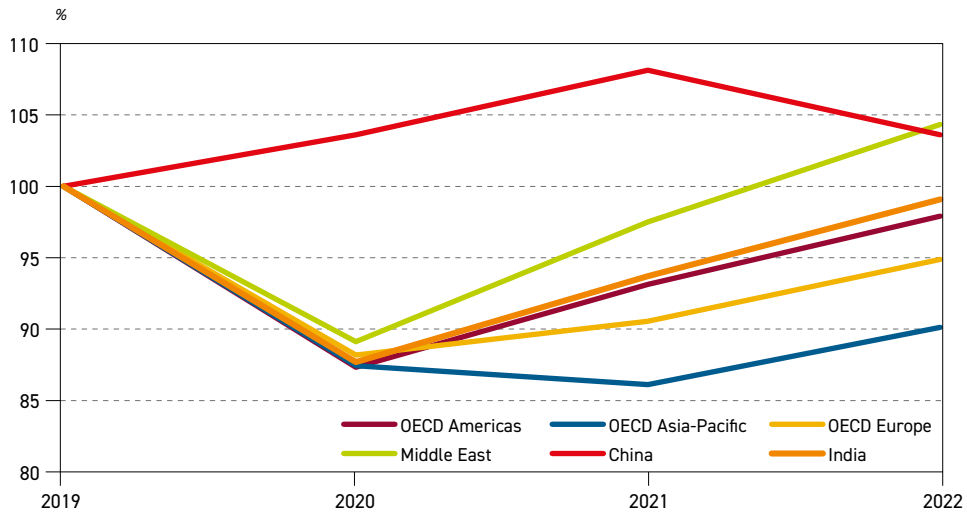
5.1.1 Recent developments in the downstream sector

During 2022, the downstream market witnessed major stress tests amid strong demand growth in the post-pandemic recovery and geopolitical tensions. Refinery runs increased in almost all major regions, with the exception of China, due to continued pandemic-related lock-downs. Nevertheless, China's refinery throughputs recovered strongly in late 2022 and 1H23, in line with the relaxation of COVID-related regulations and the consequent demand increase.

The pandemic related demand drop in 2020, coupled with mounting competitive pressure by East-of-Suez newly commissioned plants and stringent environmental standards on refined fuels, triggered a wave of refinery closures. More than 4 mb/d of refining capacity closed between 2020 and 2023. The vast majority of closures took place in developed countries and regions, including the US, Europe, Canada, Japan, Australia and New Zealand.

Figure 5.1 shows refinery runs indexed to 2019, the drop in 2020 and the recovery in subsequent years. Refinery runs in 2022 in major developing regions and countries, such

Figure 5.1
Refinery throughputs, indexed to 2019



Source: OPEC.

as the Middle East and China, were significantly above 2019 levels. This was due to demand growth and the commissioning of new refinery projects. Runs in India were close to their pre-pandemic levels in 2022. In developed countries, runs in 2022 were considerably lower than in 2019. This was especially the case for Europe and OECD Asia-Pacific. Slower demand recovery and refinery closures were the major reasons for this.

The year 2022 was also challenging in term of geopolitics. The start of the conflict in Eastern Europe, and related EU sanctions on Russian crude and product imports led to significant uncertainties related to the country's supply. The aforementioned refinery closures and limited products exports from China also reduced the available refining capacity across the year. In addition, due to record high natural gas prices many consumers looked to switch to alternatives, including diesel. In parallel, refining costs increased considerably in 2022, partly due to high gas prices. Consequently, gasoline and diesel crack spreads reached record high levels, with the gasoil spread to Brent in Northwest Europe (NWE) reaching levels of $70/b in October 2022 (on a monthly average).

However, the market stabilized somewhat in late 2022 and early 2023. Despite EU and US sanctions and price caps, Russian crude oil producers and refiners were able to reroute large portions of their product exports to destinations in non-EU Europe, Africa, Middle East, Latin America and Asia. Furthermore, the downstream market witnessed some large capacity additions in 2022 and early 2023, including the Al-Zour refinery in Kuwait and the Lianyungang refinery in China. This reduced fears of potential tightness in product markets.

In mid-2023, the downstream market was strong, especially for gasoline, and much more stable compared to 2022. As the Reference Case shows, however, expected high demand growth in the years to come is set to be higher than refinery capacity additions. In addition, further medium-term capacity closures will likely materialize. All this will likely tighten the downstream market, leading to increasing utilization rates, especially in developing countries.

Nevertheless, a number of uncertainties are forecast to remain. These are related to demand growth, the timely expansion of new refining capacity, Russian refinery throughputs and product exports, China's export policy, to name a few. This chapter will discuss the major driving forces in the downstream and highlight potential challenges in the years to come.

5.1.2 Base refinery capacity in 2022

This section provides a detailed update on base capacity assessments – distillation and secondary capacity, including condensate splitters – of refineries worldwide. It includes additions to existing refineries, new refineries that have come on stream, as well as closures that occurred during 2022.

It is important to note that the applied approach is that refineries, unless officially closed, are included in the database of so-called 'nameplate' capacity, although effective capacity may be identified as being well below the nameplate level. Overall, it should be stated that no single data source for global and regional refinery capacities could be relied upon entirely. The quality and availability of capacity reporting varies by refinery, so there is always an element of determining a 'best estimate' for base capacity. This applies for primary capacity, especially secondary capacity, and for new projects and closures.

Table 5.1 provides details by region and process on the 101 mb/d of assessed base refinery capacity (distillation) as of January 2023. This includes capacity additions and closures that occurred during 2022, as well as other necessary adjustments to the base capacity. Last year saw a relatively high level of closures of above 1 mb/d, mainly triggered by the COVID-19 pandemic. While this was slightly lower compared to 2020 and 2021, it was still far above average annual closures of around 0.6 mb/d that occurred in the preceding five years. Together, with capacity additions and necessary capacity adjustments to the base capacities of individual refineries, these factors led to a net assessed capacity of 101 mb/d at the start of 2023.

At the regional level, Other Asia-Pacific lost 0.2 mb/d, whereas Russia & Caspian and the Middle East were the regions where capacities increased. The US & Canada, as well as Europe, each lost distillation capacity relative to 2022. Other regions had very little, if any, capacity change during 2022. Developments in 2022 confirm the long-term trend of a refining capacity migration from developed to developing countries. This is clearly the result of oil demand trends.

Secondary capacity

Recent refinery capacity additions are complex with expanding secondary processing capacity per barrel of primary distillation capacity. Furthermore, an increasing number of existing refiners have geared production towards petrochemical feedstock production, and new refineries are increasingly designed to yield the maximum level of petrochemical feedstock. This is in line with demand development, given rising demand for high-quality products, as well as tightening regulations related to product specifications, especially sulphur levels. The consequence is increasing market competition, which has also led to the closures of older and simple units, especially in developed regions.

Global vacuum distillation capacity currently stands at an average 38.5% of crude (atmospheric) distillation capacity, upgrading at 44.5%, gasoline octane units at 20.8% and

desulphurization at 68.5%. A review of data from previous years confirms these ratios reflect a steady increase over time.

Figure 5.2 summarizes the data from Table 5.1 as percentages of crude distillation capacity. The table highlights refinery complexity variations between regions. The US & Canada continue to hold the highest levels of upgrading, gasoline production and desulphurization relative to distillation. This reflects a traditionally complex refining system. However, state-of-the-art refinery capacity additions, particularly in the Middle East, China and Other Asia-Pacific, are raising overall secondary capacity there relative to distillation, with some countries coming closer to US & Canada levels.

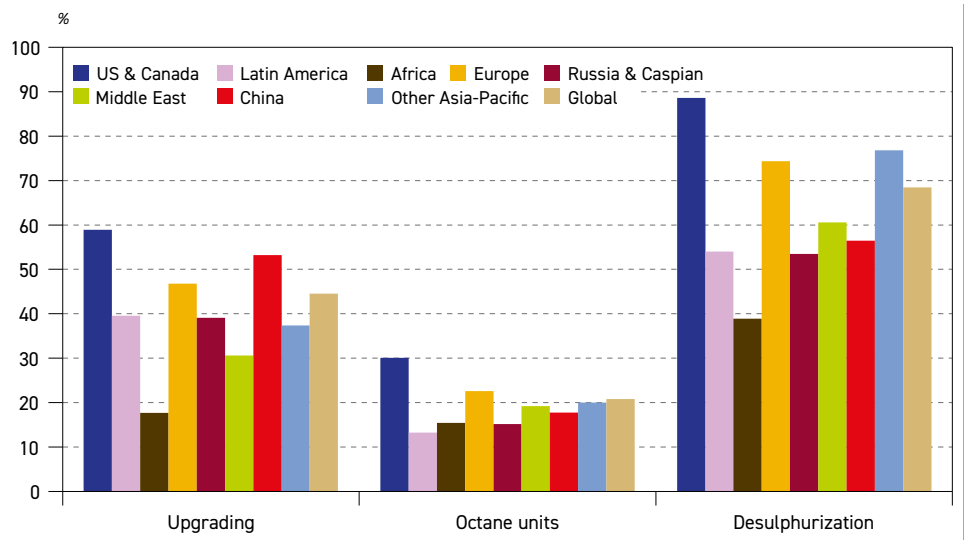
For upgrading capacity, the US & Canada has the highest ratio at almost 59% of distillation capacity, followed by China at 53 % and Europe at 47 %. All other regions show values in the 30–40% range, apart from Africa at close to 18%.

Table 5.1
Assessed available base capacity as of January 2023 *mb/d*

	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	World
Distillation									
Crude oil (atmospheric)	19.4	7.8	3.8	14.9	7.8	10.7	17.6	19.0	101.0
Vacuum	8.8	3.4	0.9	6.3	3.2	3.1	7.3	5.9	38.9
Upgrading									
Coking	2.8	0.9	0.1	0.8	0.6	0.4	2.3	1.1	9.0
Catalytic cracking	5.7	1.6	0.2	2.2	0.9	1.1	4.3	3.5	19.5
Hydro cracking	2.4	0.2	0.2	2.4	0.9	1.0	2.5	1.7	11.2
Visbreaking	0.1	0.4	0.2	1.4	0.7	0.6	0.2	0.6	4.0
Solvent deasphalting	0.4	0.1	0.0	0.2	0.0	0.2	0.1	0.2	1.2
Octane units									
Reforming	3.7	0.6	0.5	2.4	0.8	1.4	2.4	3.0	14.8
Isomerization	0.8	0.1	0.1	0.6	0.3	0.5	0.2	0.4	3.0
Alkylation	1.3	0.2	0.0	0.2	0.1	0.1	0.2	0.4	2.5
Polymerization	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
MTBE/ETBE	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.1	0.6
Desulphurization									
Naphtha	4.7	0.8	0.5	2.9	1.0	2.1	2.4	3.1	17.6
Gasoline	2.9	0.5	0.1	0.7	0.3	0.4	1.6	1.4	7.8
Middle distillates	6.5	2.5	0.8	5.7	2.5	3.2	4.8	6.9	32.9
Heavy oil/Residual fuel	3.1	0.4	0.0	1.8	0.4	0.8	1.1	3.2	10.8
Sulphur (short tons/day)	42,428	7,282	3,589	20,091	8,537	14,666	23,296	39,442	159,332
Hydrogen (million scf/d)	6,389	1,251	354	5,047	2,182	3,373	6,875	6,405	31,876

Source: OPEC.

Figure 5.2
Secondary capacity relative to distillation capacity, January 2023



Source: OPEC.

In terms of upgrading specifics, there are significant regional differences. The US & Canada, Latin America and China account for the highest levels of coking, around 26% of total upgrading in each region. They also account for two thirds of total global coking capacity. This partly reflects the relatively high supplies of extra heavy grades from Canada and Latin America.

The same regions, plus Other Asia-Pacific, have the highest proportion of catalytic cracking at around 49%. All regions, with the exceptions of Latin America and Africa, show significant levels (21–34%) of hydrocracking in total upgrading. The advantage of hydrocracking is the relatively high flexibility in light *versus* middle distillate production. The distribution of mild upgrading, notably visbreaking, varies widely with significant proportions only in Europe, Russia & Caspian, Other Asia-Pacific and the Middle East.

For octane units, the US & Canada is an outlier at over 30% of distillation capacity. This is in line with the region's exceptionally high gasoline consumption. Europe is at around 23%, which is a significant share of gasoline demand. This also relates to the presence of installed gasoline capacity that was there before the continent's dieselization shift, one that led to a gasoline surplus. The Middle East, China and Other Asia-Pacific are in the range of 18-20%, while Latin America, Russian & Caspian and Africa, exhibit lower octane unit proportions, in the range of 13–15%.

Desulphurization levels vary strongly across regions depending on their fuel standards and the quality of crude slates. The highest share of desulphurization is in the US & Canada at almost 90%, which is significantly higher compared to other region. For instance, Africa's share of desulphurization was at just below 40% in 2022. Refineries in the US & Canada have traditionally processed a large proportion of heavy and medium-sour crudes, mostly from Latin America and the Middle East. Domestically produced heavy barrels in Canada are also almost exclusively processed in the region.

Europe and Other Asia-Pacific, which include countries such as Japan and South Korea that possess substantial amounts of residual desulphurization capacity, also have relatively high proportions of desulphurization capacity, at around 75 % and 77%, respectively. The Middle East is lower at 61%, while in the remaining regions – Latin America, Russia & Caspian and China – the level is in the 54–57% range. Africa's lower level (39%) reflects the fact that the region is in the earlier stages of progressing toward ultra-low sulphur (ULS) standards for gasoline and diesel. In addition, a large share of Africa's crude supply is sweet and, therefore, needs less desulphurization.

In Europe, the high desulphurization ratio reflects strict product quality regulations because of the implementation of ULS fuel standards. In Other Asia-Pacific and the Middle East, the high and rising levels reflect a strong movement to ULS standards, plus a situation where today large new refineries are invariably built for elevated levels of clean fuel output to ULS standards. The same trend is under way in China.

As would be expected, the regions with the highest levels of desulphurization relative to crude capacity also have the highest levels of sulphur recovery and hydrogen capacity.

5.2 Distillation capacity outlook

5.2.1 Medium-term distillation capacity additions

This section focuses on the medium-term development of the downstream sector. This is based on a thorough review of refining projects, their status and progress. New projects and the expansion of existing units for both distillation and secondary capacities are listed and examined. It should be noted that these projections do not include small and under-the-radar additions (so-called 'creep' capacity), which is the natural addition of capacity to an existing facility that has little or no capital expenditure.

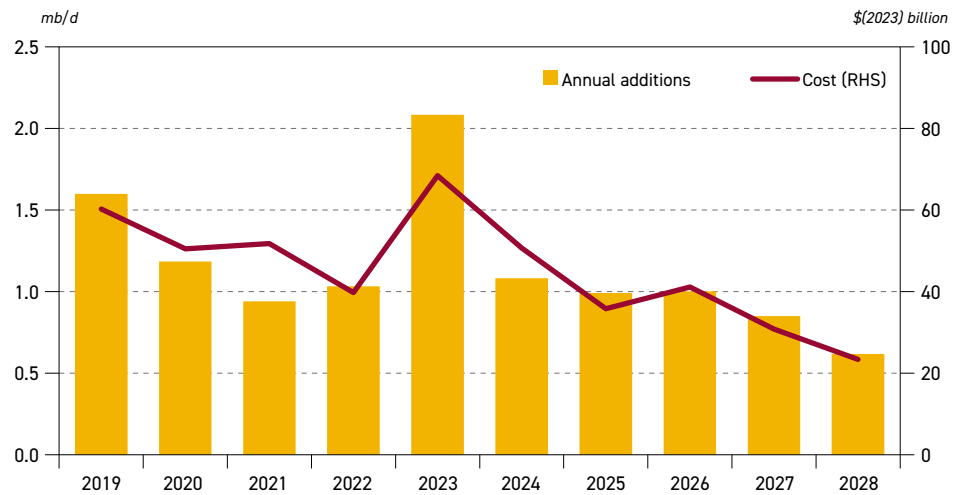
Global assessed refining capacity additions between 2023 and 2028 are at 6.6 mb/d. In terms of total new refining volume, this figure is slightly lower compared to the WOO 2022.

In part, this is due to the significant capacities commissioned in 2022, including the first phase of the Al-Zour refinery in Kuwait, and in China, Lianyungang and the first phase of the Jieyang refinery. On top of these, several smaller expansions were recorded, including in Indonesia, Malaysia, Colombia and Peru.

There remains a trend for refining capacities to migrate from developed to developing regions, namely the Asia-Pacific, the Middle East and Africa. The three regions are set to accommodate the largest share of medium-term capacity additions, representing almost 90% of the total. Strong demand growth, as well as rising product export strategies in these regions, are the major drivers behind this trend.

Figure 5.3 presents annual global distillation capacity additions and the expected investment volume related to new refining projects for the period 2019–2028. The global average rate of capacity additions for the period from 2023–2028 is forecast at around 1.1 mb/d, which is slightly lower relative to the WOO 2022. It is interesting to note that 2023 is set to see the largest capacity addition over the entire period, at 2.1 mb/d. This includes many large and medium-capacity refineries, some of which were partly commissioned in 2022 with full

Figure 5.3
Annual distillation capacity additions and total project investment



Source: OPEC.

commissioning during 2023. These projects are spread across the Middle East, Africa and the Asia-Pacific.

From 2023 onwards, the rate of additions drops to 1.1 mb/d in 2024, then to 0.9 mb/d in 2027 and around 0.6 mb/d in 2028. This reflects the smaller number of refining projects in the later part of the medium-term, as well as their lower probability of coming online. This is also due to the conservative approach taken when estimating the probability that a specific project is commissioned or not, a reflection of the high uncertainty in the refining industry. These uncertainties are generally related to such issues as funding, technical issues, market uncertainties and supply chain disruptions.

Medium term projections for refinery additions by region are in Table 5.2 and Figure 5.4. It is clear that medium-term capacity additions are concentrated in developing regions, namely the Asia-Pacific, Middle East and Africa. Combined, they account for more than 5.8 mb/d (88%) of the total 6.6 mb/d. The medium-term outlook contains several large projects, many of which have petrochemical integration too.

China is set to be the single largest country contributor to medium-term capacity additions. It is set to add 1.2 mb/d between 2023 and 2028. The country is reshaping its downstream sector by building several petrochemical-integrated mega-refineries and phasing out smaller ones. On top of the two projects commissioned this year, this includes several other projects, such as the 400 tb/d Yulong refinery with commercial operations slated for 2024 and the 300 tb/d refinery in Panjin by Huajin Aramco Petrochemical Company. This company is a joint venture between Aramco, NORINCO Group and Panjin Xincheng Industrial Group.

Refinery capacity is set to expand by 1.9 mb/d in Other Asia-Pacific. Strong demand growth is the major driver of refinery capacity additions in these countries. India is also developing an

expansion of existing facilities and focusing on the petrochemical sector. The country's target is to reach 9 mb/d of refining capacity by 2030. The largest refinery project in India is the 1.2 mb/d plant in western Maharashtra, developed by Aramco and ADNOC and several Indian state-run companies. Due to recent land acquisition issues, however, the mega-project could be redesigned and consist of several smaller refineries.

Other important projects in the region include plants in Indonesia, led by Pertamina, with foreign participation from the likes of Aramco and Rosneft, as well as moderate capacity additions in Malaysia, Thailand and Pakistan.

The Middle East is projected to see its refinery capacity increase by 1.6 mb/d between 2023 and 2028. Almost half of this growth is likely to materialize in 2023. This consists of the Al-Zour refinery in Kuwait (410 tb/d phase 2 and 3), Oman's 230 tb/d Duqm refinery and Iraq's 150 tb/d Karbala refinery.

Estimates suggest that Africa will experience medium-term distillation capacity additions of 1.2 mb/d. A significant portion of this increase is attributed to Nigeria's Dangote refinery, which accounts for 650 tb/d of much-needed capacity expansion in the country. The refinery was officially inaugurated in May 2023 with commercial operation slated to start later this year. Moreover, Nigeria is set to witness several small modular refineries established in the medium-term, with capacities of up to 20 tb/d each.

In other countries of Africa, there are plans to construct new refineries. This includes the 100 tb/d refinery in Soyo, Angola, set to come online by 2025. In Algeria (Hassi Messaoud) and Egypt (Alexandria), modest refining capacity expansions are expected. Furthermore, several sub-Saharan countries, including Ghana, Guinea, Senegal, and the Republic of the Congo, are projected to commission new refinery units, primarily of a modular nature. These expansions aim to address the region's rapidly growing refined product demand and to reduce product imports at the same time.

Table 5.2
Distillation capacity additions from existing projects by region, 2023–2028 *mb/d*

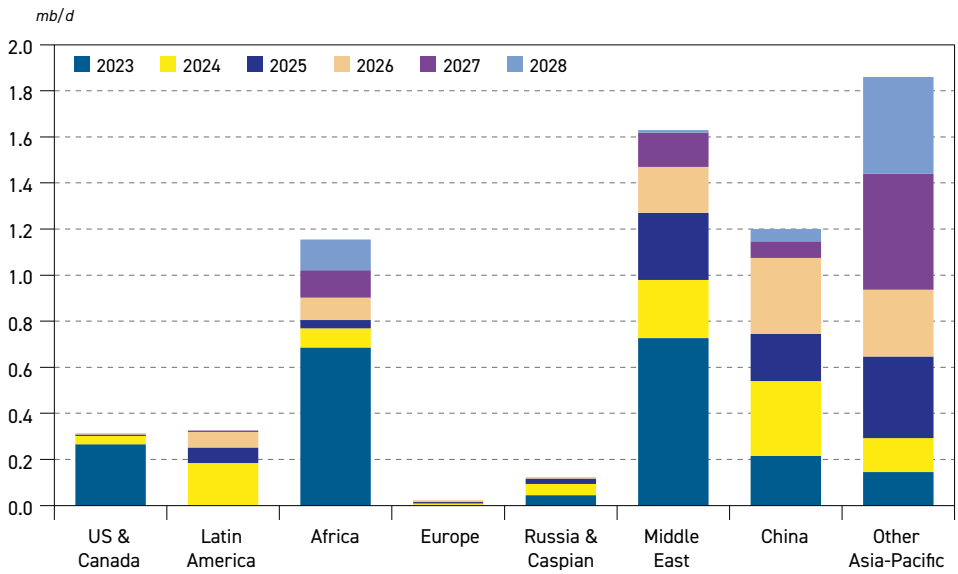
	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia Pacific	World
2023	0.3	0.0	0.7	0.0	0.0	0.7	0.2	0.1	2.1
2024	0.0	0.2	0.1	0.0	0.0	0.3	0.3	0.1	1.1
2025	0.0	0.1	0.0	0.0	0.0	0.3	0.2	0.4	1.0
2026	0.0	0.1	0.1	0.0	0.0	0.2	0.3	0.3	1.0
2027	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.5	0.9
2028	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.4	0.6
2023–2028	**0.3**	**0.3**	**1.2**	**0.0**	**0.1**	**1.6**	**1.2**	**1.9**	**6.6**
Share	*4.7%*	*4.9%*	*17.4%*	*0.3%*	*1.8%*	*24.6%*	*18.1%*	*28.1%*	*100.0%*

Source: OPEC.

Latin America, the US & Canada and Russia & Caspian are likely to see very modest refinery capacity expansions over the same period, with 320 tb/d, 310 tb/d and 120 tb/d, respectively. This incremental capacity represents existing plants expansion or relative small new capacity projects, the exceptions being the 340 tb/d Dos Bocas refinery in Mexico and the 250 tb/d Beaumont refinery in the US. The refinery was commissioned earlier this year. No new projects are planned for Canada.

Europe is the only region where medium-term distillation capacity expansions are virtually zero. The one small addition is in Türkiye, which is unlikely to be commissioned before 2025. This reflects the expected peak in European oil demand in the coming years. Consequently, this could result in additional capacity closures or conversions to bio refineries.

Figure 5.4
Distillation capacity additions from existing projects, 2023–2028



Source: OPEC.

The medium-term projection for new refining capacity is derived from a list of announced projects totalling over 20 mb/d. However, it is expected that only a portion of these projects will materialize. The total medium-term capacity additions of 6.6 mb/d encompass projects at various stages of development. Approximately 2.4 mb/d of capacity is either under construction or near that stage. These represent the projects with the highest certainty of being realized in the medium-term.

Additionally, there are projects amounting to more than 4 mb/d that are mostly in the early stages of development, yet have progressed sufficiently in terms of financing and engineering to be considered as 'firm' medium-term additions. Nevertheless, there is a significant level of uncertainty surrounding these projects, with a potential risk that some may only commence beyond the medium-term, or be cancelled for various reasons.

5.2.2 Long-term distillation capacity additions

This section focuses on long-term refining capacity additions. It is fully aligned with the underlying Reference Case assumptions. The long-term projections also take into account medium-term refinery capacity additions (Section 5.2.1) and announced refinery closures (Section 5.2.5).

Table 5.3 shows distillation capacity additions in the medium- and long-term. It includes assessed refinery projects in the period 2023-2028 and generic projects thereafter. As already noted, medium-term additions are estimated at 6.6 mb/d, while in the long-term a further 12.5 mb/d of distillation capacity is required. Long-term additions are not linked to specific projects, but are estimated as required in order to meet long-term demand for refined products. They also include debottlenecking additions, totalling around 0.7 mb/d by 2045. In total, refinery capacity additions are calculated at 19.2 mb/d at the global level. These additions will also largely offset future refinery closures, most of which are expected in developed countries where demand is expected to decline.

Table 5.3
Refinery distillation capacity additions by period *mb/d*

	Distillation capacity additions starting 2023			
	Assessed projects*	New units	Total	Annualized
2023–2025	4.2	0.2	4.3	1.4
2025–2030	2.5	3.3	5.8	1.2
2030–2035	0.0	4.3	4.3	0.9
2035–2040	0.0	3.2	3.2	0.6
2040–2045	0.0	1.5	1.5	0.3
	Cumulative distillation capacity additions			
	Assessed projects*	New units	Total	Annualized
2023–2025	4.2	0.2	4.3	1.4
2023–2030	6.6	3.5	10.1	1.3
2023–2035	6.6	7.8	14.5	1.1
2023–2040	6.6	11.0	17.6	1.0
2023–2045	6.6	12.5	19.2	0.8

* *Firm projects exclude additions resulting from capacity creep.*
Source: OPEC.

Similar to demand trends, the rate of refinery capacity additions is set to decline towards the end of the outlook period. The initial period to 2025 is likely to see additions of 4.3 mb/d and capacity growth for the period 2025–2030 is almost 6 mb/d. The subsequent five-year periods, however, are projected to have somewhat lower additions. In the last five years of the outlook, the global downstream sector is forecast to see incremental refining capacity of 1.5 mb/d.

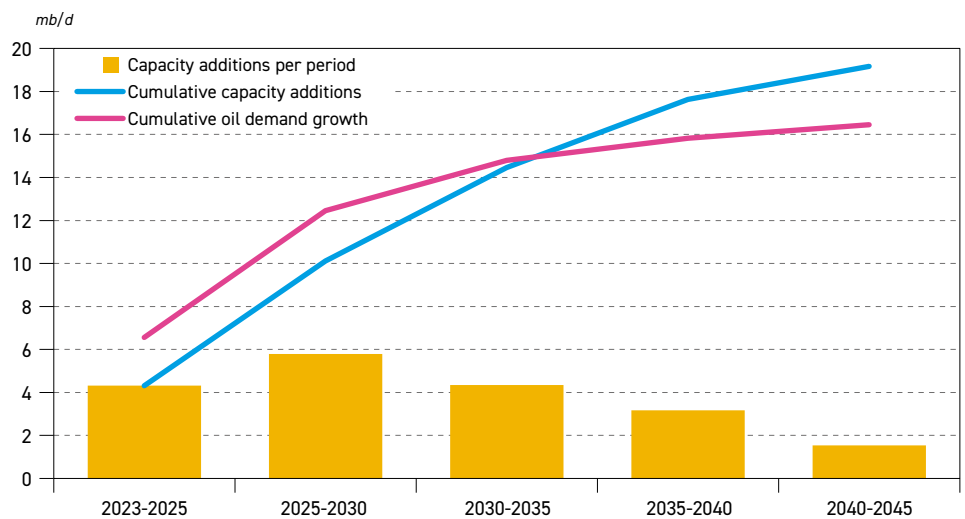
The average annual rate of global additions drops from 1.4 mb/d p.a. in the period to 2025 to 0.3 mb/d between 2040 and 2045. This means that refinery additions at the end of the

outlook period will likely be expansions of existing capacity, rather than many new greenfield projects.

Figure 5.5 compares global refining capacity additions to oil demand, inclusive of all non-oil liquids, in the period to 2045. Cumulative oil demand growth to 2035 is estimated at 14.8 mb/d, which is stronger compared to cumulative capacity additions in the same period. After 2035, however, cumulative capacity additions are higher relative to total oil demand growth. By 2045, oil demand growth relative to 2022 is just under 16.5 mb/d, which is below global refining capacity additions of 19.2 mb/d.

This is due to refining capacity additions following regional demand trends. The large majority of new capacity is set to come online in regions where demand is expected to grow. As already noted in Chapter 3, non-OECD oil demand (mostly the Asia-Pacific, Middle East and Africa) is set to increase by 25.7 mb/d between 2022 and 2045. At the same time, OECD oil demand is projected to decline by 9.3 mb/d, which is why relatively limited capacity additions are expected in this region. As OECD oil demand starts declining and non-OECD countries increase their refining capacity, the OECD downstream sector will come under pressure due to declining utilization rates. This could lead to further shutdowns in the long-term (see section 5.2.5).

Figure 5.5
Distillation capacity additions and oil demand growth, 2023–2045



Source: OPEC.

Regional additions

Global refining capacity additions between 2023 and 2045 are estimated at 19.2 mb/d. Medium-term additions are projected at 6.6 mb/d, while required additions beyond 2028 are at 12.5 mb/d. Similar to medium-term trends, the majority of the refining capacity additions are expected to occur in developing regions, predominantly the Asia-Pacific, the Middle East and Africa.

Long-term refining capacity increments in Other Asia-Pacific (excluding China) is estimated at 7.1 mb/d, in line with strong demand growth. India is the single largest contributor to capacity additions in this region.

China is expected to add 3.5 mb/d over the same period. Oil demand in China is expected to reach a plateau after 2035. Consequently, around 80% of additions will be required before 2035, some of which will likely replace old and inefficient refining capacities in the country.

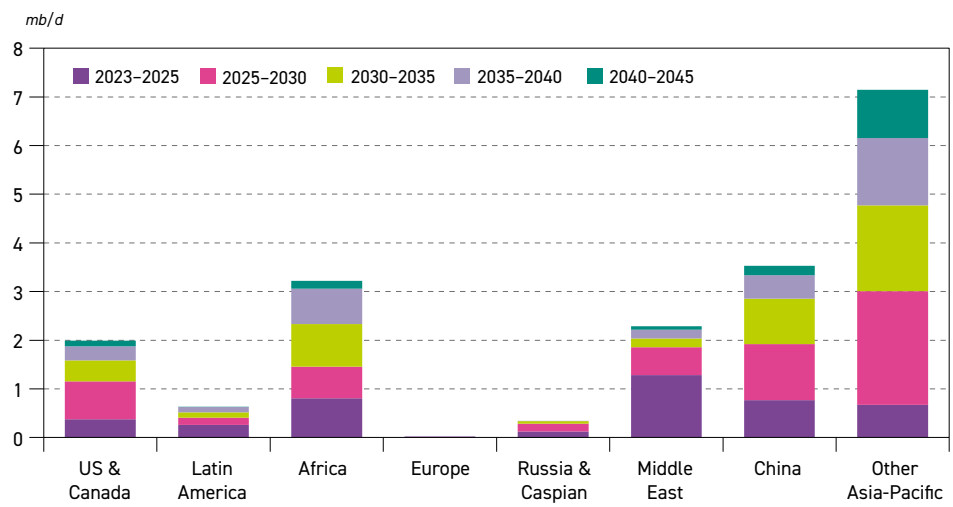
Both Other Asia-Pacific and China are likely to see new projects involve several OPEC Member Countries, such as Saudi Arabia and the United Arab Emirates, with joint venture agreements already in place.

Africa's capacity expansions are projected at 3.2 mb/d between 2023 and 2045. These additions will help to satisfy domestic demand growth, as well as reduce refined product imports, especially in West Africa. New refining capacities can also benefit from local crude oil supplies. However, project implementation, including financing and technical issues, remains a challenge on the continent.

The Middle East is set to add 2.3 mb/d of new capacity in the long-term. Of this, 1.6 mb/d is expected to come online by 2028, which means that additions thereafter are only moderate. The region has commissioned several large state-of-the-art refineries in recent years, which will not only help meet expanding domestic demand, but also increase refined product exports to international markets.

Additions in other regions are minor. Total incremental refining capacity in Latin America is estimated at around 0.65 mb/d between 2023 and 2045. These additions are significantly lower relative to oil demand growth in the same period. This is due to two reasons. First,

Figure 5.6
Crude distillation capacity additions, 2023–2045



Source: OPEC.

Latin America has a large number of plants that are currently under-utilized. Some of these plants could be modernized, which would help to increase refined products output. Second, the region is likely to see increasing inflows of refined products from the US, where surplus refining capacity is set to turn to international product markets.

Long-term refinery additions in the US & Canada are expected at 2 mb/d, with more than half being commissioned before 2030. The region's downstream sector has reached maturity and further additions are likely to be limited, generally replacing some older and less efficient plants.

Similarly, in Russia & Caspian, no major refinery additions are expected, with only minor expansions of existing plants. Total long-term refinery additions in the period to 2045 are projected at 0.3 mb/d. Finally, in Europe almost no new refining capacity is projected for the period between 2023 and 2045, which is in line with this region's expected demand decline.

5.2.3 Medium-term balance for the refining sector

This section focuses on the downstream market outlook by taking into consideration capacity additions, regional oil demand and oil supply. The outlook is divided into two sub-sections – the medium-term and long-term – which follow two different approaches.

The medium-term outlook looks at refinery additions as laid out in Section 5.2.1 and compares this with the so-called 'call-on-refining' relative to the base year of 2022. In other words, this analysis shows how the market may change compared to the base year. The call-on-refining is based on oil demand growth. It also considers demand for various non-refinery fuels, such as NGLs, CTLs, GTLs and biofuels.

The analysis covers the global downstream market, as well as major regions. The long-term outlook looks at modelling results over the period 2028–2045 and projects refinery throughputs and respective utilization rates at the regional level, including crude and product movements (see Chapter 6).

Medium-term global balance

As already noted, medium-term primary capacity additions are projected at 6.6 mb/d globally. On top of these additions, modelling results suggest further debottlenecking or 'creep' capacity additions of around 0.4 mb/d by 2028, mostly in the US & Canada, but also parts of the Asia-Pacific due to the large base of existing refineries. Consequently, total distillation capacity additions between 2023 and 2028 are estimated at roughly 7 mb/d. As per the methodology applied, assumed medium-term refinery closures are not taken into account at this stage, but are discussed separately later.

The methodology also assumes that new refining capacities may reach the maximum assumed utilization rate of 90% throughout the year. This is considered a reasonable assumption at the global level. Consequently, this provides insight into the potential incremental crude runs or potential refining capacity between 2023 and 2028. Furthermore, as this outlook is on an annual basis, this methodology attempts to capture uncertainties related to the start-up date of refining capacity within the year. This is why the calculation takes into account only one-half of the current year (n) and one-half of the previous year (n–1). With this approach, the

cumulative global potential refining capacity is set to reach levels of around 6.5 mb/d by 2028, compared to 2022.

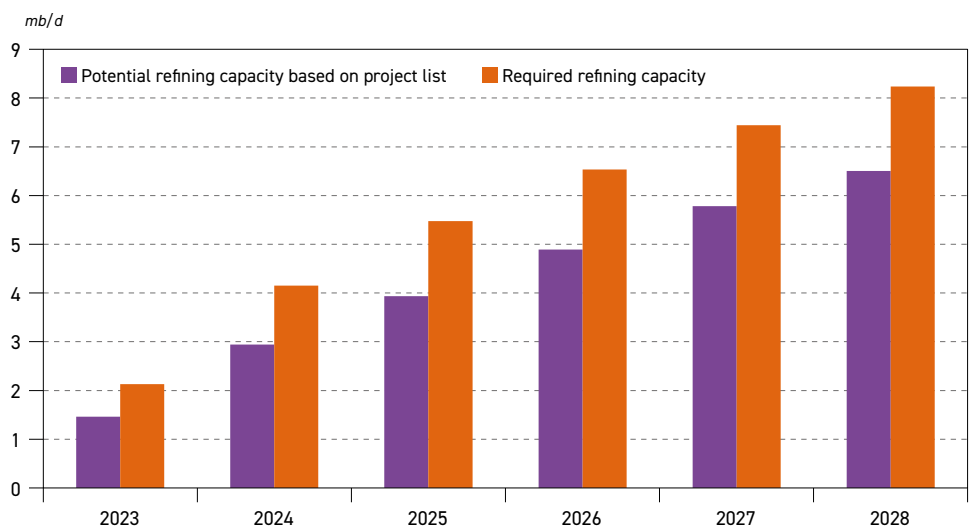
In the next step, the cumulative required incremental crude runs at the global and regional level are calculated. This is the so-called 'call-on-refining' and is based on demand patterns that take into account non-refinery fuels, such as NGLs, biofuels, CTLs and GTLs, which bypass refinery processing. This section covers balances from the perspective of distillation capacity, crude runs and total demand without considering specific refined products that are discussed later.

While medium-term global oil demand growth is estimated at 10.6 mb/d, the total required incremental crude runs are calculated at 8.2 mb/d. In the final step, the potential incremental crude runs are compared with the cumulative incremental refined product demand at an annual level.

The analysis is done at the global level and for each of the major regions. The resulting balances show the incremental refining capacity compared to incremental refined product demand relative to the base year of 2022. This is a good indicator of the state and the direction of the downstream market in the medium-term, both globally and regionally.

Figure 5.7 provides a summary assessment of the global cumulative medium-term potential for incremental distillation refining capacity compared to the required incremental product supply from refineries relative to 2022. It is important to note that market conditions during 2022 were largely driven by geopolitical uncertainties and expectations of supply shortages. Many of these expectations did not materialize, however, leaving the downstream market more balanced than initially assumed.

Figure 5.7
Additional global cumulative refinery crude runs, potential* and required**



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

** *Required: based on projected demand increases, assuming no change in refined products trade pattern.*
Source: OPEC.

At the global level, the trajectory of incremental refining capacity and required refining capacity shows a tightening market throughout the medium-term. In 2023, the required refining capacity is around 0.7 mb/d higher compared to the potential incremental capacity. This then increases to 1.5 mb/d in 2025 and further to 1.7 mb/d by 2028, due to strong demand growth.

It is important to note that there are wide regional differences that are explained in more detail below. Furthermore, compared to the WOO 2022, the potential cumulative medium-term refining capacity has been revised down slightly, whereas the incremental required capacity has been revised down considerably. This is due to the stronger medium-term demand outlook in the WOO 2022, part of which was post-pandemic recovery.

Medium-term regional balances

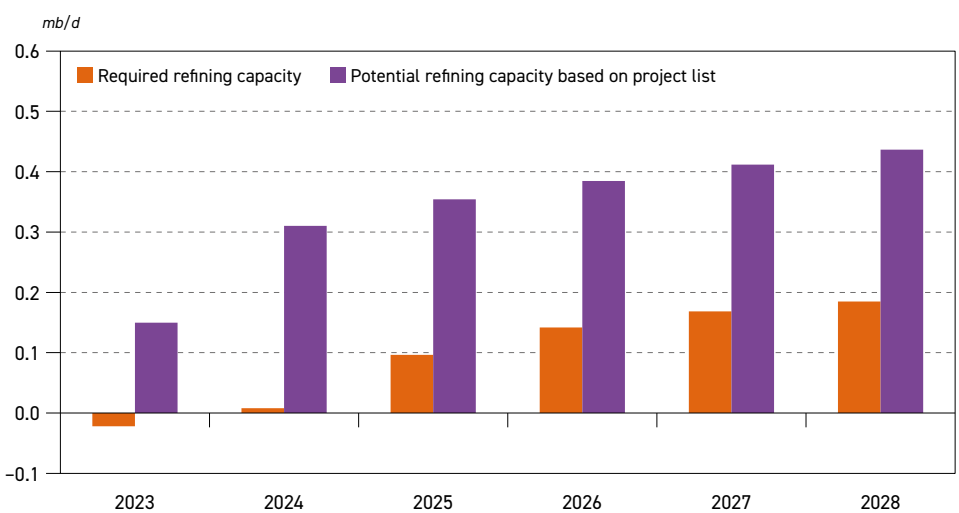
This section focuses on the regional medium-term balances. Figure 5.8 to Figure 5.15 present a comparison of data drawn for all major regions in the medium-term.

Figure 5.8 relates to the medium-term balance for the US & Canada. Relative to 2022, the potential incremental refining capacity is expected to increase gradually to levels around 0.45 mb/d in 2028. As already discussed, this region is expected to see the commissioning of only one major medium-term project, in combination with minor expansions of existing capacity.

At the same time, the required refining capacity increases only gradually throughout the medium-term, reaching 0.2 mb/d in 2028. The gap between potential and required incremental refining capacity in the medium-term remains in the range of 0.25 mb/d.

It is worth emphasizing that with its complex refining system and ample domestic supply, the US & Canada is likely to remain competitive in the international market. This should keep utilization rates in this region at high levels during the medium-term, which is discussed later.

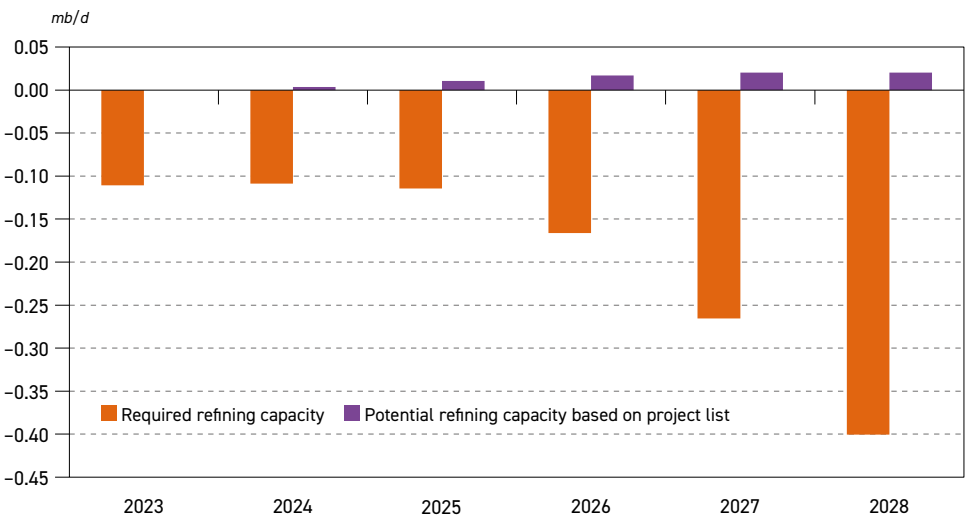
Figure 5.8
Additional cumulative crude runs in US & Canada, potential and required



Source: OPEC.

Europe exhibits a more pessimistic picture for the downstream market, relative to 2022 (Figure 5.9). Cumulative potential refining capacity in Europe is set remain virtually zero between 2022 and 2028, as almost no new distillation expansions are expected. The required incremental refining capacity for the same period is projected to drop from around –0.1 mb/d in 2023 to –0.4 mb/d in 2028, in line with declining demand and a rising share of biofuels in the fuels mix.

Figure 5.9
Additional cumulative crude runs in Europe, potential and required



Source: OPEC.

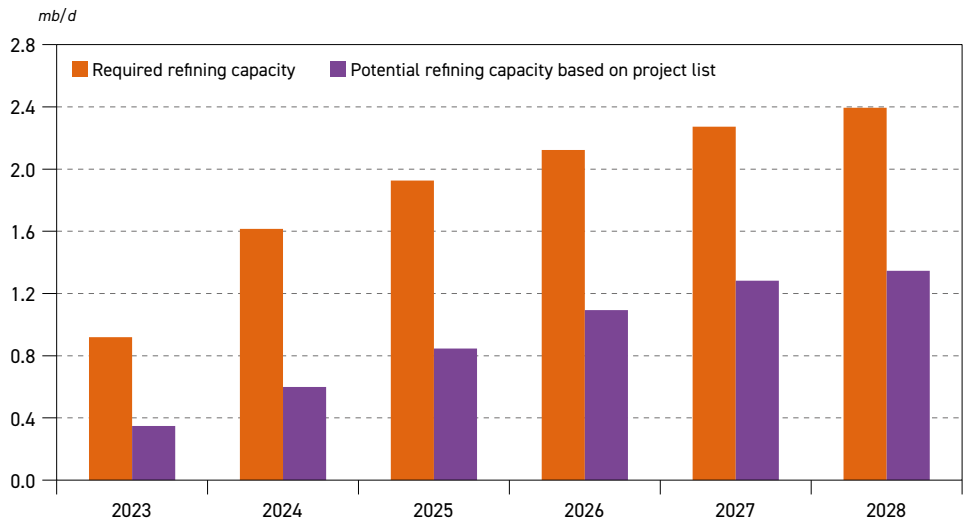
As European refineries are less competitive than their US counterparts, it is likely that the drop in the required refining capacity will lead to further closures. Announced and assumed closures in Europe of around 0.55 mb/d between 2023 and 2028 are likely to partly offset the widening gap between potential and required refining capacity. At the same time, European refinery throughputs could see an increase due to a tightening global downstream market, as mentioned earlier.

In China (Figure 5.10), the required cumulative refining capacity increases strongly relative to 2022. It is estimated at 0.9 mb/d in 2023 and then reaches 2.4 mb/d in 2028. This strong rise also includes the recovery of refinery throughput in 2023. This compares to the relatively low levels of 2022, partly due to COVID-related measures and lockdowns.

At the same time, the potential incremental refining capacity is forecast to increase from 0.35 mb/d in 2023 to 1.35 mb/d in 2028. In 2023, the gap between the required and potential incremental refining capacity is estimated at around 0.6 mb/d, signalling a stronger downstream market relative to 2022. The gap then widens in 2024 to around 1 mb/d on the back of strong demand growth and is still around this level in 2028. Accordingly, refinery utilization rates are likely to increase significantly over the medium-term.

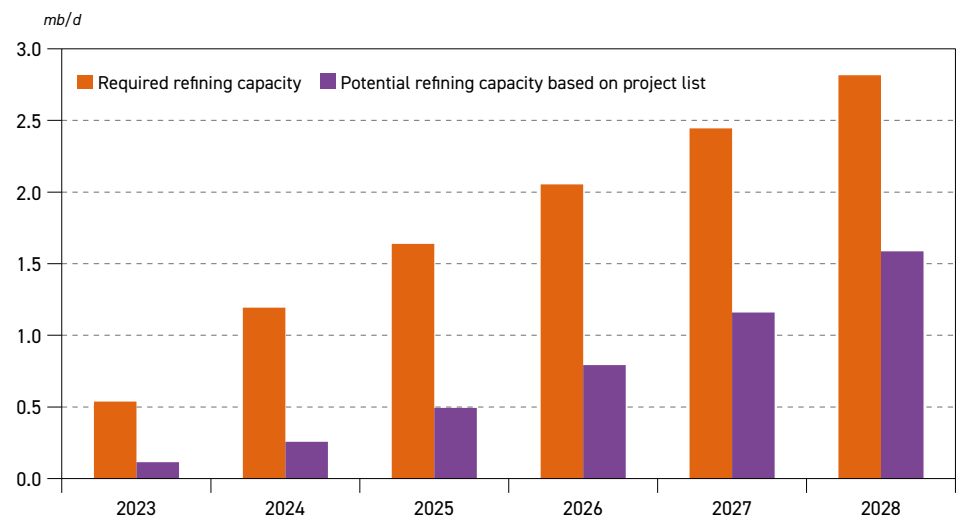
Figure 5.11 shows the market balance for Asia-Pacific (excl. China). Due to strong demand growth, the required incremental refining capacity relative to 2022 is projected to increase from 0.5 mb/d in 2023 to 2.8 mb/d in 2028.

Figure 5.10
Additional cumulative crude runs in China, potential and required



Source: OPEC.

Figure 5.11
Additional cumulative crude runs in Asia-Pacific (excl. China), potential and required

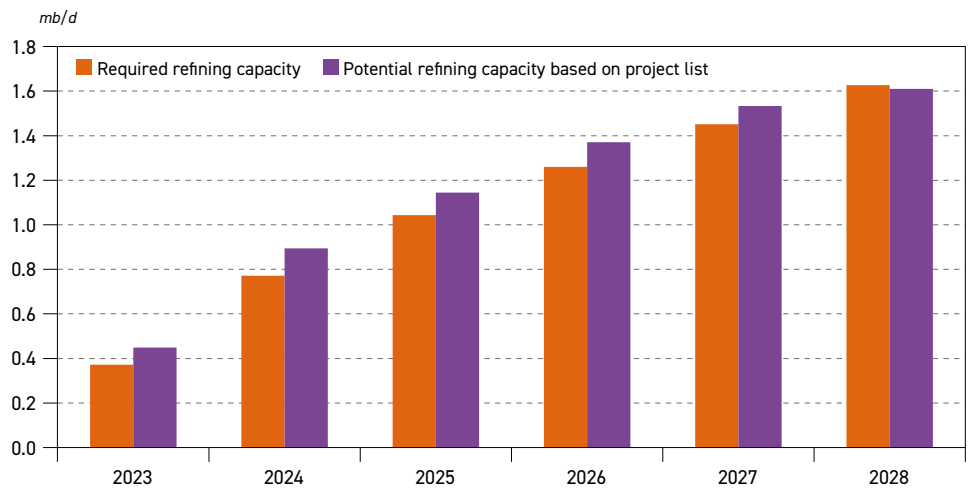


Source: OPEC.

In parallel, the potential incremental refining capacity increases from 0.1 mb/d in 2023 to 1.6 mb/d in 2028. The gap between required and potential capacity increases gradually to 1.3 mb/d in 2026 and falls from this level only slightly by 2028. Similar, to China, this will possibly lead to stronger utilization rates, as well as higher product imports. Regions like the Middle East and the US & Canada may provide additional barrels over the medium-term.

In the Middle East (Figure 5.12), demand growth leads to a strong increase in required incremental refining capacity relative to 2022. It rises from 0.4 mb/d in 2023 to 1.6 mb/d in 2028. The robust rise in potential incremental refining capacity is due to numerous projects expected to come online in this region over the medium-term.

Figure 5.12
Additional cumulative crude runs in the Middle East, potential and required



Source: OPEC.

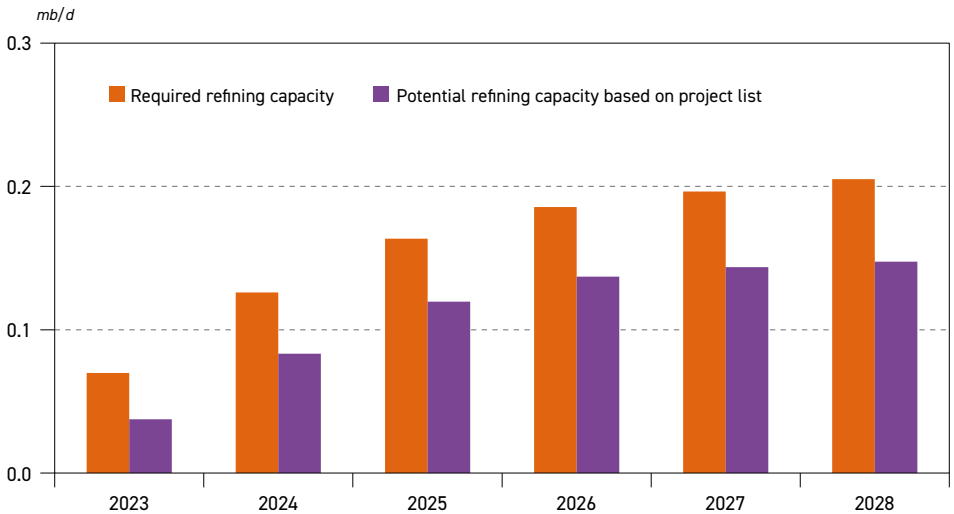
In 2023, potential refining capacity is estimated at around 0.4 mb/d and this increases to 1.6 mb/d in 2028. Consequently, there is a marginal surplus of potential incremental refining capacity relative to the required capacity in the Middle East between 2023 and 2027. In 2028, the Middle East downstream market appears balanced, relative to 2022 levels.

In Russia & Caspian (Figure 5.13), required incremental refining capacity is forecast to increase over the medium-term. However, the level is modest, reaching 0.25 mb/d in 2028 from almost zero in 2023. To some extent, this level is followed by rising potential incremental refining capacity, most of which is linked to minor existing downstream capacity expansions. It reaches 0.15 mb/d in 2028. Consequently, the market in Russia & Caspian is set to remain largely balanced.

It is important to note that the required refining capacity relates only to domestic demand trends. However, the downstream sector in Russia & Caspian is largely linked to product exports. The EU has imposed an import ban on Russian products, effective as of early 2023, and while Russia has managed to reroute large parts of its EU product exports to other destinations, it remains to be seen whether these exports will be able to compete against Middle East and US product exports in the medium-term.

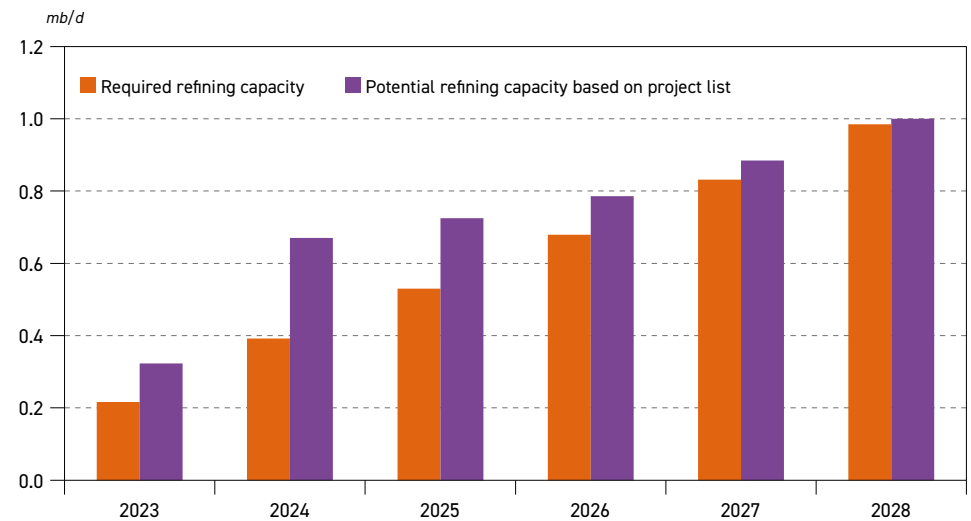
Figure 5.14 shows the medium-term downstream market balance for Africa. The potential incremental refining capacity increases strongly in the early years of the medium-term, which is linked to the start-up of the Dangote refinery in Nigeria (discussed earlier). It climbs to almost 0.7 mb/d in 2024, relative to 2022. What follows is slower growth thereafter, with the potential capacity reaching 1 mb/d in 2028.

Figure 5.13
Additional cumulative crude runs in the Russia & Caspian, potential and required



Source: OPEC.

Figure 5.14
Additional cumulative crude runs in Africa, potential and required



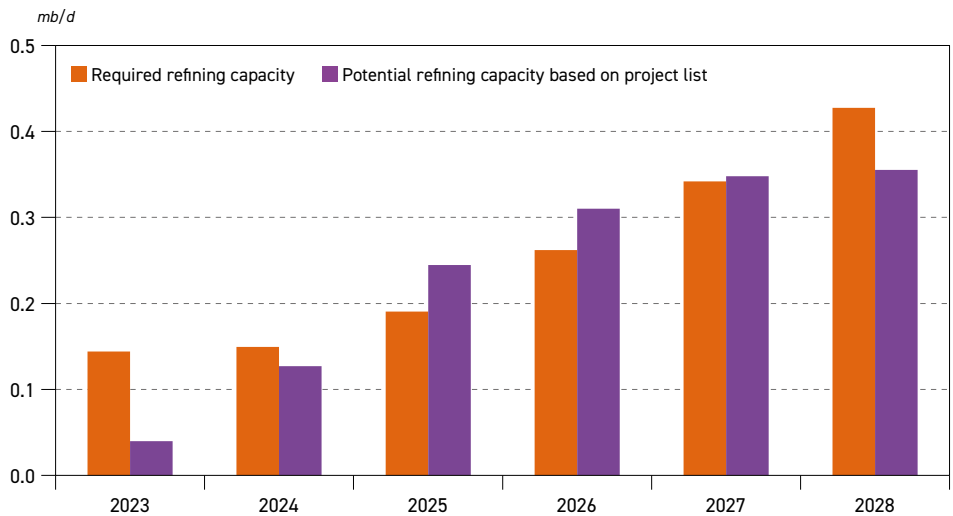
Source: OPEC.

Required cumulative refining capacity increases more gradually from 0.2 mb/d in 2023 to 1 mb/d in 2028. Consequently, the medium-term balance shows a moderate surplus of potential refining capacity in 2024 and 2025. This will help to reduce refined product imports to Africa in these years. This trend, however, will be offset by rising required refining capacity in the years following. In 2028, the market is more or less balanced relative to 2022, thus possibly restoring the product imports seen in this Outlook's base year.

The downstream balance in Latin America is shown in Figure 5.15. The incremental required refining capacity increases stepwise to 0.45 mb/d in 2028, based on rising demand. The incremental potential capacity is mostly projected to increase too, which is largely based on Mexico's Dos Bocas refinery. Potential incremental capacity reaches levels of 0.35 mb/d in 2028. Required refining capacity remains above incremental potential capacity throughout the medium-term, thus supporting the downstream market.

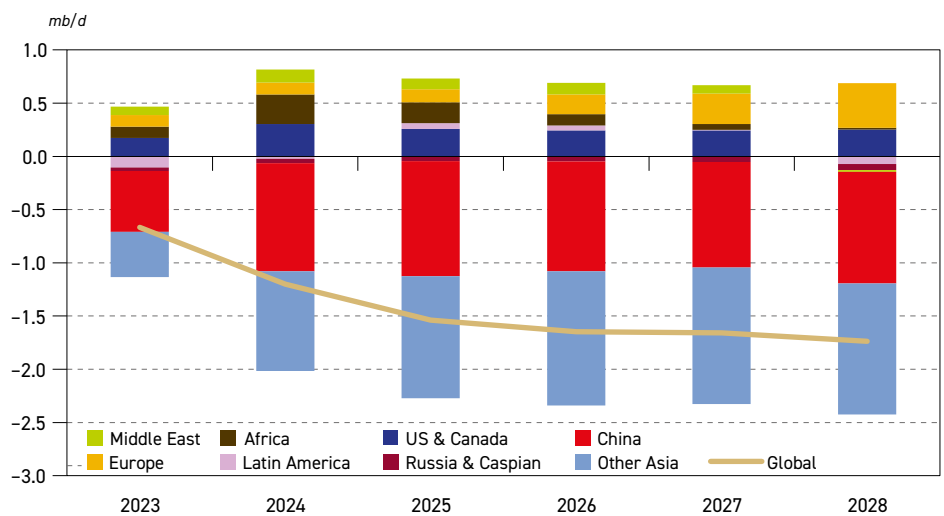
Figure 5.16 summarizes the cumulative medium-term balance by region and globally. It shows how the difference between incremental potential and required refining capacity changes

Figure 5.15
Additional cumulative crude runs in Latin America, potential and required



Source: OPEC.

Figure 5.16
Net cumulative regional refining potential surplus/deficits *versus* requirements



Source: OPEC.

over the medium-term. The largest deficit of refining capacity relative to requirements is expected in the Asia-Pacific (incl. China), due to strong medium-term demand growth. The deficit peaks at levels around 2.3 mb/d in 2026, and stays at this level thereafter.

On the other side, a surplus of refining capacity relative to requirements is expected in the US & Canada and Europe, increasing gradually to 0.7 mb/d by 2028. This is primarily the consequence of stabilizing and declining demand in these regions. Driven by an expansion of the refining system, by the end of the medium-term the Middle East is expected to see a balanced market relative to 2022. Other regions show a rather limited surplus and/or deficit throughout the medium-term.

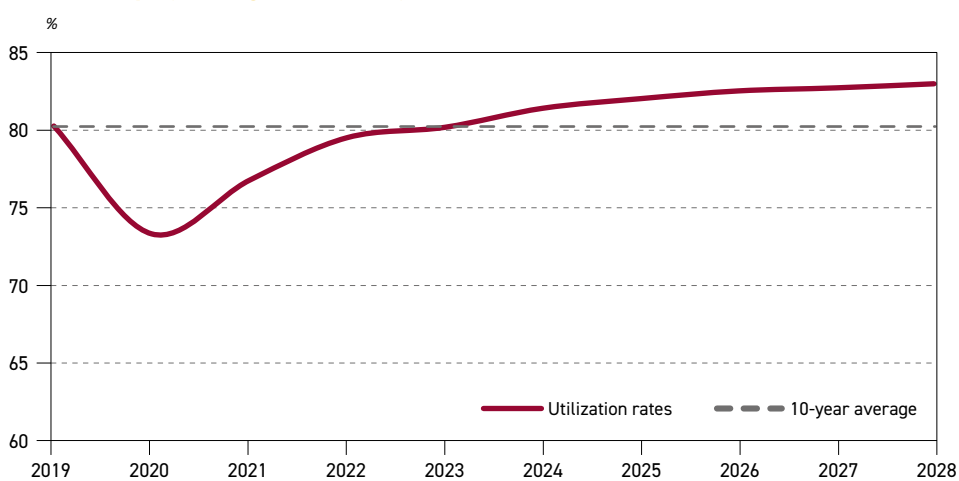
The global balance in 2028 shows a deficit of potential refining capacity of around 1.7 mb/d relative to requirements. It is important to note, however, that this analysis does not include closures (discussed in 5.2.5). This means that if all closures materialize as planned, the overall deficit could be even higher. This points towards a stronger downstream market throughout the outlook period when compared to 2022.

Medium-term refinery utilization and throughputs outlooks

This section discusses medium-term global refinery utilization and refinery throughputs. Unlike the previous section, this analysis includes assumptions on medium-term closures, estimated at 1.2 mb/d. It also shows assumed crude runs, the effects of historical and projected closures and estimates spare refining capacity in the period to 2028.

Figure 5.17 shows global utilization rates in the period 2019–2028. Global utilization rates were at strong levels of around 80% in 2019, but these dropped to below 74% in 2020 due to the demand shock caused by the COVID-19 pandemic. The post-pandemic recovery has been gradual – with levels around 76.8% in 2021 and 79.5% in 2022. For 2023, the average global utilization rate is estimated at 80.2%, thus hitting the pre-pandemic level.

Figure 5.17
Historical and projected global refinery utilization, 2019–2028



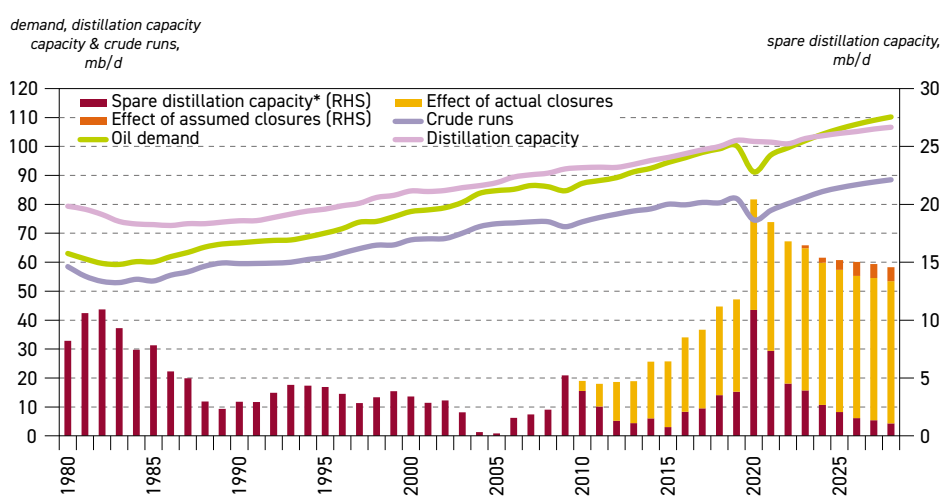
Source: OPEC.

In the coming years, utilization rates are projected to increase gradually and reach 82% in 2025, followed by a further increase towards 83% by the end of the medium-term. This is due to a combination of strong demand growth, somewhat slower capacity additions and refinery closures. It is important to note that in a tightening downstream market, any potential delay in capacity expansions could tighten it further.

The global utilization is calculated based on nominal capacities, which are assumed as available over the medium-term. However, countries can restrain access to international markets for their refiners due to various reasons, including security of supply. This effectively lowers the availability of refining capacity and puts more pressure on the rest of the global downstream system. Furthermore, many countries maintain relatively old and inefficient refineries, which run at relatively low levels – especially in Africa and Latin America. This means that refinery utilization rates in some regions have to be well above 80% to maintain a global rate of around 83% by 2028.

Figure 5.18 highlights the evolution of global oil (liquids) demand, crude and condensate throughputs, as well as the nominal distillation capacity at the global level. The historical trend shows a gradual convergence of global oil demand and nominal distillation capacity. This is due to the increasing share of demand attributed to non-refinery fuels, such as NGLs (surpassing refinery systems), biofuels, CTLs and GTLs. The increasing share of these liquids leads to a reduced share of refinery products in total oil demand. This has kept refining capacity additions lower relative to oil demand increments.

Figure 5.18
Global oil demand, refining capacity and crude runs, 1980–2028



* *Effective 'spare' capacity estimate based on assumed 84% utilization rate, accounting for already-closed capacity.*
Source: OPEC.

Global oil demand is projected to increase from around 99.5 mb/d in 2022 to 110.2 mb/d in 2028, an increase of 10.6 mb/d. At the same time, refinery runs are projected to rise roughly by 8.2 mb/d to 88.5 mb/d in 2028. Figure 1.18 also shows the effects of realized and assumed closures. Since 2010, more than 12 mb/d of refining capacity has been shut. In the pandemic

period (2020–2022) alone, more than 4 mb/d was decommissioned. Another 1.2 mb/d is assumed to be decommissioned in the period 2023–2028.

This is the basis for the calculation of so-called spare refining capacity, where the maximum global utilization rate is around 84%. This is historically the highest observed level. Consequently, the level of spare capacity was at its highest in 2020, at almost 11 mb/d. However, as demand recovered in the years after, spare capacity dropped to 4.5 mb/d in 2022. The trend is set to continue with spare capacity falling to about 2 mb/d in 2025 and then further to around 1 mb/d in 2028. This outlook assumes that all projected refining capacity additions are built on time, which means that any delays could lower the level of spare capacity further.

5.2.4 Long-term balance for the refining sector

This section focuses on long-term crude and condensate throughputs, as well as long-term utilization rates at the global and regional level. These are based on modelling cases and in line with demand (Chapter 3) and supply (Chapter 4) assumptions. Assumptions on medium-term refining capacity additions and refinery closures are also an integral part of the modelling cases.

Table 5.4 shows crude units throughputs and respective utilization rates in the period to 2045. While these take expected medium-term closures into account, no further closures are

Table 5.4
Crude unit throughputs and utilization rates, 2022–2045 *mb/d*

	Total crude unit throughputs *mb/d*								
	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	Global
2022	17.7	4.5	1.9	11.9	6.6	7.8	13.5	16.5	80.3
2025	17.7	5.3	2.8	11.9	6.3	9.0	15.6	17.2	85.7
2030	18.1	5.5	3.7	11.6	6.4	9.5	16.3	18.5	89.6
2035	17.9	5.9	4.2	11.2	6.1	9.9	16.5	19.5	91.1
2040	17.8	6.3	4.8	9.8	6.0	10.0	16.4	20.4	91.5
2045	17.3	6.5	5.0	9.5	6.0	10.1	16.4	21.1	91.9
	Crude unit utilizations *% of calendar day capacity*								
	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	Global
2022	91.1	57.0	50.8	80.0	84.5	72.9	76.5	86.6	79.5
2025	89.9	65.7	63.3	80.9	79.9	75.9	84.3	88.3	82.0
2030	89.6	67.8	72.0	81.4	79.8	76.7	83.0	85.0	81.8
2035	86.6	71.2	70.1	78.7	75.4	78.1	80.1	82.8	80.0
2040	85.1	75.0	71.2	69.2	73.7	78.5	77.7	81.9	78.1
2045	82.1	77.4	73.4	67.1	74.2	78.3	77.1	81.4	77.5

Source: OPEC.

assumed. Global refinery throughputs increase from levels just above 80 mb/d to 89.6 mb/d in 2030. This is in line with rising demand. However, global refinery throughputs are set to enter a period of slower growth from 2030 onwards and reach levels around 92 mb/d in 2045. This is due to oil demand trends and an increasing share of non-refinery fuels, including biofuels and synthetic fuels and rising volumes of NGLs that surpass refinery systems.

The global utilization rate increases in the period to 2025, reaching 82%, up 2.5 pp compared to 2022. However, as new capacity is commissioned in the medium- and long-term, the global utilization rate is set to decline gradually to 77.5% in 2045. Consequently, some further refinery closures are possible beyond 2028, if more sustainable utilization rates are to be maintained (discussed in section 5.2.5)

There are clear regional long-term trends. Refinery throughputs are set to decline in developed regions, including the US & Canada, Europe, developed Asia and Russia & Caspian. This will be more than offset by refinery throughputs increasing in developing regions, especially Asia-Pacific, the Middle East and Africa.

In the US & Canada, refinery throughputs increase slightly from 17.7 mb/d in 2022 to above 18 mb/d in 2030. Thereafter, however, they start to decline and reach 17.3 mb/d in 2045. The drop in refinery throughputs in this region is significantly less than the demand drop. As the modelling results suggest, the US & Canada refining sector would compensate a share of the lost demand by rising exports to the global market. Utilization rates in this region are set to decline gradually from above 91% to close to 82% in 2045. While the rate in 2045 is still relatively high, some closures in this region are possible beyond 2028, especially related to less efficient and smaller plants.

In Europe, the situation for the refining sector looks somewhat gloomier in the long-term. Refinery throughputs are projected to remain stable at levels just below 12 mb/d until 2030, but then witness a decline to 9.5 mb/d in 2045. The utilization rate is set to drop from 80% in 2022 to 67.1% in 2045. This could evidently lead to the decommissioning of some refining capacity. Some of these capacities could be converted to new business models. These include the production of biofuels, synthetic fuels, hydrogen and possibly recycling.

In Russia & Caspian, refinery runs are projected to drop from 6.6 mb/d in 2022 to 6 mb/d in 2045. The major driver is the expected long-term decline in Russian product exports. On the back of the Russia-Ukraine conflict that began in early 2022, the EU has introduced sanctions on Russian oil imports, including oil products since early 2023. To date, Russia has managed to reroute a large share of its product exports away from the EU to Africa, non-EU Europe, the Middle East and even Latin America.

However, due to rising competition from other regions (e.g. the US and the Middle East) and new refining capacities in developing countries, refinery runs in Russia & Caspian are expected to decline gradually in the long-term. Utilization rates will likely fall accordingly, from almost 85% in 2022 to 74% in 2045, which may lead to some closures in the next decade.

Refinery runs in the Middle East are expected to grow robustly in the long-term, reaching levels just above 10 mb/d in 2045, up from 7.8 mb/d in 2022. Demand growth is the major driver, but also rising flows to other regions, thus replacing some crude with product exports. Ample domestic supplies also support expanding refining activity in this region. Utilization rates are projected to increase from 73% in 2022 to almost 78.5% in 2045. Some limited closures and rationalizations are possible and with some witnessed in the recent past.

In China, refinery runs were subdued in 2022 at 13.5 mb/d due to pandemic-related restrictions and limited product exports to international markets. However, runs increased strongly in 2023, averaging around 14.5 mb/d in 1H23. Due to strong medium-term demand growth, runs are expected to continue increasing, reaching 16.5 mb/d in 2035. Thereafter, runs will likely remain around this level. This is due to limited demand growth, and a higher share of non-refinery fuels in the overall mix. Consequently, refinery utilization rates in China are expected to increase from 76.5% in 2022 to 84.3% in 2025, which will be followed by a gradual decline to almost 77% in 2045. This may lead to some closures, which would likely affect old and inefficient teapot refineries.

Refinery runs in Asia-Pacific (excl. China) are forecast to increase by around 4.5 mb/d, from 16.5 mb/d in 2022 to just above 21 mb/d in 2045. This is supported by strong demand growth, of which India accounts for around 60%. Utilization rates are set to peak at around 88.3% in 2025, followed by a gradual decline to about 81.5% in 2045, as new capacity comes online.

Refinery runs in Africa are expected to increase significantly from just below 2 mb/d in 2022 to 5 mb/d in 2045. New refineries (including modular ones) contribute most to this increase in throughputs, but the modernization of existing plants is part of the story too, especially in West Africa. This is why the timely construction of new plants is crucially important for the African refining sector. Nevertheless, the increase in refinery runs is set to remain below demand growth for the same period.

Africa's refinery utilization rates are also expected to increase, from 51% in 2022 to 73.4% in 2045. This leaves further space for improvements, especially related to the existing refining system. Further and faster modernization efforts, could lead to refinery runs and utilization rates moving even higher. However, it is likely that Africa will be exposed to increased international competition, especially from the US, where refiners will increasingly turn to exports.

Latin America shows a similar picture. Refinery utilization rates are relatively low at 57% in 2022, with many old and inefficient refineries. Another reason is the relatively high level of product imports from the US, as Latin American refiners struggle to compete against their US counterparts. In the long-term, runs are projected to increase from 4.5 mb/d in 2022 to 6.5 mb/d in 2045, which is supported by ample domestic crude oil supply. Consequently, utilization rates are set to increase to almost 77.5% in 2045.

5.2.5 Refinery closures

This section discusses refinery closures in the medium- and long-term at the global and regional level. Two different approaches are applied in the analysis. Refinery closure projections in the medium-term include firm and probable closures, largely based on announcements and analysis of refinery closures. In the long-term (beyond 2028), the outlook is much more uncertain. Analysis is based on projections for regional utilization rates, and a conclusion is drawn on how many closures are needed to keep regional utilization rates at technically and financially sustainable levels.

Refinery closures in the medium-term

Table 5.5 and Figure 5.19 provide an overview of recent and projected refinery closures by major region for the period to 2028.

Between 2020 and 2022, about 4.3 mb/d of refining capacity closed, mainly affecting older and less efficient refineries. Although potential closures were anticipated even before 2020, the primary trigger for most of these closures was the demand collapse caused by the COVID-19 pandemic and the resulting lockdown measures. Around 90% of these closures occurred in developed countries in Europe, the US & Canada and Asia-Pacific. China also closed significant refining capacities. This was due to government policies to close old and inefficient teapot refineries and replace them with new projects. Africa also witnessed closures during the period from 2020–2022, primarily attributed to South Africa.

Looking ahead, it is projected that 1.2 mb/d of capacity will end operations between 2023 and 2028. Closures will be located in Europe, the US & Canada and developed Asia-Pacific. No closures have been announced or are expected in other regions.

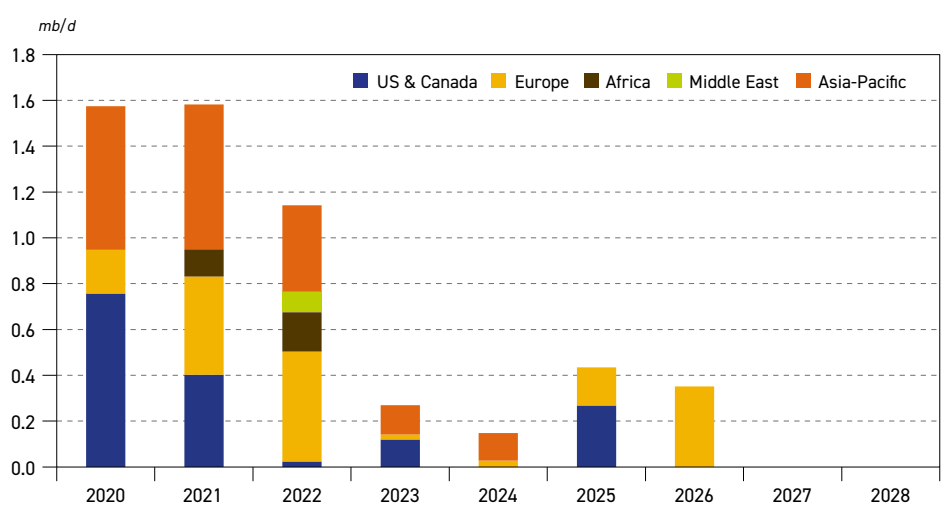
Table 5.5
Net refinery closures by region, recent and projected

mb/d

	Total 2020–2022	2023	2024	2025	2026	2027	2028	Total 2023–2028
US & Canada	1.2	0.1	0.0	0.3	0.0	0.0	0.0	0.4
Latin America	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Europe	1.1	0.0	0.0	0.2	0.4	0.0	0.0	0.6
Russia & Caspian	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Africa	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Middle East	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asia-Pacific	1.6	0.1	0.1	0.0	0.0	0.0	0.0	0.2
Total	**4.3**	**0.3**	**0.1**	**0.4**	**0.4**	**0.0**	**0.0**	**1.2**

Source: OPEC.

Figure 5.19
Refinery closures by region, recent and projected



Source: OPEC.

Europe is set to account for almost half of the closures to 2028. This includes the closure of several relatively large refineries such as Shell's Wesseling refinery in Germany. In the US, the Phillips 66 refinery in San Francisco was scheduled to shut down last year, but the actual closure took place earlier this year and it is now to be converted into the world's largest renewable fuels facilities. The shutdown of LyondellBasell refinery in Houston was postponed from 2023 to 2025. The remaining closures will likely materialize in the Asia-Pacific region, primarily in Japan, represented by the Eneos' Refinery in Wakajama and Idemitsu's refinery in Yamagushi.

It is important to highlight that the projected medium-term capacity closures are significantly lower when compared to the closures witnessed in the past three years. To put it in perspective, the average closures observed during the previous three years exceeded 1.4 mb/d annually. The annual average closures expected in the medium-term, however, are around 0.3 mb/d. This indicates that after the pandemic-induced closures of the most vulnerable refineries, the wave of capacity shutdowns seems have come to an end. Moreover, high refining margins since the 2H22 have provided relief for many plants. Nevertheless, increasingly stringent policies could force many refiners to reduce their refining capacities, particularly the most vulnerable ones.

Refinery closures in the long-term

As per the applied methodology, refinery closures in the long-term (beyond 2028) are not explicitly projected. Instead, only so-called implied refinery closures are indicated, based on the long-term modelling results. In more detail, implied refinery closures are back calculated while targeting a long-term sustainable average utilization rate at a regional level. In developed regions, this rate hovers around 80%, but it is different in other regions such as Africa and Latin America.

The general assumption is that most of these implied closures will be composed of simple and less efficient plants. These refineries would struggle to compete against complex and integrated plants, once utilization rates start declining. It is important to note that long-term modelling cases already take into account projected medium-term closures (2023–2028), totalling 1.2 mb/d.

As already discussed, the global average utilization rate is projected to increase from 79.5% in 2022 to 82% in 2025, due to strong demand growth and a moderate amount of refinery closures in this period. However, the global utilization rate drops gradually from levels close to 82% in 2025 to 77.5 % in 2045. This decline is driven foremost by developed regions where oil demand is expected to plateau and then drop, such as the US & Canada, Europe, Russia & Caspian and developed Asia. Although increasing, average utilization rates in Africa and Latin America are expected to remain well below 80% throughout the outlook period.

This development will necessarily lead to a further rationalization of refining capacity in the long-term. On top of the medium-term closures, refining capacity of up to 4 mb/d could be closed if reasonable utilization rates are to be maintained.

Due to the demand decline, potential long-term closures in Europe are the highest. In addition, in the international downstream market, European refiners will likely struggle against their US counterparts due to generally lower complexity levels, as well as limited access to ample domestic supplies. Consequently, almost 2.5 mb/d of capacity could face shutdown in

this region by 2045. It is important to note that Europe serves as a significant refined product supplier to Africa. If projected additions in Africa do not materialize, this may provide some support to the European refining market and postpone closures to later dates.

In the US & Canada, the average utilization rate in 2045 remains above 80%. However, limited closures of some less complex units are possible given the history of strong utilization rates in the US that have at times been above 90%. However, support could come from rising product exports to international markets. Other regions could also see some closures. This includes China, where less efficient teapot refiners could be challenged to operate in a market dominated by large integrated plants. Some teapot plants have already been shut and replaced by large refineries with petrochemical integration, such as the Yulong plant.

Finally, in Latin America and Africa, closures are possible throughout the outlook period. Both regions have a large number of older refineries, which operate at relatively low or even close-to-zero utilization rates. Some countries are trying to modernize existing refineries, for example, NNPC refineries in Nigeria, but these efforts remain limited across these regions. This is why closures in these two regions can be expected.

5.3 Secondary capacity

Refining capacity is generally denoted by primary distillation capacity. However, it is the secondary capacity that includes conversion and product quality improvement units that are crucial for processing crude fractions into finished products that deliver most of a refinery's 'value-added'. Secondary capacity provides flexibility to the refining system to meet final product demand, including seasonal and structural changes. The development of secondary capacity goes hand-in-hand with evolving refined product demand and product specifications, such as sulphur content and/or octane units.

This section looks into secondary capacity additions in the medium- and long-term by major categories of secondary units, including conversion, desulphurization and octane units. Similar to distillation capacity, the Reference Case provides projections for secondary capacity additions in the medium-term (based on review of new refinery projects) and in the long-term (based on the modelling results).

5.3.1 Medium-term secondary capacity additions

As already highlighted, medium-term distillation capacity additions are estimated at 6.6 mb/d. On top of these, significant secondary capacities are set to be commissioned as shown in Table 5.6. These include 4.5 mb/d of conversion/upgrading capacity, 5.8 mb/d of desulphurization capacity and 1.7 mb/d of octane units. The majority of these additions are forecast to come online in the Middle East and Asia-Pacific, as well as Africa. These regions account for almost 80% of conversion additions, 84% of desulphurization additions and 87% of new octane units. This is somewhat lower compared to the share these regions have in distillation capacity additions. This is due to additions of secondary capacity in other regions, related to upgrades and/or modernization of existing refineries.

Furthermore, the rate of secondary capacity additions in relation to new primary capacity is relatively high as many new refineries (especially in the Middle East and Asia-Pacific) are highly complex plants, built to process medium- and heavy-sour crude.

Table 5.6
Secondary capacity additions from existing projects, 2023–2028 *mb/d*

	By year		
	Conversion	Desulphurization*	Octane units
2023	1.3	2.0	0.6
2024	0.8	1.1	0.3
2025	0.6	0.8	0.2
2026	0.7	0.8	0.2
2027	0.6	0.7	0.2
2028	0.5	0.5	0.2
	By region		
	Conversion	**Desulphurization***	**Octane units**
US & Canada	0.1	0.3	0.0
Latin America	0.3	0.3	0.1
Africa	0.6	0.8	0.3
Europe	0.0	0.1	0.0
Russia & Caspian	0.6	0.3	0.1
Middle East	0.6	1.9	0.4
China	1.1	0.9	0.4
Other Asia	1.2	1.3	0.4
World	**4.5**	**5.8**	**1.7**

* *Desulphurization capacity in this table includes naphtha desulphurization.*
Source: OPEC.

Conversion units

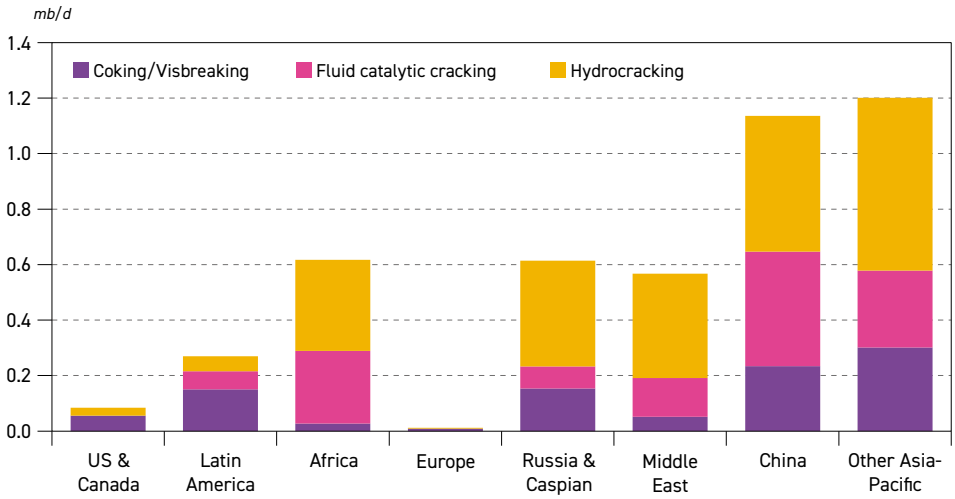
More details related to conversion capacity additions are provided in Figure 5.20. Out of 4.5 mb/d of conversion unit additions, more than 50% are for hydrocracking units. Hydrocracking is the preferred technology, due to its inherent flexibility for the production of middle and light distillates. Furthermore, refiners are set to add around 1.25 mb/d of FCC and 1 mb/d of coking capacity.

The vast majority of conversion capacities are projected to occur in the Middle East, Asia-Pacific and Africa. China is expected to add 1.15 mb/d of conversion capacity, while other countries in the Asia-Pacific are set to commission 1.2 mb/d of new conversion capacity in the medium-term. The Middle East and Africa are expected to add 0.6 mb/d each. Russia & Caspian is also likely to see relatively significant conversion capacity additions (especially hydrocracking) of 0.6 mb/d, in efforts to upgrade existing plants and reduce fuel oil output. It should be mentioned, however, that delays related to new capacities in Russia & Caspian are possible due to Western sanctions.

Desulphurization units

New desulphurization capacities totalling 5.8 mb/d are likely to be added over the medium-term. This level is only slightly lower than the expected distillation capacity addition of 6.6

Figure 5.20
Conversion projects by region, 2023–2028



Source: OPEC.

mb/d in the same period. It reflects the increasingly stringent product specifications and regulations related to transportation fuels, including the IMO sulphur content cap in marine fuels.

More than 30% of desulphurization capacity additions are set to come in the Middle East. This is even higher than distillation capacity additions and can be explained by the relatively high sulphur content of Middle Eastern crudes. It also reflects the modernization of some plants in this region with the aim to change the feedstock to heavier grades compared to the original design.

China and the Asia-Pacific are forecast to add 0.9 mb/d and 1.3 mb/d of new capacity, respectively, and Africa is set to see 0.8 mb/d of new desulphurization capacity. The US & Canada, Russia & Caspian and Latin America will likely expand their desulphurization capacities by 0.3 mb/d each over the medium-term.

The majority of desulphurization capacity additions, around 2.8 mb/d, is linked to middle distillates. Around 1.5 mb/d is for naphtha processing, 0.7 mb/d is for gasoline and the rest is for heavy streams (e.g. vacuum gasoil and residue).

Octane units

The review of refinery projects sees octane unit additions of 1.7 mb/d for the period 2023-2028, in line with rising gasoline demand in developing regions. Asia-Pacific is set to add 0.8 mb/d of octane units, followed by the Middle East (0.4 mb/d) and Africa (0.3 mb/d). Additions in other regions are rather modest as gasoline demand is expected either to stagnate or reach a peak during the medium-term.

Around 70% of the 1.7 mb/d total octane unit additions is for catalytic reforming. This will be accompanied by around 0.3 mb/d of isomerization capacity and 0.2 mb/d of alkylation capacity. Only minor capacity additions of methyl tertiary-butyl ether (MTBE)/ethyl tertiary-butyl ether (ETBE) are possible in developing countries, particularly the Asia-Pacific.

5.3.2 Long-term secondary capacity additions

The basic driver of secondary capacity additions is the level and composition of oil demand, evolving product specifications, as well as crude oil quality. Many recent additions comprised relatively large and complex units with high levels of upgrading, desulphurization and related secondary processing, generally with a focus on petrochemical feedstock. This will likely continue in the future, which is in line with oil demand trends.

At the global level, demand for ethane/LPG and naphtha is set to expand robustly in the medium- and long-term, supported by a continued focus on petrochemicals. Global gasoline demand is expected to increase until 2030, followed by slower growth thereafter. This is mostly due to the offsetting effect between OECD and non-OECD demand trends. Middle distillates demand growth is expected to be robust, especially for jet/kerosene. In addition, with a rising share of heavy barrels in the long-term, requirements for additional upgrading and desulphurization will increase.

It should be noted that condensate splitters that are currently primarily being built in the Middle East, are one exception to the overall trend towards increased complexity. Condensate splitters tend to bring only limited secondary processing, often related to light products, such as naphtha and gasoline, and are centred on catalytic reforming, isomerization and hydrotreating. This trend could continue, as the share of condensates and NGLs is likely to increase.

Table 5.7
Global capacity requirements by process, 2023–2045 *mb/d*

	Existing projects	Additional requirements		Total additions
	to 2028*	2028–2035	2035–2045	to 2045
Crude distillation	**6.6**	**7.8**	**4.7**	**19.2**
Conversion	**4.5**	**4.1**	**2.1**	**10.7**
Coking/Visbreaking	1.0	1.1	0.5	2.7
Catalytic cracking	1.2	1.3	0.8	3.3
Hydro-cracking	2.3	1.6	0.8	4.7
Desulphurization**	**4.3**	**9.6**	**5.6**	**19.5**
Gasoline	0.7	2.3	1.3	4.3
Distillate	2.8	6.6	4.0	13.4
VGO/Resid	0.8	0.7	0.3	1.8
Octane units***	**1.67**	**2.9**	**1.5**	**6.1**
Catalytic reforming	1.17	1.6	0.9	3.7
Alkylation	0.16	1.1	0.4	1.7
Isomerization	0.30	0.0	0.1	0.5
MTBE	0.04	0.1	0.1	0.2

* *Existing projects exclude additions resulting from 'capacity creep'.*

** *Naphtha desulphurization not included.*

*** *New units only (excludes any revamping).*

Source: OPEC.

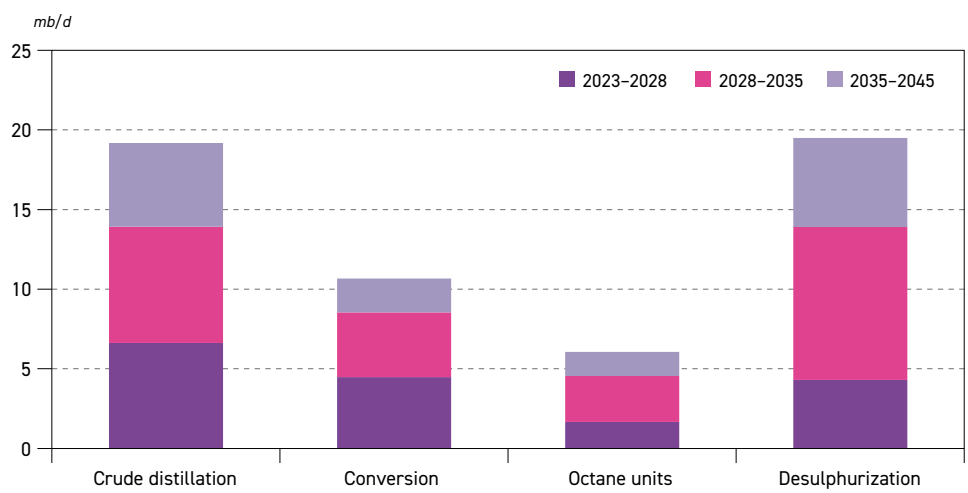
In setting out to capture the outlooks for global and regional refining, particularly future processing needs by type of unit, the modelling has to manage a number of challenges. One is the evolution of refinery process technology. This tends to be stable, with only gradual changes over time, mainly as catalysts slowly improve. That said, significant process improvements and novel technologies warrant close monitoring.

The emerging trend to increase petrochemical yields represents a second potential modelling challenge. While many existing refineries in the US and Europe have some degree of petrochemical capability, the number of large integrated refining plus petrochemical 'mega-projects' continues to rise, especially in the Middle East and the Asia-Pacific. Several of these new complexes are designed to produce a significant share – 40% or more – of petrochemical feedstocks. In addition, the relatively novel 'crude-to-chemicals' technologies are the next step in this direction.

Table 5.7 and Figure 5.21 show global secondary capacity requirements in addition to required primary capacity additions in the period to 2045. On top of 19.2 mb/d for distillation capacity, there are requirements for around 10.7 mb/d of conversion capacity, 19.5 mb/d for desulphurization and 6.1 mb/d for octane units.

Similar to distillation capacity, the majority of secondary capacity additions are expected to materialize before 2035. They mostly cover the expansion and modernization of existing plants.

Figure 5.21
Global capacity requirements by process type, 2023–2045

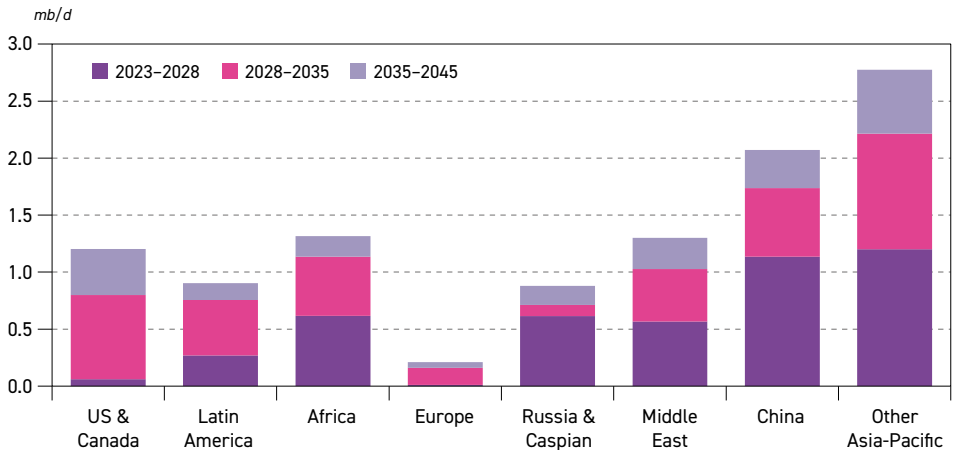


Source: OPEC.

Conversion units

Figure 5.22 shows long-term conversion capacity requirements by region. The majority of additions are in the Asia-Pacific, Middle East and Africa, accounting for 70% of the total. It is important to note that other regions, such as Latin America, Russia & Caspian and US & Canada are also set to see sizeable long-term conversion capacity additions. In the

Figure 5.22
Conversion capacity requirements by region, 2023–2045



Source: OPEC.

medium-term, conversion capacity additions are at almost 68% of incremental distillation capacity. However, this ratio drops between 2028 and 2035 to around 55% and then further to around 40% between 2035 and 2045.

The global required level of conversion capacity is 10.7 mb/d, of which 4.7 mb/d is accounted for by hydrocracking, 3.3 mb/d by FCC and 2.7 mb/d by coking/visbreaking (Table 5.7). Hydrocracking is expected to remain the preferred upgrading option for many refiners beyond the medium-term mainly due to the inherent flexibility to alter yields to emphasize either naphtha/gasoline or distillates. Today, their use is generally associated with the increasing production of the latter (jet/kerosene and gasoil/diesel). The majority of hydrocracking additions is required in the Asia-Pacific, Middle East and Africa, around 3.6 mb/d, where new large refinery additions are required. Significant long-term additions are also forecast for Russia & Caspian and Latin America, around 0.4 mb/d each. Due to the expected demand patterns and the already sufficient installed capacities, US & Canada is set to require only minor expansions of up to 200 tb/d, while Europe will see virtually zero additions.

FCC additions are driven predominantly by gasoline demand. This is why the majority of new FCC units are expected in developing regions, where gasoline demand is still likely to increase in the medium- and long-term. At the same time, gasoline demand in developed countries is expected to peak in the coming years and then start declining in the long-term, which would not encourage FCC additions.

A total of 3.3 mb/d of FCC additions are projected as required between 2023 and 2045. Asia-Pacific alone is set to add around 1.8 mb/d of new FCC capacity. Africa's FCC requirements in the long-term are around 0.4 mb/d and reflects the shortage of domestic gasoline production. The Middle East is projected to commission about 0.7 mb/d of FCC capacity. Smaller additions are projected for Russia & Caspian, in line with efforts to meet domestic gasoline demand that requires the further expansion of existing plants. Minor FCC additions are projected for other regions.

As for coking/visbreaking requirements, the Reference Case sees the need for 2.7 mb/d of new coking/visbreaking (mostly coking) capacity to 2045. Additions of around 1 mb/d are projected for the medium-term, with 1.1 mb/d forecast between 2028 and 2035 and 0.5 mb/d beyond that.

US & Canada is expected to add almost 0.7 mb/d of coking capacity over the entire outlook, while Latin America requires 0.3 mb/d of new capacity. The major driver for these additions are the increasing flows of heavy supplies in Canada and Latin America. (It should be noted that the modelling projections exclude oil sands and heavy Venezuelan or other upgraders as they employ projected volumes for crude streams delivered to market, i.e. downstream of upgraders and blending.)

Further additions are projected for Asia-Pacific (1.2 mb/d in total), mostly driven by the increasing imports of heavier crudes. Africa and Russia & Caspian are expected to add around 0.15 mb/d of coking capacity each by 2045.

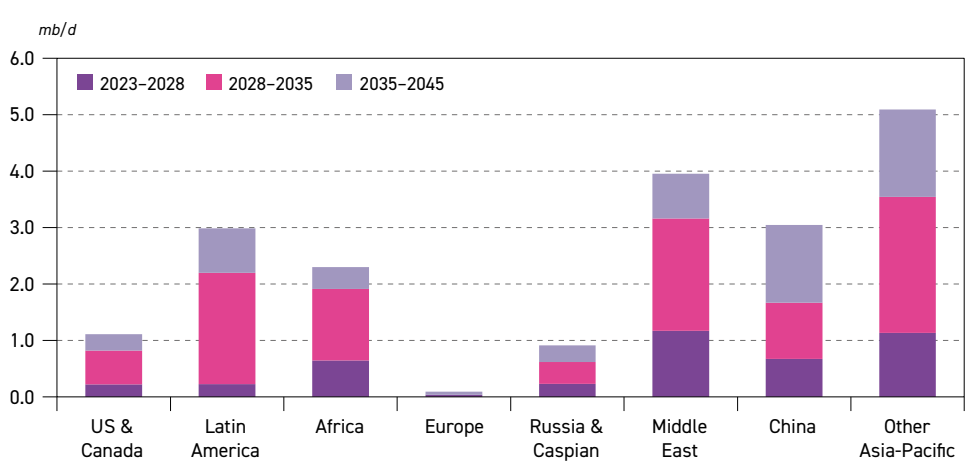
Desulphurization units

Total desulphurization capacity requirements over the outlook period are around 19.5 mb/d. This is slightly higher than distillation capacity additions by 2045. This reflects the shifts to higher-quality fuels and increasingly stringent environmental regulations related mostly to transportation fuels, especially in developing countries. In the long-term, the rising sulphur content of the average barrel is another driver of these additions.

Around 4.3 mb/d of capacity is set to be added over the medium-term. Additions increase to 9.6 mb/d in the period 2028–2035, followed by slower growth with projected additions of 5.6 mb/d in the last decade of the outlook.

Figure 5.23 shows desulphurization capacity requirements by region and period. Asia-Pacific is likely to add 8.1 mb/d of desulphurization capacity, mostly in Other Asia-Pacific (excl.

Figure 5.23
Desulphurization capacity requirements by region*, 2023–2045



* *Projects and additions exclude naphtha desulphurization.*
Source: OPEC.

China). The Middle East is projected to add almost 4 mb/d, partly due to the high sulphur content of Middle East crudes. Africa is projected to see desulphurization additions in the range of 2.3 mb/d. A large share of Africa's crude supply has relatively low sulphur content, thus requiring lower desulphurization additions. Accordingly, the ratio of desulphurization relative to distillation capacity additions in Africa is around 70%, far lower than the Middle East at more than 150%.

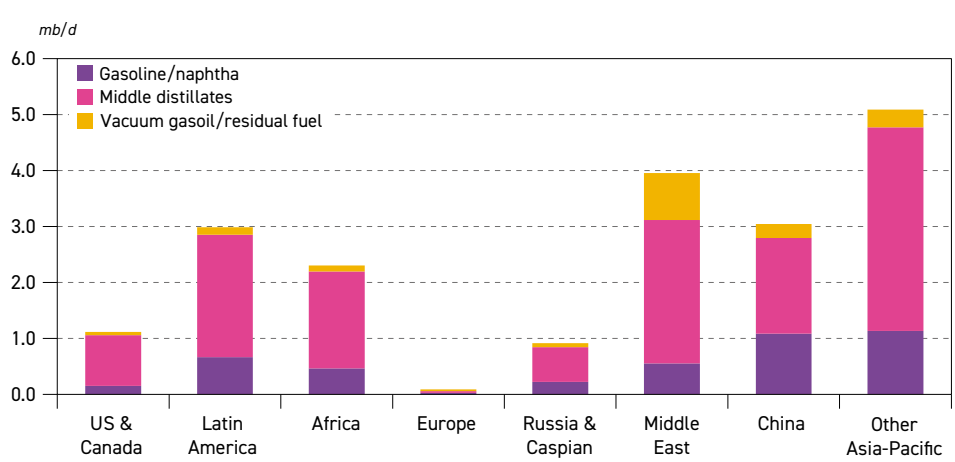
Desulphurization additions in Latin America are significant and estimated at 3 mb/d. They are mostly related to exiting refineries and driven by ULS standards. Russia & Caspian and the US & Canada are forecast to see additions of 0.9 mb/d and 1.1 mb/d, respectively.

In terms of the various products, middle distillate desulphurization capacities of around 13.4 mb/d account for more than two thirds of total desulphurization additions. Increasing demand for middle distillates (diesel and jet/kerosene) and stricter regulations on sulphur levels in diesel (towards ULS standards) are the major driver for this expansion. This is why the expansion of middle distillate desulphurization occurs mostly in developing regions, including the Asia-Pacific, the Middle East, Africa and Latin America.

Gasoline desulphurization additions (excluding naphtha) are estimated at around 4.3 mb/d and also focused on the aforementioned regions. It is in those regions that gasoline demand is still set to grow, and where regulatory steps towards ULS gasoline standards are taking place.

Finally, around 1.8 mb/d of desulphurization capacity for vacuum gas oil (VGO)/residual fuel is expected. One of the key drivers is rising very low sulphur fuel oil (VLSFO) demand due to the IMO Sulphur Rule. The Middle East accounts for around 45% and the Asia-Pacific for more than 31%. Both regions process predominantly crude with a high sulphur content. Most of the rest of the VGO/residual fuel desulphurization capacity will be required in Latin America, with some in Africa and minor amounts in developed regions.

Figure 5.24
Desulphurization capacity requirements by product and region*, 2023–2045

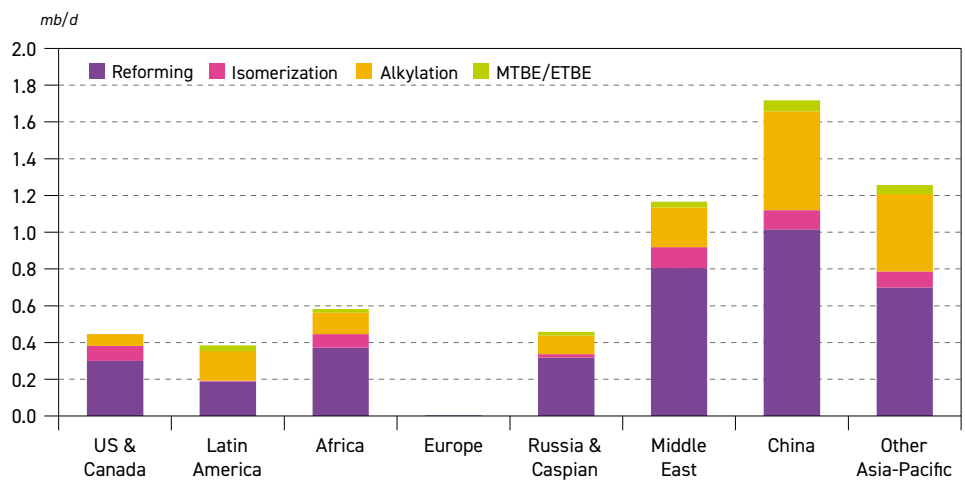


* *Projects and additions exclude naphtha desulphurization.*
Source: OPEC.

Octane units

As per the modelling results (Figure 5.25), around 6.1 mb/d of octane units will be required over the long-term. The majority of these additions are expected in the Asia-Pacific and the Middle East, driven by rising gasoline demand. The Middle East is set to add 1.2 mb/d, China 1.7 mb/d and Other Asia-Pacific 1.2 mb/d. In Africa, additions will be moderate at 0.4 mb/d, also driven by rising gasoline demand. Russia & Caspian, which is traditionally a gasoline-driven market, is expected to add around 0.4 mb/d.

Figure 5.25
Octane capacity requirements by process and region, 2023–2045



Source: OPEC.

Octane unit additions are dominated by catalytic reforming, with around 3.7 mb/d in the period to 2045. Isomerization and alkylation account for 2.1 mb/d. Reforming and isomerization raise naphtha's octane content and thus enable additional naphtha – including that from condensates – to be blended into gasoline. MTBE/ETBE additions will be minor, around 0.2 mb/d at the global level during the entire outlook period. Some markets in Asia still use MTBE as a gasoline enhancer and are the major drivers for these additions.

5.3.3 Implications for refined products supply and demand balances

In assessing the effects of capacity additions on regional product balances, it is important to note that refiners always have some limited flexibility to optimize their product slates, depending on changing market circumstances, economics and the availability of feedstock. This also includes adjusting the yields based on seasonal changes. This can be done by changing feedstock composition (crude slate) and by adjusting process unit operating modes. Table 5.8 presents an estimation of the cumulative potential incremental output of refined products resulting from existing projects by major product category in the period 2023–2028. It also corresponds with the potential incremental output shown in Section 5.2.3.

The potential refining capacity in the period 2023–2028 is around 6.5 mb/d, assuming a maximum utilization rate of 90%. The balance is relative to the base year of 2022, and does not include assumed medium-term closures.

Table 5.8
Global cumulative potential for incremental product output*, 2023–2028 *mb/d*

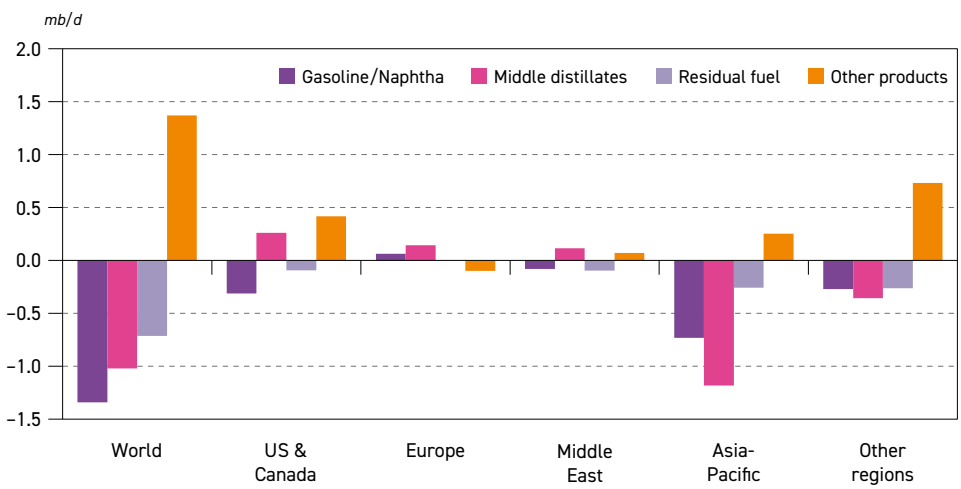
	Gasoline/ Naphtha	Middle distillates	Fuel oil	Other products	Total
2023	0.5	0.8	0.1	0.7	2.0
2024	0.8	1.2	0.1	0.9	2.9
2025	1.1	1.6	0.0	1.2	3.9
2026	1.4	2.1	0.0	1.5	4.9
2027	1.7	2.5	–0.1	1.7	5.8
2028	1.9	2.8	–0.1	1.9	6.5
Share	*29%*	*43%*	*–1%*	*29%*	*100%*

* *Based on assumed 90% utilization rates for the new units.*
Source: OPEC.

The majority of new incremental production is related to middle distillates, at 2.8 mb/d, or 43% of the total. This is in line with expectations for diesel and jet/kerosene demand. Gasoline/naphtha incremental output is at 1.9 mb/d, mostly in developing regions. The potential output of other products is at 1.9 mb/d too. The potential output for fuel oil is negative and reflects the increased conversion of fuel oil into high-quality products.

Figure 5.26 presents the resulting balance by major product group and region. It is calculated based on the difference between incremental potential output and projected demand. Demand for refinery products is calculated considering any refinery streams, including biofuels, CTLs, GTLs and NGLs. It is important to mention that surpluses can be the result of declining demand.

Figure 5.26
Expected surplus/deficit* of incremental product output from existing refining projects, 2023–2028



* *Declining product demand in some regions contributes to the surplus.*
Source: OPEC.

The cumulative deficit is estimated around 1.7 mb/d in 2028 with all major products showing deficits. Gasoline/naphtha lead the way in a range of 1.3 mb/d, followed by diesel in a range of 1 mb/d.

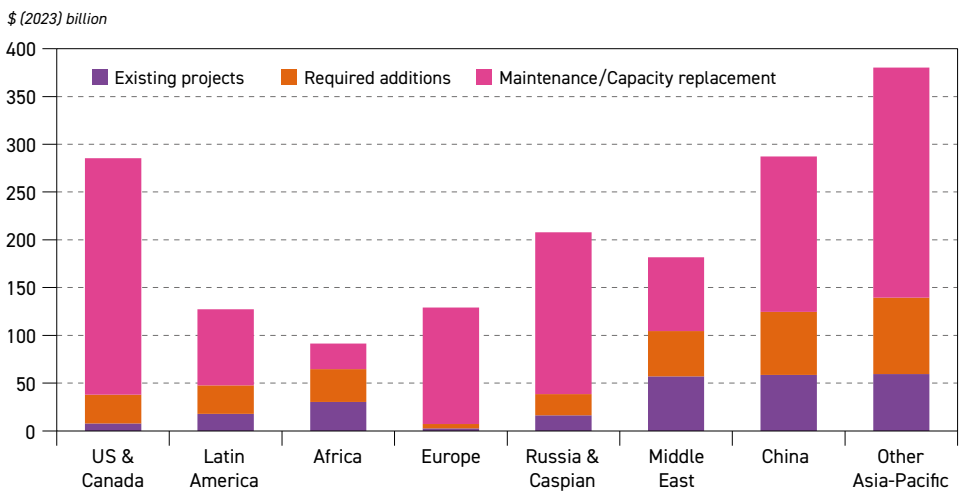
Regionally, surpluses are visible in the US & Canada and Europe, mostly for middle distillates and other products.

For Asia-Pacific (incl. China), a deficit is forecast. In this region, all major fuels show a deficit, especially gasoline/naphtha and middle distillates. This may lead to higher throughputs in these regions relative to 2022, and/or increased product imports if projected demand is to be met.

5.4 Investment requirements

This section provides details related to downstream investment requirements in three different categories, as shown in Figure 5.27. The first category includes investment costs related to identified refining projects (Section 5.2.1) that are expected to be commissioned between 2023 and 2028. Investment costs in this category are based on reported information to the extent possible.

Figure 5.27
Refinery investments by region, 2023–2045



Source: OPEC.

The second category covers investment requirements for refinery projects beyond 2028. As these projects are generic ones, estimates are based on unit refining capacity costs at the regional level. The third and final category is related to continuous replacement and maintenance CAPEX throughout the period to 2045.

For the first category, a total investment cost of $250 billion is estimated. It is important to note that this is only slightly lower compared to the WOO 2022 despite significantly lower capacity additions. This is partly due to rising investment costs and cost overruns related to

several projects in the medium-term. The largest share of medium-term CAPEX is located east of Suez. The Middle East, China and Other Asia-Pacific are expected to invest $175 billion in the medium-term, almost equally distributed across the three regions.

As already discussed in Section 5.2.1, there are many new projects in the pipeline, some of which are large. This includes several projects in China and the Middle East. In Africa, medium-term investment volumes are at just above $30 billion, while those in Latin America are at almost $18 billion. Relatively strong medium-term investment of $16.5 billion is projected for Russia & Caspian, part of which is related to the expansion of secondary capacity. In the US & Canada, medium-term investments are limited to $8 billion and mostly linked to the new Beaumont refinery in the US. In Europe, downstream capital expenditures are at $2.5 billion, linked to minor projects at existing plants.

In the period beyond 2028, total refining investment requirements are calculated at almost $315 billion. The investment volumes are again dominated by the Asia-Pacific (including China) and the Middle East. Investment requirements in China and Other-Asia Pacific are around $145 billion for the period 2028–2045. Investment volumes in the Middle East are at close to $50 billion for the same timeframe. In other developing regions, notably Africa and Latin America, required downstream investments are projected at around $30 billion each. This relates to significant distillation new builds in Africa, as well as the relatively high need for secondary unit expansions in Latin America.

In the US & Canada, investment volumes are estimated at close to $30 billion. In this region, secondary capacity expansion is an important driver of long-term investment. This partly relates to the gradual change in the refinery feedstock, with the average crude barrel becoming heavier due to additional volumes from Canada, Latin America and the Middle East. In Russia & Caspian, investment volumes in the long-term are estimated close to $22 billion between 2028 and 2045, most of which will be dedicated to the expansion of secondary capacity. In Europe, downstream-related investments beyond 2029 are at $5 billion. This focuses on the limited expansion of secondary capacity.

Finally, maintenance requirements and the 'capital replacement' of installed refining capacity are calculated at above $1.1 trillion for the period 2023–2045. The assessment of this category assumes that the annual capital needed for capacity maintenance and replacement is around 2% of the cost of the installed base. The leading region in terms of maintenance investments is the US & Canada at almost $250 billion, followed by Other Asia-Pacific at around $240 billion. China and Russia & Caspian also have relatively large replacement costs of around $163 billion and $170 billion, respectively.

In summary, this brings the total downstream investment requirements to roughly $1.7 trillion over the entire outlook period.

5.5 Refining industry implications

The global downstream market faces several major uncertainties in the medium- and long-term. Oil demand in developing countries is set to expand strongly in the coming years, which is set to tighten downstream markets in these regions with rising utilization rates. This is especially the case for the Asia-Pacific, where oil demand growth is significantly higher compared to refining capacity additions. At the same time, oil demand in developed countries is likely to see slower growth in the medium-term and a decline in the long-term,

possibly leading to lower utilization rates, but also rising product exports to developing regions.

The Russian downstream sector remains another uncertainty in the years to come. In 2023, Russian refiners have thus far managed to reroute most of their product exports from the EU to other regions. It remains to be seen, however, whether this trend can be sustained over the medium-term. Any decline in these flows would tighten the downstream market further.

Beyond the medium-term, the refining sector is set to follow two parallel pathways. Refining capacity additions will continue in developing countries with new greenfield refineries. Most new projects, as in previous years, are likely to have high levels of complexity, including petrochemical integration. New technologies, such as crude-to-chemicals, can also help to address the changes in the long-term composition of oil demand. Towards the end of the outlook period, it is likely that most of the new additions will be expansions of existing capacity, due to a demand growth slowdown and rising levels of non-refinery fuels.

In developed countries, refineries will already face declining demand for traditional fuels over the medium-term. This is why many market participants in these regions are trying to reinvent their business models. There are strong efforts to increase the production of biofuels, bio-methane, synthetic fuels (including methanol and ammonia) and potentially low-carbon hydrogen (green and blue). The co-processing of bio-feedstock is also one possibility.

There are further potential strategies in the plastics sector, including recycling, the conversion of plastics to fuels and the production of bioplastics. All this requires the adoption and implementation of new technologies and infrastructure at scale. Consequently, given the required time and investments to scale up new technologies, it is clear that traditional refining will remain the dominant part of the downstream business in these regions too.

A key future focus is on lowering the downstream carbon footprint, in developing and developed regions alike. This is possible through rising energy efficiency and the integration of renewables in downstream operations. CCUS can also provide a strong push for emissions reductions within the downstream sector. To meet the global challenge related to reducing emissions, as well as ensuring energy affordability and energy security, it is clear that all available technologies should be employed. With established and new technologies, the downstream sector is in a perfect position to support the further development of the global oil and energy sectors.

Oil movements

Key takeaways

- The embargo of major Western economies (especially the EU) on imports of Russian crude and products has reshuffled global oil flows. In order to replace Russia's volumes, the EU has already increased imports from the Middle East, Africa, Caspian and the US. At the same time, Russia has managed to re-route a large share of its exports to other destinations.

- This outlook assumes that the embargo will have lasting consequences. This means that Europe will likely see higher inflows of crudes from other regions compared to recent years. It also assumes non-EU Europe will continue to import some Russian crude in the medium- to long-term. Nevertheless, a high degree of uncertainty remains.

- Driven by strong demand growth, global interregional crude and condensate trade is expected to reach levels around 39.3 mb/d in 2025, up by more than 3 mb/d relative to 2022. Growth continues in the long-term with total crude and condensate flows increasing stepwise to 45.3 mb/d by 2045, driven by rising oil demand and declining supply in importing regions. Major export growth contributors are the Middle East and Latin America, as well as the US & Canada in the medium-term.

- Middle East exports are forecast to increase from 18.3 mb/d in 2022 to almost 26 mb/d in 2045, in line with rising demand for OPEC liquids and lower long-term exports from other sources. The main destination is the Asia-Pacific, which is set to account for around 85% of total Middle East exports by 2045. Flows to Europe are likely to increase in the medium-term, partly due to the EU ban on Russian crude.

- Due to rising supply, Latin America is projected to increase its crude and condensate exports from 3.2 mb/d in 2022 to 5.8 mb/d in 2040, before dropping marginally to 5.5 mb/d in 2045. The main destinations for Latin American crude are the US & Canada and the Asia-Pacific, combined with limited volumes to Europe.

- Crude and condensate exports from Russia & Caspian are set to drop from 6.3 mb/d in 2022 to below 5 mb/d in 2025, in line with supply declines in Russia. However, export levels recover towards 5.9 mb/d in 2040 and beyond, due to rising supply and lower domestic crude use. The main destination for these volumes is the Asia-Pacific, due to the effect of the EU import ban.

- Rising US & Canada supply helps to boost exports from 3.3 mb/d in 2022 to around 4.8 mb/d in 2030. After a period of stagnation, exports are likely to decline gradually to 3.2 mb/d in 2045, due to lower US production levels.

- The Asia-Pacific remains by far the main destination for global crude and condensate exports. Total imports increase gradually from 23 mb/d in 2022 to 32.6 mb/d in 2045. This translates into its global market share rising from around 64% in 2022 to almost 72% in 2045.

Oil trade flows are a crucial part of the global oil and product market and enable the integration of different regions into the overall global system. They help balance the market, and alleviate supply shortages and surpluses at the regional level. This integration increases producer and consumer flexibility and reduces possible demand and supply shocks.

This chapter examines the main trends related to the trade movements of crude oil and condensates, as well as intermediate and refined products, between major downstream regions as defined in the Annex B. Projections are based on the assumptions and modelling results discussed throughout this Outlook, including oil demand (Chapter 3), supply (Chapter 4) and refining (Chapter 5). Projections on trade movements also include assumptions regarding logistics developments.

6.1 Logistics developments

The development of logistics infrastructure is crucial for maintaining oil trading and exporting capacity and the availability of crude oil and products for markets. For this reason, significant inter-regional developments have a major impact on oil flows and are considered among the key inputs in the modelling of global trade movements.

Both crude oil and product movements are impacted and influenced by infrastructure. Developments in land-based infrastructure – mainly pipelines and, to a lesser extent, rail systems – affect both short- and long-distance inland and marine movements. International market access and export flexibility are especially impacted by infrastructure development, including long-distance pipelines, coastal terminals and berthing capacity for moving crude oil, products and other liquid hydrocarbons.

Certain regions require continuous attention because of their potential to alter inter-regional crude trade. This applies especially to China, the Middle East, the Russia & Caspian, along with the US & Canada. Over the past year or so there have also been new developments in Europe, a reaction to recent geopolitical uncertainties.

6.1.1 The US & Canada

The US & Canada has entered into a period of modest crude oil production growth, which coupled with the completion of several major infrastructure projects over the past few years, has seen the region enter a period of sufficient takeaway and export capacity that can accommodate future growth.

The biggest threat to takeaway capacity still lies with continued public resistance and political opposition, occasionally leading to legal challenges to already operating capacity, as well as new projects. It could be argued that with energy security concerns, the chances of shutting down existing infrastructure are lower than in previous years, but the threat remains that an unexpected court ruling could change the infrastructure situation overnight.

US

US crude oil and condensate exports (excluding NGLs) reached 3 mb/d in mid-2019, broadly stayed at that level through 2020 and 2021, and then rose to a record high of 3.6 mb/d in 2022. In conjunction with record exports, US refinery utilization rates also rose to near pre-pandemic levels in 2022. Additionally, it must be noted that exports are predominantly very

light streams not readily suited to US refineries, hence, the continuation of the export of light grades, while heavier crudes are still imported. The vast majority of US exports, almost 3.5 mb/d in 2022, were from the US Gulf Coast, highlighting the reality that infrastructure developments in that region are critical to the overall US logistics picture.

Despite the cancellation of several oil infrastructure projects, and given the setbacks to US production in recent years, the rapid build-out of pipeline capacity over the past few years has left the US with ample takeaway capacity. This is especially the case with the Permian/Eagle Ford Basins and from Cushing to the Gulf Coast. Even allowing for a relatively robust recovery in US tight oil production (Chapter 4), the Permian/Eagle Ford takeaway capacity – now close to 8 mb/d – should be sufficient, with arguably no new pipeline projects required to handle Permian production.

Elsewhere, the US interior also has sufficient takeaway capacity with planned and existing pipelines, but there are regulatory uncertainties that could affect this. In July 2020, a federal court ordered the shutdown of the 750 tb/d Dakota Access pipeline out of the Bakken pending further environmental reviews. This marked the first time an existing pipeline had been ordered shut. Subsequent rulings have allowed the pipeline to remain operational until reviews are completed, but its future is uncertain. In January 2022, an approval for an additional expansion of the Dakota Access Pipeline was halted by an Illinois court. This expansion would have brought an approximate 350 tb/d of increased capacity to the pipeline allowing for a potential operational capacity of 1.1 mb/d.

Nonetheless, the Bakken region, in particular, has a large amount of rail capacity that can act as a buffer to mitigate any potential pipeline problems, particularly if Dakota Access was shut down, which remains a possibility.

Resistance continues to new pipeline developments and existing pipeline infrastructure. Most projects today are subject to lawsuits, including at the state level. In addition, state regulatory authorities frequently require lengthy reworking and extensions of environmental reviews. Several recent rulings in federal courts regarding the inadequacy of environmental reviews have resulted in project delays and higher costs. The bottom line is that it is becoming increasingly difficult for US operators to build major new pipelines, with a number of currently operating pipelines facing costly lawsuits and the risk of closure.

Given that adequate takeaway capacity exists for the major US producing basins, and that new projects are subject to costly litigation, the era of new large-scale pipeline projects in the US is likely over. The majority of future capacity expansion is likely to be made up of smaller scale debottlenecks of existing infrastructure. Considering the high costs and uncertain timing of new pipeline projects, producers are likely to be more willing to rely on rail to clear the marginal production from any given region.

As for export terminal capacity, currently the Louisiana Offshore Oil Port (LOOP) is the only US crude oil export terminal capable of fully loading VLCCs. Originally designed to take imports, and to work with the Capline pipeline to take mainly imported crudes into the US interior, the facility has also been exporting local Gulf of Mexico medium sour crudes and light sweet grades since 2019.

The Biden Administration approved plans to build the largest oil export terminal on the US Texas Gulf Coast. The Sea Port Oil Terminal (SPOT) will add approximately 2 mb/d to US oil

export capacity, and it is the first approved of four proposed oil export projects on this coast. The project is estimated to receive a license and begin construction by the end of 2025.

Furthermore, the NOLA Oil Terminal began construction and completed its water-side Phase 1 in mid-2022, with land-side Phase 2 currently in the development stage. This new terminal will be able to accommodate vessels that would otherwise be too large and deep to dock in the Mississippi River. The project includes crude oil pipelines, ships, a barge dock system and land-side storage facilities with a potential 10-million-barrel capacity.

Canada

Cross-border pipelines and projects from Canada into the US affect both countries. The current outlook is for Canadian crude and condensate production to see modest increases in the medium- to long-term (Chapter 4). On this basis, few additions to takeaway capacity are required over the next few years. Minor debottlenecking projects and system optimization on both 'mainline' (Enbridge and TC Energy, formerly TransCanada) and secondary cross-border pipelines into the US could add up to an additional 400 tb/d in the coming years. These incremental debottlenecking projects may be more politically viable and lower cost than a new mainline project.

Currently, the Trans Mountain Pipeline Expansion is the only major capacity addition still planned. This project will add approximately 600 tb/d of capacity to the pipeline, for a total of 890 tb/d. The project continues to face delays, but is expected to be completed in late 2023, with deliveries beginning in 2024. The project has also incurred dramatic cost escalations, with the current estimated price at US$23.2 billion *versus* US$5.7 billion when the project was purchased by the Canadian government in 2018. This project would potentially enable Canada to open up export markets other than the US, for example, the Asia-Pacific, since it would lead to most, or all, of the additional crude volumes being shipped by tanker from the pipeline's Westridge terminal near Vancouver.

Canadian infrastructure is also vulnerable to court action that could change the outlook on takeaway capacity. Enbridge is locked in a dispute with the State of Michigan over how, and when, to replace an underwater section of Line 5. Although the US Army Corps of Engineers have begun the Environmental Impact Statement (EIS) process for the replacement of the pipeline tunnel under the Straits of Mackinac, they estimate the statement will not be issued until spring of 2025. The EIS was originally expected to be issued in late 2023, but with this new delay, Enbridge expects completion of the project in 2030 if an EIS is approved.

Line 5 has a capacity of 540 tb/d and carries crude oil and NGLs from Western Canada to the US Midwest and to Ontario. The state has sued to close the line permanently over fears of leaks, while Enbridge is seeking state and federal permits for a new 8 km tunnel to replace the existing exposed section of the ageing underwater line. The State of Michigan ordered the pipeline shut as of May 2021, however, it continues to operate while Enbridge appeals the decision. The Canadian government has intervened in the process stating that Michigan's order to close the pipeline violates a treaty that governs cross-border infrastructure.

Similar to the US, it appears certain that a high-paced build-out of pipelines and related infrastructure is unlikely. Potentially, it will be some time, if ever, before logistics capacity once again becomes a constraint to supplying US and Canadian crudes to market.

6.1.2 Other regions

The outbreak of conflict in Eastern Europe prompted several countries in Europe to reconsider their crude oil and products import strategy, with the aim to strengthen their energy security. The reflection has led to the exploration of different options, such as debottlenecking or expanding the capacity of existing infrastructures, as well as reviving previously abandoned projects or creating new ones.

Seeking new crude oil supply routes, Serbia plans to finalize domestic sections of its new crude oil import pipelines from Hungary and Romania by 2027. State pipeline operator Transnafta is expected to proceed with the construction of the national section of the pipeline to Hungary by 2026–2027. The Algyo-Novi Sad pipeline to Hungary would have a capacity of 110 tb/d. This link could connect the 95 tb/d Pancevo refinery in Serbia to the Druzhba pipeline system, with a distribution centre in Szazhalombatta in central Hungary. Serbia also plans to connect existing domestic pipelines to the Pancevo refinery by developing a short 7 km crude oil import pipeline between the Mokrin dispatch station in the northeast of the country and its border with Romania by 2027.

Furthermore, to keep operations running at its 190 tb/d refinery after the Russian crude exemption ends in 2024, Bulgaria is pushing to revive an old plan for a 300 km oil pipeline to transport crude oil from the Greek port of Alexandroupolis to Bulgaria's Black Sea port of Burgas.

Poland's PKN Orlen plans to revive the once abandoned pipeline project to transport Caspian crude oil from the Black Sea to Poland. The pipeline would connect Ukraine's port of Odessa and Poland's port of Gdansk. The construction would provide Poland with an additional source of non-Russian oil.

Kazakhstan is looking for ways to reduce its dependence on the CPC pipeline system leading to the Black Sea, which is its main export outlet. Kazmunaigaz and China's CNPC have reached an agreement to expand oil and gas pipelines. This would mean increasing the capacity of the existing oil pipelines within Kazakhstan (Atyrau-Kenkiyak and Kenkiyak-Kumkol). This would remove bottlenecks in the Kazakh pipeline system and allow for the full utilization of the existing 400 tb/d Atasu-Alashankou pipeline to China.

Finally, Russia is reportedly preparing to reopen rail-loading facilities on a number of idle tank cars in Eastern Siberia. This would allow it to boost crude oil shipments to China and the Asia-Pacific region. The reopening of the Meget rail tank loading terminal in East Siberia may enable producers to transport between 62 tb/d and 145 tb/d by rail from Russia to China, as well as 145 tb/d to the Kozmino terminal at the Pacific Coast.

6.2 Oil movements

The integrated global downstream sector relies on the ability to move crude oil, condensates, refined products and various intermediate streams within, and between, countries and regions, driven generally by economics, but also long-term interest, and in some cases by geopolitics. The downstream infrastructure (pipelines and shipping capacity) enable downstream market participants to move large amounts of oil liquids between almost any two regions of the world, over short and long distances, via a variety of transport modes.

These interregional movements enable adequate physical supply, as well as trade and competition between different suppliers, as they respond to price signals between regions.

The ability to move crude oil and products also helps avoid short-term shortages of fuel in specific regions at any given time. For example, the market's ability to respond to price signals and swiftly deploy tankers or other logistics can help offset shortages caused by weather-related issues, as has been shown in the past.

Various factors affect the direction and volume of crude and condensate, as well as product trade movements. These involve oil demand trends, including seasonal changes; the production and quality of crude and non-crude streams; product quality specifications and related changes; refining sector availability and configurations; potential trade barriers or policy-driven incentives; the capacity and economics of existing transport infrastructure, such as ports, tankers, pipelines and railways; ownership interests; term contracts; crude and product price levels and differentials; freight rates; and, at times, geopolitics. In fact, there is never only one factor influencing petroleum flows, rather a combination of several influences at the same time.

The downstream sector and its development are key elements in this regard. Based on the economics of oil movements and refining, there is a general preference to locate refining capacity in consuming regions due to lower transport costs for crude oil compared with oil products.

Strategic reasons, including those related to security of supply also play a role. Recent trends in the downstream sector confirm this – the majority of refining capacity additions in recent years have materialized in developing regions with strong oil demand growth, led by the Asia-Pacific. The refining outlook (Chapter 5) shows a continuation of this trend in the long-term. As a result, crude and condensate account for the majority of trade, especially over long distances. However, refining hubs in developed countries with highly complex plants, such as in the US, are competing increasingly in the international product market, in line with slower domestic demand growth and available feedstock at competitive prices.

Furthermore, for producing and consuming countries alike, there is an emphasis on securing refined product supply through domestic refining rather than imports, regardless of economic factors. For producing countries, there is the additional consideration of seeking to increase domestic refining capacity in order to not only cover domestic demand, but also to benefit from the export of value-added products beyond crude oil. Benefits for the local economy including labour markets are also motivation for building refining capacity.

Given the considerations highlighted, oil movements are not always the most economical or efficient in terms of minimizing overall global costs. In contrast, movements generated in the models used for this Outlook are based on an optimization procedure that seeks to minimize global costs across the entire refining/transport supply system, in accordance with existing and additional refining capacity, logistical options and costs.

Generally, few constraints are applied to crude oil and product movements in the modelling approach, especially in the longer-term, for which it is impossible to predict what ownership interests and policies of individual companies and countries might be. The differences between short-term market circumstances, such as constraints resulting from ownership interests and term contracts, and a longer-term modelling approach, with few restrictions on movement and that operates to minimize global costs, mean it is necessary to recognize that model-projected oil movements cannot fully reflect short-term factors. Therefore, they may project oil trade patterns that are not direct extensions of those that occur today.

Nevertheless, the model-based results presented in this section provide a useful indication of future crude oil movement trends, which necessarily function to resolve regional supply and demand imbalances for both crude and products. Of course, these projections are dependent on a number of assumptions used in this Outlook, which, if altered, could materially affect projected movements.

Key elements in the model-based projections are the volumes and qualities of both crudes produced and products consumed by region, and how these change over time. Another element is the location and capability of refining capacity. Over the longer-term, the relative economics of building new refinery capacity in different regions, and the ability of existing refineries to export and compete against imports, all affect the trade patterns of crude and products. There is also an interplay between freight and refining costs (capital and operating costs). Broadly, higher freight rates tend to curb interregional trade and encourage more refining investment, while lower freight rates tend to enable greater trade and competition between regions, and serve to provide more opportunity to regions with spare refining capacity to export products.

This approach alone, however, is not well suited for modelling and estimating the impact of geopolitics on oil trade. The conflict in Eastern Europe reshuffled global oil trade flows during 2022 and 1H23. New trade links were established and old ones discontinued. Several countries and/or regions have introduced an oil embargo on Russian oil imports, including the EU, the UK and the US. Due to traded volumes, the EU's embargo has by far the largest impact. It became effective from late 2022 for crude, except for some countries in Central Europe, and early 2023 for refined products. In addition to the oil embargo, G7 countries introduced a price cap on traded Russian oil and products. In 2023, Russian oil exports to the EU plunged. The EU imported additional barrels from the US & Canada, Africa, the Middle East and the North Sea (e.g. Norway).

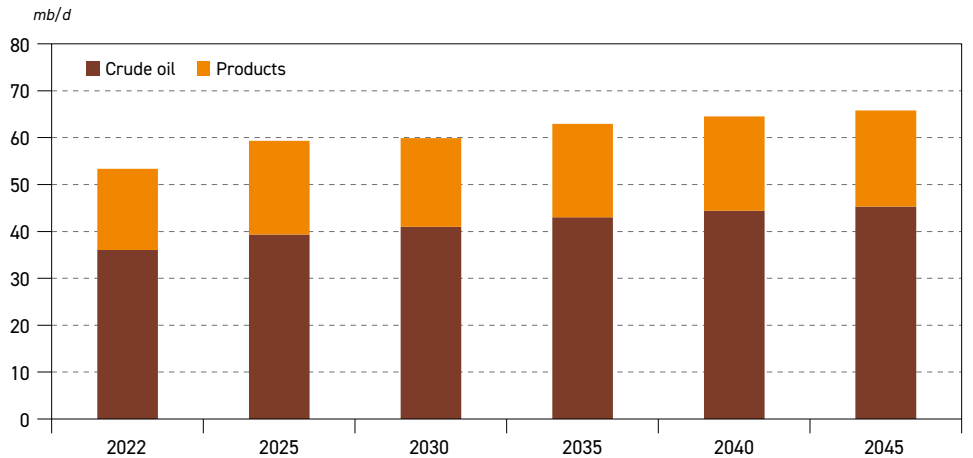
At the same time, Russian oil producers have managed to reroute a large part of their exports to other destinations, especially to India and China, but other destinations too. Similarly, Russian refiners have been successful in rerouting their exports of refined products, including destinations in non-EU Europe, Africa, the Middle East and even Latin America. This was possible due to hefty discounts on Russian crude and product barrels.

This reshuffling was not based on economics, but was the result of geopolitical developments. However, the Reference Case cannot fully mirror the modelling results as they are based on an optimization procedure, but it is important to reflect geopolitical realities.

This outlook assumes that the EU's oil embargo will have lasting consequences. This means that Europe will likely see higher inflows of crudes from other regions compared to recent years. Nevertheless, it also assumes that Europe (e.g. non-EU Europe) will continue to import some Russian crude in the medium- to long-term. However, a high degree of uncertainty remains. It is important to note that the regional definition underlying this outlook sees Europe as one region (including the EU, as well as other European countries). Russia is part of a larger Russia & Caspian region, including large oil producers, such as Kazakhstan and Azerbaijan. This has to be considered when referencing this outlook.

Figure 6.1 shows global oil trade for crude and products between 2022 and 2045. Only trade between major regions is shown, which means intra-trade movements are not included.

Figure 6.1
Interregional crude oil, condensate and products exports, 2022–2045



Source: OPEC.

Global trade in 2022 was estimated at 53.3 mb/d, slightly higher compared to 2021. However, these levels are still somewhat lower than pre-pandemic volumes of around 56 mb/d. Crude and condensate trade was assessed at 36 mb/d, with product trade at 17.3 mb/d.

By 2025, oil trade is set to increase to just below 59.3 mb/d. This is in line with rising global oil demand, especially in developing countries. Refining capacity additions in the period to 2025 are insufficient to cover growing demand, resulting in rising refined product trade. In 2030, global trade is projected to inch up to just under 60 mb/d. The slower growth in trade can be attributed to refining capacity expansion in developing regions that leads to lower crude and product trade. These regions are set to increase the local use of crude, thus limiting their crude exports and product imports. Nonetheless, after 2030, global oil trade is expected to increase gradually to almost 66 mb/d in 2045.

Crude oil and condensate exports account for almost 70% of the total interregional oil trade. In 2022, global crude and condensate movements were estimated at 36 mb/d. In line with demand growth, crude and condensate flows are expected to increase to above 39 mb/d in 2025. In subsequent years, global crude and condensate trade is projected to increase gradually to reach 41 mb/d in 2030 and 45.3 mb/d in 2045. This is due to strong demand growth, especially in the Asia-Pacific, as well as declining supply in several importing regions. For example, Europe and the Asia-Pacific in the long-term.

Total interregional product trade starts from a level close to 17.3 mb/d in 2022, before increasing to almost 20 mb/d by 2025, in line with strong demand growth. Similar to crude and condensate trade, product movements drop around 1 mb/d by 2030, due to refining capacity additions, which limits the need for product flows. In the longer-term, product trade increases gradually to 20.5 mb/d by 2045. Growing demand in developing regions and the rising availability of refining capacity in developed regions, where demand is set to decline somewhat, contributes to this trend.

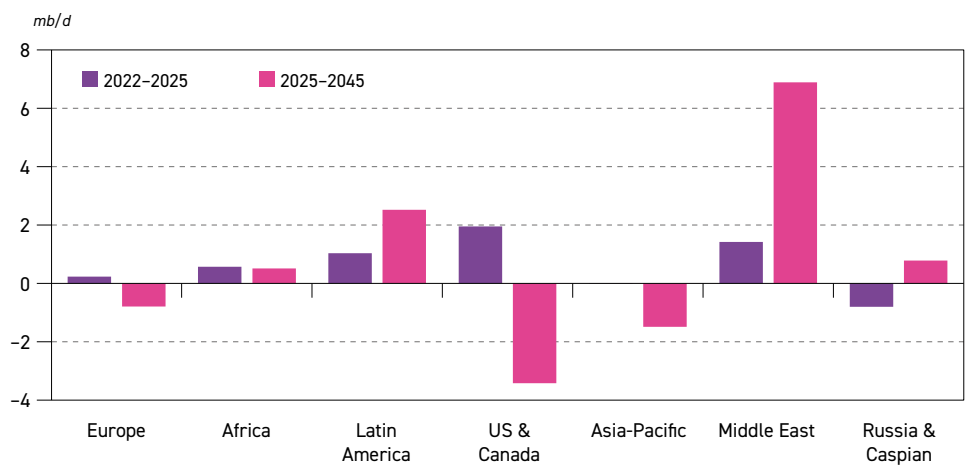
6.3 Crude oil and condensate movements

This section discusses global crude and condensate supply developments by downstream regions, as defined in Annex B. This is fully in line with projections provided in Chapter 4. Crude and condensate supply developments explain changes in long-term trade movements. The latter is discussed later in this section with a focus on the main exporting and main importing regions.

Crude and condensate supply

The analysis below relates only to crude and condensates, which includes oil sands and synthetic crudes, but excludes other liquids, such as biofuels, synthetic fuels, CTLs, GTLs and NGLs. As shown in Figure 6.2, crude and condensate supply is expected to increase strongly by almost 4.5 mb/d between 2022 and 2025. This is mainly due to three regions: US & Canada (nearly 2 mb/d), the Middle East (1.4 mb/d) and Latin America (1 mb/d). Minor growth is also expected in Africa and Europe (mostly Norway). This is partly offset by declines of more than 0.8 mb/d in Russia & Caspian.

Figure 6.2
Change in crude, condensate and synthetic crude supply between 2022 and 2045



** Excludes biofuels, synthetic fuels, CTLs, GTLs, and NGLs.*

Source: OPEC.

Between 2025 and 2045, total crude and condensate supply expands by a further 5 mb/d. This is a combination of strong supply increases in regions, such as the Middle East and Latin America, which are partly offset by projected declines in several regions such as Europe, Asia-Pacific and the US & Canada.

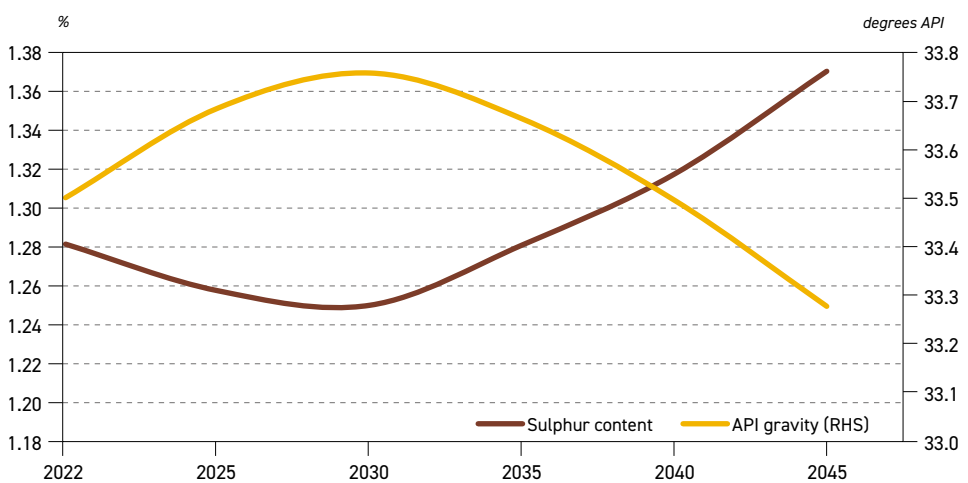
The US & Canada supply is projected to decline by 3.4 mb/d as US tight oil supply peaks, which more than offsets gains from other sources, such as Canadian oil sands. Asia-Pacific crude and condensate supply is set to decline by 1.5 mb/d given it has a significant share of ageing oil fields. European crude and condensate supply (mostly the North Sea) is forecast to drop by 0.8 mb/d, as new additions are not likely to offset natural declines from old fields.

These declines are more than offset by the expected increase of almost 7 mb/d in the Middle East. This growth is set to come mostly from Middle East OPEC Member Countries. Significant gains of nearly 2.5 mb/d are also expected in Latin America, including further growth in Brazil, Guyana, Argentina and Venezuela, which is partly offset by declines in Mexico and Colombia. Modest increases of 0.8 mb/d are expected for Russia & Caspian (mostly Russia), and 0.5 mb/d for Africa.

The developments in the composition of global supply are likely to lead to gradual quality changes in the average global crude barrel (Figure 6.3). Driven by expansions of US light-sweet supply (mostly tight oil) and other countries, such as Kazakhstan, as well as higher condensate volumes, the average API gravity of crude and condensate supply is set to increase from around 33.5° API in 2022 to almost 33.8° API in 2030. At the same time, the average sulphur content drops from 1.28% in 2022 to 1.24% in 2029/30.

Post-2030, the average API gravity starts falling, in line with declining tight oil production and the rising supply of medium and heavy crudes from the Middle East, Latin America and Canada. At the end of the outlook period, the average API gravity is estimated at 33.3°, slightly lower compared to the starting point in 2022. The average sulphur content increases from 1.22% in 2030 to 1.37% in 2045.

Figure 6.3
Global average API gravity and sulphur content



Source: OPEC.

Crude and condensate oil movements

Figure 6.4 presents global crude oil and condensate exports by major exporting region. It should be noted that only movements between these regions is considered, with the intra-trade movements not included. Total crude oil and condensate flows were estimated at around 36 mb/d in 2022, above 2021 levels, but still lower relative to pre-pandemic levels in 2019. Total crude and condensate exports are set to increase to above 39 mb/d by 2025, driven by increasing oil demand in the medium-term.

Global crude and condensate exports are expected to expand further to almost 41 mb/d in 2030 due to strong demand growth. Global trade continues increasing even post-2030

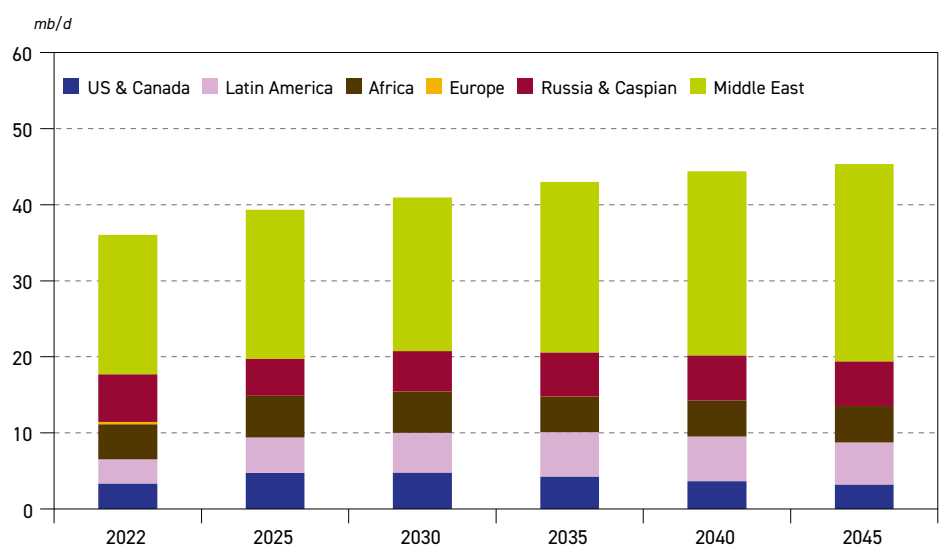
and reaches 45.3 mb/d in 2045. This growth is not only driven by rising demand, but also declining oil supply in many importing regions, especially the Asia-Pacific.

In terms of the export mix, the Middle East remains the most dominant exporting region. From 18.3 mb/d in 2022, crude and condensate flows from the Middle East are likely to reach levels of almost 26 mb/d in 2045. Another region, which sees steady increases in crude and condensate exports over most of the forecast period is Latin America. Total export volumes from this region increase strongly from 3.2 mb/d in 2022 to 5.2 mb/d in 2030, which is in line with increasing supply in this region. However, the export growth continues only modestly in the following decade, reaching 5.89 mb/d in 2040. In the last five years of the outlook period, exports from Latin America are expected to decline and reach a level 5.5 mb/d by 2045. This is in line with the drop in Latin American supply towards the end of the outlook period.

African crude and condensate exports increase initially from around 4.6 mb/d in 2022 to 5.5 mb/d in 2025. However, due to rising local crude use in Africa, total outflows decline to 4.7 mb/d from 2035 onwards. Exports from Russia & Caspian are set to decline from 6.3 mb/d in 2022 to just below 5 mb/d in 2025, which is due to the expected drop in Russian oil supply over this period. Exports are set to recover gradually in the long-term reaching 5.3 mb/d in 2030 and further to around 5.9 mb/d from 2040 onwards. The increase in crude and condensate exports is supported by rising supply in Kazakhstan, recovering output in Russia and somewhat lower local crude use in this region over the long-term.

Finally, US & Canada crude and condensate exports are projected to increase considerably within this decade. From around 3.3 mb/d in 2022, they increase to around 4.8 mb/d in 2025 and are still at this level by 2030. However, as US tight oil starts to decline, total crude and condensate exports from the US & Canada region drop to around 3.7 mb/d in 2040 and further to 3.2 mb/d in 2045.

Figure 6.4
Global crude and condensate exports by origin*, 2022–2045

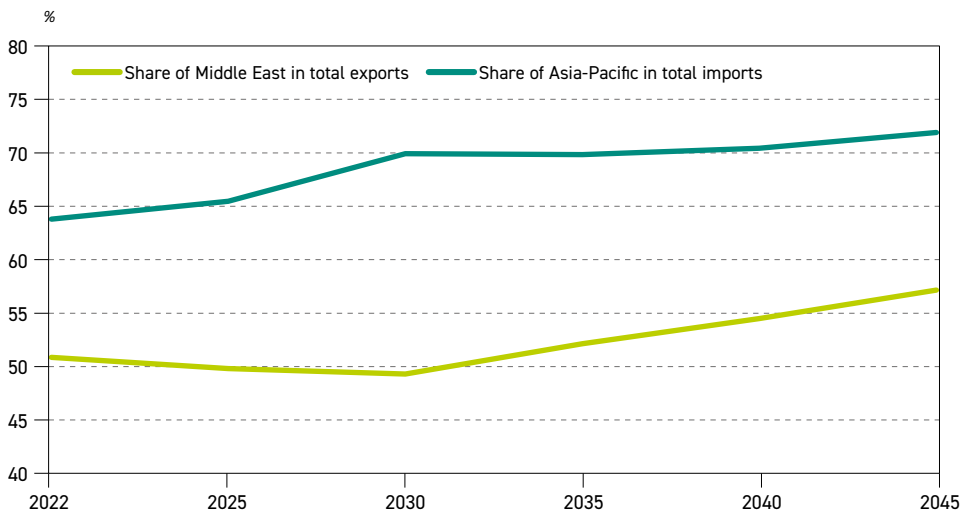


** Only trade between major regions is considered, intratrade is excluded.*
Source: OPEC.

As shown in Figure 6.5, Middle East exports of crude and condensate represented roughly 51% of global trade flows in 2022. This share is set to decline to just below 50% in 2025 and 2030 as exports from other regions increase, especially from Latin America and the US & Canada. However, the share increases thereafter, reaching 57.2% in 2045 following an increase in exports. This is in line with rising Middle East exports, as well as declines from other exporting regions.

On the import side, Asia-Pacific more than mirrors the dominance of the Middle East. The region has the major share of total interregional trade, estimated at around 64% in 2022. Due to rising import volumes throughout the outlook period, as well as the decline of other regions, predominantly Europe, the share of Asia-Pacific in the global crude and condensate market increases further to almost 72% in 2045.

Figure 6.5
Share of Middle East and Asia-Pacific in global crude and condensate trade, 2022–2045



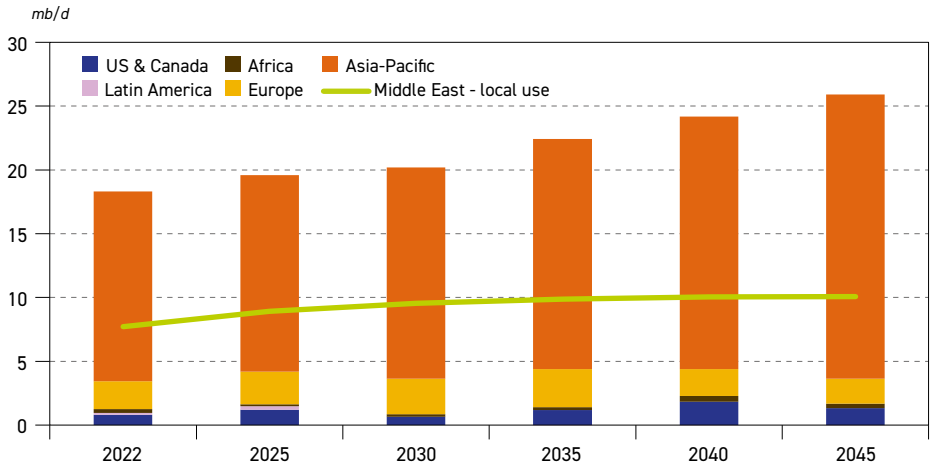
Source: OPEC.

Figure 6.6 highlights crude and condensate exports from the Middle East by destination. Total export levels increase from 18.3 mb/d in 2022 to 19.6 mb/d in 2025 and further to 20.2 mb/d in 2030. Thereafter, total crude and condensate exports from the Middle East continue increasing gradually climbing to almost 26 mb/d in 2045, driven by crude and condensate supply trends. Asia-Pacific is the prime destination for Middle East barrels with volumes increasing steadily from just below 15 mb/d in 2022 to 16.6 mb/d in 2035. The growth in Middle East flows to the Asia-Pacific accelerates post-2035 and increases to 22.3 mb/d in 2045.

Exports to Europe are projected to increase to around 2.5 mb/d by 2025 and further to 3 mb/d in 2035. Part of the Middle East flows to Europe represent a replacement of Russian exports to the EU. However, as European demand is set to decline in the long-term, flows from the Middle East are likely to fall gradually and reach levels of just below 2 mb/d in 2045.

Exports to the US & Canada are projected to increase from 0.8 mb/d in 2022 to almost 1.2 mb/d in 2025, partly due to the high demand for medium-sour barrels in the US. In the longer-term, Middle East flows to the US & Canada are projected to increase further to 1.8 mb/d in 2040, partly due to strong demand for medium-sour grades. In the last five years of the outlook, exports are projected to decline to 1.3 mb/d in 2045. This can be explained by

Figure 6.6
Crude and condensate exports from the Middle East by major destination, 2022–2045



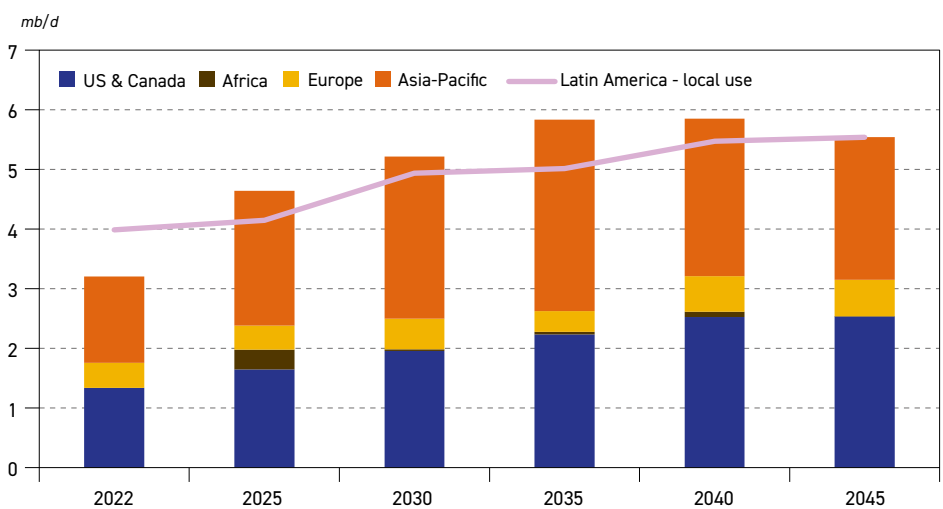
Source: OPEC.

lower demand in the US & Canada, the higher supply of heavier grades in Canada and higher imports of Latin American barrels. The Middle East is also expected to export minor volumes of just below 0.5 mb/d to Africa throughout the outlook period (mostly East and North Africa).

Local crude use in the Middle East is projected to rise continuously in line with increasing refining capacity in the region that is required to cover rising domestic demand and product exports. From around 7.7 mb/d in 2022, local crude use is set to increase to just above 10 mb/d in 2045.

Crude and condensate exports from Latin America are shown in Figure 6.7. From levels of just 3.2 mb/d in 2022, exports are set to increase strongly to around 4.6 mb/d in 2025, 5.8

Figure 6.7
Crude and condensate exports from Latin America by major destination, 2022–2045



Source: OPEC.

mb/d in 2035 and 5.9 mb/d in 2040. Only towards the end of the period are exports projected to drop and reach a level of 5.5 mb/d in 2045.

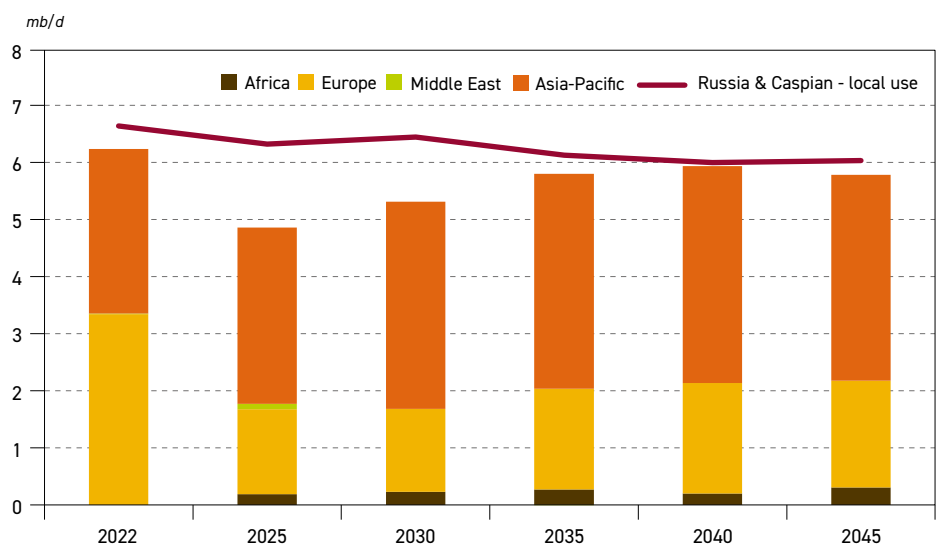
There are two major destinations for Latin American barrels – US & Canada and Asia-Pacific. Export volumes to the US & Canada increase from 1.3 mb/d in 2022 to 2 mb/d in 2030 and further to roughly 2.5 mb/d from 2040 onwards. The physical proximity of the two regions and relatively low freight costs favour these flows. In addition, Latin America produces medium- and heavy-sour grades, which are the preferred feedstock of US refiners.

Exports to the Asia-Pacific are expected to increase from almost 1.5 mb/d in 2022 to 3.2 mb/d in 2035. A large share of Asian refineries are highly complex and capable of processing heavier grades and even extra heavy crudes. However, Latin American flows to the Asia-Pacific are projected to drop in the last decade of the outlook, reaching 2.4 mb/d in 2045. This is the consequence of stagnating Latin American crude output and an increasing focus on the US. Europe is likely to see limited inflows of Latin American barrels, from around 0.35 mb/d in 2022, volumes are set to increase to 0.5 mb/d in 2030 and 0.6 mb/d in 2045.

Latin American local crude use is set to increase from about 4 mb/d in 2022 to around 5.5 mb/d from 2040 onwards. This is in line with expectations of higher refinery throughputs in this region.

Figure 6.8 illustrates crude and condensate exports from the Russia & Caspian region. Total outflows drop from above 6 mb/d in 2022 to just below 5 mb/d in 2025, which is mostly the result of the expected drop in Russian oil supply. Thereafter, exports increase again and come close to 2022 levels from 2035 onwards, in line with recovering Russian supply and the continuous rise of Kazakhstan output. In 2045, total crude and condensate exports from Russia & Caspian are estimated at 5.9 mb/d. Due to the already mentioned EU embargo on Russian imports, crude and condensate exports from Russia & Caspian to Europe is expected to decline from 3.3 mb/d in 2022 to around 1.5 mb/d in 2025. Volumes are expected to increase somewhat in the longer-term, but are set to stay below 2 mb/d, which is well below 2021 and 2022 levels.

Figure 6.8
Crude and condensate exports from Russia & Caspian by major destination, 2022–2045



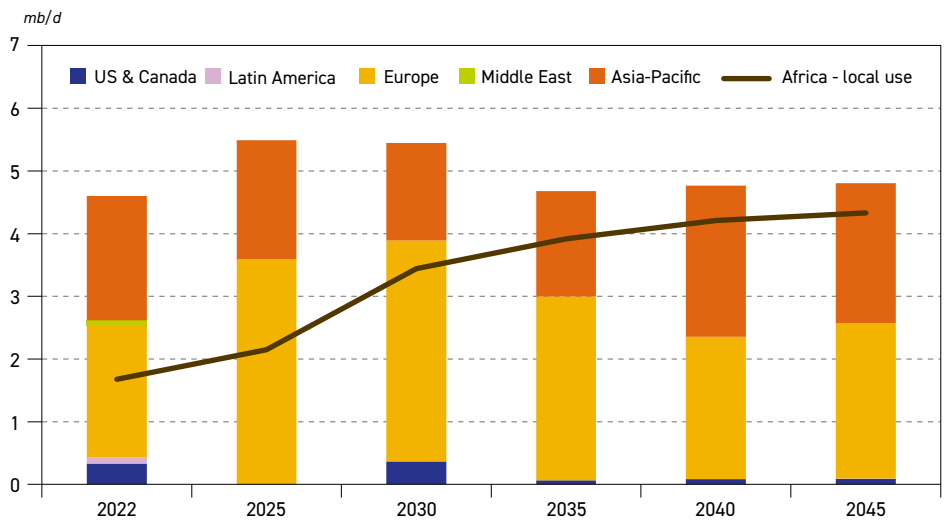
Source: OPEC.

At the same time, crude and condensate exports from Russia & Caspian to the Asia-Pacific are set to increase from almost 2.9 mb/d to 3.1 mb/d in 2025 and further to around 3.8 mb/d in 2040, followed by a minor drop to 3.6 mb/d in 2045. Limited flows to Africa are projected, with possible buyers mostly in the Mediterranean market.

Local crude use in Russia & Caspian is projected to decline gradually from 6.6 mb/d in 2022 to 6 mb/d from 2040 onwards. It is estimated that Russian refiners will export less products in the long-term. This is the result of rising competitiveness in the international downstream markets and the absence of EU buyers due to the import embargo.

Crude and condensate exports from Africa (Figure 6.9) are set to increase from 4.6 mb/d in 2022 to 5.5 mb/d in 2025, in line with rising supply. However, exports are projected to decline thereafter to levels around 4.7 mb/d in 2035, which is the result of stagnating supply and rising local crude use. The latter is expected to double from around 1.7 mb/d in 2022 to 3.4 mb/d in 2030 and then further to 4.3 mb/d in 2045. This strong increase in local crude use is possible only if the refining sector manages to expand its capacities in line with requirements. Should Africa face delays in the expansion of its refining capacity, crude and condensate exports could be higher in the long-term.

Figure 6.9
Crude and condensate exports from Africa by major destination, 2022–2045



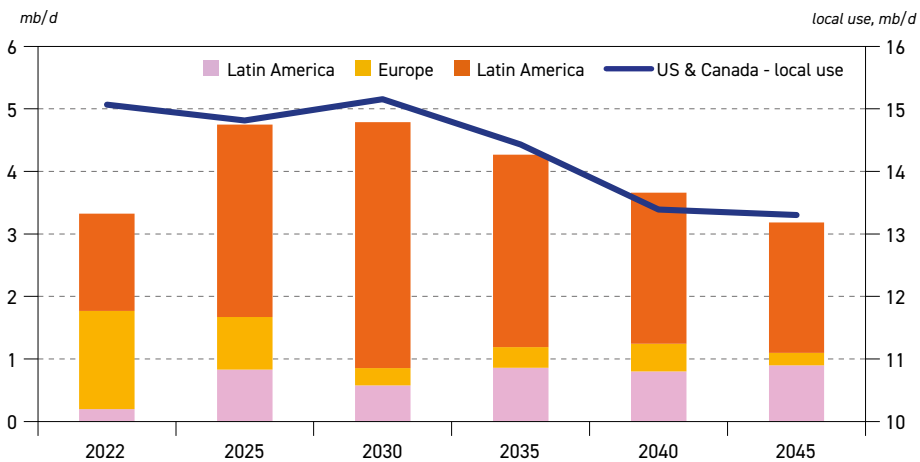
Source: OPEC.

Europe is the main destination for African barrels, particularly following the EU embargo on Russian crude imports. From around 2.1 mb/d, African flows to Europe are projected to increase to 3.5 mb/d in 2025, but then see a decline in the long-term, dropping to levels between 2.3 mb/d and 2.5 mb/d by 2040 and thereafter. The decline is the consequence of declining European oil demand and lower overall crude and condensate imports.

Africa exported around 2 mb/d of crude and condensate to the Asia-Pacific in 2022. The level, however, is set to decline gradually to around 1.6 mb/d in 2030 and 2035. Post-2035, due to lower demand in Europe, higher flows to the Asia-Pacific are expected, climbing to 2.2 mb/d by 2045. Limited flows to US & Canada are forecast, as African barrels are expected to face competition from Latin American exports in this market.

The US & Canada is already an established exporter of crude and condensate to international markets. These are mostly light-sweet US supplies, suitable for markets with high gasoline demand and petrochemical feedstock requirements. In 2022, crude and condensate exports from the US & Canada were estimated at 3.3 mb/d (Figure 6.10). In the first four months of 2023, exports increased to around 3.8 mb/d. In line with rising supply, total crude and condensate exports from the US & Canada are expected to increase to around 4.8 mb/d in 2025 and 2030. Nevertheless, with supply set to decline from the end of this decade, exports are anticipated to decline too, dropping to 3.2 mb/d in 2045.

Figure 6.10
Crude and condensate exports from US & Canada by major destination, 2022–2045



Source: OPEC.

In 2022, crude exports to Europe were at 1.6 mb/d. This was a sizeable increase relative to 2021, mostly due to the efforts of European refiners to replace Russian barrels. In the medium- and long-term, however, US & Canada exports are expected to decline to around 0.8 mb/d in 2025 and then to levels below 0.5 mb/d. European refiners are generally geared towards diesel production, which is not the best match for US light barrels.

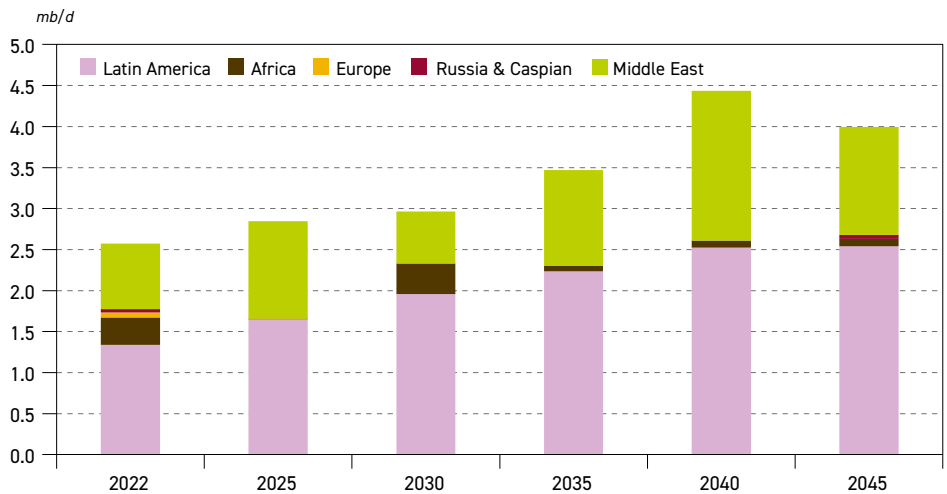
US & Canada volumes to the Asia-Pacific are projected to increase from 1.6 mb/d in 2022 to almost 4 mb/d in 2030, as many Asian refiners have petrochemical integration. Shipments are set to decline gradually thereafter and reach 2.1 mb/d in 2045. Latin America is also expected to import more US & Canada supplies relative to the 0.2 mb/d received in 2022. This is due to the lower complexity of the Latin American refining system, for which US supplies represent a desirable feedstock.

Local crude oil use in the US & Canada is projected to increase from above 15 mb/d in 2022 to 13.3 mb/d in 2045. This is the result of declining demand and lower refinery runs in the region.

Figure 6.11 to Figure 6.13 shows crude and condensate imports for the three largest importing regions, the US & Canada, Europe and the Asia-Pacific.

While being a significant crude and condensate exporter, the US & Canada is expected to continue importing crudes, due to the complexity of its refining system and the composition of demand (Figure 6.11). In 2022, the region imported around 2.6 mb/d of crude oil, mostly from Latin America, the Middle East and Africa. Imports are set to grow, reaching 4.4 mb/d in 2040, but then dropping thereafter to around 4 mb/d.

Figure 6.11
Crude and condensate imports to the US & Canada by origin, 2022–2045



Source: OPEC.

The majority of crude and condensate flows to the US & Canada came from Latin America in 2022 at around 1.3 mb/d, most of which were heavy and medium-sour barrels. With the expected rise in Latin American supply, these flows are expected to almost double by 2040, reaching 2.5 mb/d in 2040 and staying stable thereafter.

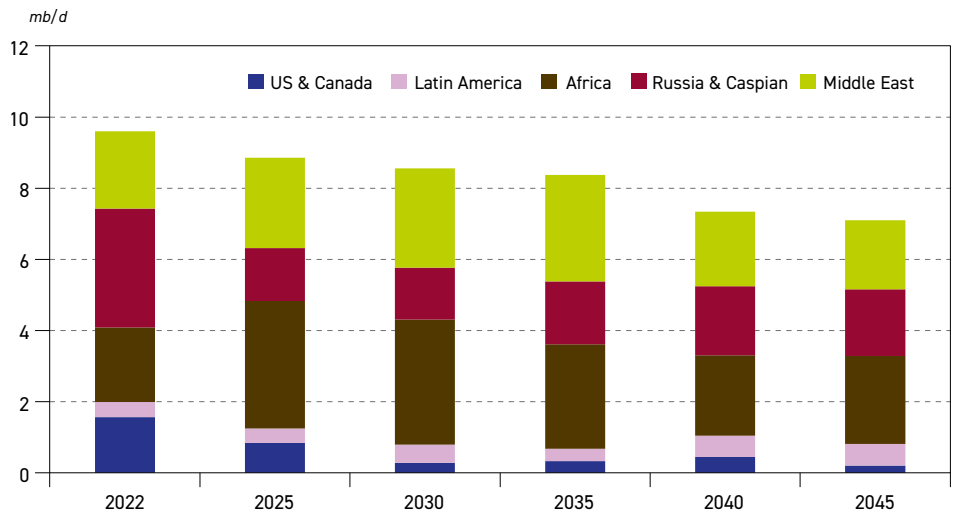
Imports from the Middle East were estimated at 0.8 mb/d in 2022 and this is set to increase to 1.8 mb/d by 2040, albeit after a temporary drop around 2030. Some limited flows from Africa are possible throughout the outlook period, but these are not set to be above 0.4 mb/d.

Figure 6.12 shows European crude and condensate imports by origin. The overall import level is projected to drop from above 9.5 mb/d in 2022 to 8.5 mb/d in 2030 and then further to 7.1 mb/d by 2045. This reflects declining demand and lower refinery throughputs in Europe, which is only partly offset by declining domestic European supply.

Due to the oil embargo, crude and condensate imports from Russia & Caspian are set to decline from 3.3 mb/d in 2022 to around 1.5 mb/d in 2025. It is expected that flows will improve somewhat, but would only reach levels of around 1.9 mb/d in 2040 and 2045, which is still significantly lower relative to 2022.

This mirrors the increase of imports from the Middle East and Africa. Given the need for diversification, EU refiners have turned increasingly to Middle Eastern crudes, which in terms of quality are similar to Russian grades. Middle East flows to Europe were estimated at 2.2

Figure 6.12
Crude and condensate imports to Europe by origin, 2022–2045



Source: OPEC.

mb/d in 2022, which were considerably higher compared to 1.3 mb/d in 2021. Imports from the Middle East are expected to increase further, reaching 3 mb/d in 2035. Due to lower demand, however, these flows are set to drop to just below 2 mb/d in 2045.

Imports from Africa were estimated at 2.1 mb/d in 2022 and are expected to increase strongly in 2025, reaching 3.6 mb/d. The main reason is the EU's oil embargo on Russian crude. In the following years, however, imports from Africa are projected to decline gradually to around 2.5 mb/d by the end of the outlook. Inflows from Latin America are set to remain limited throughout the forecast period hovering around 0.5 mb/d, which is not far off levels observed in 2022.

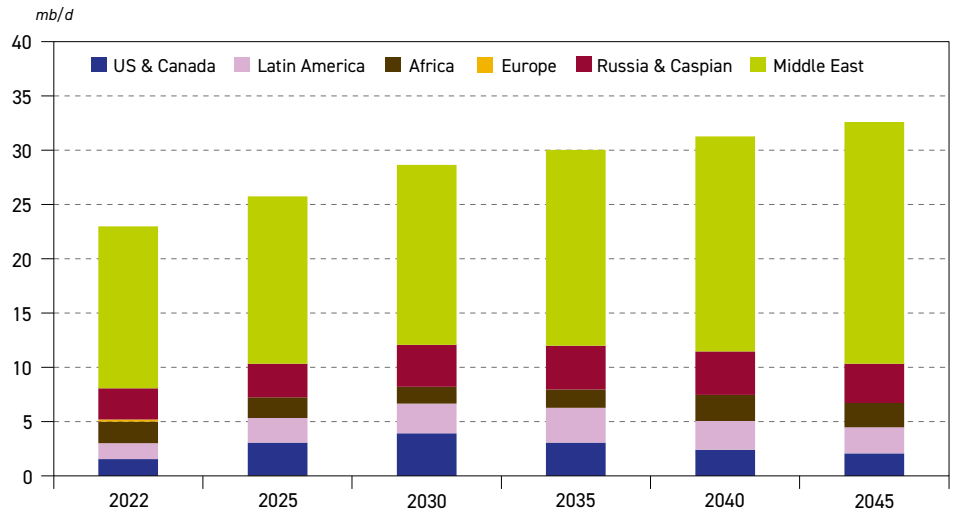
Finally, imports from the US & Canada, which were assessed at close to 1.6 mb/d in 2022 are projected to decline to 0.8 mb/d in 2025. A further drop to levels below 0.5 mb/d is expected for the remainder of the outlook. This reflects the demand patterns of European refiners, which are in favour of middle distillate-rich crudes. In addition, it assumes that Europe will find sufficient additional barrels in Africa and the Middle East.

Figure 6.13 highlights crude and condensate imports to the Asia-Pacific, with overall levels increasing steadily from 23 mb/d in 2022 to 28.6 mb/d in 2030 and further to 32.6 mb/d by 2045. Consequently, the share and importance of the Asia-Pacific in the global crude and condensate trade is set to increase further, as already highlighted in Figure 6.5.

The Middle East remains the most important crude supplier to the Asia-Pacific with volumes increasing modestly from just below 15 mb/d in 2022 to 16.6 mb/d in 2030. However, the size of exports increases strongly thereafter, in line with rising demand for OPEC liquids and reaches 22.3 mb/d in 2045.

The Russia & Caspian is set to become the second largest supplier to the Asia-Pacific in the medium- and long-term. This is in line with the efforts of Russian producers to reroute their

Figure 6.13
Crude and condensate imports to Asia-Pacific by origin, 2022–2045



Source: OPEC.

exports away from the EU. From around 2.2 mb/d in 2021, imports have already increased to 2.9 mb/d in 2022, with most of the additional barrels being absorbed by India and China. Flows are expected to increase further and reach 4 mb/d in 2035 and 2040. In the last five years of the outlook period, however, shipments are estimated to drop to 3.6 mb/d, as more Russia & Caspian crude goes to Europe.

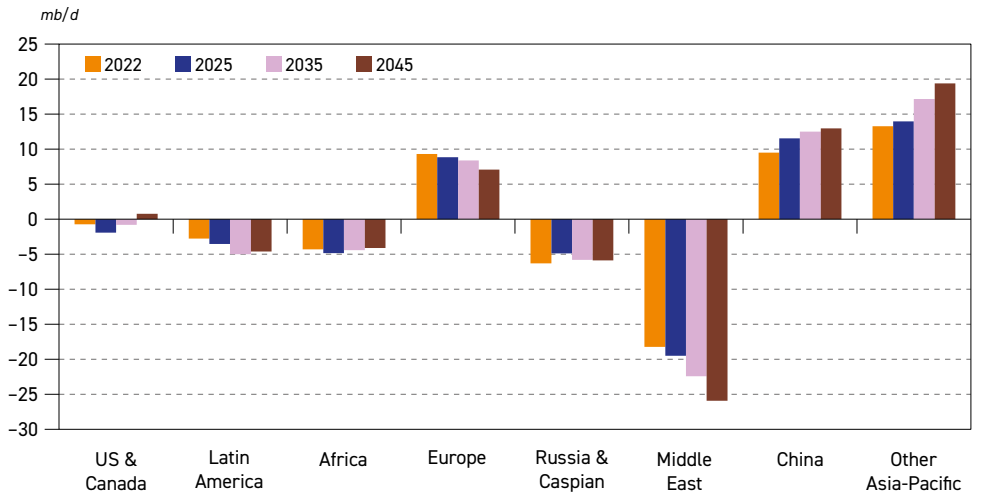
Imports from Africa to the Asia-Pacific are projected to decline from 2 mb/d in 2022 to around 1.6 mb/d in 2030 and 2035, as Europe seeks to replace Russian barrels. Nevertheless, volumes increase thereafter to reach 2.2 mb/d by the end of the period. Imports from Latin America rise from almost 1.5 mb/d in 2022 to 3.2 mb/d in 2035 as production in this region increases. In the last decade of the outlook period, however, these volumes drop and reach 2.4 mb/d in 2045.

Inflows for crude and condensate barrels from the US & Canada increase from almost 1.6 mb/d in 2022 to around 4 mb/d in 2030, as US light-sweet grades are a good match for the light distillate-rich crudes required in the Asia-Pacific. Due to declining supply in the US, these volumes are set to drop to 2.1 mb/d by 2045.

The resulting regional net crude and condensate imports are shown in Figure 6.14. The largest increase in net imports is expected for Other Asia-Pacific (excl. China), with volumes rising from 13.3 mb/d in 2022 to 19.4 mb/d in 2045. Net imports to China are set to increase in the medium-term, from 9.5 mb/d in 2022 to just under 12 mb/d in 2025. This is followed by modest increases thereafter, reaching around 13 mb/d in 2045. At the same time, European net imports are set to decline gradually throughout the forecast period. From around 9.3 mb/d in 2022, volumes are forecast to drop to 7.1 mb/d in 2045.

On the net export side, the largest change is observed in the Middle East, where net exports are projected to increase from 18.2 mb/d in 2022 to almost 26 mb/d in 2045. Net exports in Latin America are set to increase from 2.7 mb/d in 2022 to 4.4 mb/d in 2035. However, as

Figure 6.14
Regional net crude and condensate imports, 2022, 2025, 2035 and 2045



Source: OPEC.

exports decline somewhat, net export levels are projected to drop to 4.1 mb/d in 2045. Net exports from Russia & Caspian fall from 6.3 mb/d in 2022 to just below 5 mb/d in 2025, but this is followed by a gradual increase to 5.9 mb/d in 2045.

The US & Canada was a net crude and condensate exporter in 2022, at around 0.7 mb/d. With rising domestic supplies, net exports are set to increase to 1.9 mb/d in 2025. Volumes then decline gradually as the region becomes a net importer due to declining supply. Finally, in Africa net exports are projected to see a temporary medium-term increase from 4.3 mb/d in 2022 to 4.8 mb/d in 2025. However, they are then set to decline to 4.1 mb/d in 2045.

6.4 Refined product movements

As already discussed, refined product movements between the seven major regions are significantly lower relative to crude and condensate flows. This is due to the preference of consuming countries to increase domestic refining and import crude and condensates, and to benefit from lower transportation costs for crude and/or condensates relative to refined products. This is why the majority of refined products are produced and consumed within the respective regions.

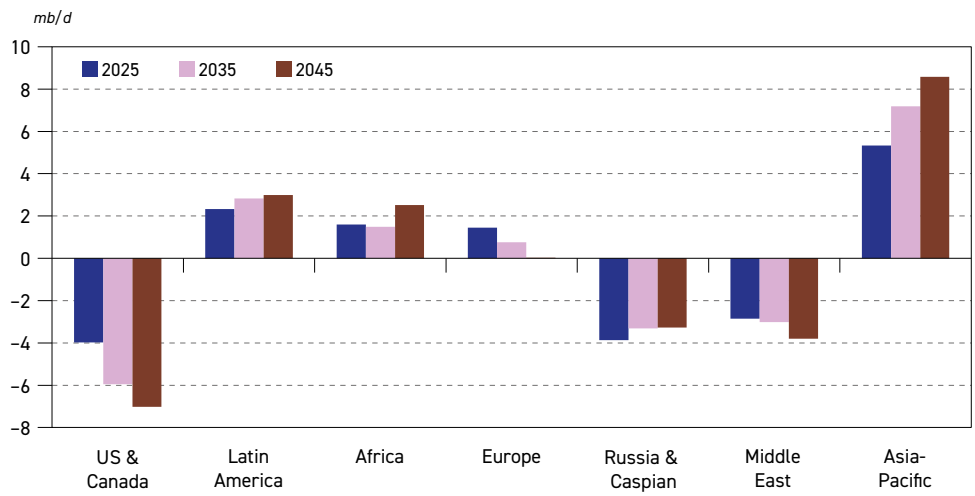
In other words, a large part of refined product trade remains an intratrade issue (trade within the region itself). However, there are still significant refined product flows from regions with sufficient refining capacities to others where local product demand is higher compared with local refinery output. In some cases, large crude oil producers (e.g. several countries in the Middle East) choose to expand their refining capacity and replace a portion of their crude exports with product exports. Consequently, future trends depend on local demand growth, as well as available and new refining capacity (see Chapter 5).

Figure 6.15 shows projected product net imports by major region. Net imports to the Asia-Pacific are set to increase from 5.3 mb/d in 2025 to almost 8.6 mb/d in 2045. On the net

import side, increases are expected in Africa, from around 1.6 mb/d in 2025 to 2.5 mb/d in 2045, and in Latin America, from 2.3 mb/d in 2025 to 3 mb/d in 2045. In Europe, net imports are set to drop and reach a balance by 2045.

This will be covered by rising net exports in the US & Canada, from 4 mb/d in 2025 to 7 mb/d in 2045, and the Middle East, from 2.8 mb/d in 2025 to 3.8 mb/d in 2045. Net exports in Russia & Caspian decline somewhat, but remain significant at 3.3 mb/d in 2045.

Figure 6.15
Regional net product imports, 2025, 2035 and 2045



Source: OPEC.

Climate change, sustainable development and energy policies

Key takeaways

- A rapidly changing global landscape, driven by high inflation, energy security concerns and geopolitical tensions continues to keep uncertainty elevated for all countries. The main objective of response actions, policies and measures – many of which are relevant to the energy sector – is, therefore, to limit global warming and build a resilient and sustainable future, ensuring that no one is left behind.

- Energy security and energy availability remain prime concerns for all countries, alongside actions to address climate change and economic disruptions, and to increase resilience. Many countries currently aim to put their economies on a pathway toward a low-emissions, high-growth model in the pursuit of sustainable development objectives and in light of national circumstances.

- At recent UN negotiation sessions, both developed and developing countries have reiterated their commitment to enhancing their climate-related ambitions in the context of sustainable development. The importance of addressing implementation gaps, with developed countries fulfilling their commitments to support provided to developing countries – including through climate finance – has been highlighted.

- Noting that projected GHG emissions from current pledges would make it likely that global warming would exceed the Paris Agreement target, UNFCCC Parties await the outcome of the first global stocktake at COP28, which should consider the importance of eradicating poverty within and between countries, including by supporting nationally determined sustainable development pathways.

- Implementation of the SDGs has stagnated and the world is likely to continue falling behind in attaining SDG 7 on universal energy access. Issues related specifically to energy poverty eradication need to be addressed, acknowledging national capabilities and solutions that are context specific.

- Major policy announcements in the US, EU and China, as well as other countries, continue to drive a change in the makeup of the long-term energy mix, recognizing that expected future energy demand requires unprecedented investment and collaboration. The importance of accelerating the diffusion of technologies through appropriate policies and the promotion of international cooperation are vital.

- To this end, hydrogen, CCUS, Direct Air Capture, Carbon Dioxide Removal and the Circular Carbon Economy are interconnected concepts at the forefront of addressing climate change and transitioning to a sustainable future. These technologies have the potential to help transitions to low-emissions economies, mitigate the impacts of climate change, as well as address energy security and resilience.

As the world continues to enhance its efforts to address matters related to energy security, energy affordability and the need to reduce global emissions, a wide range of policies and measures have already been enacted or are being considered for implementation that are aimed at building resilient and sustainable economies. The key outcome and decisions of multilateral processes, especially those related to the implementation of the Paris Agreement and the 2030 Agenda for Sustainable Development, are also playing a pivotal role in determining which direction the world could follow on matters related to climate change and socio-economic development. This chapter includes a brief overview of major policy announcements, NDCs and long-term strategies addressing climate change and sustainability issues. These also serve as the basis for the scenarios discussed in Chapter 8.

7.1 Climate change and sustainable development

Almost eight years after the adoption of the Paris Agreement, as well as the 2030 Agenda for Sustainable Development and its SDGs, there is broad consensus on the need to urgently scale up climate-related action and support developing countries in pursuit of sustainable development objectives. The challenges facing the world in reducing global GHG emissions and fulfilling implementation gaps in line with national circumstances are stark, necessitating critical improvements in multiple areas.

Intense negotiations under the UNFCCC allowed progress on long-anticipated processes, especially on matters relating to the Paris Agreement rulebook. However, there have been setbacks due to inherent implementation uncertainties. Progress towards achieving the SDGs has stagnated, particularly in developing countries, owing to amplified adverse impacts arising from the COVID-19 pandemic, geopolitical tensions and the global economic situation.

Countries are effectively called to work together in solidarity, acknowledging that appropriate policies and sound science would be required to support fair and inclusive growth. Energy security also remains a key concern for all countries, along with the need for action to address climate change and economic disruptions, and increase resilience. In this context, it is acknowledged that there is no one-size-fits-all approach, while the identification of science-based, viable and coherent solutions is considered essential to find the right balance between any potentially competing priorities.

Indeed, at the latest UN negotiation sessions, both developed and developing countries reiterated their commitment to enhancing their climate-related ambitions in the context of sustainable development. As stipulated in the Paris Agreement, developed countries were called to take the lead in reducing global emissions, recognizing that significant mitigation and adaptation actions are needed in order to achieve the agreement's long-term goals, based on the best available science and the principle of equity, while taking into account common but differentiated responsibilities and respective capabilities. In addition, the provision of support in terms of climate finance, technology development and transfer, and capacity building have been recognized as key enablers for increased action and implementation.

Anticipating the outcome of the first global stocktake, the Parties to the Paris Agreement have also stressed the importance of eradicating poverty within and between countries, supporting nationally determined sustainable development pathways. Facilitating policies, technological improvements and innovation could support efforts to maximize co-benefits and minimize the adverse impacts of climate mitigation response measures. In addition, various suitable

and flexible options could be identified, particularly for developing countries, taking national circumstances into account.

Moreover, developing countries have underscored the need to scale up financial support in the form of grants and concessional finance, noting that peer-to-peer cooperation is essential to share knowledge and lessons learned. On technological advancement, countries have stressed their different starting points and national capabilities. Across the board, however, the use of technologies such as CCUS is considered critical as part of long-term low-emission development strategies, including in developing countries. Systemic approaches and capacity building – comprising institutional capacity – are also considered essential for the implementation of climate policies.

Accelerating climate action in a just, equitable and sustainable manner requires holistic approaches embedded in domestic priorities, while simultaneously taking into account alignments with the SDGs and national development strategies. International cooperation could also address barriers and challenges for all countries to adapt to the impacts of climate change and mitigate them, including through enhanced access to adequate financing, and knowledge and experience sharing.

Scientific evidence – as provided by the recently released Synthesis Report of the IPCC Sixth Assessment Report (AR6) – notes the importance of sufficient financing and the need to incentivize the uptake of technologies and capacity building in developing countries. In addition, it indicates that increased ambition and mitigation policies for climate action have contributed to a decrease in carbon intensity and improvements in energy efficiency. That said, it also notes that the pace and scale of action are currently insufficient to tackle climate change and limit global warming to well below 2°C.

More specifically, evidence outlines that an emissions gap persists, exacerbated by an implementation gap in terms of achieving the long-term temperature target of the Paris Agreement. Countries are also experiencing an investment gap, especially developing countries, due to the unfulfilled commitments of developed countries to support them, limited concessional finance and public investment that is constrained by debt.

As a scientific input to UNFCCC processes, including the first global stocktake under the Paris Agreement, the recent IPCC report considers for future policies and measures regarding both adaptation and mitigation. Countries are subsequently called on to reduce global emissions while scaling up practices to enhance the development of climate resilience. At the same time, it is acknowledged that those who contributed the least to climate change are often the most vulnerable to its impacts. The lack of access to modern energy services for millions of people in developing countries is also emphasized. Therefore, fairness is one of the presented solutions, along with increased financing for climate action.

Similarly to the analysis presented in Chapter 2 of the WOO, the IPCC report shows that total GHG emissions continue to increase, noting that historical and current emission contributions vary substantially across regions. It stresses that the remaining carbon budget could be largely depleted under a 2°C target, assuming that annual CO_2 emissions remain at 2019 levels. Projected GHG emissions from current pledges – namely, Parties' NDCs announced prior to COP26 – would make it likely that global warming would exceed the Paris Agreement target. As a result, the report concludes that rapid and deep emission reductions are needed under pathways consistent with the agreement's long-term goals.

In addition, the report underscores that a broad portfolio of options is available to transform global energy systems. That said, different contexts, the availability of natural resources and national circumstances significantly affect abatement approaches and mitigation actions – including their pace – across regions and countries. The report presents carbon dioxide removal (CDR) as being critical to limiting the global temperature rise to well below 2°C. This entails both natural (conventional) solutions – like sequestering and storing carbon in trees and soil – and novel technologies that directly take CO_2 out of the air. With this in mind, it is key that technology transfer is supported for ambitious climate action.

Elsewhere, the report notes that insufficient financial resources are a barrier to adaptation, and cautions that feasible and effective adaptation options may become less effective with increasing global warming. At present, as per the report, adaptation is fragmented, incremental and distributed unequally across regions.

Ultimately, the report highlights the need for collective efforts to adapt to climate change and mitigate its effects, leaving no one behind, as the world moves towards a climate resilient and sustainable future. Climate resilient development involves integrating measures to adapt to climate change with actions to reduce or avoid emissions in ways that provide wider benefits. Noting that climate change could threaten efforts to meet several SDGs, the report concludes that it is critical to avoid unintended consequences and mitigate trade-offs through just transition principles, processes and practices. Overall, challenges stemming from climate change could be addressed by implementing appropriate policies, while adhering to the principles and provisions of the UNFCCC and the Paris Agreement.

Given the above, and looking ahead to COP28 in Dubai, United Arab Emirates (30 November –12 December 2023), a record number of mandated technical workshops, high-level events, ministerial roundtable discussions, global dialogues and summits are taking place. For example, the Climate Ambition Summit, organized by the UN Secretary-General in September 2023, in New York. These events ensure that a high level of attention is being devoted to climate-related matters and consider interlinkages with parallel UN processes that could support global efforts for a sustainable future. As elaborated on further later, these activities and events aim to build momentum and impact the formation of future policies and climate actions, and ensure sustainable development.

7.1.1 UN climate process and the Paris Agreement implementation

In an era of considerable uncertainty, challenges and cascading crises at various levels, UNFCCC Parties gathered at the COP27 in November 2022, in Sharm el-Sheikh, Egypt, with climate negotiations touching on substantive matters required for the full operationalization of the Paris Agreement.

Following extensive negotiations, a set of decisions was adopted on matters relating, *inter alia*, to the work programme for urgently scaling up mitigation ambition and implementation, the work programme on the global goal on adaptation (GGA) and technical aspects for Article 6 of the Paris Agreement on market and non-market approaches. Further issues concerned a new collective quantified goal on climate finance, and the first global stocktake under the Paris Agreement. These decisions contribute to evolving negotiation processes under the UNFCCC and the evolution of Parties' policies and measures for climate mitigation and adaptation actions.

The Parties could also reach agreement on the establishment of funding arrangements for assisting developing countries that are particularly vulnerable to the adverse impacts of climate change in responding to loss and damage, including a dedicated fund. Details concerning this will likely be decided at COP28, expected to be supported by new and additional resources from a wide variety of financial resources.

Moreover, various announcements were made during COP27. For instance, Indonesia announced a Just Energy Transition Partnership, agreed at the G20 Summit held in parallel with COP27. This is expected to mobilize about $20 billion over the next three to five years. Additional Parties also joined the Global Methane Pledge that was launched at COP26.

A key outcome of COP27 was the Sharm el-Sheikh Implementation Plan, composed of two cover decisions. According to these, the Parties decided, *inter alia*, to:

- Establish a work programme on just transition that would consider pathways to achieve the Paris Agreement goals;
- Urge the Parties that have not communicated new or updated NDCs or Long-Term Low Emission Development Strategies (LT-LEDS) to do so by COP28, taking into account different national circumstances;
- Retain the call to accelerate efforts towards the phasing down of unabated coal power and the phasing out of inefficient fossil fuel subsidies, providing support to vulnerable populations and recognizing the need for support towards a just transition (as per the Glasgow Climate Pact, adopted at COP26). The need for more secure, reliable and resilient energy systems was highlighted too, supporting cooperative actions; and
- Urge developed countries to provide enhanced support to assist developing countries in mitigating and adapting to climate change, noting with concern the growing gaps between the needs of developing countries and support provided by developed countries for developing countries' efforts to implement their NDCs while addressing increased indebtedness.

On other critical issues, the Parties took note of the emission and implementation gaps under existing pledges, and decided that under the Mitigation Work Programme (MWP), the Parties would aim to explore topics and identify opportunities and gaps to reduce global emissions, without establishing new goals on emission reductions. Two dialogues on increased ambition and implementation and in line with the Paris Agreement's goals will be held on an annual basis in this coming decade. The first global dialogue on the MWP and an investment-focused event has already taken place in conjunction with the 58th sessions of the UNFCCC Subsidiary Bodies (SB58) that convened from 5–15 June 2023, in Bonn, Germany. These events focused on just energy transition.

Matters relating to the GGA were extensively negotiated at COP27. A framework to guide achievements regarding this goal was launched, along with a review of progress in achieving and enhancing adaptation action and support. Negotiations will continue at COP28, while a workshop of the Glasgow Sharm el-Sheikh Work Programme on the GGA at SB58 considered potential metrics, indicators and methodologies for establishing the GGA framework.

In Sharm el-Sheikh, numerous technical and complex issues were considered in terms of a more detailed framework for trading international carbon credits under Article 6 of the Paris Agreement. Parties have advanced work on guidance related to cooperative approaches, noting the importance of capacity building in developing countries. At the same time,

mandated workshops and technical expert dialogues were held in conjunction with SB58 – including developing technical reports – with the objective of having balanced treatment and outcomes on all sub-items of Article 6 on market and non-market approaches.

On climate finance issues, the Parties have expressed concern about current flows that fall short of the support needed by developing countries, undermining trust and multilateralism. With developed countries not having fulfilled their collective pledge to provide developing countries with $100 billion in climate finance per year, negotiations continued in Sharm el-Sheikh on a post-2025 climate finance target. They eventually agreed to strengthen the *ad hoc* work programme on the New Collective Qualified Goal (NCQG) on climate finance, aiming to achieve meaningful outcomes on all elements and set a goal in 2024, and considering the needs and priorities of developing countries. A technical expert dialogue convened during SB58 reflected on the growing needs of developing countries, and, *inter alia*, highlighted the importance of ensuring improved access to new, affordable and long-term climate finance.

In addition, the mid-way point of the first global stocktake was reached at COP27. This process concerned thematic tracks on mitigation, including response measures; adaptation, including loss and damage; means of implementation and support; and integrated and holistic approaches. The third and final technical dialogue was held at SB58 in Bonn, thus concluding the technical assessment phase, while the political phase will conclude at COP28. A consideration of outputs will take place in Dubai, providing evidence regarding any collective progress on attaining the Paris Agreement goals.

Given the above, both the Glasgow Climate Pact and the Sharm el-Sheikh Implementation Plan urged Parties that had not yet communicated new or updated NDCs to do so as soon as possible, and to revisit and strengthen their 2030 targets to align with the Paris Agreement goals. At the time of writing, a total of 176 Parties had submitted their new or updated NDCs to the UNFCCC Secretariat, accounting for almost 93% of global GHG emissions.

The majority of the Parties presented a quantified mitigation target, whereas a few do not have a numerical target and have submitted only strategies, policies, plans and actions for low-emission development. Many of the Parties included an economy-wide target covering all sectors (including the energy sector) and/or all GHG emissions, with more new or updated NDCs incorporating an absolute emission reduction target.

Measures relating to energy supply, transport, buildings and industry are priority areas for Parties' NDCs – including those for renewable energy sources and energy efficiency improvements, but also for supporting CCUS technologies and circular economy strategies. Many developing countries highlighted their efforts to provide energy access.

About half of the Parties have considered mitigation co-benefits resulting from adaptation action and/or economic diversification plans. Moreover, many of the Parties have communicated information on matters relating to socio-economic impacts of climate response measures. For example, it is often highlighted that a low-emissions development would entail distributional consequences within and between countries. Furthermore, some of the Parties stressed the need to adopt just transition principles and integrate equity principles into climate action.

A higher number of the Parties indicated in new or updated NDCs their intention to use cooperative approaches under Article 6 of the Paris Agreement. Moreover, almost all NDCs referred to the importance of building sustainable and resilient economies, while taking

into account the SDGs. Besides links between mitigation action and the attainment of SDGs, an adaptation component is incorporated in many NDCs too. In addition, actions to support the Parties' adaptive capacity was highlighted to strengthen their resilience and reduce vulnerability to climate change.

To this end, a number of the Parties – particularly developing countries – have a standalone section in their NDC-submissions on means of implementation (namely, their conditional element), referring to finance, technology transfer and capacity building. Quantitative information about the financial support needed for NDC implementation was often included, with some of the latest NDCs presenting updated estimations or providing this information for the first time. Some also referred specifically to the limited adequacy of international financial support for adaptation compared with the scale of needs, particularly in developing countries.

In terms of global GHG emission reductions, the full implementation of new or updated NDCs would correspond to higher emission reductions. However, this would only partially offset emissions growth and reduce the estimated emissions gap compared to the level of reductions required to put the world on a 2°C pathway.

At the same time, the number of Parties who submitted their LT-LEDS increased to 67 strategies – accounting for about 72% of global GHG emissions – including from developing countries. Some of the Parties referred to their long-term targets in their submitted NDCs as well, while a limited number communicated updated LT-LEDS.

Based on these submissions, the Parties highlighted linkages between long-term mitigation strategies and the implementation of national development plans aimed at achieving sustainable development. On potential synergies between climate action and the attainment of SDGs, many of the Parties referred to matters relating to economic growth and economic diversification, improved energy security and access to affordable energy, as well as technology development and innovation. Uncertainties relating to finance, including access to new sources, the cost and availability of technologies, and different national circumstances and capabilities, were emphasized as challenges in implementing long-term aspirations.

Some of the Parties stressed the need to ensure fairness, equity and inclusiveness. Moreover, they presented potential social and economic impacts arising from the operationalization of their long-term strategies. Similarly to NDCs, the majority of LT-LEDS included a quantified emission reduction target, whereas a few of the Parties presented specific policies and actions. The Parties presented different mitigation pathways, indicating their contributions to collective efforts to reduce global emissions, with some focusing on energy. Yet most emission reductions expected by 2050 are likely to occur after 2030.

Some LT-LEDS also stressed the importance of the provision of means of implementation and the need for international cooperation when focusing on adaptation actions. To achieve the Paris Agreement's long-term goals, the Parties often underscored that there is significant leeway in policies and actions; however, it would be important to ensure that their contributions to collective efforts for tackling climate change are aligned with the principles and provisions of the Convention and the agreement.

In light of the above, many Parties are expected to support a balanced treatment between mitigation, adaptation and means of implementation at COP28, including through addressing

the finance needs of developing countries, the critical role of technology development and transfer, and support for capacity building.

7.1.2 SDG 7 in the context of sustainable development

At the midway point of implementing the 2030 Agenda, the SDGs are in a critical state; the world is lagging behind in meeting most of the goals, including SDG 7 related to access to clean, reliable and affordable energy. The current geopolitical context and economic crises have influenced many nations to redirect their focus towards energy security, especially as it has become increasingly clearer that energy is indispensable in achieving SDGs.

As global dialogues gear towards managing the energy sustainability trilemma – affordability, energy security, and sustainability – SDG 7 contains dedicated sub-targets that include goals for universal access to energy (SDG 7.1), renewable energy (SDG 7.2), energy efficiency (SDG 7.3), and two enabling targets related to financial flows to developing countries for clean energy development and international cooperation.

While acknowledging the substantial progress made globally to date in expanding electricity access, considerable efforts are still required to fully achieve SDG 7. According to the 2023 UN progress report, in 2021, 675 million people still lacked electricity access globally, most of whom are located in the least developed countries (LDCs), while 2.3 billion people still do not rely on clean fuels and technologies for cooking.

Primary energy intensity also declined to 0.6% in 2020 based on the latest official UN reports, making it the worst year for energy intensity improvement since the 2007 global financial crisis. To satisfy the SDG 7.3 target by 2030, the world must have an average annual improvement of 3.4%. Meanwhile, international public finance flows that support clean energy in developing countries have been constantly dropping since the COVID-19 pandemic. In 2021, the public finance made available for clean energy R&D was only $10.8 billion, an 11% drop from 2020, and 35% less than the decade-long average from 2010–2019.

In 2021, global leaders gathered together for the first High-Level Dialogue on Energy (HLDE), which provided a platform to discuss the implementation of energy-related goals and the SDG 7 targets. The HLDE resulted in the Global Roadmap for Accelerated SDG 7 Action, which serves as a guiding document for collaborative, cross-sectoral energy actions, emphasizing widespread and intensified impact that surpasses isolated and fragmented strategies. The roadmap also laid down two sets of milestones for 2025 and 2030 that could ensure cohesive and consistent achievement of the SDG 7 targets, while also supporting other SDGs and the emission reduction objectives of the Paris Agreement.

To further support the milestones identified in the roadmap, UN-Energy, the principal mechanism within the UN system for inter-agency collaboration on energy, released the UN-Energy Plan of Action Towards 2025. This laid down the thematic orientation of UN-Energy, including its members and partners. The plan outlines the strategies UN-Energy will adopt to accelerate actions, catalyze multi-stakeholder participation, grow the momentum of the SDG 7 global campaign, inform the global agenda, and effectively monitor and disseminate outcomes.

Another key outcome of the HLDE came in the form of Energy Compacts, which serve as voluntary pledges for action to drive progress towards achieving the targets of SDG 7. These

pledges identify key deliverables, milestones, and timeframes that contribute towards the 2030 fulfillment of SDG 7. According to the UN-Energy 2022 Annual Progress Report on Energy Compacts, more than 200 Energy Compacts were submitted by UN Member States, regional/local governments, the private sector, and NGOs.

These approaches aim to build on the ambitions that will drive a transformative change through just, inclusive, and equitable energy transitions. These initiatives also set the strategic course for the Global Stocktaking on SDG 7, an event mandated by the UN General Assembly (UNGA), which is scheduled to occur in 2024.

The High-Level Political Forum (HLPF) is the central UN platform following up and reviewing the 2030 Agenda and the SDGs. Recognizing energy as a central component of the 2030 Agenda has prompted the HLPF 2023 to conduct an in-depth review of SDG 7. This is occurring alongside the reviews of SDG 6 on clean water and sanitation, SDG 9 on industry, innovation, and infrastructure, SDG 11 on sustainable cities and communities, and SDG 17 on partnerships in achieving the SDGs. This multi-faceted approach to the reviews has been adopted to keep in mind the integrated, indivisible, and interlinked nature of the SDGs.

The 2023 HLPF received even more prominence, as the year marks the mid-point of the 2030 Agenda. It helped inform and shape the SDG Summit on the sidelines of the 78th UNGA in September 2023. The theme of HLPF 2023, 'Accelerating the Recovery from the Coronavirus Disease (COVID-19) and the Full Implementation of the 2030 Agenda for Sustainable Development at all levels,' acknowledges that progress towards most of the SDGs is badly lacking. This has been compounded by the continuing impacts of the COVID-19 pandemic, the geopolitical situation in Eastern Europe, and the financial, food, energy, and humanitarian crises triggered by these events. The forum was an occasion for the participants to discuss effective and inclusive recovery measures in addressing the impacts of COVID-19 on the SDGs, while also exploring actionable policy guidance for the full implementation of the 2030 Agenda at all levels.

In light of the above, the overall advantages of energy-focused actions needs to be emphasized, especially considering SDG 7's potentials to yield considerable co-benefits in other sectors. The 2023 Energy Progress Report, produced by the five SDG 7 custodian agencies, has identified and examined the specific interlinkages between SDG 7 and the other SDGs.

Reliable and accessible electricity is crucial to attain high quality education (SDG 4) and good health and wellbeing (SDG 3). The educational journey of students and teachers is enhanced when stable and consistent access to electricity in educational institutions and homes is ensured. For example, enhanced academic performance, literacy, and school completion rates can be achieved through more time to study after dark, the use of computers, and the availability of internet connectivity. The relevance of this link to SDG 4 was underscored during the pandemic, when some students' inability to continue their education due to a lack of electricity and internet connectivity at home became apparent in many regions, perpetuating inequality. Similarly, reliable electricity is also a crucial requirement for healthcare facilities, powering critical medical equipment and enabling life-saving emergency operations.

Access to energy is also intertwined with women's economic empowerment and gender equality (SDG 5). Electrification policies and regulations that take into account the specific needs of women and girls and are sensitive to their empowerment can help increase women's participation in business activities and drive more inclusive solutions for electricity access.

This will also enable policymakers and practitioners to develop more robust statistics. This will help track the impacts of inclusive energy policies on women's entrepreneurship and empowerment.

The fulfilment of SDG 7 necessitates the presence of good regulatory and policy frameworks, which in turn can stimulate income generation and employment (in line with SDG 8) in local communities. Investment in integrated access planning and the expansion of on-grid and off-grid systems is essential to make these frameworks a reality. In addition, technological innovation and digitalization (SDG 9) can be utilized to close the energy access gap, reduce costs, enhance value chain efficiencies, and improve data collection and accountability. The integration of digital technologies into national institutional networks and legal frameworks for energy products and services offers significant opportunities for governments to expand and improve grid services.

Ultimately, the world has considerable work to do towards achieving energy security, affordability and access. In the 2023 UN-produced SDG progress report, the necessity for concerted efforts in achieving energy security was emphasized, including identifying priority actions required to accelerate energy access. These included addressing the critical obstacles to the deployment of clean energy in developing countries, tripling finance and investment for clean energy and energy efficiency, mobilizing funding to support the Energy Compacts, and fortifying international cooperation and collaboration.

7.2 Energy policies of major economies

Developments in recent years have shown that the energy and climate challenges facing the world are enormous and complex. This has been demonstrated by tensions and conflicts over energy affordability, energy security and the need to reduce emissions in regions around the world. Additionally, geopolitical tensions pose enormous challenges for policymakers, particularly for developing countries, which are more than ever faced with energy security and economic issues. For others, the focus is on stricter energy efficiency measures and increased renewable energy support policies. The result is a variety of policy mechanisms that seek to address local, nation and international goals.

7.2.1 United States

The US is gradually refining its energy policies and climate change regulations, as demonstrated below.

The IRA supports new investments in energy production. The Act includes $370 billion in investment over the next ten years for energy security and climate change and offers financial incentives to accelerate innovation and the adoption of clean energy technologies. This is set to be achieved using tax credits or breaks, with the goal being to improve energy efficiency and foster a gradual switch to renewable energy sources. In turn, this should result in improved energy consumption in homes and businesses and see a drop in the general cost barrier to renewable energy sources entering the market. Furthermore, the IRA encourages additional tax incentives for the use of emission reduction technologies, including the implementation of CCUS technology and green hydrogen.

Other initiatives include the Federal Sustainability Plan. This regulation aims to contribute to GHG emission reductions of 65% by 2030 and achieving net-zero in 2050. In detail, the plan

focuses on generating 100% emissions-free electricity by 2030. The Federal Sustainability Plan further implies that, by 2032, CO_2 emissions in the building portfolio will decrease by 50% and by 100% in 2045.

Pivoting towards the oil and gas sector, the US administration issued a stop on oil and gas leasing in 2021, suspending operations in various projects. This includes on regulations limiting the availability of federal land for drilling, and in terms of increasing royalty rates driven by environmental concerns. These payments constitute a percentage of the overall value of the resource extracted. However, the ban was lifted in 2022.

The US Methane Emission Reduction Act introduces a regulation that combats methane emissions and focuses primarily on the oil and gas sector. Its roadmap promotes a decrease of 65% in methane emissions by 2025. Agencies like the Environmental Protection Agency have introduced the revised New Source Performance Standards to control methane and other emissions in the oil and gas sector. Additional regulations govern well closures, assuring that emissions are controlled until all wells are sealed.

7.2.2 European Union

The EU Green Deal utilizes a number of policy mechanisms for its member states. The most direct are those that set quantitative targets for the share of renewable sources in the energy mix. In 2021, an increase to 40% was slated for the EU's target for the share of renewable energy in 2030, only for the arrival of the REPowerEU plan the following year that boosted the target to 45%.

In 2021, the EU also released its 'Fit for 55' package aimed at supporting the achievement of a 55% reduction in GHG emissions by 2030 compared to 1990 levels – a target that the EU has enshrined into law. The purpose of the package was more than a singular initiative, as it set out to update several existing regulations, directives and standards, as well as to establish new ones. The result has been a flurry of changes in EU energy policies since 2021. Recent developments have been particularly important for the transportation sector, for example, related to overall fuel demand and the type of fuel demand.

Most recently, there has been agreement on the ReFuelEU Aviation proposal, which was part of the 'Fit for 55' measures. Once formally adopted, this legislation will mandate the use of SAF. This will apply to flights within the EU and to flights leaving the EU. The initiative will first require a minimum share of SAF in the fuel mix of 2% by 2025 before it increases over time to reach 70% by 2050. It further requires an increase of Power-to-Liquid fuels or E-Fuels in this mix (35% of the mix by 2050), but this does not include fuels made from food and feed crops. This followed a similar agreement for using sustainable fuels in the EU's shipping industry.

New legislation also sets stricter performance standards for new vehicles, which is likely to support a gradual shift towards EVs. This includes a 55% reduction in CO_2 emissions for new cars and a 50% reduction for new vans from 2030 to 2034, compared to 2021 levels, and a 100% reduction in CO_2 emissions for both new cars and vans from 2035.

It should be noted that in some countries there has been pushback against some EU environment and next zero policies. For example, the Polish government in June said it would file a lawsuit against an adopted EU regulation requiring all new cars in Europe to be zero-emission as of

2035. In Germany, the ruling national coalition came close to breaking point earlier this year over the phasing out of oil and gas for heating, and the policy was eventually watered down. In Italy, the government has asked the EU to water down a directive aimed at improving the energy efficiency of buildings and re-write plans to phase out combustion engine cars.

7.2.3 China

Based on the 14th FYP on Modern Energy Systems, China aims to pivot towards a more sustainable energy system by expanding capacities and investments regarding clean energy sources.

The 'Two Session' held on 13 March 2023 in Beijing defined the key macroeconomic requirements for the end of the year, focusing on economic growth and energy priorities. The Chinese government has set its GDP growth goal at around 5% and anticipates a recovery in energy consumption. Additionally, Beijing has put limits on coal-to-gas switching.

China has also established a carbon peaking and carbon policy system defined as the '1+N' policy framework. This top-down policy implementation framework comes from two documents, namely the Working Guidance and Action Plan. The former defines a high-level framework that paves the road to achieving the climate goals. The latter provides insights about the action plans on a more detailed (regional) basis to fulfil energy-related targets. The framework elaborates on policies such as the following:

- Opinions to Strictly Control Energy Efficiency of Key Industries to Facilitate Energy Conservation and Emissions Mitigation;
- The Implementation Plan to Retrofit and Upgrade Coal-fired Power Plants;
- Opinions to Strengthen Industry-Financing Nexus to Facilitate Green Industrial Development;
- Opinions to Facilitate State-Owned Companies' Work towards Carbon Peaking and Carbon Neutrality;
- The Implementation Plan for Industrial Carbon Peaking;
- The Implementation Plan to Promote Technologies Supporting Carbon Peaking and Carbon Neutrality (2022–2030); and
- Central bank's lending tool to support carbon emissions reduction.

China forecasts that its non-fossil fuel energy use leveraging transparent photo-electro-chemical cells is set to expand from an initial market share of 14.3% at the end of 2021 to a 20.6% share in 2025 and 25.6% by 2030. This meets the set goals of 20% and 25%, respectively. Adding wind to solar, the government estimates that by 2030 their market share will surpass coal. Moreover, energy and carbon intensity in China are expected to drop by 13.5% and 18% by 2025, respectively. By 2030, carbon intensity is set to decline by 65% from its 2005 levels.

The 14th FYP further highlighted a 'New-Type Energy Storage Development' so as to move into large-scale development by 2025. Moreover, the introduction of new electrochemical energy storage is said to reduce costs by 30%. This is based on breakthroughs in long-term storage technologies, such as hydrogen energy storage and thermal energy storage. It is expected that the new-type of energy storage will be fully operational by 2030.

In terms of pump storage development, it is expected that the Chinese government will double cumulative operating capacity by 2025 and reach 62 GW. Further sustainable growth is expected to lead to 120 GW in 2030 and to 412 GW in 2035.

In January 2023, the Chinese government drafted a blueprint on a new type of power system development, providing a timeline for construction. The Ulanqab-Beijing hydrogen demonstrator pipeline was also recently launched as the country's first long-distance hydrogen project. The project's goal is to promote large-scale deliveries of green hydrogen, while reducing the costs and restrictions associated with this transportation mode. The pipeline has a total length of 400 kilometres. The expected transmission capacity is set to initially be around 100,000 tonnes per year, before ultimately expanding to 500,000 tons per year.

7.2.4 India

At COP27 in Sharm El-Sheikh, India reiterated its commitment to a goal of reaching net-zero emissions by 2070, meeting 50% of the country's cumulative installed electric power capacity from clean energy sources and by 2030 reducing the emission intensity of GDP by 45% below 2005 levels. Additionally, India submitted its long-term low emission development strategy to the UNFCCC, committing to a just, sustainable and all-inclusive transformation of its energy system. The LT-LEDS is based on pathways that consider the following:

- Low emission electricity systems;
- An integrated, efficient, and inclusive low-emission transport system;
- Adaptation in urban design, energy and material-efficiency in buildings, as well as sustainable urbanization;
- Economy-wide growth decoupling from emissions and an efficient, innovative low-emission industrial system;
- CO_2 removal and related engineering solutions;
- Enhanced forest and vegetation coverage consistent with socio-economic and ecological considerations; and
- Economic and financial aspects of low-emission development.

Each of these pathways is supplemented by a wide spectrum of policy proposals and programmes including in urban planning, municipal services, improved fuel and energy efficiency, EVs and recycling. Furthermore, in an attempt to promote international dialogue and technological exchange, the Indian government, through the LT-LEDS, reminded the global community that under the UNFCCC, developed countries have committed to transferring technology on concessional terms to developing countries. As part of India's Third Biennial Update Report, the country provided a comprehensive list of critical technologies required to realize its LT-LEDS aspirations.

In February 2023, the Indian government presented its latest full budget, with over US$8 billion directed at the realization of new clean energy projects, including green hydrogen and renewable energy initiatives. Moreover, an additional US$4.3 billion was allocated solely to the realization of India's 2070 net zero goal.

India's National Electricity Plan 2023 (NEP2023) was released in May 2023. This outlined the government's current projections for peak national electricity demand and requirements for

renewable and fossil-fuel based generation capacity to 2032, taking into consideration the country's climate mitigation ambitions. According to the document, the share of countrywide non-fossil based generation capacity is projected to grow to 57.4% by the end of 2027 and 68.4% by the end of 2032.

7.2.5 Other regions and countries

Russia

Currently, the Russian Federation's 'Reduced GHG Socio-economic Development Strategy until 2050' that was adopted in October 2021 remains the country's key strategic document aimed to realize its contribution for the Paris Agreement implementation.

The strategy's main goal is to achieve carbon neutrality by 2060 and considers technological, financial and fiscal policy measures aimed at reducing GHGs as an additional driver of the economy's technological renewal. These measures include carbon pricing mechanisms, GHG quota systems, the introduction of regulatory requirements for the mandatory use and promotion of technologies with low emissions and high energy and resource efficiency, and adjustments to the mineral extraction tax, among others.

However, the extent to which Russia is able to realize its climate mitigation ambitions is predominantly influenced by the country's ability to tackle and adapt to the impacts of sanctions.

In early February 2022, the Russian government prepared the strategy's draft implementation plan containing measures aimed at emission reductions. Such measures included, for example, ESG and carbon reporting obligations, comprehensive green debt financing support, tax exemptions, the introduction of emissions' quotas in separate sectors and the approval of a carbon credit registration mechanism.

Initially, it was assumed that its final version would be available in March 2022; however, increased geopolitical uncertainty led to the postponement of its publication. In July 2022, the Russian Union of Industrialists and Entrepreneurs (RSPP) requested that the Government postpone the adoption of the Strategy's implementation plan until as late as 2023, citing inadequate access to low-emission technologies.

United Kingdom

The UK government has developed multiple policies, regulations, and initiatives to secure energy supplies and accelerate the diversification of energy sources while meeting Paris Agreement-related goals. Its main focus is to ensure the security and cost-efficacy of future energy supplies.

In April 2022, the UK government introduced its Energy Security Strategy with the aim of reducing dependency on imported fossil fuel supplies and meeting a net-zero target by 2050. The strategy calls for the expanded utilization of North Sea resources, which was further underscored when the government granted 100 new North Sea oil and gas licences in July 2023, as well as the adoption of hydrogen as an alternative to natural gas. It also underscored the importance of leveraging the expertise acquired in offshore oil and gas to help develop offshore wind solutions.

In 2022, the UK's Department for Energy Security & Net Zero implemented a carbon pricing policy through the Carbon Price Support (CPS) and the UK Emissions Trading Scheme (UK ETS). CPS is a tax on carbon content in fossil fuels used for power generation designed to promote investment in low-emission energy sources. It provides an incentive for power generators to decrease emissions.

The carbon pricing policy allocates UK Allowances that determine the amount of GHGs that companies can emit. Excess emissions require the purchase of additional permits from the carbon market. This move supports the UK's goal of transitioning to a low-emission economy and reaching net zero by 2050. In addition to the CPS and UK ETS, the UK government has also proposed a carbon border tax, similar to the EU's CBAM, which would impose tariffs on imported goods based on their carbon content. The proposal is currently under consideration and is expected to be implemented in the mid-2020s.

In the midst of geopolitical tensions in Eastern Europe and the post-pandemic demand recovery, wholesale gas prices reached extraordinary levels, putting inflationary pressure on the cost of living in the UK. In May 2022, the UK government responded by implementing the Energy Profits Levy Act, increasing taxes on energy companies from 25% to 35% until March 2028. As a result, total effective tax rates in the oil and gas sector have risen to 75%, leading to a substantial reduction in profits. The government also changed the investment allowance to 29%, but kept it at 80% for investments aimed at emission reduction efforts.

Brazil

Based on its NDC, Brazil aims to reduce GHG emissions to 50% by 2030, compared to 2005 levels, and reach carbon neutrality by 2050.

The Ministry of Environment launched the National Zero Methane Program in March 2022. The objective of the regulation is to stimulate the carbon market and advance sector agreements. The ministry is mainly seeking to leverage technology in biogas and bio-methane operations to help mitigate methane emissions.

On the investment front, the Brazilian energy ministry updated its fuel pricing policy to focus more on production costs than on international price parity. The expansion of gas processing and the extension of flow capacity are part of a $ 10.8 billion investment in refining, gas and power and logistics. As a result, Petrobras, the Brazilian state oil company, will reduce fuel costs for gasoline and diesel at the pump.

In addition, the Brazilian National Bank for Economic and Social Development is investing R$ 24 million to support renewable energy expansion, including projects for biogas, wind and solar energy.

The Brazilian government has also implemented a policy leveraging subsidies for truck and taxi drivers and state tax breaks are being granted to ethanol producers to leverage ethanol as a competitive fuel in the transportation sector. Moreover, two resolutions set the emission standards for light-duty and heavy-duty vehicles that will start to impact new vehicles in 2022, and all vehicles starting from 2023. The emission standards will be fully implemented by 2025.

7.2.6 Hydrogen, CCUS/CCS and CCE

Hydrogen, CCUS and the Circular Carbon Economy (CCE) are three interconnected concepts at the forefront of addressing climate change and transitioning to a sustainable future. These technologies have the potential to help moving toward a low-emissions economy, mitigate the impacts of climate change, and address energy security and resilience. However, their value chains are still in their early stages, and their growth and penetration in the global energy system will depend on policy support and investment.

The importance of hydrogen and CCUS as essential elements in achieving a reduction of CO_2 emissions were highlighted in the IPCC's AR6. In recent years, many countries have begun to rapidly adopt policies related to these technologies, establishing their own objectives and action plans, which take into account specific needs and available resources. This sub-section aims to outline the most important policies and developments in this respect, at both regional and national levels.

United States

In the US, the Bipartisan Infrastructure Law (BIL) was passed by Congress and signed by US President in November 2021. This legislation provides $62 billion for the US Department of Energy (DoE), including $9.5 billion allocated for clean hydrogen and $12 billion to be spent on CCUS over the following five years. As previously stated, the IRA signed into law by the US President in August 2022 includes additional policies and incentives for hydrogen, such as tax credits, which are expected to stimulate the growth of a clean hydrogen market in the country. The legislation also extended the construction start date of eligible projects to the end of 2032, lowered capture thresholds, including direct pay, and expanded transferability.

The DoE's National Clean Hydrogen Strategy and Roadmap draft indicate that the country has the potential to generate a significant demand for clean hydrogen in the next few decades. The department's analysis suggests that by 2030, 2040, and 2050, the US could have demand for at least 10 Mt, 20 Mt, and 50 Mt of what it terms 'clean' hydrogen per year, respectively.

The DoE also published its strategy for advancing CCS. Its strategic vision establishes a framework for making informed carbon management decisions regarding emissions reductions.

European Union

The EU has adopted several initiatives and measures pertaining to hydrogen and CCUS deployment, such as the Hydrogen Strategy for a Climate-Neutral Europe, released in July 2020. This strategy notes that the share of hydrogen in Europe's energy mix is projected to grow from less than 2% to 13–14% by 2050. Furthermore, it includes a roadmap to 2050 based on three phases.

The first phase is 2020–2024 and is expected to see the installation of at least 6 GW of renewable hydrogen electrolyzers in the region and the production of up to 1 mt of renewable hydrogen. The second phase is from 2025–2030 and is forecast to see at least 40 GW of renewable hydrogen electrolyzers installed by 2030 and the production of up to 10 mt of renewable hydrogen. The third phase is set to last up to 2050 and see renewable hydrogen technologies reach maturity so as to be deployed in a large-scale manner, specifically reaching all hard-to-abate sectors.

Alongside this strategy, various measures have been proposed to facilitate public and private financing, such as the European Clean Hydrogen Alliance, Clean Hydrogen Partnership and the creation of the European Hydrogen Bank.

Hydrogen is also a central pillar in packages such as Fit-for-55 and REpowerEU. In terms of the latest developments in the Fit-for-55 package process, in March 2023 the European Council agreed on its negotiating positions on two proposals that set common internal market rules for renewable and natural gases and hydrogen. The next step will see negotiations in the European Parliament.

These proposals aim to create a regulatory framework for infrastructure and markets dedicated to hydrogen and the integrated planning of networks. They also lay down rules for consumer protection and aim to strengthen security of supply.

Several modifications to the package were adopted in June 2022. The Council differentiated between discounts on the tariffs of gases of renewable origin (100%) and those on low-emission gases (75%) in the gas network, and introduced a 100% discount for capacity-based transmission and distribution tariffs to underground gas and LNG storage facilities.

Canada

Early in 2022, the Canadian government released its first Emissions Reduction Plan under the Canadian Net-Zero Emissions Accountability Act. It provides a roadmap for how Canada will meet its NDC target to reduce GHG emissions to 40–45% below 2005 levels by 2030, and put the country on a path to achieving net-zero emissions by 2050.

Part of this plan includes developing hydrogen and CCUS strategies to incentivize the development and adoption of these technologies. In March 2023, Canada issued its 2023 federal budget, which strongly supports CCUS and clean hydrogen production via an investment tax credit. It renewed the proposal of an up-to 40% refundable credit for hydrogen production through electrolysis or from natural gas, provided that CO_2 emissions are abated through CCUS.

In addition, the 2023 budget renewed incentives for DAC and CCUS projects included in the 2022 budget and expanded the CCUS Investment Tax Credit framework to the geological storage in British Columbia.

Norway

In 2020, Norway developed its hydrogen strategy, which aims to establish a domestic hydrogen industry by 2030. The strategy focuses on promoting the production and use of both green and blue hydrogen, with the goal of reducing the cost of hydrogen. To achieve this, the government has provided funding for R&D, pilot projects and infrastructure for hydrogen production and distribution. Norway is also participating in several international collaborations to promote the use of hydrogen, including the European Clean Hydrogen Alliance and the Hydrogen Council.

Norway is a leader in CCUS technology, with the Sleipner and Snøhvit projects being some of the most well-known examples. The government is currently working on a new national

strategy for CCUS, which will focus on scaling up the technology and making it more cost-effective. The strategy will include funding for R&D, as well as incentives for companies to invest in CCUS projects. In addition, the government is exploring the potential for using offshore wind to power CCUS projects.

United Kingdom

The British Energy Security Strategy, published in April 2022, includes a target of 10 GW capacity for hydrogen production in 2030, of which 5 GW is to come from hydrogen produced from electrolysis. In addition, the 2025 targets of the strategy include achieving up to 1 GW of electrolytic hydrogen, designing new business models for hydrogen transport and storage infrastructure and the establishment of a hydrogen certification system.

In respect to CCUS, the UK government has focused its policy goals on creating momentum around CCUS funding schemes and policy announcements. The government's 10-point plan for a low-emission industrial revolution includes commitments to invest in CCUS in four industrial clusters and to capture up to 30 mt of CO_2 per year by 2030. The government expects two of these clusters to be ready by the middle of this decade, while the other two should be completed by 2030. This process was supported by the 2023 announcement of a longer-term funding package of up to £20 billion for CCUS in the UK.

Australia

The Australian government issued the Australia's National Hydrogen Strategy in 2019, which includes 57 coordinated government actions aimed at addressing barriers to hydrogen development in three key areas: increasing demand, achieving low-cost hydrogen production at scale and reducing hydrogen delivery costs.

For CCUS, the Low Emissions Technology Roadmap released in 2020 has put the deployment of CCUS technology at scale among its priorities. In this context, the government has pledged more than $500 million so far to CCUS hubs in seven regions of the country. In addition, it has granted some $50 million for CCUS pilot projects or pre-commercial projects through the CCUS Development Fund.

Japan

In March 2019, the country's Ministry of Economy, Trade and Industry (METI) issued the third Strategic Roadmap for Hydrogen and Fuel Cells to complement and build on the Basic Hydrogen Strategy and the Fifth Strategic Energy Plan. Together, they define the overall policy framework for the development of Japan's hydrogen economy for the next decade and beyond, including objectives to develop an integrated hydrogen supply chain; reduce hydrogen production costs; enhance storage and transportation of hydrogen and expand industrial and consumer use of hydrogen and ammonia.

Under those strategic objectives, Japan aims to reduce the delivered cost of hydrogen to JPY30/Nm^3 (Nm^3 stands for normal cubic metre) by around 2030 and subsequently to JPY20/Nm^3; reduce the cost of water electrolysis systems by 75%; increase the number of FCEVs to 200,000 by 2025 and 800,000 by 2030; and construct hydrogen refuelling stations in 320 locations by 2025.

In July 2021, the government updated its Green Growth Strategy, identifying 14 growth sectors for the Japanese economy, including hydrogen and ammonia, and presenting a

concrete national vision and goals such as increasing annual hydrogen consumption to 3 mt by 2030 and 20 mt by 2050.

In October 2021, METI published the sixth iteration of its Strategic Energy Plan, which adopts the core targets for hydrogen/ammonia under the Green Growth Strategy (as described above). The strategy introduced a co-firing target of 30% hydrogen and 70% natural gas in gas-fired power plants and the construction of pure hydrogen-fired power plants by 2030, as well as hydrogen/ammonia to comprise 1% of Japan's overall power generation by the same time horizon.

Moreover, Japan's long-term CCS roadmap includes a target to develop 120–240 mt/y of CO_2 storage capacity offshore by 2050. In order to achieve this target, in January 2023, METI announced its intention to have 6 mt/y to 12 mt/y of CO_2 storage capacity by 2030. Part of this plan sees the adoption of a necessary legislative framework and the support of research into technology aimed at reducing CO_2 separation and recovery costs.

South Korea

South Korea has set ambitious goals for the use of hydrogen by 2040. To increase consumption, it plans to expand its annual market from 0.13 mt to 5.26 mt. For the transportation sector, the 2040 target is to produce 6.2 million FCEVs, of which 3.3 million will be for export and 2.9 million for domestic sales, in addition to establishing 1,200 hydrogen fuelling stations across the country.

To support this plan, the South Korean government plans to import up to 600,000 and 200,000 tonnes of hydrogen annually from Malaysia and the United Arab Emirates, respectively, by 2027 and beyond.

China

China's hydrogen strategy is set out in the March 2022 document, entitled, 'Medium and Long-term Plan for the Development of Hydrogen Energy Industry (2021–2035)'. The plan envisages the establishment of a hydrogen energy industry development system by 2025, with innovative capabilities and core manufacturing technologies and processes. China is targeting the production of 100,000 to 200,000 tonnes of green hydrogen annually and to have about 50,000 FCEVs on its roads by 2025.

By 2030, China aims to have a well-established industrial layout, with the extensive use of hydrogen production from renewable energy. It is estimated that China's hydrogen demand will reach 35 mt by 2030 and 60 mt by 2050, from 20 mt in 2022.

CCUS is also an integral part of China's efforts to reduce emissions. Overall, estimates show that CCUS in the country would contribute to the annual reduction of 0.6 bt to 1.5 bt of CO_2 by 2050 and 1 bt to 1.8 bt by 2060. It is worth noting that China currently has about 100 CCUS demonstration projects in different scales and phases, with a total CO_2 capture capacity of 4 mt and an annual injection capacity of 2 mt.

India

Hydrogen will likely play a crucial role in helping India to mitigate climate change. India hopes to become a global hub for green hydrogen production and exports. Towards this end,

the Ministry of New and Renewable Energy released the National Green Hydrogen Mission document in January 2023. The key objectives are to boost green hydrogen production capacity to at least 5 mt/y by 2030, with the potential to reach 10 mt/y if export markets grow. Moreover, India hopes to develop a robust domestic electrolyzer manufacturing ecosystem by setting financial incentive mechanisms.

The Ministry of Petroleum and Natural Gas has initiated efforts to provide opportunities for collaboration and knowledge sharing, and prepare a unified and practical strategy for the development and implementation of CCUS techniques in India's oil and gas sector. A roadmap, entitled '2030 Roadmap for CCUS', is being prepared to provide the necessary direction and guidelines for all oil and gas companies to develop and scale up CCUS.

Middle East and Africa

Saudi Arabia aims to be the world's top provider of carbon-free hydrogen, with a target to produce 2.9 mt/y by 2030, rising to 4 mt/y before 2035. The **United Arab Emirates** has established the Dubai Hydrogen Alliance to accelerate the transition to a low-emission economy and support the global initiatives of the Hydrogen Council. **Qatar** has signed several memorandums of understandings (MoU) with Japanese and South Korean companies to explore hydrogen cooperation and investment opportunities. **Oman** announced its Green Hydrogen Strategy in October 2022, targeting the production of 1 mt/y of green hydrogen by 2030.

The potential of hydrogen as an energy carrier has also garnered interest from several African countries. In May 2022, the African Hydrogen Partnership (AHP) was formed with the objective of fostering collaboration in this area. The Algerian Ministry of Energy and Mines presented its Hydrogen Development Roadmap in March 2023, which aims to make **Algeria** a pioneer country at the regional and international level in the production and commercialization of this energy by producing between 30 and 40 billion KW of hydrogen by 2040 at a very competitive price.

As many agree there is no one-size-fits-all solution to tackling climate change, it is imperative to pursue all options to manage GHG emissions. To this end, CCE is considered to be a more holistic and pragmatic approach to managing emissions. It recognizes that CO_2 and other GHGs are not only drivers of climate change, they are also valuable resources that can be managed in a circular and sustainable manner. Indeed, CCE contributes to supporting sustainable development by ensuring access to energy for all, expanding economic growth, promoting innovation, encouraging responsible consumption and production and strengthening efforts to tackle climate change. This is why countries like Saudi Arabia have made CCE a central pillar of their net-zero strategy, with G20 leaders also endorsing CCE at the 2020 summit in Riyadh.

Energy scenarios

Key takeaways

- Given the increasingly polarized global discourse on energy issues and the recent focus on steering energy transitions in a particular direction, notably away from some energies, there is a need to refocus on more comprehensive, realistic and resilient pathways that support and enable sustainable development, ones that leave no one behind.

- The uneven distribution of adverse impacts across countries and regions arising from the implementation of response measures, mainly those of climate mitigation action on energy systems, have raised concerns regarding developing countries' right to development.

- Subscribing to a dominant narrative about the way forward is unhealthy, given that solutions can be found in all energies and a plethora of relevant technologies. In this regard, this Outlook presents two alternative scenarios.

- The 'Advanced Technology' Scenario illustrates a technology-driven means of limiting the global temperature increase to well below 2°C, while curbing the negative economic impact on developing economies, especially energy-exporting ones, and ensuring maximum energy security. The scenario assumes a much greater diffusion of CCUS, CCS and DAC technologies in industrial sectors, stronger investment in hydrogen supply networks, and the increasing adoption of a CCE framework across the global economy.

- This scenario shows a possible pathway where both a higher share of renewable energy and technological options that support the continued use of oil and gas complement each other in a way that mitigates potential adverse impacts on the economies of energy exporting developing countries.

- Primary energy demand in the Advanced Technology Scenario by 2045 will be almost 55 mboe/d lower compared to the Reference Case. The share of non-fossil fuels in this scenario is projected to gradually expand to around 45% by 2045.

- Global oil demand in this scenario will stabilize at a level above 100 mb/d in the period to around 2035 and then slowly moderate to 98 mb/d over the last ten years of the forecast period. This represents a demand decline of around 18 mb/d compared to the Reference Case in 2045.

- By contrast, the 'Laissez-Faire' Scenario, assumes a faster return to higher economic growth during the medium-term and maintains this stronger growth in the long-term, especially for developing countries. Policies will tighten in the future, contributing to improved efficiencies and supporting the further expansion of renewables; however, in an isolated manner given the absence of a coordinated move to reduce future emissions. Moreover, protectionism and unilateralism will play a more important role in prioritizing local development needs over global issues.

- Both primary energy demand and oil demand in this scenario are consistently higher compared to the Reference Case. Oil demand passes 113 mb/d by 2030 and continues growing to 122 mb/d in 2045. Compared to the Reference Case, this represents a difference of more than 1 mb/d by 2030, which then expands to 6.3 mb/d in 2045.

The continued uncertainties arising from geopolitical tensions, inflationary pressure, high debt levels and the repercussions of the COVID-19 pandemic present a systemic risk to the global economy. This period of uncertain conditions also highlights the need to support and enable sustainable development, leaving no one behind and setting the world on a resilient and just pathway. Moreover, one thing is clear, sustainable development requires energy.

As evident from the analysis incorporated in Chapter 7, significant efforts are already underway to align policies, mitigation actions and response measures. These have the ultimate objectives of sustainable development, while tackling challenges related to climate change, ensuring socio-economic development, as well as addressing energy security concerns. Enhancing energy affordability and reliability also requires adequate investment and financing to accelerate the transformation of energy systems, including through energy efficiency improvements and technological advancement.

Importantly, the uneven distribution of adverse economic impacts across countries and regions arising from the implementation of response measures, mainly those of climate mitigation action on energy systems, have raised concerns regarding developing countries' right to development. It is these countries – generally with little or no responsibility for climate change – that are, and will increasingly be disproportionately affected by it, as well as the measures taken to respond to it. In addition, they remain without the promised support from developed countries to help them mitigate the impacts and adapt to the changing environment.

At the same time, oil and gas exporting countries, particularly OPEC Member Countries and non-OPEC countries participating in the Declaration of Cooperation (DoC), continue to respond to international markets that require stability and the sustainability of oil and gas supplies. Despite calls to cease the licensing or funding of new oil and gas projects, as well as halting the expansion of existing oil and gas reserves, which could undermine energy security and exacerbate market volatility, producing countries remain focused on efforts to provide long-term market stability by implementing pro-active and pre-emptive plans. It is also reflected in their credentials as reliable and responsible suppliers, and their actions and support for technological innovation, such as CCUS and DAC technologies and hydrogen, in order to advance low-emission development practices.

As such, different viewpoints are emerging with regard to various possible trajectories in moving towards a more sustainable common energy future. Subscribing to a dominant narrative for all nations is unhealthy, and hence the world should remain more open-minded about different possible solutions to the challenges faced. This is all the more poignant given the immense breadth and depth of these challenges, as well as the seemingly accelerating speed at which technology and innovation progresses.

To this end, this Chapter aims to examine alternative plausible energy pathways. This takes into account the need to urgently accelerate the transformation of energy systems in an orderly, equitable and inclusive manner that recognizes the importance of energy security, supports sustainable development and efforts to eradicate energy poverty, while also ensuring that both adequate finance and advanced technology are available, including in developing countries.

Specifically, this Chapter describes two alternative scenarios relative to this Outlook's Reference Case. First, an 'Advanced Technology' Scenario illustrates a technology-driven

means of limiting the global temperature increase to well below 2°C, while curbing the negative economic impact on developing economies, especially energy-exporting ones, and ensuring maximum energy security. Second, the 'Laissez-Faire' Scenario demonstrates how a more optimistic and more equitable outlook for developing economies and a pushback on current net zero policies and targets could result in higher long-term energy and oil demand.

The analysis in this Chapter serves to illustrate that alternative pathways exist and are feasible. In particular, the findings provide insights into how future energy demand and the energy mix are likely to be affected, but also estimates the adverse distributional impacts of response measures and the corresponding level of global emission reductions.

8.1 Alternative energy scenarios

This Outlook considers two alternative scenarios to the Reference Case described in detail in Chapters 1–7. Each scenario is based on a distinct set of assumptions in respect to economic development, adopted energy policies, investment priorities and the use of available technology options. The first shows a possible pathway to achieve emissions reduction consistent with the main goals of the Paris Agreement, in which both a higher share of renewable energy and technological options supporting the continued use of oil and gas supplement each other in a way that mitigates potential adverse impacts on the economies of energy exporting developing countries.

The second scenario highlights possible challenges inherent in the ongoing energy transition. It considers a possible situation where faster economic growth, especially in developing countries, combined with policies fostering development needs – including improved energy access and the further eradication of energy poverty, faster industrialization and urbanization – result in higher future energy requirements and with the continued use of oil and gas to facilitate this growth.

The results of these two scenarios, in terms of future energy demand, the energy mix, are compared with the Reference Case to highlight the major differences and assess potential socio-economic impacts.

The background, key elements and analysis of each scenario is presented below.

Advanced Technology Scenario

The Advanced Technology Scenario starts with the same basic socio-economic Reference Case assumptions on global population and economic development to 2045. However, it differs from the Reference Case through a much greater diffusion of CCUS, CCS and DAC technologies in industrial sectors, stronger investment in hydrogen supply networks, and the increasing adoption of a CCE framework across the global economy. These technologies and necessary adjustments in energy policies result in a global emissions reduction pathway that is consistent with the long-term goals of the Paris Agreement to limit the temperature rise to below 2°C.

Moreover, the advancement of CCS, DAC and other CDR technologies, with large-scale deployment of bioenergy with CCS in the second half of the century, enables a continued elevated use of hydrocarbons, with the exception of coal as demand for this energy source falls. Moreover, nuclear power plays a more significant role compared to the Reference Case.

Laissez-Faire Scenario

The Laissez-Faire Scenario assumes a faster return to higher economic growth during the medium-term and maintains this stronger growth in the long-term, especially for developing countries. As a result, Africa, India, and developing countries in Asia and Latin America see their economies expand faster compared to the Reference Case.

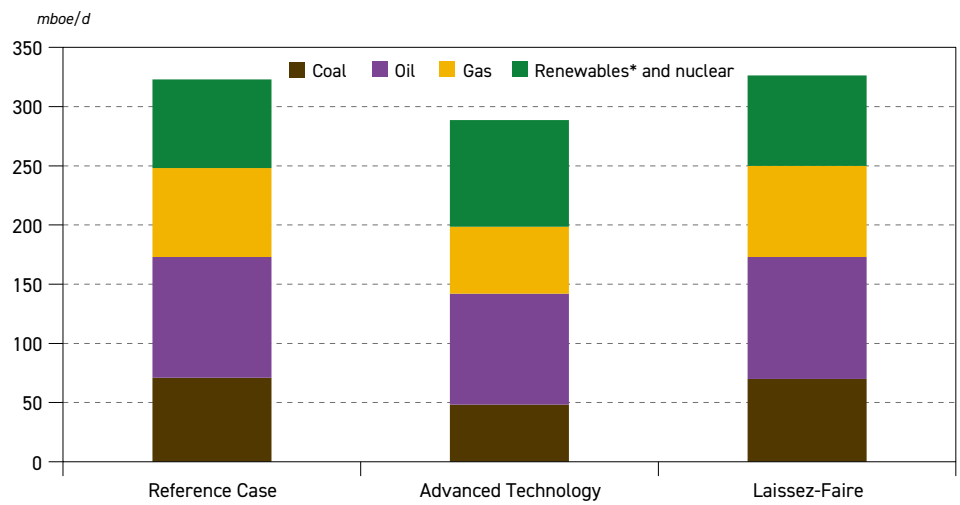
In turn, this leads to higher levels of industrialization and urbanization, which then results in a larger middle class and improved living conditions for many millions of people. Part of this change will be improved energy access in the least developed regions, the further eradication of energy poverty and a quicker transition to modern energy sources, including renewable energy, oil, gas and nuclear power, especially in the second part of the forecast period.

In this scenario, policies will tighten in the future, contributing to improved efficiencies and supporting the further expansion of renewables; however, in an isolated manner given the absence of a coordinated move to reduce future emissions. Moreover, protectionism and unilateralism will play a more important role in prioritizing local development needs over global issues.

8.2 Energy demand and the energy mix

The implications of the varying narratives for alternative scenarios on global primary energy demand are summarized in Figures 8.1 and 8.2 (for select years) and Figure 8.3 (for the period of 2020–2045).

Figure 8.1
Global primary energy demand in the Reference Case and in alternative scenarios, 2030

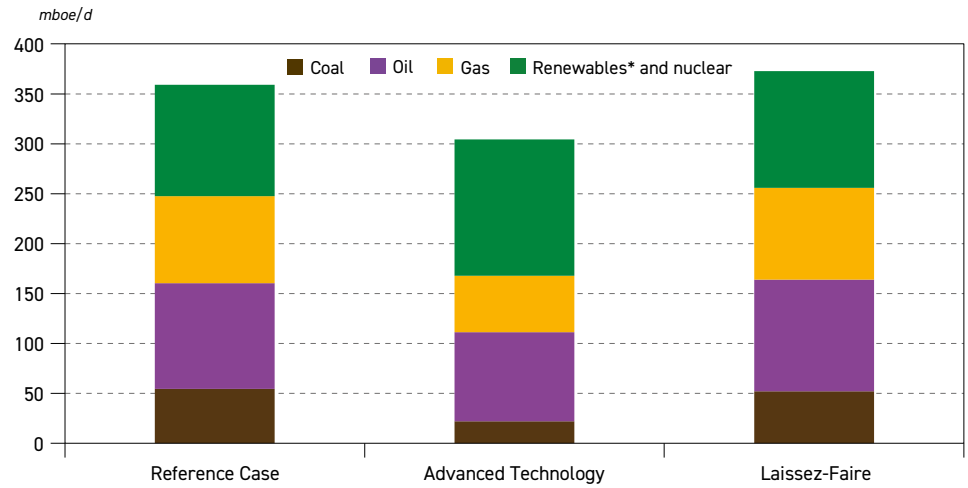


** Note: Renewables include hydro, biomass, wind, solar and geothermal energy.*

Source: OPEC.

Primary energy demand in the Advanced Technology Scenario is projected to decline by almost 3 mboe/d between 2022 and 2030 on the back of efficiency improvements in electricity generation, as growing demand for electricity is covered by renewables and nuclear. Moreover, coal, and partly gas, will be displaced by renewables which, combined

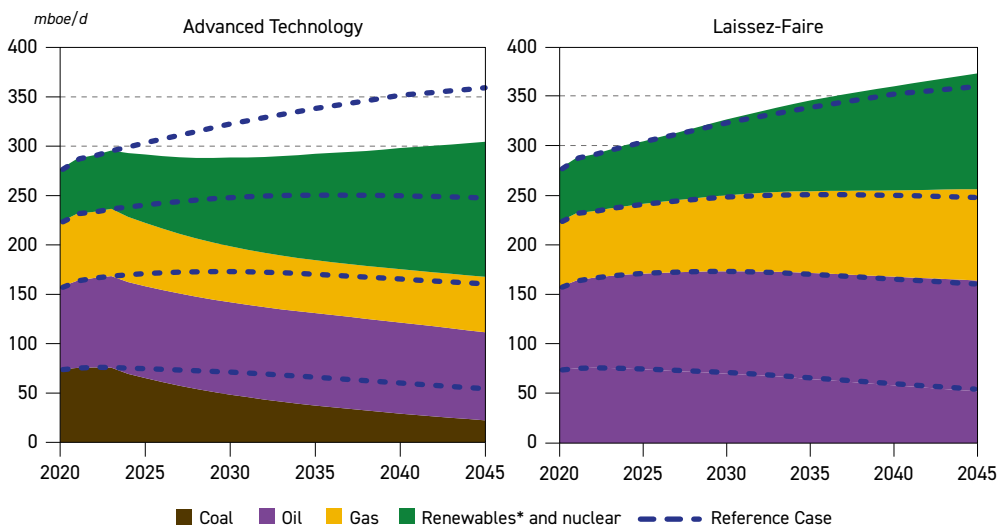
Figure 8.2
Global primary energy demand in the Reference Case and in alternative scenarios, 2045



** Note: Renewables include hydro, biomass, wind, solar and geothermal energy.*
Source: OPEC.

with improved efficiencies in other sectors, contributes to lower energy demand. Efficiency improvements and the faster penetration of EVs – compared to the Reference Case – will also partly affect oil demand. By 2030, energy demand in this scenario will be more than 34 mboe/d lower compared to the Reference Case. During the remainder of the forecast period, however, total energy demand is set to return to an upward trajectory as incremental demand requirements, mainly from developing countries, will more than offset further efficiency improvements.

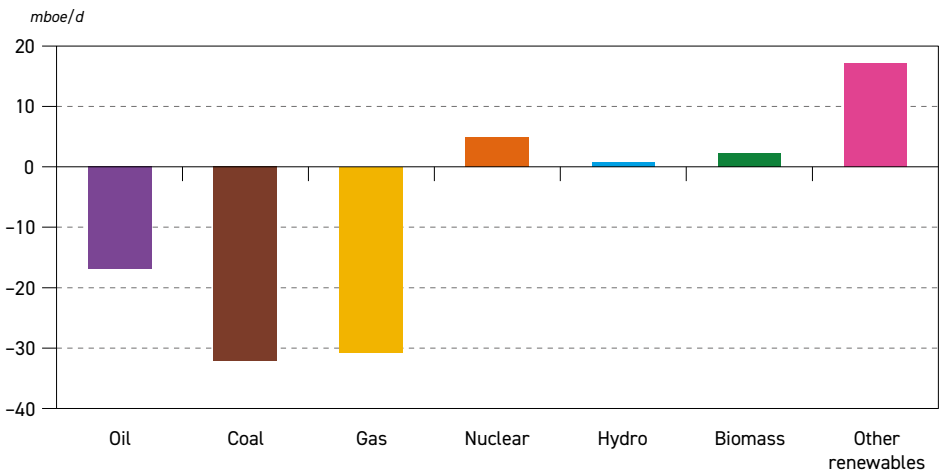
Figure 8.3
Global primary energy demand in the Reference Case and in alternative scenarios, 2020–2045



** Note: Renewables include hydro, biomass, wind, solar and geothermal energy.*
Source: OPEC.

Given the ambition to reduce emissions to levels consistent with the Paris Agreement, coal demand in this scenario is already reduced by almost 28 mboe/d over the current decade and by another 26 mboe/d by the end of the forecast period. The net effect is that coal demand in this scenario will be 32 mboe/d lower compared to the Reference Case (Figure 8.4).

Figure 8.4
Change in primary energy demand between the Advanced Technology Scenario and the Reference Case in 2045



Source: OPEC.

Gas demand will be mostly affected by substitution with renewable sources, electrification of the residential and industry sectors and energy efficiency improvements in major developed and developing countries, chiefly the US and China. Therefore, demand for natural gas declines by more than 10 mboe/d in the period to 2030, but will then stabilize at this lower level and even marginally increase over the last ten years of the forecast period supported by available CCS capacity.

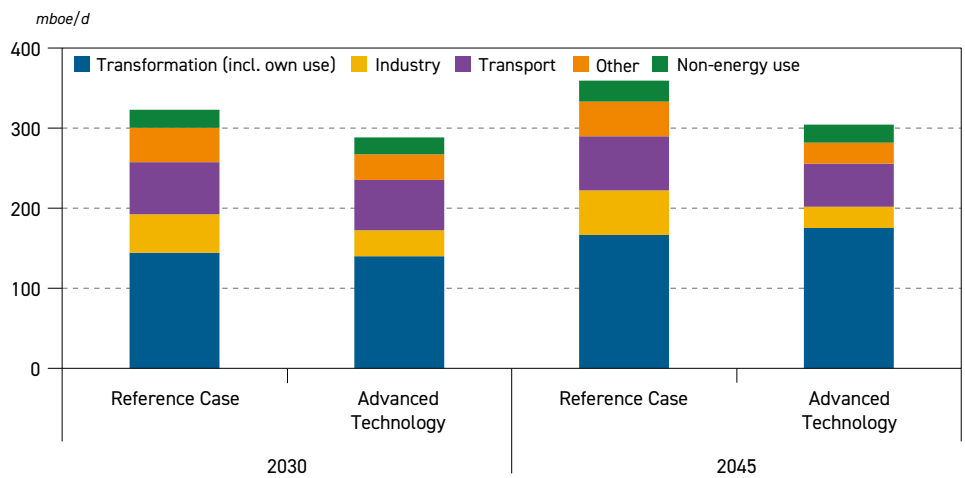
The corresponding change for oil demand will be lower. Emissions reductions achieved via substitution in the power sector combined with the extended use of CCS, and DAC at a later stage, will lessen the need for oil substitution in hard-to-abate sectors, especially the transportation and petrochemical sectors. Moreover, CCS technology will also allow the industrial use of oil and refinery operations will see significantly reduced emissions. Therefore, oil demand remains close to current levels for another two decades before it declines to around 89 mboe/d towards the end of the forecast period. It is worth noting that this future oil demand pattern is the result of the offsetting effects between growing demand in developing countries and declines in developed ones.

In contrast to oil, demand for renewable and nuclear energy extends its strong growth and is projected to reach almost 90 mboe/d in 2030 and close to 137 mboe/d by 2045. This is more than 25 mboe/d higher than the Reference Case level at the end of the forecast period.

The assumed policy setup and choice of technologies in the Advanced Technology Scenario has a substantial impact on sectoral energy demand too, as presented in Figure 8.5. In the

period to 2030, global energy demand in all major sectors is projected to decline. This decline in the sectors of final energy consumption is driven by electrification and the use of more efficient technologies across all sectors. The 'low hanging fruits' in this respect are in the industry and residential sectors where future energy demand is projected to decline most. The corresponding decline in the industry sector is in the range of 16 mboe/d compared to the Reference Case, followed by 'other' (including the residential sector), with a demand drop of around 11 mboe/d.

Figure 8.5
Global energy demand by sector in the Reference Case and Advanced Technology Scenario, 2030 and 2045



Source: OPEC.

The overall energy demand in the transformation sector is little different to that of the Reference Case. However, there will be a shift in the pattern of electricity generation, in particular, with renewable electricity replacing the inefficient use of coal, which allows for a comparable amount of electricity with a lower input of primary fuels.

The changes between the Reference Case and Advanced Technology Scenario are even more pronounced when moving towards 2045. At the global level, the difference in energy demand between these two scenarios is close to 55 mboe/d, of which 29 mboe/d is associated with energy savings in the industry sector on the back of the further penetration of energy efficient technologies, hydrogen use and increased recycling rates. Somewhat lower, but a still significant reduction in energy demand in the range of 17 mboe/d is projected for 'other' sectors, which includes the residential, commercial and agriculture sectors. This could be achieved by applying stricter building codes and widespread building insulation, more efficient lighting, heating and cooling systems and more efficient equipment and vehicles in the agriculture sector.

Moreover, the faster penetration of EVs in terms of road transportation, more efficient rail transportation and further improved efficiencies in other transport modes are projected to lower energy demand in the global transport sector by around 14 mboe/d, compared to the Reference Case. However, the demand reduction in these sectors is partly offset by higher

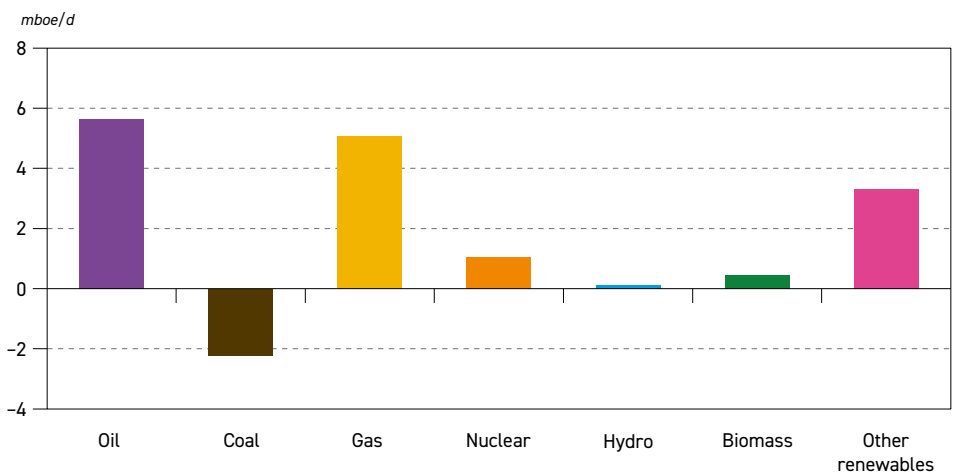
energy demand in the transformation sector by 2045, which is expected to be more than 8 mboe/d higher than in the Reference Case.

Driven by increasing demand for electricity, renewable energy sources continue to expand. Nonetheless, the potential displacement of coal from the power sector will largely be exploited by the end of the forecast period; hence, the effect of higher efficiency in electricity generation will be diminished. Moreover, the availability of CCUS technology enables a revival in gas demand during the last ten years of the forecast period, which helps to meet electricity demand without increasing CO_2 emissions.

The energy demand pattern in the Laissez-Faire Scenario is projected to move in a different direction. Global primary energy demand in this case is projected to continue growing over the forecast period, predominantly driven by faster economic development in developing countries. The underlying global GDP growth rates assumed in this scenario are not significantly different to the ones used in the Reference Case. Nevertheless, the cumulative effect of long-term annual growth rates that are higher on average by around 0.3% is sufficient to push global GDP levels in this scenario around $14 trillion higher compared to the Reference Case by 2045, with a large part of it taking place in developing countries.

Accordingly, as presented in Figures 8.6 and 8.7, global primary energy demand in the Laissez-Faire Scenario would be 13.4 mboe/d higher than in the Reference Case by 2045. This gradual emerging gap compared to the Reference Case would mainly be met by oil and gas, contributing an additional 5.5 mboe/d and 5.1 mboe/d, respectively, to expanding energy needs in developing countries.

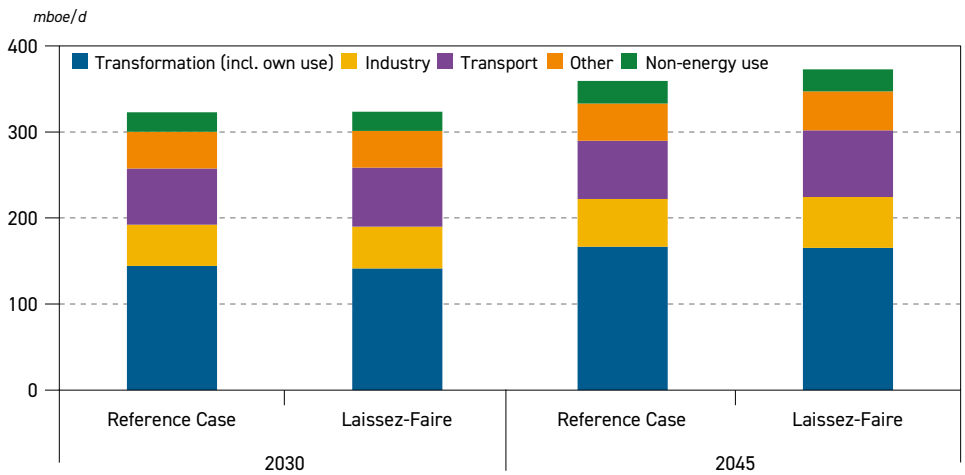
Figure 8.6
Change in the primary energy demand between the Laissez-Faire Scenario and the Reference Case in 2045



Source: OPEC.

While oil and gas continue to grow in this scenario, solar and wind have by far the fastest demand growth, increasing by almost 38 mboe/d between 2022 and 2045. This is more than 3 mboe/d higher than Reference Case projections. Adding incremental demand for nuclear, hydro and bioenergy pushes up overall demand growth for these forms of energy by almost 60 mboe/d over the forecast period.

Figure 8.7
Global primary energy demand by sector in the Reference Case and Laissez-Faire Scenario, 2030 and 2045



Source: OPEC.

Similar to the Reference Case, coal demand is projected to decline in the Laissez-Faire Scenario. The overall coal demand decline is projected in the range of 24 mboe/d between 2022 and 2045, which is around 2.2 mboe/d more than in the Reference Case.

As discussed earlier, the Advanced Technology Scenario sees a reduction in global energy demand, particularly from hydrocarbons, compared to the Reference Case. There are two main reasons for this. First, this scenario assumes a faster penetration of technologies with better energy efficiency across all consumption sectors, such as more efficient transportation, heat pumps for more efficient heating and cooling, building insulation, efficient appliances and lighting, among others. As a result, energy demand declines, reflecting the assumed rate of penetration of these technologies.

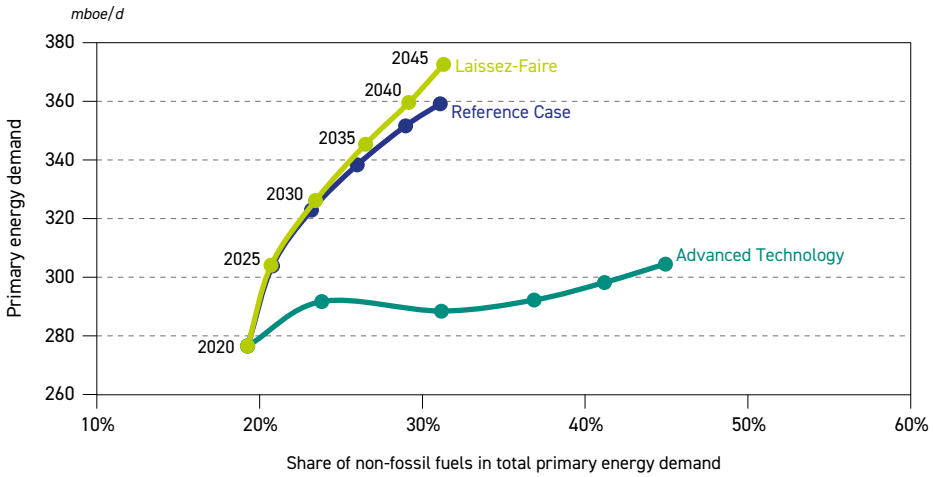
The second reason relates to a higher share of renewable electricity in the energy mix where transformation/energy losses are much lower compared to electricity produced from hydrocarbons. Therefore, primary energy demand falls despite the fact that final energy consumption available to consumers might be comparable.

The dynamics of this link between the level of primary energy demand and the share of non-fossil energy types in the energy mix of specific scenarios is captured in Figure 8.8. It shows that the Advanced Technology and Laissez-Faire Scenarios, as well as the Reference Case, evolve in a different way and represent fundamentally different energy systems at the end of the forecast period.

The share of non-fossil fuels in the Advanced Technology Scenario is projected to gradually grow to around 45% by 2045. This share, in combination with the use of CCUS in this scenario, would be sufficient to achieve the required emissions reduction. Moreover, a larger contribution of natural gas together with a lower reduction of coal demand compared to other scenarios focusing on a higher share of renewable energy sources, will allow for a larger electricity baseload. Therefore, the intermittency issue, electricity storage and investments

to shift to a higher degree of electrification (e.g. in the road transport, residential and industry sector) is expected to be less of a problem in the Advanced Technology Scenario.

Figure 8.8
Global energy system in the Reference Case and in alternative scenarios, 2020–2045



Source: OPEC.

Obviously, these features are also inherently present in the Reference Case and Laissez-Faire Scenario as they also gradually incorporate a higher share of renewables and nuclear energy. Combined, in the Laissez-Faire Scenario, this grows from around 20% in 2020, to 23% in 2030 and then to more than 31% in 2045. However, energy demand in these scenarios continues growing as other factors outweigh the impact of efficiency improvements and the rising share of renewables. A visible way to demonstrate this is the declining energy intensity clearly present in both scenarios, as well as in the Reference Case.

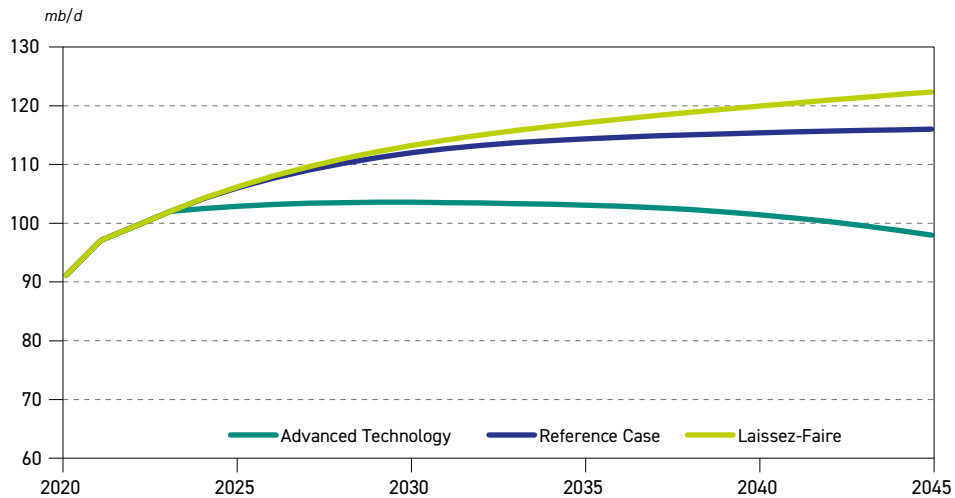
8.3 Oil demand

Figure 8.9 translates projections previously presented in terms of energy content into a volumetric basis for readers familiar with the barrel per day unit. In this case, oil demand typically also includes other liquids blended with refined products, such as biofuels, GTLs and CTLs. Therefore, these figures are not directly comparable with those mentioned in the previous part of this Chapter as both units and coverage differ.

Oil demand in the Advanced Technology Scenario is affected by policies aimed at emissions reduction. In this scenario, lower energy-related emissions are achieved by a combination of a higher contribution of renewable energy to the future energy mix and by the expanded use of hydrogen, CCUS, DAC and a CCE framework. The introduction of these technologies allows for a smoother transition to a lower-emission system in which oil demand is less adversely affected compared to other scenarios focusing on renewables only.

As a result, oil demand in the Advanced Technology Scenario remains consistently below the levels projected in the Reference Case. However, it does not drop precipitously to much lower

Figure 8.9
Global oil demand in the Reference Case and in alternative scenarios, 2022–2045



Source: OPEC.

levels as the technology setup either directly supports the continued use of oil, or lowers the pressure for its reduction by achieving required emission reductions in a more cost-effective way in other sectors.

Therefore, global oil demand stabilizes at levels above 100 mb/d in the period to 2035 and then starts slowly declining towards 98 mb/d over the last ten years of the forecast period. Nevertheless, this represents a demand decline of more than 18 mb/d compared to the Reference Case in 2045.

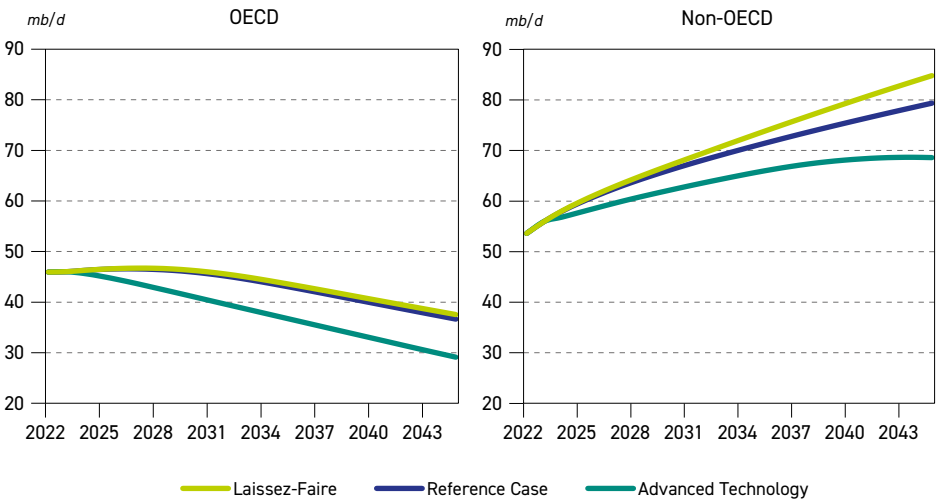
Turning to the Laissez-Faire Scenario, oil demand in this case is projected to move consistently above Reference Case levels. The two main reasons for this demand pattern are stronger economic growth, mainly in developing countries, and the absence of coordinated efforts to have stricter policy measures targeting emissions reduction.

Faster economic growth in non-OECD countries helps to create a larger middle class, as well as higher urbanization and industrialization. This provides governments with more resources to expand the infrastructure required to improve access to electricity and enable the use of modern energy sources. As part of this trend, as presented in Figure 8.10, oil demand in these countries grows to almost 85 mb/d in 2045, which is 5.4 mb/d higher compared to the Reference Case.

The Laissez-Faire Scenario also assumes stronger economic growth in OECD countries. In this case, however, part of the potentially higher oil demand is offset by additional policy measures, the faster penetration of more efficient technology and even faster growth in renewable energy (compared to the Reference Case) that will further displace coal demand and limit oil and gas demand growth.

Therefore, the overall change in OECD oil demand is less than 1 mb/d by 2045, compared to the Reference Case. The net effect will be that oil demand in the Laissez-Faire Scenario passes

Figure 8.10
OECD and non-OECD oil demand by scenario, 2022–2045



Source: OPEC.

the 113 mb/d mark by 2030 and continues growing towards 123 mb/d in 2045. Compared to the Reference Case, this represents a difference of more than 1 mb/d in 2030, which then expands to 6.3 mb/d in 2045.

Figure 8.10 shows that developments in the Advanced Technology Scenario will unequally impact regional oil demand. In the OECD case, the faster penetration of EVs combined with efficiency improvements in the industry and residential sectors pushes oil demand consistently to lower levels, with a difference to the Reference Case of almost 5 mb/d in 2030 and 7.5 mb/d in 2045. At the same time, non-OECD oil demand is relatively less affected in the period to around 2035, as more time will be needed for technology transfer to developing countries.

Moreover, large emission reductions over this period will be achieved by the expansion of renewables, with coal and gas substitution. This, however, will change over the last ten years of the forecast period when EVs and more efficient technologies penetrate non-OECD markets too. As a result, non-OECD oil demand under this scenario stabilizes at a level above 68 mb/d towards the end of the forecast period. It then slowly departs from the trends outlined in the Reference Case with the demand gap widening to almost 11 mb/d in 2045.

The two scenarios described in this chapter make evident that feasible alternatives to this Outlook's Reference case exist, and would have a significant bearing on future oil demand and the overall energy mix. They also show that there are alternative pathways to reduce future emissions in a sustainable way that minimize adverse economic effects. Therefore, it is important that all viable mitigation options, technological innovations, improved energy efficiency measures and enhanced investment for universal, reliable and affordable energy access, are part of future solutions. Moreover, innovative solutions could lead to the creation of new jobs and new value-added potential, reducing the adverse impacts of climate mitigation response measures.

A global challenge such as climate change requires a global response, and a coherent approach is needed to set the world on a sustainable, more resilient, equitable and fair

pathway. Therefore, it is necessary to promote partnerships and cooperative initiatives to invest in technology and innovation that could enable inclusive and just solutions.

Indeed, cooperation is considered critical for the implementation of stringent environmental policies that aim to catalyze energy transitions. An important role is given to international cooperation that enhances collective climate mitigation action and stimulate rapid change in energy systems, while recognizing that sustainable development and just transitions remain priorities for developing countries. An enhanced provision of means of implementation for developing countries could play an important role in making socio-economic conditions more favourable to ambitious mitigation efforts.

To this end, sustainable energy transitions should be socially equitable and just. Shifting development pathways to increase sustainability is a shared aspiration. Yet the appropriate set of policies depends on national circumstances and capacities – as reflected in the core principles of the UNFCCC. Since countries differ in starting points and history, and have different needs and capabilities in terms of facilitating the economic, social and environmental dimensions of sustainable development, Thus, countries have different priorities.

Finally, approaches that address emissions within the energy sector provide an opportunity for the industry to contribute to the Paris Agreement. One prominent approach is the CCE, which targets emissions avoidance, abatement, and removal. The CCE provides for a wide range of technologies that form a closed-loop system for managing emissions, and at the same time, enable economic growth. This approach is being adopted by a number of oil producing countries. In addition, technological innovation, especially in technologies related to emissions abatement (e.g. CCUS) and emissions removal (e.g. DAC), must be part of the solution.

Annex A
Abbreviations

AHP	African Hydrogen Partnership
AI	Artifical Intelligence
AR6	(Sixth) assessment report
bcm	Billion cubic metres
BEV	Battery electric vehicle
BIL	Bipartisan Infrastructure Law
BoJ	Bank of Japan
BRICS	Brazil, Russia, India, China and South Africa
bt	Billion tonnes
BTC	Baku-Tbilisi-Ceyhan
CAFE	Corporate Average Fuel Economy
CBAM	Carbon Border Adjustment Mechanism
CCE	Circular Carbon Economy
CCUS	Carbon capture, utilization and storage
CDR	Carbon dioxide removal
CFCs	Carbon fibre re-enforced composites
CGD	City Gas Distribution
CII	Carbon Intensity Indicator
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
COTC	Crude-oil-to-chemicals
CPC	Caspian Pipeline Consortium
CPS	Carbon Price Support
CTLs	Coal-to-liquids
DAC	Direct air capture
DoC	Declaration of Cooperation
DoE	Department of Energy (US)
EEXI	Energy Efficiency Existing Ship Index
EIS	Environmental Impact Statement
ESG	Environmental, social and governance
ETBE	Ethyl tertiary butyl ether
ETS	Emissions Trading System
EU	European Union
EVs	Electric vehicles
FCC	Fluid catalytic cracking
FCEVs	Fuel cell electric vehicles
FPSO	Floating production storage and offloading vessel
FYP	Five-Year-Plan
GDP	Gross domestic product
GGA	Global goal on adaptation
GHG	Greenhouse gas
Gt	Gigatonnes
GTLs	Gas-to-liquids

GW	Gigawatt
HEE	Hygienic earth energy
HEV	Hybrid electric vehicle
HLDE	High-Level Dialogue on Energy
HLPF	High-Level Political Forum
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICEs	Internal combustion engines
IIF	Institute of International Finance
ILBI	International Legally Binding Instrument
IMO	International Maritime Organization
IPPC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
IRENA	International Renewable Energy Agency
km	Kilometre
KMZ	Ku-Maloob-Zaap
LDCs	Least developed countries
LNG	Liquefied natural gas
LOOP	Louisiana Offoshore Oil Port
LPG	Liquefied petroleum gas
LTAG	Long-Term Aspirational Goal
LT-LEDS	Long-Term Low Emission Development Strategies
mb/d	Million barrels per day
mboe/d	Million barrels of oil equivalent per day
Mbtu	Million British thermal units
METI	Ministry of Economy, Trade and Industry
mpg	Miles per gallon
mt/y	Million tonnes per year
MTBE	Methyl tertiary butyl ether
MWP	Mitigation Work Programme
NCQG	New Collective Qualified Goal
NDCs	Nationally determined contributions
NEP	National Electricity Plan
NGLs	Natural gas liquids
NGVs	Natural gas vehicles
NOCs	National Oil Companies
NWE	Northwest Europe
OECD	Organisation for Economic Co-operation and Development
p.a.	Per annum
PHEV	Plug-in hybrid electric vehicle
POX	Partial oxidation

pp	Percentage point
PPP	Purchasing power parity
PV	Photovoltaic
RCS	Regional Connectivity Scheme
RSPP	Russian Union of Industrialists and Entrepreneurs
RPKs	Revenue passenger-kilometres
SAF	Sustainable aviation fuel
SB58	Subsidiary Bodies
SDGs	Sustainable Development Goals
SNR	Steam naphtha reforming
SPOT	Sea Port Oil Terminal
SUVs	Sport utility vehicles
SYR	Synthesis Report
tb/d	Thousand barrels per day
TTF	Title transfer facility
TWh	Terawatt hour
UK	United Kingdom
ULS	Ultra-low sulphur
UN	United Nations
UNDESA	UN Department of Economic and Social Affairs
UNFCCC	UN Framework Convention on Climate Change
UNGA	UN General Assembly
US	United States
VGO	Vacuum gasoil
VLCCs	Very large crude carriers
VLSFO	Very low sulphur fuel oil
VMT	Vehicle miles travelled
WOO	World Oil Outlook (OPEC)
y-o-y	Year-on-year

Annex B
OPEC World Energy: regional definitions

OECD

OECD Americas
Canada
Chile
Colombia
Costa Rica
Guam
Mexico
Puerto Rico
United States of America
United States Virgin Islands

OECD Europe
Austria
Belgium
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Latvia
Lithuania
Luxembourg
Netherlands
Norway
Poland
Portugal
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingdom

OECD Asia-Pacific
Australia
Japan
New Zealand
OECD Asia Oceania, Other
Republic of Korea

NON-OECD COUNTRIES

Latin America
Anguilla
Antigua and Barbuda
Argentina
Aruba
Bahamas
Barbados
Belize
Bermuda
Bolivia (Plurinational State of)
Brazil
British Virgin Islands
Cayman Islands
Cuba
Dominica
Dominican Republic
Ecuador
El Salvador
French Guiana
Grenada
Guadaloupe
Guatemala
Guyana
Haiti
Honduras
Jamaica
Martinique
Montserrat
Netherlands Antilles
Nicaragua
Panama
Paraguay
Peru
St. Kitts and Nevis
St. Lucia
St. Pierre et Miquelon
St. Vincent and the Grenadines
Suriname
Trinidad and Tobago
Turks and Caicos Islands
Uruguay

Middle East & Africa

Bahrain
Benin
Botswana
Burkina Faso
Burundi
Cameroon
Cape Verde
Central African Republic
Chad
Comoros
Côte d'Ivoire
Democratic Republic of the Congo
Djibouti
Egypt
Eritrea
Ethiopia
Gambia
Ghana
Guinea
Guinea-Bissau
Jordan
Kenya
Lebanon
Lesotho
Liberia
Madagascar
Malawi
Mali
Mauritania
Mauritius
Mayotte
Morocco
Mozambique
Namibia
Niger
Oman
Qatar
Réunion
Rwanda
Sao Tome and Principe
Senegal
Seychelles
Sierra Leone
Somalia
South Africa
South Sudan
Sudan
Eswatini
Syrian Arab Republic
Togo
Tunisia
Uganda
United Republic of Tanzania
Western Sahara
Yemen
Zambia
Zimbabwe

India

India

China

People's Republic of China

Other Asia

Afghanistan
American Samoa
Bangladesh
Bhutan
Brunei Darussalam
Cambodia
China, Hong Kong SAR
China, Macao SAR
Cook Islands
Democratic People's Republic of Korea
Fiji
French Polynesia
Indonesia
Kiribati
Lao People's Democratic Republic
Malaysia
Maldives
Micronesia (Federated States of)
Mongolia
Myanmar
Nauru
Nepal
New Caledonia
Niue
Pakistan
Papua New Guinea
Philippines
Samoa
Singapore
Solomon Islands
Sri Lanka

Thailand
Timor-Leste
Tonga
Vanuatu
Viet Nam

OPEC
Algeria
Angola
Republic of Congo
Equatorial Guinea
Gabon
IR Iran
Iraq
Kuwait
Libya
Nigeria
Saudi Arabia
United Arab Emirates
Venezuela

EURASIA

Russia
Russian Federation

Other Eurasia
Albania
Armenia
Azerbaijan
Belarus
Bosnia and Herzegovina
Bulgaria
Croatia
Cyprus
Georgia
Gibraltar
Kazakhstan
Kyrgyzstan
Malta
Montenegro
Republic of Moldova
Romania
Serbia
Tajikistan
Republic of North Macedonia
Turkmenistan
Ukraine
UzbekistanRepublic of North Macedonia
Turkmenistan
Ukraine
Uzbekistan

Note: For Chapter 3 'Oil demand', the OPEC region countries are distributed into their respective geographical regions.

Annex C
World Oil Refining Logistics and Demand: regional definitions

US & CANADA

Canada
United States of America

LATIN AMERICA

Greater Caribbean

Anguilla
Antigua and Barbuda
Aruba
Bahamas
Barbados
Belize
Bermuda
British Virgin Islands
Cayman Islands
Colombia
Costa Rica
Cuba
Dominica
Dominican Republic
Ecuador
El Salvador
French Guiana
Grenada
Guadeloupe
Guatemala
Guyana
Haiti
Honduras
Jamaica
Martinique
Montserrat
Netherlands Antilles
Nicaragua
Panama
Puerto Rico
St. Kitts & Nevis
St. Lucia
St. Pierre et Miquelon
St. Vincent and The Grenadines
Suriname
Trinidad and Tobago
Turks And Caicos Islands
United States Virgin Islands
Venezuela, Bolivarian Republic of

Mexico

Mexico

Rest of South America

Argentina
Bolivia (Plurinational State of)
Brazil
Chile
Paraguay
Peru
Uruguay

AFRICA

North Africa/Easter Mediterranean

Algeria
Egypt
Lebanon
Libya
Mediterranean, Other
Morocco
Syrian Arab Republic
Tunisia

West Africa

Angola
Benin
Cameroon
Republic of Congo
Côte d'Ivoire
Democratic Republic of Congo
Equatorial Guinea
Gabon
Ghana
Guinea
Guinea-Bissau
Liberia
Mali
Mauritania
Niger
Nigeria
Senegal
Sierra Leone
Togo

East/South Africa
Botswana
Burkina Faso
Burundi
Cape Verde
Central African Republic
Chad
Comoros
Djibouti
Ethiopia
Eritrea
Gambia
Kenya
Lesotho
Madagascar
Malawi
Mauritius
Mayotte
Mozambique
Namibia
Réunion
Rwanda
Sao Tome and Principe
Seychelles
Somalia
South Africa
South Sudan
Sudan
Swatini
Uganda
United Republic of Tanzania
Western Sahara
Zambia
Zimbabwe

EUROPE

North Europe
Austria
Belgium
Denmark
Finland
Germany
Iceland
Ireland
Luxembourg
Netherlands
Norway
Sweden
Switzerland
United Kingdom

South Europe
Cyprus
France
Gibraltar
Greece
Italy
Malta
Portugal
Spain
Turkey

Eastern Europe
Albania
Belarus
Bosnia and Herzegovina
Bulgaria
Croatia
Czech Republic
Estonia
Hungary
Latvia
Lithuania
Montenegro
Poland
Republic of Moldova
Romania
Serbia
Slovakia
Slovenia
Republic of North Macedonia
Ukraine

RUSSIA & CASPIAN

Caspian Region
Armenia
Azerbaijan
Georgia
Kazakhstan
Kyrgyzstan

Tajikistan
Turkmenistan
Uzbekistan

Russia
Russian Federation

MIDDLE EAST

Bahrain
IR Iran
Iraq
Jordan
Kuwait
Oman
Qatar
Saudi Arabia
United Arab Emirates
Yemen

ASIA-PACIFIC

Pacific Industrialized
Australia
Japan
New Zealand

Pacific High Growth
Brunei Darussalam
Indonesia
Malaysia
Philippines
Republic of Korea
Singapore
Thailand

China
People's Republic of China

Rest of Asia
Afghanistan
American Samoa
Bangladesh
Bhutan
Cambodia
Cook Islands
Fiji
French Polynesia
Guam
India
Democratic People's Republic of Korea
Kiribati
Lao People's Democratic Republic
Maldives
Micronesia, Federated States of
Mongolia
Myanmar
Nauru
Nepal
New Caledonia
Niue
Pakistan
Papua New Guinea
Samoa
Solomon Islands
Sri Lanka
Timor-Leste
Tonga
Vanuatu
Viet Nam

Annex D
Major data sources

Airbus
American Chemical Society (ACS)
American Petroleum Institute (API)
Argus Media
Asia-Pacific Economic Cooperation (APEC)
Baker Hughes
Barclays Research
Bloomberg
Boeing
BP Statistical Review of World Energy
Brazil, Ministry of Mines and Energy
Brookings Institute
Bunkerworld
Canada, National Energy Board
Canadian Association of Petroleum Producers
Canadian Energy Research Institute
Center for Strategic and International Studies (CSIS)
China National Petroleum Corporation (CNPC)
Citigroup
Climate Action Tracker
Consensus forecasts
Deloitte
Deutsche Bank
E&P Magazine
The Economist
Economist Intelligence Unit
Energy Research Institute of the Russian Academy of Sciences (ERI RAS)
Energy Intelligence Group
EnSys Energy & Systems, Inc
Ernst & Young
EUREL
European Automotive Manufacturers Association (ACEA)
European Commission
European Council
European Environment Agency
Eurostat
Evaluate Energy
Gas Exporting Countries Forum (GECF)
Global Carbon Capture and Storage Institute (GCCSI)
Global Commission on the Economy and Climate
Global Wind Energy Council
Goldman Sachs
GSMA Intelligence
Haver Analytics
HSBC
Hydrocarbon Processing
International Commodities Exchange
IEA Monthly Oil Data Service (MODS)
IEA Oil Market Report
IEA World Energy Outlook

IHS Markit
Institute for Essential Services Reform (IESR)
IMF, Direction of Trade Statistics
IMF, International Financial Statistics
IMF, Primary Commodity Prices
IMF, World Economic Outlook
India, Ministry of Petroleum & Natural Gas
Institute of Energy Economics, Japan (IEEJ)
Institut Français du Pétrole (IFP)
Interfax Global Energy
Intergovernmental Panel on Climate Change (IPCC)
International Air Transport Association (IATA)
International Association for Energy Economics (IAEE)
International Atomic Energy Agency (IAEA)
International Civil Aviation Organization (ICAO)
International Council on Clean Transportation (ICCT)
International Maritime Organization (IMO)
International Monetary Fund (IMF)
International Renewable Energy Agency (IRENA)
International Road Federation, World Road Statistics
International Union of Railways (UIC)
Japan, Ministry of Economy, Trade and Industry (METI)
Japan Automobile Manufacturers Association, Inc (JAMA)
Joint Aviation Authority (JAA)
Joint Organisations Data Initiative (JODI)
Journal of Petroleum Technology
Kennedy School of Government, Harvard University
McKinsey Global Institute
National Development and Reform Commission (NDRC)
National Energy Administration of the People's Republic of China (NEA)
National Renewable Energy Laboratory
Natural Gas World Magazine
New York Mercantile Exchange
OECD Trade by Commodities
OECD/IEA, Energy Balances of non-OECD countries
OECD/IEA, Energy Balances of OECD countries
OECD/IEA, Energy Statistics of non-OECD countries
OECD/IEA, Energy Statistics of OECD countries
OECD/IEA, Quarterly Energy Prices & Taxes
OECD, International Trade by Commodities Statistics
OECD International Transport Forum, Key Transport Statistics
OECD, National Accounts of OECD Countries
OECD Economic Outlook
Oil & Gas Journal
OPEC Annual Statistical Bulletin (ASB)
OPEC Fund for International Development (OFID)
OPEC Monthly Oil Market Report (MOMR)
OPEC World Oil Outlook (WOO)
Oxford Economics
Oxford Institute for Energy Studies

Petroleum Economist
Petroleum Intelligence Weekly
Platts
PricewaterhouseCoopers
Rystad Energy
Seatrade
Smart Energy International
Society of Petroleum Engineers (SPE)
Solomon Associates
Stratas Advisors
Sustainable Energy for All
Turner Mason and Company
UN Department of Economic and Social Affairs
UN Energy Statistics
UN Food and Agriculture Organization (FAO)
UN International Trade Statistics Yearbook
UN National Account Statistics
UN Conference on Trade and Development (UNCTAD)
UN Development Programme (UNDP)
UN Economic and Social Commission for Asia and the Pacific (UNESCAP)
UN Educational, Scientific and Cultural Organization (UNESCO)
UN Environment Programme (UNEP)
UN Framework Convention on Climate Change (UNFCCC)
UN International Labour Organisation (ILO)
UN Statistical Yearbook
UN World Tourism Organization (UNWTO)
US Bureau of Labor Statistics
US Department of Energy (DoE)
US Department of the Interior (DoI)
US Energy Information Administration (EIA)
US Environmental Protection Agency (EPA)
US Geological Survey (USGS)
Wood Mackenzie
World Bank
World Coal Association
World Coal Institute
World Energy Council
World Economic Forum
World Nuclear Association
World Resources Institute
World Trade Organization (WTO), International Trade Statistics

Organization of the Petroleum Exporting Countries
Helferstorferstrasse 17
A-1010 Vienna, Austria
www.opec.org
ISBN 978-3-9504890-6-4

www.opec.org

ISBN 978-3-9504890-6-4