Organization of the Petroleum Exporting Countries

2022 World Oil Outlook 2045

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Acknowledgements

Secretary General, Chairman of the Editorial Board
Haitham Al Ghais

Director, Research Division, Editor-in-Chief
Ayed S. Al-Qahtani

Head, Energy Studies Department, Editor
Abderrezak Benyoucef

Main contributors
Chapter 1: Key assumptions
Mohammad AlKazimi, Joerg Spitzy, Jan Ban, Eleni Kaditi, Hans-Peter Messmer, Masudbek Narzibekov, Boris Kudashev, Daniel McKirdy

Chapter 2: Energy demand
Haris Aliefendic, Jan Ban, Reem AlNaeimi, Mohammed Attaba

Chapter 3: Oil demand
Jan Ban, Hans-Peter Messmer, Mohammed Attaba, Christian Diendorfer

Chapter 4: Liquids supply
Julius Walker, Mohammad AlKazimi

Chapter 5: Refining outlook
Haris Aliefendic, Mohammed Attaba

Chapter 6: Oil movements
Haris Aliefendic

Chapter 7: Energy policy, climate change and sustainable development
Julius Walker, Eleni Kaditi, Daniel McKirdy, Boris Kudashev, Irene Etiobhio, Mohammed Attaba, Christian Diendorfer

Chapter 8: Energy scenarios
Jan Ban, Julius Walker, Eleni Kaditi

Other contributors
Behrooz Baikalizadeh, Mohammad Zarie Zare, Mhammed Mouraia, Mohamed Sarrab, Tona Ndamba, Yacine Sariahmed, Asmaa Yaseen, Ali Dehghan, Nadir Guerer, Aziz Yahyai, Pantelis Christodoulides, Douglas Linton, Hannes Eichner, Roland Kammerer, Viveca Hameder, Klaus Stoeger, Mohammad Sattar, Zairul Arifin, Mihni Mihnev, Justinas Pelenis, Mansoureh Ghodsi

Editorial Team
James Griffin

Design & Production Team
Carola Bayer, Andrea Birnbach

Editorial Support
Daniel McKirdy, Sonja Soliman, Dorit Aschauer

OPEC's Economic Commission Board (as of September 2022)
Samir Madani, Ntika Mbiya Ricardo, Antimo Asumu Obama Asangono, Fernand Epigat, Afshin Javan, Mohammed Saadoon Mohsin, Abdullah Al Sabah, Abdulnasser Lamin Mohamed Gnedi, Mele Kyari, Yousef Al Salem, Salem Hareb Al Mehairi, Ronny Rafael Romero Rodriguez

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Foreword

The world of energy has witnessed a significant shift in focus since the publication of last year's World Oil Outlook (WOO) in October 2021. Back then, policymakers were gearing up for COP26 in Glasgow, Scotland. It was a time when the narrative around the energy transition appeared to be focused on the question: are you for, or against fossil fuels?

To OPEC, this question offered a false dichotomy. It limited what options were available, placed some energy sources on the sidelines and looked to be focused on a single 'one size fits all' strategy.

At the COP, while recognizing the urgent need to reduce emissions, we stated that the prevailing view that the energy transition is a linear trajectory from oil and other fossil fuels to renewables was misleading and potentially dangerous to a world that will continue to be thirsty for all energy sources.

The importance of utilizing all energy sources has been a central theme of all OPEC's WOOs, including this year's 16^{th} edition. It is crucial we appreciate just what each energy source can provide, as we look to answer the questions related to energy affordability, energy security, and the need to reduce emissions.

Over the past year, it is evident that we have witnessed more of these questions being asked, on the back of challenges related to the recovery from COVID-19, geopolitical tensions, the lack of investments and the continuing scourge of energy poverty. This has been a positive development. Maintaining this renewed focus will be vital in the years and decades ahead.

To place expected future energy demand in some context, the WOO sees the need to annually add on average 2.7 million barrels of oil equivalent a day in the period to 2045. This requires huge investments.

Moreover, for the oil industry alone we also need to add 5 million barrels of oil a day (mb/d) every year to just maintain current production at around 100 mb/d, given an average annual industry decline rate of around 5%.

The overall investment number for the oil sector is $12.1 trillion out to 2045. However, chronic underinvestment into the global oil industry in recent years, due to industry downturns, the COVID-19 pandemic, as well as policies centered on ending financing in fossil fuel projects, is a major cause of concern.

OPEC Member Countries remain committed to investments to ensure oil supply meets demand and to further decarbonize the industry. They are also making significant investments in other energies, such as renewables, nuclear, gas and hydrogen. We believe that an all-options, all-solutions and all-technologies must be utilized.

OPEC and its partners in the Declaration of Cooperation (DoC) are fully committed to helping ensure the oil industry has a sustainable and stable environment that enables investments to be made. This can be viewed in its actions over the past year in terms of reinstating production adjustments, and I have no doubt the multilateral approach of the DoC will continue to be beneficial in the years ahead.

However, no one entity can act alone. The investment challenge requires all industry stakeholders to work together to ensure a long-term investment-friendly climate, with sufficient finance available. One that is sustainable and works for both producers and consumers, and developed and developing countries.

I would like to put on record my thanks to the role of my predecessor, the late Mohammad Sanusi Barkindo, in evolving the publication during his time at the helm. I know we can further build on what has been established, particularly with the excellent team we have at the Secretariat.

I would like to also thank each and every staff member that has been involved in putting together this year's WOO. It is a great achievement and we should all be proud of their dedication and commitment.

For the readers, I hope this provides you with a better understanding of OPEC and the possible energy futures we all may face. We welcome your feedback.

Haitham Al Ghais
Secretary General

Executive Summary

Non-OECD countries to boost global population to 9.5 billion people by 2045

The global population is set to increase by 1.6 billion between 2021 and 2045, from 7.9 billion to 9.5 billion. Population growth in the non-OECD region accounts for over 96% of the expected total increase, with the OECD accounting for under 4%. The global working-age population (aged between 15 and 64) is anticipated to expand by 870 million throughout the projection period. Overall, the relative share of the global working age population is set to fall slightly, from 65% in 2021 to 63% in 2045. Urbanization is forecast to expand further in the coming decades, with 66% of the world's population projected to live in cities by 2045.

Global GDP is set to increase by 3% p.a. on average over the period 2021–2045

The medium-term economic growth dynamic will be influenced by the outcome of the COVID-19 pandemic, the inflationary trend in connection with financial tightening, and the consequences of the Russia-Ukraine conflict. Towards the end of the medium-term period, Gross Domestic Product (GDP) growth will settle at 3.1%. Within the OECD, economic growth is forecast to average 1.7% per annum (p.a.) for the period 2021–2045. Global growth through to 2045, estimated at 3% p.a. on average, will be largely driven by non-OECD countries. These countries are expected to expand by 3.8% p.a., primarily through improving labour productivity and a growing working age population.

Annual real GDP growth rates *% p.a.*

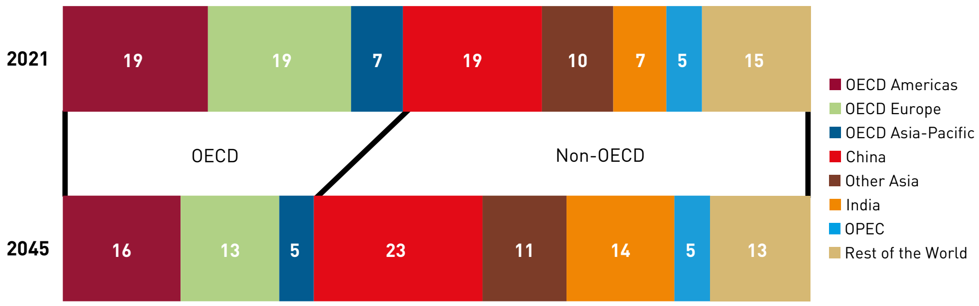
	2021–2027	2027–2035	2035–2045	2021–2045
OECD	2.0	1.6	1.5	1.7
Non-OECD	4.2	4.0	3.4	3.8
World	**3.2**	**3.0**	**2.7**	**3.0**

Source: OPEC.

The global economy in 2045 will be double the size it was in 2021

Based on 2017 purchasing power parity (PPP), global GDP is projected to rise from around $133 trillion in 2021 to almost $270 trillion in 2045. China and India alone will account for 37% of global GDP in 2045, whereas the OECD will account for slightly less at 34%. OECD Americas is forecast to remain the region with the highest GDP per capita, followed by OECD Europe and OECD Asia-Pacific. The regional grouping of Middle East & Africa (excluding OPEC Member Countries) will still have the lowest GDP per capita and it is expected to be the only region where the average income is less than $10,000 (2017 PPP) in 2045.

Distribution of the global economy, 2021 and 2045



Source: OPEC.

In times of high uncertainty, policy focus shifts to energy security

The cover decision of COP26 – the 'Glasgow Climate Pact' – highlighted the need to enhance action across the world on climate change mitigation, adaptation, finance and increasing cooperation. Parties to the Paris Agreement were also called to update 2030 emission reduction targets before COP27. Yet, in the current geopolitical context, besides a pressing need to increase climate ambitions, countries are increasingly focused on energy security issues. There is now more attention on an energy sustainability trilemma, related to affordability, energy security and reducing emissions, evidenced in many countries publicly recognizing the need for inclusive and resilient approaches, including through more investments in oil and gas projects going forward.

Technology will continue to play a vital role in shaping the future energy mix

The WOO assumes the continuous evolution of technology, which will continue to play an important role in shaping the future energy mix. Despite fast progress in the penetration of electric vehicles (EVs), internal combustion engines (ICEs) are expected to remain the dominant technology for both passenger and commercial road transport segments, with continuously improving fuel efficiency. In a similar vein, conventional aircraft engines will remain the leading technology in the aviation sector. The marine transportation industry has leaned towards the use of liquefied natural gas (LNG), complementing the sector's 2020 cap on the sulphur content of fuel and an industry-wide ambition for emissions reduction of 50% by 2050. Gas has steeply increased its share in power generation in recent decades, while the penetration of renewables in power generation, with an emphasis on wind and solar, will rise throughout the forecast period, increasingly displacing coal. Hydrogen is widely recognized as a significant energy carrier for the future.

Primary energy demand growth driven mostly by non-OECD

Global primary energy demand is expected to increase from 286 million barrels of oil equivalent a day (mboe/d) in 2021 to 351 mboe/d in 2045, a rise of 23%. The drivers of global energy demand are exclusively non-OECD countries, increasing by 69 mboe/d in the outlook period. India alone accounts for 28% of this expansion. With strong policy support and declining long-term costs, other renewables (mostly wind and solar) are the fastest and largest growing category in the energy mix, adding 31 mboe/d in the outlook period. Natural gas is anticipated to increase by 19 mboe/d, followed by oil with just over 12 mboe/d.

World primary energy demand by fuel type, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2021	**2025**	**2030**	**2035**	**2040**	**2045**	**2021–2045**	**2021–2045**	**2021**	**2045**
Oil	88.3	96.1	98.9	100.1	100.5	100.6	12.3	0.5	30.9	28.7
Coal	74.7	74.0	70.7	66.4	62.1	58.2	–16.5	–1.0	26.1	16.6
Gas	66.4	69.9	74.9	79.5	83.0	85.3	18.9	1.0	23.2	24.3
Nuclear	15.2	16.3	17.8	19.6	21.7	23.3	8.1	1.8	5.3	6.6
Hydro	7.5	8.0	8.7	9.4	10.1	10.4	2.9	1.4	2.6	3.0
Biomass	26.2	27.9	30.0	32.0	33.7	34.9	8.6	1.2	9.2	9.9
Other renewables	7.4	11.2	17.8	24.9	32.5	38.3	30.9	7.1	2.6	10.9
Total	**285.7**	**303.4**	**318.9**	**331.9**	**343.6**	**351.0**	**65.3**	**0.9**	**100.0**	**100.0**

Source: OPEC.

Oil is expected to remain the number one fuel in the global primary energy mix

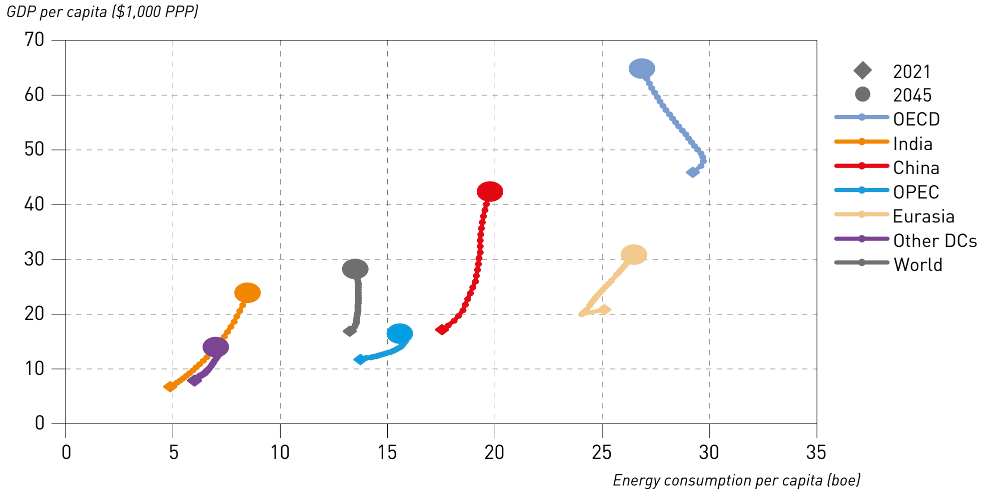
Demand for oil as a primary fuel is anticipated to increase from 88 mboe/d in 2021 to 101 mboe/d in 2045, with its share in the energy mix dropping from 31% to just below 29%. Despite decelerating oil demand growth, oil is set to retain the highest share in the global energy mix during the entire forecast period. The combined market share of oil and gas in the global primary energy mix is expected to remain above 50% to 2045.

Energy poverty remains an issue throughout the forecast period, with a wide gap between developed and developing countries

As of 2020, about 733 million people remained without access to electricity, and approximately 80% of these people are located in Africa. Moreover, about 2.4 billion people still lacked access to clean cooking solutions in 2020, accounting for one-third of the world's population. This is progress on the three billion number in 2010, with improvements in Asian economies where there was decline from around 2.1 billion in 2010 to 1.3 billion in 2020. However, this masks the deterioration in Sub-Saharan Africa where more than 920 million people did not have access to clean cooking fuels, compared to around 750 million in 2010.

Despite rising energy demand growth during the forecast period, per capita consumption in non-OECD countries will remain far below that in OECD countries in 2045. This is especially true for regions such as Sub-Saharan Africa and India.

Energy consumption per capita versus GDP at PPP per capita, 2021–2045



Source: OPEC.

Medium-term oil demand grows steadily, reaching 107 mb/d by 2027

Global oil demand is projected to reach almost 107 million barrels a day (mb/d) in 2027, representing a robust increase of 10 mb/d compared to 2021. Most of this increase will materialize in the non-OECD region, which accounts for 8.6 mb/d of the medium-term growth. Of this, however, more than 5 mb/d will be realized in the period to 2024. OECD oil demand is expected to see an increase of 1.4 mb/d by 2027, with the 2.4 mb/d expansion in the period to 2024, offset by a decline of 1 mb/d during the rest of the medium-term.

In the long-term, global oil demand increases by 13 mb/d, rising to 110 mb/d

OECD oil demand is on a declining trajectory after 2024, falling to 34 mb/d by the end of the forecast period. This represents an overall demand decline of almost 11 mb/d between 2021 and 2045. In contrast, long-term non-OECD demand is expected to increase by 24 mb/d, driven by an expanding middle class, high population growth and stronger economic growth potential. As a result, global oil demand is projected to increase by 12.9 mb/d, rising to 109.8 mb/d in 2045. Overall growth slows over the projection period, with virtually no increase after 2035, hinting to a relatively long period of plateauing oil demand at the global level. This will be driven by energy policies and technology developments that both play an increasing role in diversifying the future energy mix.

Oil demand in the Reference Case, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD	44.8	47.0	44.5	41.1	37.5	34.1	–10.7
Non-OECD	52.2	58.5	63.8	68.4	72.3	75.7	23.6
World	**96.9**	**105.5**	**108.3**	**109.5**	**109.8**	**109.8**	**12.9**

Source: OPEC.

Long-term demand growth to increasingly come from India, Africa and Other Asia

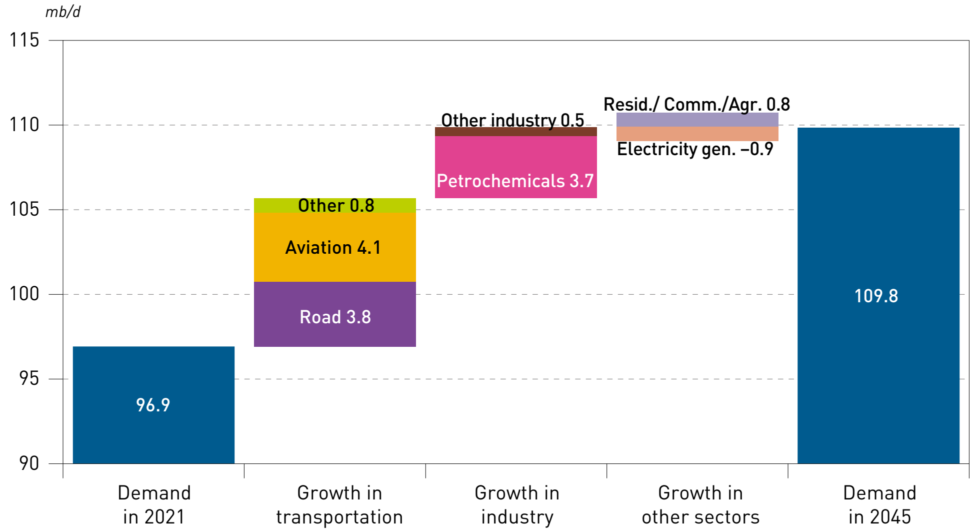
Non-OECD demand prospects are marked by strong demand growth. In the initial years of the forecast period, this growth will be driven by China. In the later period, India will take the leading role with demand growth in China slowing significantly and even turning to a marginal decline over the last five years of the forecast period. Besides India, fairly robust growth during this period is also projected for Africa and Other Asia where economic progress, urbanization, industrialization and vehicle fleet expansion will be fastest among all regions. This will result in respective demand increases of around 1.4 mb/d, 0.8 mb/d and 0.7 mb/d, for India, Africa and Other Asia, during the 2040–2045 period. Even by 2045, oil demand will still grow at a rate of more than 2% p.a. in India and Africa and 1% p.a. in Other Asia.

Aviation, road transportation and petrochemical sectors will be the main contributors to future incremental oil demand

Aviation, road transportation and petrochemical sectors will each see oil demand grow by around 4 mb/d between 2021 and 2045. The largest demand increase, estimated at 4.1 mb/d between 2021 and 2045, comes from the aviation sector. Considering 2021 as a basis for comparison, however, more than 1 mb/d of this expansion is needed to just reach pre-pandemic levels, which will likely not be achieved before 2024.

After an initial few years of growth, oil demand in the road transportation sector is expected to stay in a very narrow range of just below 47 mb/d as developments in the passenger car segment offset impacts on the commercial vehicles segment. The total vehicle fleet is anticipated to reach 2.5 billion by 2045, an increase of almost 1 billion from 2021 levels. The EV fleet approaches 540 million vehicles by 2045, representing more than 22% of the global fleet.

Oil demand growth by sector, 2021–2045



Source: OPEC.

The overall demand increase in the petrochemical sector is forecast to be 3.7 mb/d. The overwhelming majority of this growth is set to come from Asian countries and the Middle East. Minor growth is also projected for Latin America, Africa and Russia. Meanwhile, OECD oil use for petrochemicals at the end of the forecast period will be lower than in 2021, despite some temporary growth during the current decade.

Future incremental demand almost equally split between light products and middle distillates

Mirroring projected developments at the sectoral level, incremental demand is set to be almost equally split between light products and middle distillates, with virtually no growth projected for the heavy end of the refined barrel. Major demand growth over the forecast period is expected for jet/kerosene (+3.8 mb/d), followed by ethane/liquefied petroleum gas (+2.6 mb/d), diesel/gasoil (+2.4 mb/d), naphtha (+2 mb/d) and gasoline (+1.9 mb/d).

Global oil demand by product, 2021–2045

mb/d

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
Light products	44.8	49.2	50.7	50.9	51.3	51.3	6.4
Middle distillates	33.9	37.6	38.6	39.4	39.7	40.2	6.3
Heavy products	18.2	18.6	19.1	19.2	18.8	18.4	0.2
World	**96.9**	**105.5**	**108.3**	**109.5**	**109.8**	**109.8**	**12.9**

Source: OPEC.

Non-OPEC liquids supply to show healthy medium-term growth

Non-OPEC liquids supply will continue its post-pandemic rebound. It is projected to grow from 63.6 mb/d in 2021 to 71.4 mb/d in 2027, under the assumption of a strong demand recovery and on the back of supportive fundamentals. The United States (US) will remain the leading source of medium-term non-OPEC liquids supply growth, providing 3.9 mb/d, or 50% of incremental output. Other major medium-term sources of non-OPEC supply growth are Brazil (+1.2 mb/d), Guyana (+0.8 mb/d), Canada (+0.5 mb/d) and Norway (+0.4 mb/d). By contrast, geopolitical tensions related to the Russia-Ukraine conflict, are set to result in Russian liquids supply declining by 0.7 mb/d in the medium-term.

In the long-term, total non-OPEC liquids supply declines again from the early 2030s, to average 67.5 mb/d in 2045, albeit still up by 3.9 mb/d from 2021. Resource constraints see US tight oil peak at just over 16 mb/d around 2030. Thereafter, supply growth continues in Guyana, Canada, Kazakhstan, Brazil and Qatar, but is insufficient to offset non-OPEC declines elsewhere.

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

	2021	2025	2030	2035	2040	2045	Change 2021–2045
Americas	25.2	29.0	29.2	27.9	26.5	25.2	0.0
of which US	*17.8*	*21.3*	*21.3*	*19.9*	*18.5*	*17.2*	*–0.5*
Europe	3.8	4.1	4.2	4.1	4.1	4.1	0.3
Asia-Pacific	0.5	0.5	0.6	0.5	0.5	0.4	–0.1
OECD	**29.4**	**33.6**	**34.0**	**32.5**	**31.0**	**29.7**	**0.3**
China	4.3	4.6	4.5	4.4	4.3	4.2	–0.2
India	0.8	0.8	0.8	0.8	0.8	0.8	0.0
Other Asia	2.4	2.3	2.2	2.1	2.0	1.8	–0.6
Latin America	6.0	7.3	8.8	9.0	8.9	8.7	2.8
Middle East	3.2	3.5	3.8	3.8	3.8	3.8	0.5
Africa	1.3	1.5	1.8	1.7	1.6	1.6	0.2
Russia	10.8	10.2	10.4	10.5	10.5	10.4	–0.4
Other Eurasia	2.9	3.2	3.3	3.3	3.3	3.2	0.3
Other Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Non-OECD	**31.9**	**33.4**	**35.6**	**35.8**	**35.3**	**34.6**	**2.8**
Non-OPEC production	61.3	67.0	69.6	68.3	66.3	64.3	3.0
Processing gains	2.3	2.6	2.8	2.9	3.0	3.2	0.9
Non-OPEC liquids	**63.6**	**69.6**	**72.4**	**71.2**	**69.3**	**67.5**	**3.9**
OPEC liquids	**31.6**	**36.1**	**36.1**	**38.3**	**40.4**	**42.4**	**10.7**
World	**95.2**	**105.7**	**108.4**	**109.5**	**109.8**	**109.8**	**14.6**

Note: The sum of the countries/regions may not add up to the global supply total due to rounding and stock change assumptions.
Source: OPEC.

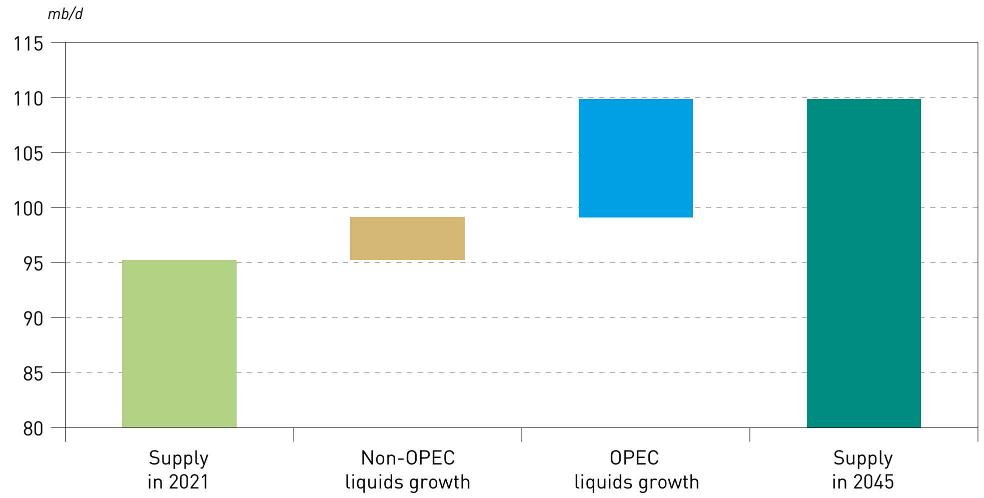
Non-crude liquids' share of global supply to increase

Non-crude liquids supply growth offsets crude oil's longer-term decline. Besides natural gas liquids (NGLs), biofuels and other liquids, including Canadian oil sands, and progressively, synthetic aviation fuel (SAF), are also important sources of new barrels. These are increasingly supported by energy policies, mandates and technology advances.

OPEC liquids to grow to 42.4 mb/d by 2045, a 39% market share

OPEC liquids are projected to expand from 31.6 mb/d in 2021 to around 36 mb/d in 2022 and hold steady around this level throughout the medium-term. After non-OPEC supply peaks around 2030, OPEC liquids are set to increase again, rising to 42.4 mb/d by 2045. Thus, OPEC's share of global liquids supply is projected to increase from 33% in 2021 to 39% in 2045.

Composition of long-term global oil liquids supply growth



Source: OPEC.

Uncertainty to the supply outlook remains high

Risks to the economic outlook, high inflation, energy policy goals confronted with energy security challenges, and questions regarding a perceived shortfall in upstream investment, coupled with persisting and new geopolitical uncertainties, means that significant risks regarding the longer-term liquids supply outlook remain.

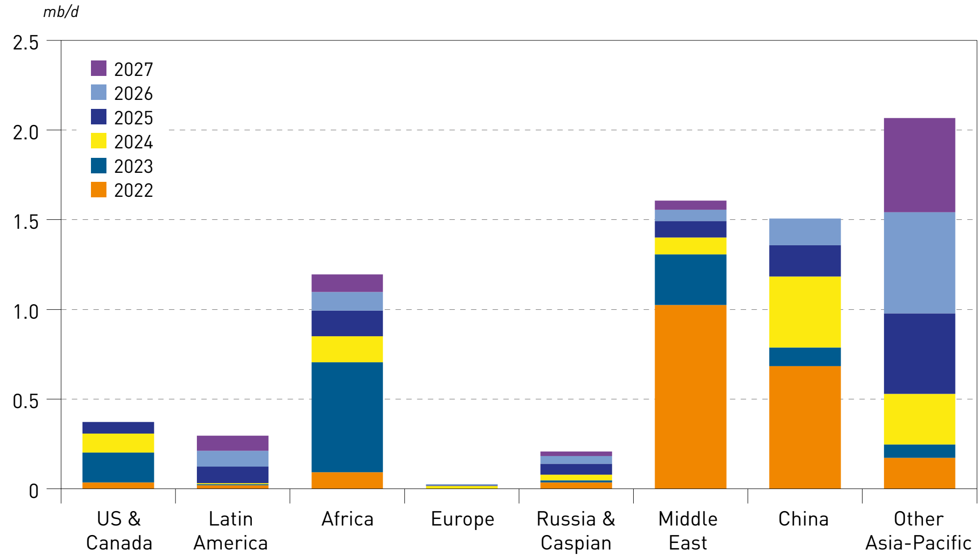
Global challenge to meet oil-related investment requirements of $12.1 trillion by 2045

Cumulative oil-related investment requirements are projected at $12.1 trillion over the entire 2022–2045 period (in 2022 US dollars). This is slightly higher than assessed in the World Oil Outlook (WOO) 2021, as upward-revised demand projections and assumed cost inflation in the short- and medium-term more than offset the forecast period being one year shorter. Upstream needs make up $9.5 trillion, while downstream and midstream requirements are $1.6 and $1 trillion, respectively.

Robust medium-term refinery capacity expansion, partly offset by expected closures

During the medium-term, around 7.3 mb/d of refining capacity additions are expected, most of which will be added in the Asia-Pacific, the Middle East and Africa. Refining capacity additions in other regions are minor and mostly limited to existing refinery expansions. The Asia-Pacific is set to add around 3.6 mb/d of refining capacity in the medium-term, which is almost half of the total additions to 2027. The Middle East and Africa are set to expand their refining capacity by 1.6 mb/d and 1.2 mb/d, respectively. At the same time, around 2.6 mb/d of refining capacity is projected to be closed, mostly in developed countries.

Distillation capacity additions from existing projects, 2022–2027

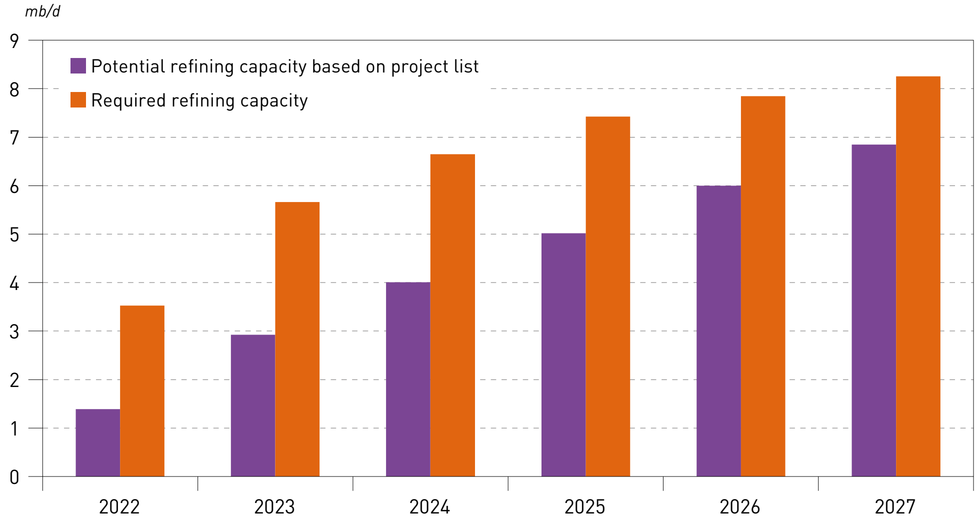


Source: OPEC.

Strong demand growth leads to tightening medium-term downstream sector

Projected downstream market balances point to a tightening downstream market in the short- and medium-term, relative to 2021. The expected deficit of potential refining capacity relative to required refining capacity is estimated to peak at around 2.7 mb/d in 2023 and 2024. Due to a demand growth slowdown and continuous capacity additions, the deficit is set to drop to around 1.4 mb/d in 2027.

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.

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Significant long-term primary and secondary refining capacity requirements

In the long-term, global refining additions are projected at 15.5 mb/d. Expected additions are front-loaded, with a significant slowdown in the rate of additions towards the end of the assessment period, in line with oil demand deceleration. Almost 90% of additions are located in the Asia-Pacific, the Middle East and Africa. Long-term secondary capacity additions are estimated at around 15.8 mb/d for desulphurization capacities, 8 mb/d for conversion capacities and 5.7 mb/d for octane units.

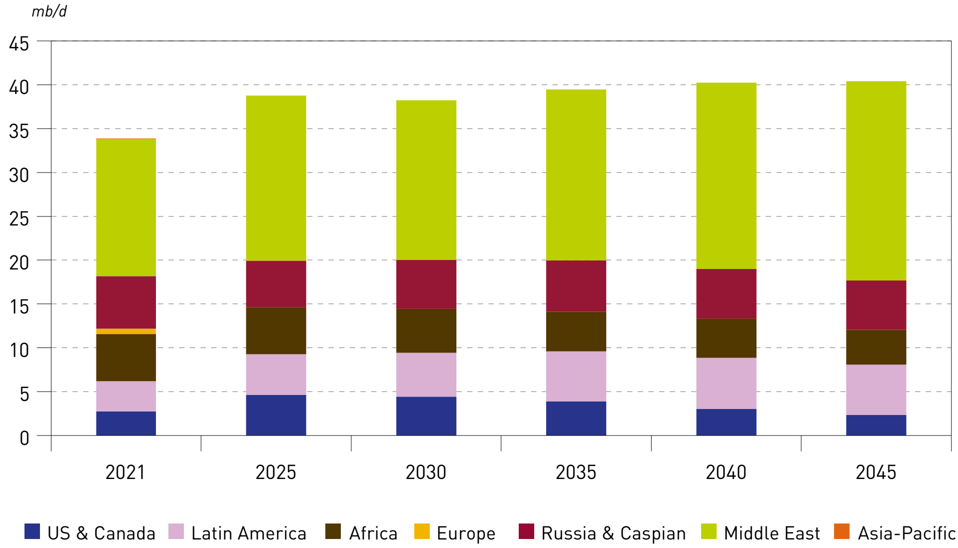
High degree of uncertainty related to European imports and Russian exports of crude and condensate

Following the outbreak of the Russia-Ukraine conflict, several regions including the European Union (EU), the United Kingdom (UK), the US and Canada have imposed a ban on oil and product imports from Russia. This outlook assumes that Europe will continue to import some Russian crude in the medium- to long-term. However, this outlook recognizes the potential lasting consequences of the oil embargo, meaning that flows from Russia to the EU are likely to be significantly lower compared to 2021.

Medium-term global crude and condensate trade to rise significantly, followed by a gradual increase thereafter

Total crude and condensate trade is expected to increase from 33.9 mb/d in 2021 to almost 40.5 mb/d by 2045. The Middle East remains by far the most important crude and condensate exporter throughout the period. In line with rising demand for OPEC liquids, it is projected to increase its exports from 15.7 mb/d in 2021 to 22.7 mb/d in 2045, or more than 56% of total trade movements. Latin American exports are set to grow strongly, reaching 5.7 mb/d in 2045, up from 3.4 mb/d in 2021. In line with supply trends, US & Canada exports are set to peak in 2025 at 4.7 mb/d, followed by a gradual decline to 2.3 mb/d in 2045.

Global crude and condensate exports by origin, 2021–2045*



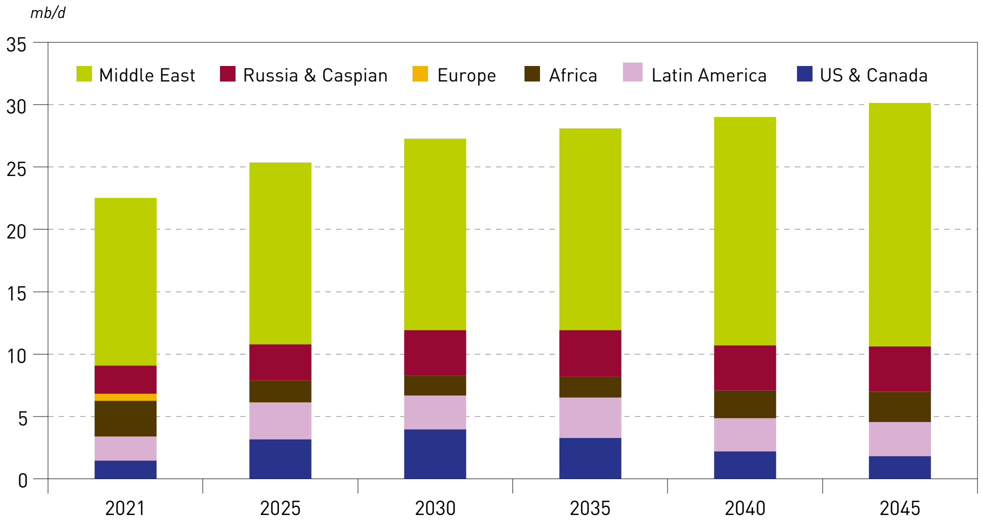
** Only trade between major regions is considered, intratrade is excluded.*

Source: OPEC.

Crude and condensate flows to Asia-Pacific increase strongly, based on robust demand growth and declining local supply

Total imports increase from 22.5 mb/d in 2021 to above 30 mb/d in 2045. The Middle East remains the most significant supplier and increases its share in total Asia-Pacific imports from around 60% in 2021 to 65% in 2045. Other regions are also projected to increase shipments to Asia-Pacific in the medium- and/or long-term, including Latin America, Russia & Caspian and the US & Canada.

Crude and condensate imports to Asia-Pacific by origin, 2021–2045



Source: OPEC.

Scenarios assess alternative energy pathways

The global economy and energy system are at a critical juncture, characterized by great uncertainty. Nations and Parties to the UNFCCC are currently called on to collectively achieve ambitious emission reductions by accelerating action on an unprecedented scale in all key sectors, including energy, transport, buildings, and industry. At the same time, there are pressing needs to alleviate energy poverty and improve energy access and living conditions for people in many developing countries. To model these challenges, alternative scenarios were developed. These scenarios indicate that alternatives to the mainstream mitigation pathways focusing on renewables exist. Crucially, different pathways have varying socio-economic implications for different economies, with some routes likely unfairly impacting energy-exporting developing countries.

Partnerships and cooperation are needed to invest in technology and innovation that could enable an inclusive, fair and just transition

The critical role of oil and gas in meeting future energy demand and achieving energy poverty eradication should be taken into consideration when developing investment plans and energy portfolios that lead to a low-emissions future. Any adverse impacts for the economies and societies of energy-exporting developing countries should be addressed in the context of equity and sustainable development.

In this respect, amid the current disruptions related to the pandemic and geopolitics, the world is losing momentum towards the attainment of Sustainable Development Goal

(SDG) 7 targets, especially on energy poverty eradication. International cooperation and finance are fundamental instruments for achieving progress on the SDGs, including on universal energy access, and ensuring a just and inclusive energy transition.

Introduction

Despite recurring waves of COVID-19 infections and some regional or localized lockdowns, the global economy surged in 2021, with GDP expanding by 5.8%, and oil demand increasing by 5.7 mb/d. Liquids supply continued to recover in lockstep with demand, heavily supported by the steady production adjustment unwinding adhered to by participants in the Declaration of Cooperation (DoC). The wise stewardship by the DoC continued to enhance stability in global oil markets during turbulent times.

The year 2021 closed out with Conference of Parties (COP26) in Glasgow, the UK, dominating headlines. Expectations ran very high before the event, with numerous countries committing to more ambitious nationally determined contributions (NDCs), or even setting net-zero emissions targets in the coming decades. Largely, this reflects the fact that the global energy transition remained high on the agenda, not least due to renewed commitment to the cause by the current US Administration, which had re-joined the Paris Agreement on its first day in office.

Only a short time later, however, talk of a potential winter energy crisis in Europe saw energy security concerns rise to the top of the global agenda for many, and just a few months later, the conflict in Eastern Europe shifted the focus even further in this direction. Policymakers have been delivered a stark reminder of some of the conflicts related to energy affordability, energy security, and the need to reduce emissions.

Moreover, subsequent sanctions on Russia and the decision by many European countries to reduce, or even eliminate, energy imports from Russia have had further major implications for energy markets, re-directing energy flows and – at least temporarily – leading to higher energy prices. The resulting mix of sanctions, inflation and higher energy prices, in turn, has had significant consequences for economic prospects, with downward revisions to the global economic growth outlook by all major institutions.

The momentum towards energy transition will not be reversed, with trends such as the push for renewable energy and the continued electrification of road transport fast progressing in several markets, supported by both policy and consumer choices. Technology advances will continue to enable both improved energy efficiency across all sectors of consumption and fuel substitution towards cleaner energy sources. Moreover, energy-saving measures implemented in response to high end-user prices, as well as political calls for solidarity and savings, may in some cases become entrenched.

The Reference Case of this year's outlook assumes a combination of a steady economic recovery, coupled with a gradual normalization and stabilization of oil markets in the short- and medium-term, to everybody's benefit, both producers and consumers.

In the long-term, the outlook assumes that oil demand growth will likely slow in the 2030s, hinting at a relatively long period of plateauing demand at the global level. This will be a phase in which non-OECD growth will offset declining OECD demand. This will be driven by energy policies and technology development that both play an increasing role in diversifying the future energy mix. Still, global oil demand will increase by close to 13 mb/d in the period 2021–2045, rising to nearly 110 mb/d in the long-term.

On the supply side, the expected peak in US tight oil sometime around 2030, and as a result, aggregate non-OPEC liquids supply, will present a challenge to OPEC Member Countries, which will be called on to responsibly fill the gap this creates. This calls for an environment in which continued long-term investment in the upstream is recognized as vital and necessary, and not needlessly demonized as has been witnessed in recent years.

On the refining side, strong medium-term demand growth is expected to lead to tightening downstream markets and significant primary and secondary refining capacity additions will be required in the long-term. In the period to 2045, global crude distillation capacity additions are estimated at 15.5 mb/d. Needless to say, this will have significant implications on re-directing future crude and refined products flow between major regions.

Lastly, to sufficiently reflect the widening range of uncertainties about the world's future energy mix, two scenarios are also presented in the last chapter of the Outlook. These indicate that alternatives to the mainstream mitigation pathways focusing on renewables exist. Crucially, different pathways have varying socio-economic implications for different economies, with some routes likely unfairly impacting energy-exporting developing countries. Moreover, the world should not lose focus on achieving the targets enshrined in the Sustainable Development Goals (SDGs), including the eradication of energy poverty, and energy access to all.

Therefore, it is necessary to promote partnerships and cooperative initiatives to invest in technology and innovation that could enable inclusive, fair and just solutions to the world's pressing climate challenges, all in the context of equity and sustainable development.

Key assumptions

Key takeaways

- Global population is anticipated to increase by around 1.6 billion, from 7.9 billion in 2021 to 9.5 billion by 2045.
- Non-OECD population growth is much higher than the OECD, driven by the Middle East & Africa, with Other Asia, OPEC and India following.
- The working-age population (15–64) is projected to rise globally by 869 million over the projection period. The relative share of the global working-age population is anticipated to drop from 65% in 2021 to 63% in 2045.
- The global urbanization rate is forecast to rise from 56% in 2021 to 66% by 2045.
- Global GDP is projected to grow by 3% p.a. on average between 2021 and 2045.
- India is expected to remain the fastest-growing major developing country, with average growth of 6.1% p.a. over the forecast period.
- Based on 2017 PPP, global GDP is projected to rise from $133 trillion in 2021 to $270 trillion in 2045.
- China and India alone are forecast to account for more than a third of global GDP in 2045, slightly higher than the OECD region's share.
- The UNFCCC Parties adopted a cover decision at COP26 in Glasgow in November 2021 – the 'Glasgow Climate Pact' – and a set of decisions on the Paris Agreement rulebook. These outcomes highlight the need to enhance action across the world on climate change mitigation, adaptation, finance and increasing cooperation.
- In addition to the pressing need to increase climate ambition, both developed and developing countries are currently striving to ensure energy security and find a resilient and sustainable way forward. In this context, the special needs and national circumstances of developing countries should be considered; ensuring energy is accessible and affordable for all.
- Both current and future technologies will play a significant role in shaping the future energy landscape. The development, and implementation, of multi-faceted technologies contributes to helping set the scene for the Reference Case.
- Hydrogen is considered in the context of the energy transition as a solution to some of the challenges, playing the role of an energy carrier.

A variety of key assumptions are made to structure this year's WOO. These include global population and demographic projections and trends; potential economic growth in the midst of a global recovery from COVID-19 and the recent accelarated financial tightening; and the expected impact of both energy policies and technology advancement on the energy sector. All assumptions have undergone thorough analysis to enable the development of the Reference Case.

1.1 Population and demographics

The average age of the global population is rising appreciably, on the back of advancements in areas such as health and nutrition, and at the same time, the world's population continues to witness gradual growth. Although the overall trend sees a general transition towards lower population growth, some regional variations can be seen within this overarching trend.

Many OECD countries already have low population growth, and many developing countries are set to undergo a similar transition in the coming decades. Demographic elements addressed in this chapter are an indispensable input to this year's WOO analysis and have been carefully analyzed.

In July 2022, the United Nations Department of Economic and Social Affairs released their latest World Population Prospects (UNDESA, 2022). The new update, the first since 2019, presents a number of important developments that are discussed in this section.

Firstly, it highlighted a continued decline in fertility rates, meaning that for the first time, the World Population Prospects shows a peak in global population in its medium variant of around 10.4 billion in 2086. In relation to the forecast period in this Outlook, total global population is anticipated to expand by 1.6 billion from its current level of approximately 7.9 billion in 2021, to almost 9.5 billion by 2045 (Table 1.1).

The population growth projection in the non-OECD region accounts for over 96% of the total growth, with the OECD accounting for under 4%. The Middle East and Africa region (excluding OPEC countries), as per the WOO's regional groupings (see Annex B), is expected to drive 48% of the population growth, with Other Asia, India and OPEC each providing between 15% and 19%. In the OECD, growth in OECD Americas will more than offset a 12 million decline in OECD Asia-Pacific.

China's population is now projected to decline by around 76 million in the next 24 years (2021–2045), by far the largest drop of major economies. This compares to population growth of 188 million in the previous 24 years (1997–2021) as seen in Figure 1.1. India's population is expected to expand by 238 million over the period 2021–2045, albeit less than the 405 million people added in the past 24 years. Similarly, population growth in the OECD region for 2021–2045 is forecast to be significantly less than the 187 million expansion in its population over the 1997–2021 timeframe.

The Middle East & Africa region and OPEC are presently experiencing rapid population growth. This trend is set to continue throughout the projection period. Given this trend, the region is expected to become home to the largest overall population by 2045. Notably, the Middle East & Africa and OPEC are the only regions projected to see an increase in their growth rate, adding 747 and 244 million people in the period between 2021–2045, respectively. This compares to the 527 million and 218 million added from 1997–2021.

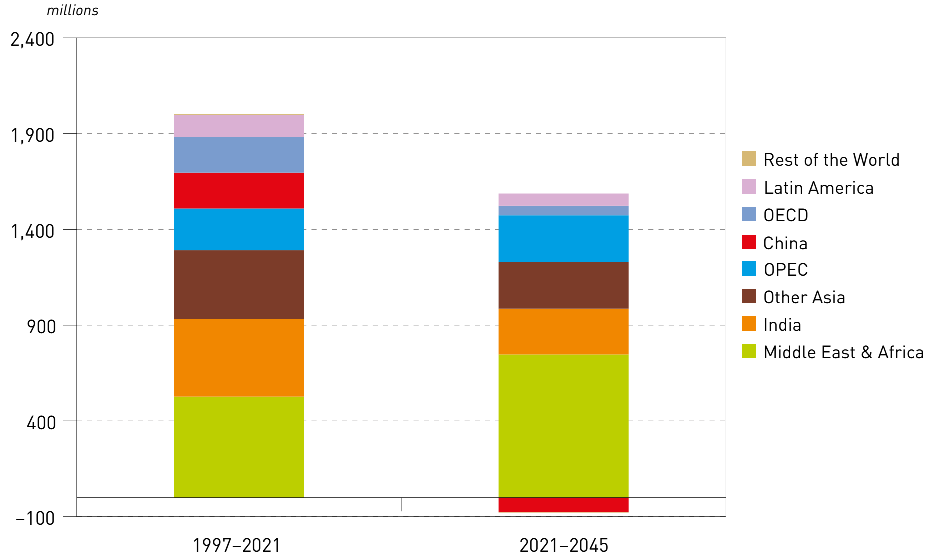
Table 1.1
Population by region

millions

	Levels						Growth
	2021	2025	2030	2035	2040	2045	2021–2045
OECD Americas	525	537	551	564	575	583	59
OECD Europe	580	584	586	587	586	584	4
OECD Asia-Pacific	216	215	214	211	208	205	–12
OECD	**1,321**	**1,336**	**1,351**	**1,362**	**1,369**	**1,372**	**51**
Latin America	478	492	508	522	533	541	62
Middle East & Africa	1,165	1,279	1,430	1,587	1,749	1,912	747
India	1,408	1,455	1,515	1,568	1,612	1,646	238
China	1,426	1,424	1,416	1,400	1,378	1,350	–76
Other Asia	1,245	1,301	1,368	1,430	1,486	1,535	290
OPEC	518	558	609	660	712	762	244
Russia	145	143	141	139	137	135	–10
Other Eurasia	197	196	200	202	204	205	8
Non-OECD	**6,581**	**6,848**	**7,187**	**7,508**	**7,809**	**8,086**	**1,504**
World	**7,902**	**8,184**	**8,538**	**8,870**	**9,179**	**9,457**	**1,555**

Source: UN, OPEC.

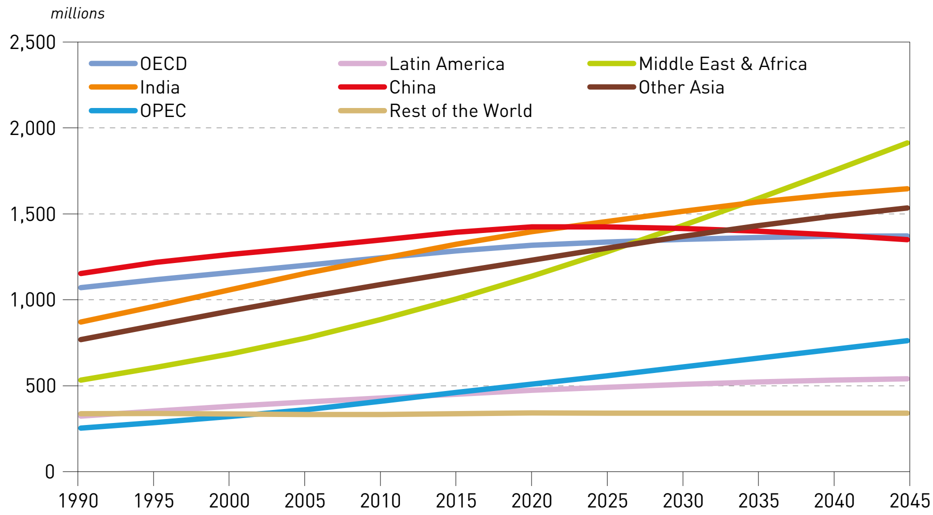
Figure 1.1
World population growth, 1997–2021 *versus* 2021–2045



Source: UN, OPEC.

By the second half of the 2020s, India's population is projected to surpass that of China (Figure 1.2). The Middle East and Africa is then expected to exceed India by around 2035.

Figure 1.2
World population trends, 1990–2045



Source: UN, OPEC.

1.1.1 Working-age population

The global working-age population (aged between 15 and 64) is expected to expand by 869 million over the projection period (Table 1.2). The relative share of the global working age population to the world's total is expected to fall slightly to 2045, from 65% in 2021 to slightly above 63%.

Regionally, China's working-age population is expected to fall by 164 million over the projection period. This tallies with the country's estimated population growth dynamics. The Middle East & Africa, with 527 million additional working age people by 2045, is projected to experience the most growth, followed by OPEC, Other Asia, and India. By 2045, the Middle East & Africa and OPEC are set to contribute more than 60% of the growth to the world's working-age population.

1.1.2 Urbanization

Urbanization is closely associated to enhanced energy access and a pivotal factor for mitigating energy poverty, with trends reflecting economic development, social issues and energy consumption. The urbanization rate measures the level of the total population living in urban areas in percentage terms. In 2021, more than 56% of the world's population lived in urban areas compared to just 43% only a few decades ago in 1990. Urbanization is expected to expand further in the coming decades, with 66% of the world's population projected to be urban by 2045.

With an average exceeding 80% living in urban areas, the OECD and Latin America are markedly the most urbanized (Figure 1.3). Within the OECD, OECD Asia-Pacific is the most urbanized at approximately 89% in 2021, followed by OECD Americas at almost

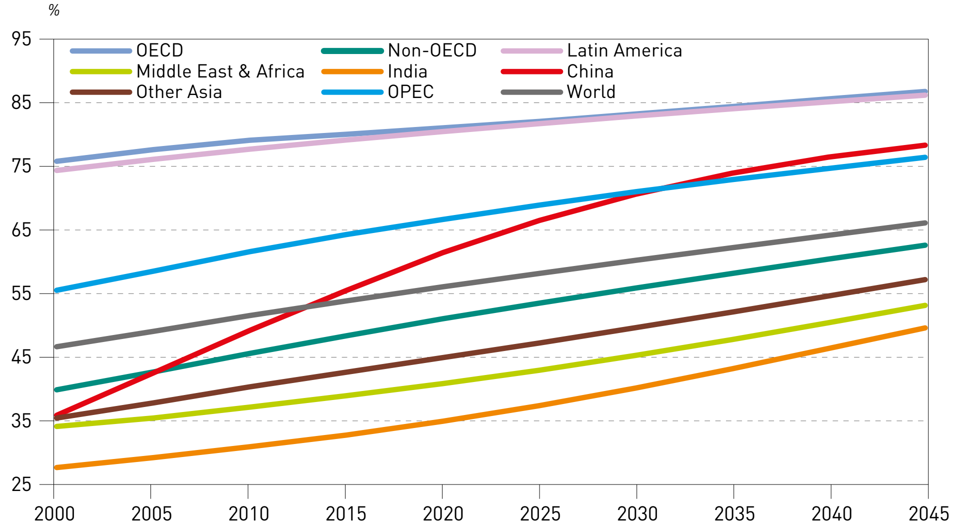
Table 1.2
Working population (age 15–64) by region

millions

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	345	350	355	359	361	363	18
OECD Europe	374	373	367	359	351	342	–32
OECD Asia-Pacific	135	133	130	125	118	113	–23
OECD	**854**	**857**	**852**	**843**	**830**	**818**	**–37**
Latin America	324	334	343	351	354	354	30
Middle East & Africa	662	740	846	956	1,072	1,189	527
India	950	995	1,043	1,079	1,102	1,117	166
China	986	987	972	931	867	822	–164
Other Asia	815	855	902	942	977	1,006	191
OPEC	311	339	377	413	447	478	167
Russia	97	94	93	92	89	85	–12
Other Eurasia	129	127	129	131	131	130	1
Non-OECD	**4,274**	**4,470**	**4,705**	**4,895**	**5,038**	**5,180**	**906**
World	**5,129**	**5,327**	**5,557**	**5,738**	**5,868**	**5,998**	**869**

Source: UN, OPEC.

Figure 1.3
Urbanization rate for selected regions, 2000–2045



Source: UN, OPEC.

83% and OECD Europe at around 77%. Latin America had an urbanization rate of almost 81%. Both the OECD and Latin America will continue to urbanize over the long-term to 2045, reaching over 86% by 2045.

China has witnessed a dramatic change in urbanization over the last 30 years or so. The country's urban population rate matched India's before 1990, but in the period since it has experienced significant growth. Moreover, and despite the decelerating rate, China is expected to urbanize to the point where it overtakes the OPEC region and is well above the global average. Chinese growth has helped drive the current overall urbanization level in Asia to almost 50%.

Remarkably, India's urbanization rate has been the lowest and it is projected to remain the lowest regionally by 2045, despite an anticipated considerable rise in the coming decades. The Other Asia region is projected to mostly shadow the trajectory of India in terms of urbanization levels through to 2045, but it starts from a higher base.

OPEC Member Countries stand at a level directly above the current global average of approximately 67%. The Middle East & Africa region is expected to witness a considerable expansion in urbanization levels in the coming decades. Yet, Africa is set to remain mostly rural, with 43% of its population projected to be living in urban areas by 2045.

1.1.3 Migration

An additional dynamic element of demographic disparities on a regional basis is the movement of population. Net migration, as depicted in Table 1.3, measures the variation of population between the medium variant case and zero migration variant case.

Table 1.3
Net migration by region

million

	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	–1.2	–1.1	–1.8	–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**	**–9.0**	**–11.1**	**–11.2**	**–11.1**

Source: UN, OPEC.

As expected, the COVID-19 pandemic's impact on mobility and international travel has affected migration across regions and countries. A significant reduction in migration flows are estimated for 2020 and 2021. The net migration figures are also heavily impacted by the Russia-Ukraine conflict, which is forecast to result in a large outflow of people from the Other Eurasia region in 2022, with an overall inflow of migrants expected in the years to 2027 as displaced populations return.

After this decade, net migration returns to a similar long-term trend seen in previous outlooks, where steady population inflows are mainly to OECD regions.

1.2 Economic growth

A variety of developments over 2021 and 2022 has created further uncertainties for the global economic growth forecast. Three main issues are currently the focus of short-term economic developments. The first is the ongoing global impacts of the COVID-19 pandemic that was central to last year's WOO projections. The other two are more recent: the consequences of the Russia-Ukraine conflict, with a variety of spillover effects, and the accelerated financial tightening across the globe, triggered by recent strong rises in inflation.

These three factors are already affecting short-term developments. Moreover, it is clear that these will have medium- and possible long-term implications too, although exactly what these are remain to be seen.

- Some pandemic consequences, and their knock-on impacts will need to be considered in the medium-term forecast. Additionally, certain elements triggered by the pandemic, such as debt levels, de-globalization, working from home, but also correspondingly, staff shortages, may also influence the longer-term outlook;
- The fallout from the Russia-Ukraine conflict has already had a significant impact on short-term developments, for example, trade and commodity flows and the consequent inflationary effects, as well as G7-led sanctions against Russia and Belarus. This could have potential consequences for the medium- to long-term;
- The impact of the third major force related to financial tightening due to rapidly rising inflation is considered more of a short- to medium-term phenomenon. The consequences of the financial tightening may continue to be intense throughout most of the medium-term period as the inflationary trend triggers central banks to tighten their monetary supply. It is assumed, however, that the impact will lessen towards the end of the period.

Beside these three major challenges, some additional factors will need close monitoring, especially in the medium- to long-term:

- High debt levels in some key economies. This primarily reflects upon sovereign debt, but private-sector debt has also risen to unhealthy levels;
- There is the possibility of rising global taxes because of high sovereign debt piles. This is particularly relevant in a rising interest rate environment, a dynamic that will increase debt service payments;
- Beside the Russia-Ukraine conflict, other geopolitical tensions may play a role.

It is important to reference some of the uncertainties that are not directly linked to the macroeconomic or geopolitical sphere, but which could potentially influence medium- to long-term growth. The obvious one is rising inequality among countries, but also within countries. This has the potential to lead to social tensions that could turn out to be impactful.

The general trend towards de-globalization may lead to rising inflation via such issues as re-shoring and friend-shoring to more expensive economies with relatively higher income levels. Moreover, it could also lead to rising global tensions, given that such policies could see exports from developing and emerging markets negatively affected. However, cost pressures may lead to rising productivity levels – a compensatory factor to rising production costs – in developed economies that are engaging in a re-shoring policy.

There is also the ongoing Environmental, Social and Governance (ESG) dynamic that could lead to further inflationary tendencies in energy supply costs, as has been witnessed at the end of 2021 and into 2022.

Furthermore, the potential decoupling trend from the US dollar, particularly in emerging and developing economies, may have far-reaching consequences too, ranging from the negative effects on the debt-driven dynamic of the US economy to a variety of outcomes when it comes to exchange rates.

While it is extremely challenging to capture the definite outcomes of all these uncertainties, particularly over the medium- to long-term, it is important to analyze them and highlight some base economic assumptions of these issues in the various sub-sections. Moreover, to better understand current and future growth trends it may be helpful to distinguish between a pre-pandemic and a post-pandemic economic environment. Some pre-COVID-19 trends have been accelerated by the impacts of the pandemic, while others have originated as a direct result of it. Furthermore, the characterization of a post-pandemic world should now be expanded to include the impacts and possible consequences of the Russia-Ukraine conflict.

1.2.1 Current situation and short-term growth

The current combination of the ongoing pandemic, the Russia-Ukraine conflict and an acceleration in financial market tightening is evidently providing numerous uncertainties to the short-term growth outlook. Global economic uncertainties, especially regarding the ongoing impacts of the pandemic, such as supply chain concerns, and geopolitical tensions in Eastern Europe, have become increasingly evident in 2022. Global inflation has risen, due to the conflict and the pandemic, among other drivers, and hence financial tightening has accelerated.

While the world has become more accustomed to living with the pandemic in 2022, it continues to impact lives and consumer spending habits and may also be an important reason for intensifying global labour market tightness, especially in the US and the Euro-zone. Additionally, increasing debt levels in major economies, often as a result of the pandemic, in combination with rising interest rates, has already led to a selective increase in bond yields, which in turn makes refinancing more challenging.

What is clear is that inflation has become a dominant concern in 2022. While some factors should be viewed as temporary with their impacts slowing in the near-term, it is evident inflation is a dampener on global growth. This inflationary dynamic has caused the US Federal Reserve (the Fed) to hike interest rates forcefully, with the European Central Bank (ECB) following. These developments will need to be carefully monitored as rising interest rates may turn out to be stress factors for many highly indebted economies.

For the short-term, it is important to note that there were massive dislocations in 2022 – some a continued consequence of effects from 2020 and 2021 – that may only see a levelling off in the medium- to long-term. The most obvious developments in 2022, mostly negative for economic growth, but some positive, were:

- There was a significant negative 1Q22 impact from the pandemic, with lockdowns in some key economies and social distancing measures leading to a slowdown in consumption, as well as industrial output. This situation continued in selective economies into 2Q22, for example, China, although it is evident that many major economies are now learning to better live with the pandemic;
- The start of the Russia-Ukraine conflict at the end of February 2022 had a variety of negative effects on 1H22. It led to sharp declines in output in Ukraine and in several affected economic sectors in Russia. This included a reduction in energy and agricultural commodity supplies, which led to sharp price hikes for related end-consumer products and services. This came in combination with the associated consequences of retracting business and consumer confidence;
- Monetary tightening, that had already started before the events in Ukraine unfolded, accelerated in 1H22. This has caused broad-based global financial tightening and led to a positive impact on the US dollar with associated, mostly negative, ripple effects for other countries. This includes additional rises in import prices in non-US dollar denominated economies, especially in terms of importing commodities;
- Positively, a gradual recovery in the contact-intensive sectors, including the sub-sectors of travel and tourism, hospitality and leisure began in 2Q22, primarily in the northern hemisphere. This was mainly down to the reduced impact of COVID-19. However, it is still forecast that these sectors will only return to 2019 levels in 2023, or even 2024;
- Alongside positives for the contact-intensive services sector, the manufacturing sector has seen a solid recovery trend too, despite some significant supply-chain bottlenecks.

The base short-term economic outlook assumes that the situation in Eastern Europe will not worsen, and that it will not cause further major spillovers into other economies, beyond its current impact. However, it will be important to monitor how consumers deal with a supply shortfall in agricultural products from both Ukraine and Russia, and what consequences a potential decline in Russian fossil fuel exports to G7 economies could have for energy supplies, energy prices and, consequently, economic growth.

Additionally, the pandemic's negative impact on mobility and growth is forecast to be limited, and less than that assumed in the previous two years.

The upside potential to the current forecast is quite limited. However, it may come from a solution to the Russia-Ukraine conflict, fiscal stimulus, where possible, and a fading pandemic, in combination with a strong rise in service sector activity, especially in the contact intensive areas. These factors could potentially, albeit with limited capacity, lift global economic growth.

1.2.2 Medium-term economic growth

The medium-term economic growth dynamic will also likely be significantly influenced by the outcome of the three major factors highlighted for the short-term. How these factors will shape the medium-term future remains uncertain, but some relevant base assumptions can be made:

- While COVID-19 is forecast to remain an issue globally, it is not anticipated to derail economic growth at levels witnessed in the period from 2020–2022. It is assumed some impacts related to seasonality could continue to occur, but that the economic impact of the pandemic will taper off. The quarterly global economic growth pattern is set to again become more equally spread and the impact from COVID-19 less significant, beginning in 2023;
- Assumptions about the Russia-Ukraine conflict are extremely challenging to make. It is assumed, however, that the conflict will not derail the global economic growth pattern at the same magnitude as it has done in 2022. While the conflict may continue, a global *modus operandi* is anticipated to be found, one that will help limit the strong rise in energy and food prices, in particular, as well as the effects of the political fallout. It is also assumed that no escalation of the conflict, nor any spill over into other arenas, especially neighbouring economies, will materialize;
- Monetary tightening is expected to continue into 2023 and beyond, but it is forecast that the pace of the 2022 interest rate hikes, particularly in the US, will not be repeated. Furthermore, it is anticipated that global inflation will peak in 2022 and then mean-revert to around 2% levels in the US and the Eurozone in the medium-term;
- From a quantitative analysis perspective, it is assumed, considering the global potential, that growth, in general, will mean-revert over the medium-term and move back towards pre-pandemic levels.

Among other important assumptions, it is forecast that the de-globalization trend will continue, albeit at a gradual pace. It will not materially alter the medium-term growth dynamic. In this respect, it is important to note that while external trade, in general, will likely become less global, it has in recent decades been regionally dominated by three main large trading hubs. One is the US-centred trade region of the Americas, dominated by North America. Another is the Europe region, with its dominant force of Germany, and the third is the Asian region, centred on China. A potential consequence of less globalized trading could be further regional inequalities as wealth transfers via exports may shift towards wealthier economies. These changes, however, will take time to evolve and may only become visible slowly over the medium-term.

The challenges of escalating debt levels have become an increasing concern, particularly given the recent swift rise in key policy rates across the world in response to rising inflation. No major dislocation as a possible outcome of 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 could potentially face default in the medium-term.

An important factor that may play a role in reducing debt are rising tax levels. In times of increasing debt, taxes commonly used to reduce debt include those on wealth, capital gains, property/real estate, inheritance, top incomes and corporate taxes, among others. Additionally, environmental taxes are likely to play a role in the coming years. A global minimum corporate tax rate as agreed upon by the G7 economies in June 2022 points in the direction of global tax hikes. The G7 agreed to a 15% minimum corporate tax rate in June, which was then endorsed by G20 finance ministers in July.

Further tax plans, especially in advanced economies, are expected to follow. For the medium-term forecast, it is assumed that rising taxes will not derail the global economic recovery and that they will be taken primarily from well-established and well-cushioned sources and that the effects of these taxes will turn out to be well-targeted. Nonetheless, further taxes could limit some growth dynamics, although it is anticipated that these will be at a limited scale.

A further knock-on result of the pandemic was that inequalities within economies and across nations rose. This development was accentuated during the pandemic via the low-interest rate regime, which was relatively more beneficiary to the wealthier parts of the population, for a variety of reasons. With the recent rise in inflation, it is again the poorer parts of society that appear to have been hit the hardest.

Among nations, it is also obvious that the global economic recovery has become increasingly divergent. Those economies that were able to contain the pandemic, particularly through widespread vaccinations, as well as those that had the financial capabilities to provide economic stimulus measures, have rebounded relatively quicker. This includes most advanced economies and China. This is in contrast to those economies that had less access to vaccinations, applied less successful containment strategies and had only limited financial resources for fiscal and monetary stimulus. This dynamic has become even more evident as inflation has risen and any further fallouts from the Russia-Ukraine situation may lead to further rises in global inequality and potentially to more accentuated political frictions.

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

Another pandemic impact was the activity drop off in contact-intensive services areas, importantly travel and tourism in 2020 and 2021. The activity has clearly picked up in 1H22, but how this evolves remains to be seen, given high fuel prices, significant staff shortages in the sector and other issues potentially holding back a broad and well-developed recovery.

As has already been seen in 1H22, non-essential business travel will likely remain reduced, private travel curtailed for some time after the pandemic, and ESG-related developments will also to some extent impact this sector. Moreover, restricted supply in air travel and rising travel costs are likely to hold back a stronger rebound. Considering that travel and tourism accounts for more than 10% of global GDP, the effect is set be felt continuously in the medium-term, particularly in regions that previously relied heavily on tourism.

Moreover, the tendency towards increased teleworking has continued with a rising number of enterprises offering this option. This trend appears here to stay, but questions remain as to what the future of homeworking looks like. Consequences may include less commuting with gradual impacts on both economic and social dimensions, hence, stationary retail sales in office areas will be less frequent. Crude oil demand may also be impacted, among others, although so far these impacts have been limited.

It is important to note that emerging and developing economies are forecast to outgrow advanced economies in the medium-term, but they will likely also face decelerating growth momentum amid maturing domestic economies. A potentially lessening global trade dynamic may support this trend too, an outcome of the deglobalization trend. Similarly, to previous WOOs, China and India, constituting the two largest emerging economies, are expected to follow this pattern and this is reflected in the medium-term forecast, as well as that for the long-term.

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

Table 1.4
Medium-term annual real GDP growth rate *% p.a.*

	2021	2022	2023	2024	2025	2026	2027	Average 2021–2027
OECD Americas	5.6	3.2	2.2	2.0	2.0	1.9	1.9	2.2
OECD Europe	6.1	3.0	2.1	1.8	1.7	1.6	1.5	2.0
OECD Asia-Pacific	3.0	2.4	1.9	1.4	1.3	1.3	1.2	1.6
OECD	**5.4**	**3.0**	**2.1**	**1.8**	**1.8**	**1.7**	**1.6**	**2.0**
Latin America	7.1	2.1	2.1	2.2	2.3	2.4	2.5	2.3
Middle East & Africa	3.4	2.9	3.2	3.2	3.3	3.4	3.5	3.2
India	8.1	7.1	6.0	6.1	6.2	6.2	6.2	6.3
China	8.1	5.1	5.0	5.1	5.2	5.1	4.9	5.1
Other Asia	3.9	4.3	4.3	4.3	4.5	4.5	4.4	4.4
OPEC	3.3	5.0	3.0	2.8	2.8	2.9	3.0	3.3
Russia	4.7	–6.0	1.2	1.6	1.6	1.5	1.5	0.2
Other Eurasia	4.9	–0.4	3.1	3.0	2.5	2.5	2.4	2.2
Non-OECD	**6.2**	**3.9**	**4.2**	**4.2**	**4.3**	**4.3**	**4.3**	**4.2**
World	**5.8**	**3.5**	**3.2**	**3.2**	**3.2**	**3.2**	**3.1**	**3.2**

Source: OPEC.

After this year's GDP growth forecast at 3.5%, it is expected that growth will retract to around 3.2% in 2023. Thereafter, growth is anticipated to remain at around this level. In 2027, at the end of the medium-term period, growth is forecast at 3.1%, impacted by slowing growth in OECD economies, but also by the maturing growth trend in emerging economies.

1.2.3 Growth by region

In **OECD** economies, higher growth is forecast to materialize at the beginning of the medium-term period due to pent-up demand, especially in the contact-intensive services sector. Growth remains supported by fiscal stimulus measures to counter the impacts of not only the pandemic, but in OECD Europe to help counterbalance the effects from the Russia-Ukraine conflict. While the yearly growth dynamic is similar to last year's assumptions, the growth is forecast at lower levels, amid the impact of inflation and financial tightening, as well the consequences of geopolitical tensions. The OECD is expected to see growth of 3% in 2022 before dropping to 1.6% at the end of the medium-term period in 2027.

OECD Americas has recovered well and leads the OECD country group growth momentum at the beginning of the medium-term period. Fiscal and monetary stimulus effects have supported this dynamic. While most of this stimulus largely ended in 2021, the positive impact on the US economy is still visible, for example, via high saving rates cushioning consumption. While it is forecast that consumption will be dented by rising inflation over 2022 and 2023, the underlying economic growth momentum is forecast to remain robust. A recovery in global trade and a sound commodities sector, especially the oil market, will add further support and this extends to the other two North American economies of Canada and Mexico. On the flip side, very high debt levels in the US, in combination with any sustained high inflation levels, could challenge the growth momentum.

Chile is also forecast to benefit from a general recovery in commodity exports, primarily its main export, copper, but it is likely to be held back by a gradual slowdown in domestic consumption growth over the medium-term.

OECD Europe's growth is forecast to be significantly challenged by the ongoing Russia-Ukraine conflict and its political outcome, as well the consequences the conflict may have on its energy supply that has the potential to be impaired, at least in the short-term. In this WOO, the impact of the energy crisis on growth in Europe is limited in scale. However, any significant shortfall in energy supply would provide further downside risk to the current base case. With fiscal support mainly counterbalancing the negative effects from the ongoing issues in Eastern Europe, rather than stimulating the economy, and with monetary tightening forecast to continue in the medium-term, the region is expected to slow and mean-revert from the rather high growth levels of 2021 and 2022.

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, tourism is forecast to pick up and play a supportive role in the Euro-zone's recovery, especially in 3Q22.

In **OECD Asia-Pacific**, Japan is forecast to witness decelerating growth in the medium-term, which was also the trend in last year's Outlook. 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. Japan, the largest economy in the region, is forecast to move back to its low-growth pattern in the medium-term as fiscal and monetary stimulus tapers off and rising import prices, alongside a weakening yen, will likely dent growth momentum at the front-end of the medium-term forecast.

The medium-term growth outlook in non-OECD countries remains relatively diverse. With generally improving commodity markets – the main export for many developing economies in these regional groups – and improving domestic activity, the outlook is expected to pick up in the coming years, although some uncertainties remain. High population growth in these economies will be beneficial too, especially in the longer-term.

In **Latin America**, the two major economies, Brazil and Argentina, have some uncertainties to deal with over the medium-term. With high debt levels, Argentina has limited fiscal space for manoeuvre and the medium-term growth momentum is forecast to be low. While Brazil is in a better situation, ongoing high inflation and the consequent strict policy of its central bank will likely dampen the near-term growth dynamic. Moreover, the effects of COVID-19 have affected almost every country in Latin America in a significant way, particularly given the economies' fragile health systems. Hence, it remains to be seen how the impacts of the pandemic will be dealt with in the near-term.

In the **Middle East & Africa**, medium-term growth is expected to rise slightly. This is supported by rising commodity demand, growing regional domestic demand and aided by the expansion of the middle class. Additionally, a continued global growth dynamic is forecast to lift foreign investment into the region too. China's role as the region's major foreign investor, and its need for natural resources, will continue to be important. However, some dampening and constraining effects may come from any further slowdown in China and the fact that some countries have relatively high sovereign debt levels and large debt servicing obligations.

China, and to some extent India, are expected to record a relatively less buoyant medium-term growth dynamic, compared to some other developing regions. China is forecast to recover some of its COVID-19 related slowdown impacts in 2024 and 2025, with growth of 5.1% and 5.2%, respectively, but thereafter growth is set to slow to 4.9% in 2027. **India**'s growth is forecast to see some acceleration from 2023 onwards, reaching 6.2% in 2027, from 6% in 2023.

Other Asia is forecast to see sound medium-term growth. Growth is forecast at 4.4% at the end of the medium-term in 2027, with slightly rising momentum over the period. This is generally in line with previous WOOs.

The **OPEC** grouping is aided by rising domestic economic activity, and benefits from solid growth momentum in commodity markets. After a strong recovery in 2022 with a growth level of 5.3%, followed by a further healthy level of 3.4% in 2023, growth is forecast to hold up well at 2.8% in 2024, before accelerating back to 3% in 2027.

In Eurasia, **Russia** constitutes the most important economy. It is evident that growth has been and will continue to be impacted by geopolitical issues, as well as the associated effects of sanctions and other political measures. It is expected, however, that Russia will rebound to growth of 1.2% in 2023, following a decline of 6% in 2022. This growth level then lifts further and is seen at 1.5% in 2027, with expectations that the economy will successfully implement reforms to counterbalance the ongoing dampening factors.

Other Eurasia is forecast to see a decline of 1.8% in 2022, but the region is then set to recover to 3% in 2023. It then sees a deceleration towards the end of the medium-term period to reach 2.4% in 2027.

1.2.4 Long-term economic growth

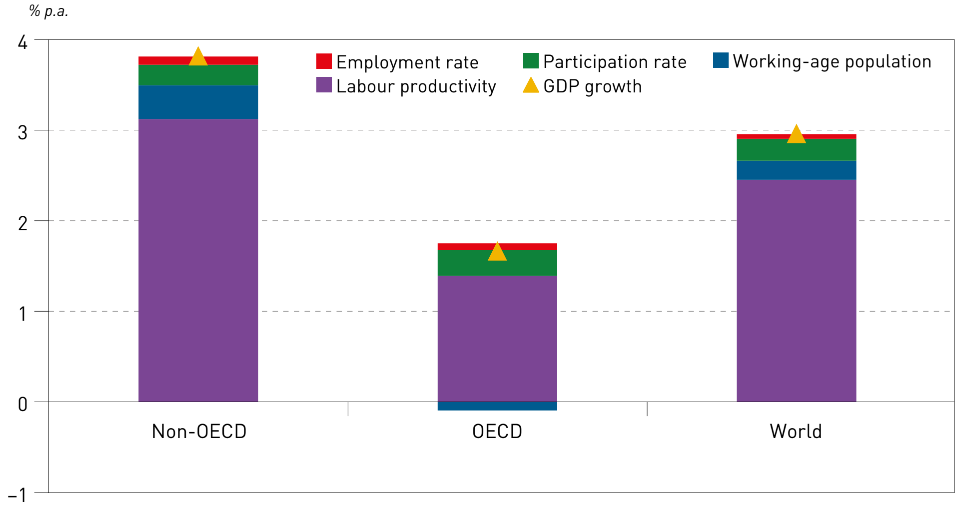
In general, long-term economic growth forecasting is a challenging task, given that it looks out over a period of 20–25 years. This year, however, it is even more complex, given the major global economic uncertainties that have already been highlighted in the short- and medium-term outlook. Understanding the long-term impacts and repercussions of the pandemic, the Russia-Ukraine conflict and rising inflation are a major challenge for economists.

Moreover, the potential changes in the energy sector may be significant for the economy. While it is clear there has been a recent shift towards alternative energy sources, especially renewables, there is also now a narrative forming about the value and competitiveness of fossil fuels in the energy mix, in a sustainable way.

Nevertheless, the main assumptions underlying long-term economic growth developments remain primarily based on productivity growth, demographic trends and labour market developments.

These elements are relatively well understood and remain the main drivers determining long-term growth trends. Within this framework, labour productivity is by far the most important contributor, both at the regional and global level (Figure 1.4). As already mentioned, further upside may come from the pandemic-induced drive towards digitalization, robotics and AI and the more effective use of these evolving technologies.

Figure 1.4
Long-term GDP growth rates by components, 2021–2045



Source: OPEC.

For non-OECD economies, with the exception of China and Russia, the rise in the working age population will be another important element for growth. A young and thriving population, in combination with advancing education, will be vital for future growth in less affluent parts of the global economy. In areas like the Middle East & Africa and OPEC, relatively lower labour productivity will continue to be compensated, or even overcome, by the positive effects of rapidly expanding populations, a rising middle-class and sovereign-led investments into domestic economies.

Several economic regions and individual economies will be affected by a decline in the working-age population. This affects primarily advanced, and maturing, emerging economies. This trend can be clearly seen in OECD Europe and OECD Asia-Pacific. Within emerging markets, Russia and China are also witnessing the impact of this trend. This dynamic will limit these economies' growth potentials, even as labour productivity is forecast to increase.

Beyond these three core factors, some gradual changes witnessed over the medium-term will also play a role in the long-term. This includes the effects of the potential positive impacts from digitalization, AI and robotics on rising productivity, as already noted.

Additionally, there are numerous potentially long-lasting effects related to rising inflation over the long-term. While only reflected and considered in a gradual manner within the current long-term framework, the evolution of rising energy prices within the ongoing energy transition and its long-term impacts is a factor that needs monitoring. For example, the current trend towards more expensive renewable energy sources may also have an impact over the long-term, lifting prices further and potentially limiting consumer demand and business investments.

Another outcome of the pandemic, albeit one that started in the years before, is the trend towards de-globalization. The pandemic has particularly laid bare the vulnerabilities of global supply chains. Moreover, the political and economic dimensions related to the Russia-Ukraine conflict has only added to this trend. With the possible consequence of re-shoring manufacturing facilities into costlier economies, inflation could be sustained to some extent.

Global GDP growth between 2021 and 2045 is expected to increase at an average rate of 3% p.a. This forecast is slightly below the assumption in the WOO 2021, when the growth forecast stood at 3.1%. However, it is above the WOO 2020 growth assumption, which stood at 2.9%. This underscores the successful efforts of fiscal and monetary stimulus, as well as the structural measures undertaken during the pandemic to support economies and lift the growth dynamic back to levels that were not foreseen at the start of the pandemic. While the ongoing Russia-Ukraine conflict has inhibited growth somewhat, and monetary tightening will no doubt have a dampening effect, the long-term global growth rate is expected to remain robust.

Global growth through to 2045 will be largely driven by non-OECD countries, in line with assumptions from previous WOO editions. These countries are expected to grow by 3.8% p.a. on average (Table 1.5), on the back of improving labour productivity and a growing working age population, even as the pace of GDP growth begins to slow. The growth dynamic for the entire forecasting period is 0.1 percentage points (pp) above that of last year.

Table 1.5
Long-term annual real GDP growth rate
% p.a.

	2021–2027	2027–2035	2035–2045	2021–2045
OECD Americas	2.2	2.0	2.0	2.1
OECD Europe	2.0	1.3	1.1	1.4
OECD Asia-Pacific	1.6	1.2	1.0	1.2
OECD	**2.0**	**1.6**	**1.5**	**1.7**
Latin America	2.3	2.2	1.7	2.0
Middle East & Africa	3.2	3.8	4.4	3.9
India	6.3	6.4	5.7	6.1
China	5.1	4.1	2.8	3.8
Other Asia	4.4	3.9	3.0	3.6
OPEC	3.3	3.2	3.2	3.2
Russia	0.2	1.6	1.3	1.1
Other Eurasia	2.2	2.7	2.3	2.4
Non-OECD	**4.2**	**4.0**	**3.4**	**3.8**
World	**3.2**	**3.0**	**2.7**	**3.0**

Source:OPEC.

It is evident that the Middle East & Africa, OPEC and Other Asia, are set to see accelerating growth trends in the long-term, ones that are faster than China.

Economic growth in Other Asia is at 3.6% p.a. over the long-term. The growth momentum is set to peak at 4.4% for the 2021–2027 period, but the growth trend holds up well and is at 3% in the last decade of the forecast.

In the Middle East & Africa, growth is estimated to average 3.9% p.a., the same level as in last year's WOO. The region is forecast to benefit from a young and growing population, as well as increased income levels as more people enter middle class. This will provide additional consumption abilities. Moreover, the region is also set to benefit from commodity market support amid global growth appreciation. Further upside may materialize if additional structural and economic reforms take place in less productive economies. A downside risk, however, relates to ongoing high-debt levels especially in low-income countries.

Russia is forecast to recover relatively well in the long-term, overcoming the current sanctions and economic downturn. Moreover, labour productivity gains may somewhat counterbalance unfavourable demographic changes and a reduction in the working-age population. Economic growth in Russia is expected to rise by 1.6% p.a. in the period 2027–2035, after very low medium-term growth of 0.2% p.a. Commodity market developments, particularly in crude oil and gas markets, will also play an important role in Russia's growth path. In the long-term, the country's declining population is expected to be the main influential force and one that prevents growth moving materially beyond the long-term average of around 1.1%, especially if no further structural reforms are implemented. Elsewhere, in Other Eurasia, marginal growth in the working-age population is set to help average GDP reach a level of 2.4% p.a. over the entire forecast period.

Latin America is expected to benefit from ongoing commodity market support and a rising and young population in most economies. At the same time, however, it is also set to face a number of challenges related to structural issues, especially in its two largest economies, Brazil and Argentina.

Brazil is expected to see the impacts of ongoing high inflation in the medium-term, and consequently high interest rates, and while it is unclear how the long-term fiscal situation will evolve, it needs to be monitored closely. Furthermore, the pace of Brazil's further structural reforms can be expected to play a role in the country's long-term growth dynamic. The ongoing sovereign-debt challenges in Argentina, as well as related issues, are anticipated to dampen growth somewhat and also require close monitoring.

The forecast anticipates that Argentina's financial issues will remain, at least in the medium-term period. Gradual reforms in Brazil are set to help build a basis for relatively robust growth in the long-term across the region. Latin America will see relatively higher growth at the front-end of the curve, and overall it is expected to achieve a 2% p.a. growth level over the total forecasting period. Given the ongoing challenges in the region, this compares to 2.3% in the previous edition of the WOO.

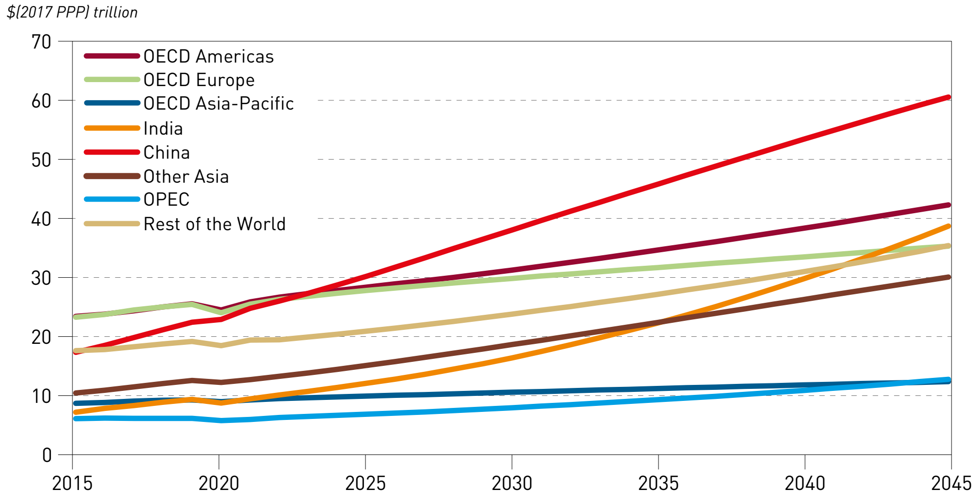
Reviewing further developments within the OECD region, economic growth is forecast to average 1.7% p.a. for the period from 2021–2045, slightly below last year's level of 1.8%. OECD Americas is anticipated to continue to lead the region's growth prospects with long-term growth at 2.1% p.a. This compares to 2.3% in last year's WOO, with this year's number taking into account some dampening effects from monetary tightening. Nonetheless, it is above the 2% level in the WOO 2020 that was forecast in the first year of the pandemic. Growth in the last decade of the period is expected to remain at a strong 2% level. Immigration into the US, and to some extent Canada, will help expand the workforce, while labour productivity growth may provide further upside.

In OECD Asia-Pacific, a declining working-age population and a maturing Chinese economy, the most important trading partner for the region, will likely drive a deceleration in economic growth. It drops to 1% p.a. for the final years of the projection period, which compares to 1.2% p.a. over the full forecast period. OECD Europe is also forecast to decelerate, amid some front-loaded impact from the Russia-Ukraine conflict, as well as general population and working-age declines. The region sees growth of 1.4% p.a. in the long-term, but it is at 1.1% p.a. for the final decade of the forecast period.

The GDP growth figures assumed in this year's WOO imply that the global economy in 2045 will be double the size it was in 2021 (Figure 1.5). Based on 2017 PPP, global GDP is projected to rise from around $133 trillion in 2021 to almost $270 trillion in 2045.

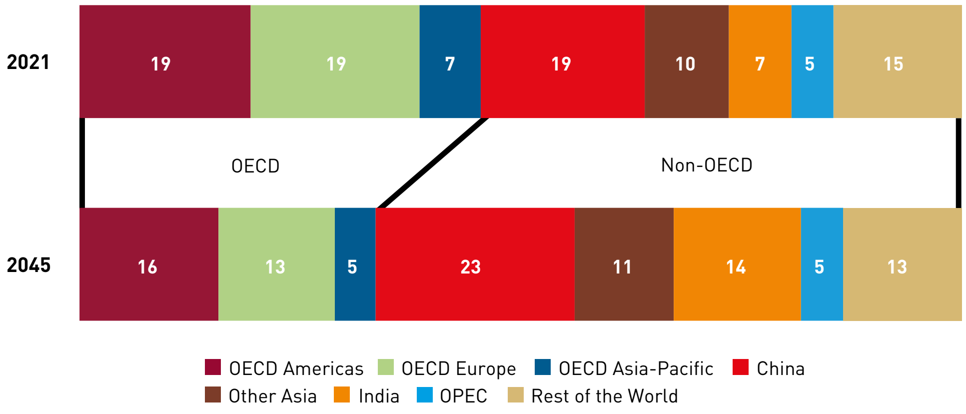
Figure 1.6 indicates that China and India alone will account for 37% of global GDP in 2045. The OECD will account for slightly less at 34%. The largest GDP appreciations over the course of the forecasting period are set to come from China and India. India

Figure 1.5
Size of major economies, 2015–2045



Source: OPEC.

Figure 1.6
Distribution of the global economy, 2021 and 2045 %



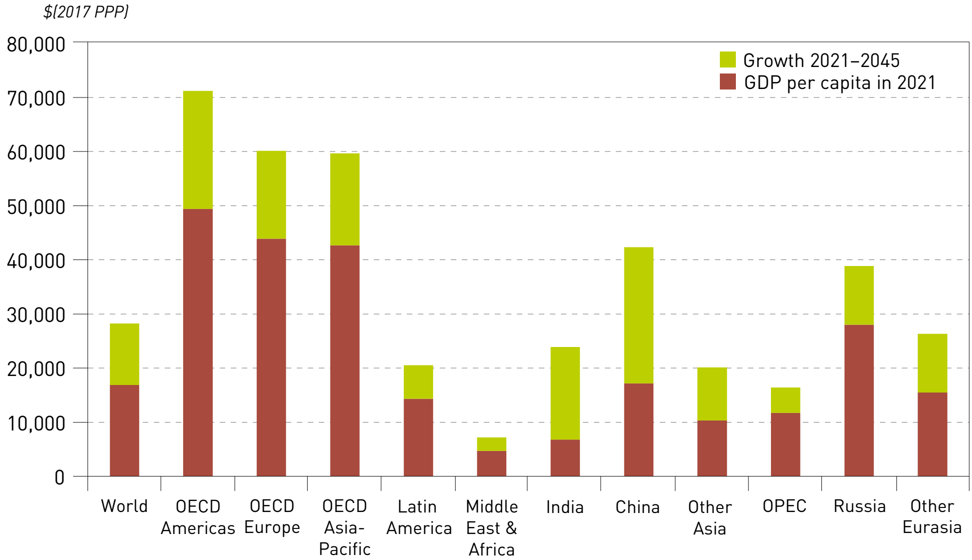
Source: OPEC.

is assumed to more than quadruple its size and add around $29 trillion to its economy, while China is expected to increase its economy by around 2.5 times and add almost $36 trillion to global GDP. This compares to an addition of $29.3 trillion from the OECD.

Despite large shifts at the regional level, the global economic picture does not see significant changes in the ranking of average income (measured as GDP per capita). OECD Americas is forecast to remain the region with the highest GDP per capita, followed by OECD Europe and OECD Asia-Pacific.

The regional grouping of Middle East & Africa will still have the lowest GDP per capita, as shown in Figure 1.7. It is also expected to be the only region where the average income is less than $10,000 (2017 PPP) in 2045. India and China are anticipated to see the biggest changes, with average income in China seen rising, closing some of the gap to OECD countries, and overtaking Russia's GDP per capita level.

Figure 1.7
Real GDP per capita in 2021 and 2045



Source: OPEC.

The global average income is projected to rise from almost $17,000 (2017 PPP) in 2021 to more than $28,000 (2017 PPP) in 2045.

1.3 Energy policies

With both developed and developing countries conscious of the urgent need to tackle climate change, a lot has happened since the 2021 edition of the Outlook in terms of the United Nations Framework Convention on Climate Change (UNFCCC) climate negotiations, as well as the Paris Agreement implementation and attainment of the SDGs under the 2030 Agenda.

COP26 took place from 31 October to 13 November 2021, in Glasgow, the UK, after a year's delay due to the COVID-19 pandemic. Following intense negotiations, UNFCCC Parties adopted a cover decision, the 'Glasgow Climate Pact', and agreed upon unresolved issues required for the Paris Agreement operationalization.

In particular, Parties agreed to *inter alia* update the 2030 emission reduction targets – namely, their NDCs – before COP27, which is scheduled to take place in Sharm el-Sheikh, Egypt from 6–18 November 2022. They also decided to proceed with submissions of long-term strategies on how to achieve net-zero emissions and align the short-term with their long-term plans, implement an annual work programme to increase ambition this decade, and consider further actions to reduce non-carbondioxide (CO_2) emissions, including methane.

Moreover, a number of declarations and initiatives were launched, such as the 'Global Methane Pledge', and the 'US-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s'. Additional countries made announcements to achieve net-zero emissions (e.g. India by 2070, and Nigeria by 2060), with many highlighting the importance of international cooperation and partnership to enhance collective climate actions.

Parties were also called on to accelerate the development and transfer of technologies, and the implementation of policies to transition towards low-emission energy systems. This included rapidly scaling up the deployment of clean power generation and energy efficiency measures, while accelerating efforts towards the 'phase down' of unabated coal power and phase-out of inefficient fossil fuel subsidies, recognizing the need for support towards a 'just transition'.

On the Paris Agreement rulebook, Parties reached an agreement on Article 6 that relates to the use of market and non-market approaches, as well as on detailed reporting requirements for all Parties and related support for developing countries, and a five-year NDC ambition cycle, among others.

Noting that the goal of developed countries to mobilize jointly $100 billion per year by 2020 had not yet been met, a process was established to discuss a new collective quantified goal on the climate finance. Developed countries were called to fulfil their commitment on the climate finance target expeditiously, whereas the UNFCCC constituted bodies have already discharged their mandated work on the subject matter.

Overall, Parties attempted in Glasgow to fill the void in climate ambition with even more pledges and announcements. Acknowledging both an 'emissions gap' and an 'implementation gap' for the world to keep the Paris Agreement temperature target in sight, the Glasgow Climate Pact reconfirmed the need to reduce global emissions, adapt to the impacts of climate change, and mobilize finance at scale.

The Intergovernmental Panel on Climate Change (IPCC) report on mitigation assesses progress in limiting global emissions, and the range of available mitigation options in key sectors – such as energy, transport and industry. It considers these in the context of sustainable development. At the same time, the IPCC report on impacts, adaptation and vulnerability assesses the complex interactions between climate change and risks for nature and people, now and into the future, and presents options to act and adapt for creating a sustainable, resilient and equitable future for all.

It is highlighted that global greenhouse gas (GHG) emissions are still on the rise, with many regions facing record-breaking extreme weather events, including long-lasting floods, heatwaves and forest fires. With an observed global warming of about 1.1°C since the pre-industrial period, millions across the globe are already vulnerable to climate change and exposed to associated risks. If emissions remain at present levels, it is shown that the remaining estimated carbon budget could be exhausted before 2030.

In addition, the IPCC report concludes that climate-resilient development corresponds to reduced risk, lower GHG emissions, and the achievement of the SDGs. This implies that adaptation to climate change and mitigation action should be implemented in a more integrated, inclusive and equitable way towards sustainable development. Multiple low-emission mitigation pathways are also assessed, most of which rely on CO_2 removal technologies.

Therefore, reducing global emissions would require *inter alia* much greater investments in low-emission energy. However, it is stressed that innovation has lagged in developing countries due to a lack of weaker enabling conditions. Many cost-effective options are already available that could offer substantial potential to reduce emissions (e.g. carbon capture and storage (CCS) technologies). Their relative potentials and costs vary across countries and in the longer-term, the cost of key technologies will fall and their effectiveness improve.

Looking ahead to COP27, Parties are expected to build momentum and assess further action for the COP agenda and beyond. Besides making progress on global emissions reduction, Parties are expected to scale up and deliver climate finance supporting actions in developing countries for their sustainable development and resilience.

There is currently a pressing need to increase climate ambition, while also ensuring energy security, and to find a resilient and sustainable way forward that leaves no one behind. The challenges are enormous due to geopolitical tensions, particularly for developing countries, which are struggling more than ever with energy security, in addition to vulnerabilities to climate change and the fallout from the COVID-19 pandemic.

In this context, energy security concerns could either hinder or support ambitious climate action. Faced with a global energy crisis and a growing anxiety of economic recession, climate mitigation and adaptation action may be of less immediate concern to some countries. Others aim for stronger energy efficiency measures and more stringent policies to support renewable energy sources. The result is a complex web of local, national, and multinational energy policies that will shape the future energy mix.

The EU, for instance, must strike a balance between the ambitious European Green Deal and the need for energy security in a continent that has been heavily reliant on fossil fuel imports from Russia, which have been disrupted due to the Russia-Ukraine conflict and the subsequent sanctions. In May 2022, the European Commission presented the REPowerEU plan to diversify energy imports in the medium-term, as well as to take steps to improve energy efficiency and accelerate the deployment of renewables. The InvestEU programme, which was originally set up as part of the EU's economic recovery package from the COVID-19 pandemic, will help provide investment towards this end.

The EU targets emissions reductions of 55% by 2030 and net-zero by 2050, with both of these targets enshrined in law after the European Climate Law came into force in July 2021. Acknowledging the need to accelerate improvements the EU Commission prepared an interlinked series of legislative proposals called the 'Fit for 55' package. Under the package, key energy policies would be revised, previous ambitions increased and new mechanisms, such as a Carbon Border Adjustment Mechanism (CBAM), introduced. The scale and the complex nature of these proposals means that deliberations and negotiations may continue for some time before agreement is reached amongst the 27 countries of the EU.

In contrast to the dynamic nature of the EU's energy policy, the US is very much stop-start. The arrival of the Biden administration revived ambition around climate change. The re-joining of the Paris Agreement on the first day of the new Presidency, new targets of at least a 50% reduction in GHG emissions by 2030 and a zero-carbon emissions power sector by 2035, were among the headline changes. However, the government has struggled to provide policy support to transition towards low- and zero-emissions energy source.

A ruling from the Supreme Court on 30 June 2022 brought into question the authority of the Environmental Protection Agency (EPA), which has been fundamental to emission reductions in previous decades through regulations, such as the Corporate Average Fuel Economy (CAFE) standard for vehicles. The Court ruling limited the authority of the EPA to directly regulate emissions from power plants, arguing that the agency had exceeded its authority.

Moreover, Congress itself has provided little support to efforts from the government in recent years. Recently, however, after a surprise deal among Democratic Party senators, the Inflation Reduction Act (IRA) was passed, providing around $369 billion to energy and climate programmes. Although smaller in size than the administration's initial proposals, which stalled in the face of opposition, this Act could support targets in the 2030s and help re-shape the country's energy mix.

For China and India, energy policies and climate ambitions have continued to evolve with several commitments in the previous 12 months. For China, earlier targets have been strengthened and new targets announced, which were reflected in the country's updated NDCs and help meet the country's major targets of peak CO_2 emissions by 2030 and carbon neutrality by 2060. India also announced its major long-term goal of reaching net-zero by 2070, while reducing projected CO_2 emissions by one billion tonnes by 2030.

Both countries are also seeing bigger roles for non-fossil fuel sources in their expanding energy mixes. China aims to reach a 25% share in primary energy consumption by 2030 (up 5 pp from its previously announced target) and India aims for 50% of power generation to be from renewable energy in 2030 (up 10 pp from its previous commitment).

With goals set for net-zero by several countries, policy efforts, in general, have continued to intensify. The strategy and objectives of the policy mechanisms and legislation being drafted and employed reflect the unique context of these countries. The trend towards a larger share of renewables is seen in many countries and regions, for example, although the component shares of the renewable energy sources varies country-by-country. In addition, several countries are looking at the long-term solutions that hydrogen offers to decarbonize those economic sectors where decarbonization is otherwise difficult. Therefore, the resultant mix of policy measures is as diverse as the countries that implement them.

What is clear is that the end of 2021 and 1H22 has shown that the 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 continued progress in 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 NDCs to the extent they are technically and financially viable.

However, 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 EVs, are not expected to be fully realized. Nevertheless, 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.

In light of the above, as well as providing more detail on the latest energy policy developments, Chapter 7 of the Outlook incorporates a dedicated section on recent developments concerning the UNFCCC climate negotiations and the Paris Agreement implementation, focusing on the latest NDCs and announcements made to reduce emissions primarily in the energy sector.

Analysis also provides insights on progress towards achieving the targets of SDG 7, especially efforts to eradicate energy poverty and build inclusive, resilient and sustainable societies through universal energy access. These developments were also taken into consideration for the scenario development and analysis incorporated in Chapter 8.

1.4 Technology and innovation

Technology has always been in a mutually dependent relationship with energy. On the one hand, it enables humankind to access vast resources to improve the quality of life. On the other, it creates an ever-increasing demand for these resources. The various components of the energy sector are closely inter-related and often in continuous competition, even if it may not appear so at first glance. Given that the oil sector is the largest segment of the energy landscape, the WOO 2022 pays special attention to recent and future technology developments in this sector.

Photovoltaic (PV) is an important example that demonstrates the significance that technology has in humankind to make use of abundant solar radiation beyond heating water. Nevertheless, there is no perfect energy source suitable for all applications as PV cells, for example, require abundant and sophisticated energy storage to bridge sunless periods. The Reference Case, therefore, assumes a gradually evolving approach to energy demand, as a whole, and oil demand, in particular, underscoring that there is no single solution to meet growing global energy needs.

The WOO assumes the continuous evolution of technology. With rising global pressure to add low-emission energy forms, as well as the increased prominence of supply security concerns, potential technology breakthroughs are also considered, especially with regard to the longer-term perspective.

1.4.1 Road transportation

ICEs have been the mainstay of the road transportation sector since the arrival of the first passenger vehicle in 1885. Only recently have battery-electric vehicles (BEVs) developed into a serious alternative in the passenger car market. Earlier attempts around 1900 did not gain much traction due to the very limited range of those vehicles in comparison with their ICE-powered counterparts – a key issue that remains today.

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

A certain degree of powertrain electrification is already a reality and will likely advance in the longer-term. However, powertrain electrification is a very broad concept, ranging from so-called 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 miles on a single charge.

Powertrain electrification in conjunction with a combustion engine is seen today, amongst others, in the form of hybrid (HEV) and plug-in hybrid electric vehicles (PHEV), which enable the main engine to run with optimum fuel efficiency at all times. Although HEVs rely entirely on fuel, as no external charging is possible, they are today on par with diesel vehicles in terms of fuel economy, but nearly exclusively built as passenger cars.

Given that HEVs typically use gasoline engines, exhaust cleaning is easier and more economic, which somewhat balances the additional cost of the second powertrain. PHEVs are especially popular in Europe and may also be charged with external power. For large and heavy vehicles, for example, large sports utility vehicles (SUVs), HEVs and PHEVs are currently, and for the foreseeable future, a solution that combines superior range with at least temporary zero local emission capabilities to comply with tightening emission standards.

The recent success of BEVs is to some extent a consequence of government incentives in many countries. In the short- to medium-term, such subsidies and privileges may fade as electric mobility becomes more mainstream. Another reason for rising BEV sales is the rapidly increasing number of available models so that today customers may find one that matches their needs. However, even with substantially improved battery technology, for example, increased capacity with reduced weight and volume, batteries may not be able to match the energy density of fossil fuels and, therefore, BEVs will struggle to match the range of ICE-powered cars.

Furthermore, software has become a very important element of modern vehicles, and not only in view of developments in navigation and entertainment systems. Although battery technology improvements are important, most of this increased range can be attributed to today's intelligent battery management software. 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. Solid-state batteries may become available towards the end of the decade and provide a further important step into the future as they are both safer and more energy dense, but it remains to be seen how fast they will penetrate the market.

Another alternative to ICE vehicles are fuel cell electric vehicles (FCEVs), the current availability of which is quite limited and it is not yet clear whether they will develop into a mainstream passenger vehicle type. With more countries and regions requesting zero emissions at the tailpipe of passenger vehicles, FCEVs may become more relevant in regions with large amounts of available hydrogen.

Fuel cells, in combination with liquefied hydrogen, may have more potential in the case of commercial vehicles. The Reference Case, nevertheless, assumes that commercial vehicles will remain more dominated by ICEs, mainly diesel engines, than the passenger car segment. Furthermore, increasing fuel efficiency in combination with tanks of 1,000 litres or so offers a considerable range advantage, even when compared to fuel cells and liquefied hydrogen. The easier handling of liquid fuels remains the first choice for the sharply increasing demand for commercial transportation in developing countries. Natural gas, either compressed (CNG) or LNG, will still occupy more than a niche in markets with abundant supply. Some Asian countries may opt for natural gas in the passenger segment too, especially where fuelling infrastructure already exists.

Apart from delivery or medium-sized trucks for day tours, batteries may not provide sufficient range. A notable exception are battery-powered urban buses that are already utilized in China and have a significant share of sales.

1.4.2 Air transportation

There remains every reason to think that air transportation will be the fastest growing transportation sector until 2045, particularly when looking at recent order books. Moreover, as the fortunes of air transportation rebound following the COVID-19 pandemic, related technologies are again in the spotlight.

Emissions from air transportation have returned as a focus of public discussion, although it should be noted that the specific efficiency (megajoule or litre of kerosene per 100 kilometres (km) of passenger transport) has decreased substantially in recent years with the accelerated introduction of more fuel-efficient airplanes. Current fuel prices are further pushing this development and accelerating fleet renovation to limit the costs for passengers and airlines. The International Air Transport Association (IATA) aims for zero-carbon growth starting from 2020, and to reduce by 50% the entire industry's CO_2 emissions by 2050, compared to 2005 levels.

The 2050 target will likely not be achieved by improving airplane efficiency alone. Flight gas turbines have become more efficient in recent decades and both, the turbine itself, as well as the fan producing most of the thrust, have advanced significantly. With the introduction of large geared fans and compression ratios of 40:1, current developments may already be reaching their efficiency limits. A further 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 to reduce the overall weight (e.g. Airbus

A350 and Boeing 787). This lowers the fuel consumption of the airplane. However, airplane design and manufacturing is fairly mature and no disruptive developments are expected from this perspective within the forecast period.

Constant fuselage and wing design improvements may lead to improved fuel efficiency as direct and induced drag is reduced. Re-designing the passenger cabin to lessen the weight and size of the seats, galley and other cabin elements, together with increasing occupancy may reduce specific fuel consumption and with minor investments compared to the development of new airplane generations. Adding two seat rows 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-km, because their additional weight increases kerosene consumption only marginally. In fact, several of these strategies are already being implemented. Another option for reducing fuel consumption is to simply minimize unnecessary airtime through flight control modernization, especially in saturated air spaces, and initiatives are already underway in this regard.

The International Civil Aviation Organization (ICAO) has started an initiative to develop and use SAF to first limit, and then reduce the industry's emissions. Such SAFs are based on biofuels, or synthetically made from hydrogen, which can be produced with renewable energy and CO_2. Additionally, the use of liquid hydrogen has been discussed, but it seems to only be a potential distant solution. SAFs appear to be one of the best choices for medium and long haul flights in the longer-term.

The role of battery-electric aviation is expected to be limited to smaller planes spanning short flight distances for the time being, for example, commuter flights below 200 to 300 km. Electric air taxis are not anticipated to contribute significantly until 2045.

The Reference Case takes stock of the latest and expected future developments in the realm of airplane efficiency, as well as the potential use of SAFs.

1.4.3 Marine transportation

The marine transportation sector is also focused on reducing emissions. This includes the 2020 cap on the sulphur content of fuel imposed by the International Maritime Organization (IMO), and an industry-wide emissions reduction of 50% by 2050 is now envisaged. In preparation for the sulphur cap, about half of the marine transportation industry leaned towards the use of LNG as a very clean fuel with the welcome side effect of decreasing CO_2 emissions by about one-quarter. Many of today's large engines for marine transportation are dual-fuel and can switch (even during operation) from liquid fuel to LNG and back. This is often an advantage if a vessel is cruising through waters with different pollution standards.

However, the new ambition to halve the entire industry's emissions, and given that marine transportation demand is projected to expand substantially over the coming decades, means further measures are necessary. Given that engines are already very efficient and achieve close to 50% fuel efficiency there is no major improvement potential remaining. Using LNG has already had a signifacant effect on emissions and could help to further limit emissions in the coming years.

Slow steaming as an instantaneous and simple strategy to reduce fuel usage is already exploited. Hull and propeller design are also expected to gradually improve, but no significant leaps are anticipated, as shipbuilding is a mature industry. The Reference Case reflects an increase in demand stemming mainly from the substantial industry expansion expected over the forecast period.

Fortunately, weight and size are not overwhelmingly important on a vessel, as in the case for airplanes. This allows the possibility to capture and store CO_2 from combusting fuel on-board and then dispose of it at ports. However, the industry is leaning more towards the use of carbon-free fuel, with ammonia currently being seriously considered. The advantage is that there is a significant amount of experience in handling large amounts of ammonia on vessels, as the existing ammonia tanker fleet indicates. As opposed to liquefied hydrogen, ammonia can be stored at a reasonable pressure of around 10 bar without cooling and at around –34°C pressure-free. However, it is not expected that such strategies will be implemented soon and the effect of using such zero-emission fuels would not be distinctly noticeable during the forecast period.

1.4.4 Conventional and renewable power generation

Throughout recent decades, power generation has been dominated by coal and in several regions gas too. New generations of so-called supercritical coal power plants, which set water under a pressure of up to 300 bar and more before heating, today surpass 45% efficiency. What was once considered a major success has today converted into a big problem as coal has the highest specific CO_2 emissions of all energy carriers. Carbon Capture, Utilization and Storage (CCUS) may reduce net emissions substantially, but it requires additional investments and reduces conversion efficiency.

Several countries and regions have, therefore, planned to phase out coal (e.g. the EU and the UK). On the other hand, a significant share of China's coal power plant fleet is relatively new and will likely be in operation for another 20 to 30 years at least, which makes China the world's largest consumer of coal for the foreseeable future. However, it can be expected that China will decommission inefficient plants earlier, meaning that the use of coal may start to decrease already in the 2030s. This is also due to newly developed plants with a combined capacity around 250 gigawatts (GW) being more efficient.

Gas has steeply increased its share in power generation in recent decades. At the same time, large combined-cycle power plants based on a combination of gas and steam turbines convert 60% and more of the gas energy into power. The WOO observes the importance of gas in this sector, especially in regions with abundant resources. The more widespread use of cogeneration for heat and power may play an important role in large urbanized areas as the waste heat from power plants can be used for space heating during winter.

Oil has not played a major role in power generation for several decades. Exceptions can be found in some oil producing countries, on islands, or in remote areas that may still rely on diesel generators. Some emergency oil-fuelled power may be added in the future to bridge times when there is a lack of power from solar and wind.

In terms of nuclear power, advancement in areas such as the development of modular reactors, the use of thorium as a fuel source, and the technique of 'breeding' to produce more fissile material from the non-fissile material that is present in the reactor, could help pave the way towards the expanded proliferation of nuclear power.

In view of the need to tackle climate change and with increased energy supply issues, nuclear power may once again gain momentum. However, the timeline from planning to commissioning a plant is typically around ten years or more, limiting the potential short-term impact. Nevertheless, the Outlook considers nuclear power as a serious opportunity for power generation in the future.

Wind and solar were regarded as largely non-competitive some 30 years ago. With substantial governmental support in the form of subsidies and other privileges, generation costs have come down to levels comparable with fossil power generation or even below these levels in the most favourable locations. In regions where traditional power generation has been strong, for example, Europe, the US and China, wind and solar now contribute an important share of the overall power generation mix.

It should also be noted that the 'capacity factor' of renewable power plants – the ratio between the energy output over a given time and the theoretical maximum output – is substantially below that of fossil fuels. For example, every megawatt (MW) peak of PV may produce 1,000MWh (Central Europe, SE China) to around 2,400MWh (Atacama) within one year, largely depending on the geographic location. These numbers correspond to a capacity factor of just 11-to-27%. Nuclear may reach 80% or more, and even coal-fired plants with adaptation to fluctuating demand usually stand at around 50%. Wind is doing better with capacity factors ranging between 30% and 45%. The consequence of a lower capacity factor is that multiples of installed power are required to achieve the same year-round power generation as traditional power plants.

The penetration of renewables for power generation, with an emphasis on wind and solar, will rise throughout the forecast period and will increasingly 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

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

There are several available technologies to produce hydrogen each at a different stage of maturity. These depend on a range of available feedstocks and enjoy varying policy support.

Currently, around half of the global hydrogen production is based on the steam naphtha reforming (SNR) process, which utilizes shorter-chain hydrocarbons (ranging from natural gas to naphtha) as a feedstock. Another widely deployed technology called partial oxidation (POX) typically uses the heavy part of the refined barrel that is decomposed into a mixture of hydrogen, CO_2 and CO at temperatures ranging from 1,300 °C to 1,500 °C and in the presence of steam and oxygen. These two processes are also well suited to being combined with CCUS in the future. Thus, providing a clean energy product, blue hydrogen, to help reduce CO_2 emissions.

Intense developments have also been carried out to strip carbon from natural gas via a technology called methane pyrolysis. The advantage of this approach is that the resultant product, apart from the desired hydrogen, is solid carbon that can easily be deposited under-, or even over ground.

Another emerging technology to produce potentially large quantities of blue hydrogen from oil-based feedstocks is Hygienic Earth Energy (HEE), developed by Proton Technologies. The HEE process involves a combination of heating oil reservoirs through the injection of high purity oxygen deep into the reservoir and harvesting pure hydrogen through a selective membrane that ensures that all other gases are confined below the ground. This technology, however, is at the early development stage and requires further progress to prove its viability.

An alternative to producing fossil fuels-based hydrogen is to use renewable energy sources through electrolysis. This may be possible in regions with abundant renewable power, either based on wind or solar. However, the challenge transporting vast amounts of hydrogen to consuming regions persists as hydrogen may have a high energy density per mass, but a very low energy density per volume, even when liquefied. If hydrogen is produced in remote areas, transportation efforts will multiply compared to natural gas or oil, for both pipeline and maritime routes.

On the demand side, hydrogen as a gaseous energy carrier can be used nearly everywhere where natural gas is employed today. It may also displace coal in steel production. However, industrial processes must be adapted significantly and this requires additional investments. Hydrogen may also become attractive as indirect energy storage, or in combination with fuel cells to decarbonize commercial road transportation, as heavy trucks for long-distance transportation are unlikely to run on battery power, even in the more distant future.

Energy demand

Key takeaways

- Global primary energy demand is expected to increase from 285.7 mboe/d in 2021 to 351 mboe/d in 2045, an increase of 23%.
- The driver of global energy demand is the non-OECD, increasing by almost 69 mboe/d in the period to 2045. India alone accounts for almost 28% of this rise.
- After a moderate medium-term increase, energy demand in the OECD is set to see a gradual decline, reaching 102.2 mboe/d in 2045, down by 3.6 mboe/d relative to 2021.
- Oil demand is anticipated to increase from 88.3 mboe/d in 2021 to 100.6 mboe/d in 2045, with its share in the energy mix dropping from almost 31% to just below 29%. Despite decelerating oil demand growth, oil is set to retain the highest share in the global energy mix during the entire period.
- Coal is the only primary fuel that sees a demand drop within the outlook period, declining from almost 75 mboe/d in 2021 to 58.2 mboe/d in 2045. Strong policy headwinds and numerous commitments to phase out and phase down coal-based power are the major drivers of this trend.
- Despite the short-term market distortions, gas demand is projected to increase by almost 19 mboe/d to 2045, supported by demand in all sectors, replacing coal and traditional biomass use. By 2030, gas is set to overtake coal and become the second largest fuel in the energy mix.
- With strong policy support and declining long-term costs, other renewables (mostly wind and solar) are the fastest and largest growing category in the energy mix, adding almost 31 mboe/d in the outlook period.
- Nuclear power is expected to increase by more than 50% from 2021 levels, reaching 23.3 mboe/d in 2045. Strong policy support and the rising need for low-carbon baseload power sources are the major drivers for this trend.
- Biomass is forecast to increase by around 8.6 mboe/d between 2021 and 2045, attributed mostly to the rising advanced use of biomass.
- Energy intensity is expected to drop in all regions, thanks to increasing energy efficiency in final usage and transformation, as well as the rising share of renewables. The largest improvements are expected in China and India.
- Despite rising energy demand growth, per capita consumption in non-OECD countries will remain far below the per capita energy usage in OECD countries in 2045. This is especially true for regions such as Sub-Saharan Africa and India.

Chapter 2 focuses on the medium- and long-term energy demand trends by primary fuels and major regions. Projections shown in this chapter take into account drivers such as demographic and economic trends, technological developments, as well as the evolution of energy policies, including those related to climate change and those linked to energy poverty and energy access (see Chapter 1 and Chapter 7). Additionally, concerns and challenges related to energy security play an important role. Since the start of the conflict in Eastern Europe in early 2022, energy security has gained a more prominent position on policy makers' agendas. All these factors help shape energy demand trends and the energy mix at a local, regional and global level.

It is important to note that 2021 is the statistical data baseline for the outlook and for those regions where data is not available, the outlook supplements these data sets with preliminary estimations.

2.1 Major trends in energy demand

In recent years, the narrative on environmental sustainability and climate change-related policies has largely dominated the energy sector. COP26 in Glasgow in late 2021 resulted in agreement on the 'Paris Rulebook' and 'Glasgow Climate Pact', as well as an agreement to phase down coal-based electricity generation. Financial investors have increasingly shifted to focus on ESG standards, with significant knock-on consequences for capital access and capital flows in the energy sector. In addition, several major western companies have announced strategic shifts, with a rising focus on renewables and a reduction in their exposure to oil and gas.

However, at the end of 2021 and into 2022, with issues related to adequate energy supplies, investments and the conflict in Eastern Europe there has been a sudden re-emergence and renewed acknowledgement of energy security and energy affordability challenges. Consequently, this has forced market participants to reorder their priorities, particularly in the short-term.

This is especially true for Europe (specifically, the EU and the UK), which, in reaction to the conflict in Eastern Europe, has decided to reduce its energy imports from Russia. Consequently, the EU and the UK have imposed a ban on coal, crude oil and refined product imports as of early 2023, albeit with some exceptions. The EU has also developed plans to reduce and potentially phase out Russian natural gas imports by 2027. Several other countries, such as the US, Canada, Australia and Japan, have imposed similar measures, but as they are far less dependent on Russian imports, the effects will be more limited. The sudden change in Europe's energy import mix has led to instability on global energy markets, including shifts in global energy trade flows, especially related to oil and gas. Even stronger market distortions can be expected once the further sanctions become effective in early 2023.

Another factor influencing the short-term energy landscape are increasing energy prices, driven mainly by the geopolitical events in Eastern Europe, but also by a shortfall in investments in recent years and rising energy demand in the post-pandemic recovery. Prices for all fuels have increased significantly since the last quarter of 2021 and this has influenced the energy mix in some countries/regions. These developments have led to governments looking at ways to offset the impact of high-energy prices, through policies (including subsidising energy bills), as well as increased efforts related to energy efficiency and renewable energy deployment. However, the leeway for governments in the short-term is rather limited. In order to offset possible shortages of natural gas, several countries and regions are likely to see a further increase in coal-based power generation, including the US and Europe.

In addition to rising energy prices, other commodity prices, such as metals and critical minerals have increased too, and in some cases by a greater amount percentage wise. Prices for commodities such as lithium, cobalt, nickel, aluminium have soared to record high levels. This translates into increasing costs for renewable energy, such as wind turbines, PV modules and batteries, with possible impacts on the expansion rate of renewables and EVs.

All this is happening in the midst of recent strong global energy demand growth, driven by a robust post-COVID recovery. Total primary energy demand increased in 2021 to around 286 mboe/d, an increase of around 4% relative to 2020. The recovery in oil demand was the strongest, given the significant drop in 2020 due to the nature of COVID-19 related measures that hit the transportation sector particularly hard. Demand for coal and gas also recovered, in line with rising demand from the industrial sector, as well as increasing electricity generation. Nonetheless, 2021 global primary energy remained slightly below pre-COVID levels in 2019.

The strong growth continued in early 1H22, supported by further post-pandemic recovery and the relaxation of pandemic-related measures in some major consuming regions. However, rising energy prices, which started increasing even before the conflict in Eastern Europe, have subdued this growth somewhat with possible further implications in late 2022 and 2023.

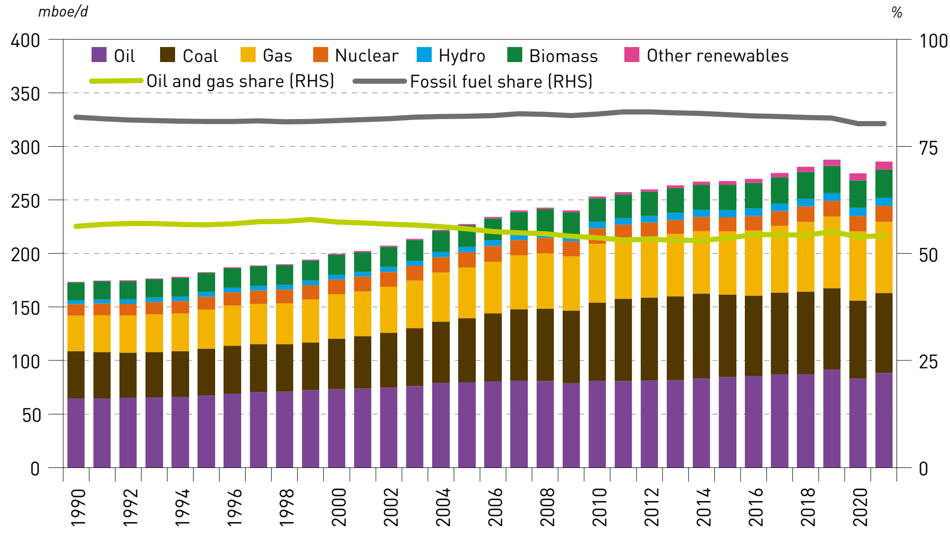
This can be viewed as a polycrisis, which is playing out at different levels of the economy and the energy market, and affecting all of its components. Thus, the Outlook takes on board significant short-term uncertainties related to the Russia-Ukraine conflict and further supply-side shocks are possible. For instance, the uncertainty related to gas pipeline flows from Russia to Europe and gas prices may lead to significant downsides related to gas demand in the coming winter or even beyond. However, the basic assumption of this Outlook is that the conflict is largely contained in the medium-term, albeit recognizing some possible lasting long-term consequences.

It is clear that the short-term energy market tightness may defer some of the long-term targets, especially those related to CO_2 emissions. For example, due to a possible shortage of gas, Germany will restart around 10.4 GW of its idled largely coal-based generation capacity in the 2H22. Other European countries are likely to follow this path. This could jeopardize some EU policy targets related to emission reductions in both the short- and medium-term.

At the same time, however, recent announcements from some developed countries have also shown an urge for even faster renewable energy deployment in some regions. In these cases, rising investment into renewables (mostly wind and solar) is seen not only as the pathway to a low carbon future, but also as a means to increase energy security and lower energy import dependence. While this can be a plausible scenario for some countries, it should be viewed as a highly uncertain one at the global level.

Before discussing medium- and long-term outlooks, it is important to recall the historical development of the global energy system. Figure 2.1 shows the evolution of energy demand and the energy mix from 1990 to 2021. Global energy demand increased from around 174 mboe/d in 1990 to 286 mboe/d in 2021. Only around 11% of this growth has come from OECD regions, with the rest occurring in developing countries, mostly those in Asia.

Figure 2.1
Primary energy demand by fuel type, 1990–2021



Source: OPEC.

In terms of the energy mix, the share of fossil fuels has remained astonishingly stable at above 80% for more than 30 years. In the same period, the share of oil and gas in the mix has also been stable, hovering at around 55%. The share of fossil fuels in the mix remained stable despite strong renewables growth in some countries (especially wind and solar) amid strong policy support and declining costs. Current long-term policies point at a fast deployment of renewables in the medium- and long-term with many countries adopting net-zero and/or carbon neutrality targets for 2050 or beyond. However, the ability of countries to implement these policies remains highly uncertain, especially given some recent backtracking as a result of the current geopolitical tensions and energy market crisis.

This Outlook assumes that even with possible delays and deferrals of energy policies due to the current crises, long-term energy and climate change policies will continue to play a decisive role in reshaping the energy landscape. However, it is clear that recent developments have unscored that policies should be carefully evolved and fine-tuned in order to avoid unintended consequences, such as energy supply shortages and price shocks. While focusing on energy sustainability, these policies should not neglect the energy security and energy affordability components of the energy sustainability trilemma. This is especially the case for developing countries, due to their vulnerability and disproportional exposure to supply and price shocks.

Table 2.1 shows global energy demand in the medium- and long-term. In this year's Reference Case, global energy demand is expected to increase from slightly below 286 mboe/d in 2021 to 351 mboe/d in 2045, an increase of 65.3 mboe/d, or 23%, over the outlook period. The Outlook shows a gradual long-term slowdown in primary energy demand growth. While the energy demand increase is almost 15.5 mboe/d between 2030 and 2035, the growth between 2040 and 2045 is only around 7.5 mboe/d. The major reason for this is slowing demographic growth, decelerating economic growth, rising energy efficiency and lower energy intensity. It should be noted, however, that this drop is much less pronounced in final energy demand, given the rising share of renewables that have little or no transformation/transmission losses and given that it replaces fossil fuels where transformation losses are significant.

Table 2.1
World primary energy demand by fuel type, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
Oil	88.3	96.1	98.9	100.1	100.5	100.6	12.3	0.5	30.9	28.7
Coal	74.7	74.0	70.7	66.4	62.1	58.2	–16.5	–1.0	26.1	16.6
Gas	66.4	69.9	74.9	79.5	83.0	85.3	18.9	1.0	23.2	24.3
Nuclear	15.2	16.3	17.8	19.6	21.7	23.3	8.1	1.8	5.3	6.6
Hydro	7.5	8.0	8.7	9.4	10.1	10.4	2.9	1.4	2.6	3.0
Biomass	26.2	27.9	30.0	32.0	33.7	34.9	8.6	1.2	9.2	9.9
Other renewables	7.4	11.2	17.8	24.9	32.5	38.3	30.9	7.1	2.6	10.9
Total	**285.7**	**303.4**	**318.9**	**331.9**	**343.6**	**351.0**	**65.3**	**0.9**	**100.0**	**100.0**

Source: OPEC.

Looking at the energy mix, demand for all primary fuels increases, with the exception of coal, which declines due to mounting pressure on the policy side. In total, coal demand declines from around 75 mboe/d in 2021 to almost 58 mboe/d in 2045, driven by commitments of countries to phase out and/or phase down coal-powered generation. **Oil** demand is expected to increase 12.3 mboe/d, reaching 100.6 mboe/d in 2045. A significant part of this growth is accounted for by the post-pandemic recovery. Beyond 2030, oil demand increases only marginally in line with stricter energy policies, efficiency gains and a switch to other fuels. Consequently, the share of oil in the primary energy mix declines from around 31% in 2021 to 28.7% in 2045. Even after this decline, oil is set to retain the number one position in the energy mix.

Natural gas demand is set to increase strongly by 19 mboe/d between 2021 and 2045. It reaches 85 mboe/d by the end of the forecast period. It is assumed that natural gas will remain a long-term fuel of choice, despite the current market distortions. The long-term potential for natural gas is based on the sufficient gas resources and its relatively low CO_2 emissions, which is why many countries intend to increase the share of gas in their energy mix. Its share in the energy mix increases, from just above 23% in 2021 to almost 24.5% in 2045. Due to coal's decline, gas becomes the second largest fuel in the mix after 2030.

Other renewables, including wind, solar, as well as geothermal, remain the fastest and largest growing source of energy demand in the medium- and long-term. With an average annual growth rate of 7.1% p.a., other renewables are set to increase from 7.4 mboe/d in 2021 to above 38 mboe/d in 2045. The growth of other renewables is only slightly lower relative to the combined demand growth of oil and gas between 2021 and 2045. Other renewables are supported by energy policies and commitments to reduce the carbon footprint of energy systems, as well as its rising competitiveness relative to other fuels. Even with this strong growth, however, the market share of other renewables is estimated at just below 11% in 2045, up from 2.6% in 2021.

Biomass demand is anticipated to increase from 26.2 mboe/d in 2021 to almost 35 mboe/d in 2045, a rise of 8.6 mboe/d over the projection period. The growth comes mostly from the advanced use of biomass for the production of biofuels and biogas, as well as in power generation. At the same time, the traditional use of biomass is expected to decline.

Demand for **nuclear energy** is set to increase from 15.2 mboe/d in 2021 to 23.3 mboe/d in 2045. This not only includes the construction of new nuclear power plants, mostly in developing regions, such as Asia and the Middle East, but also the replacement of existing capacities in OECD regions, such as Europe and the US. A strong policy push for nuclear power is expected to continue supporting this development.

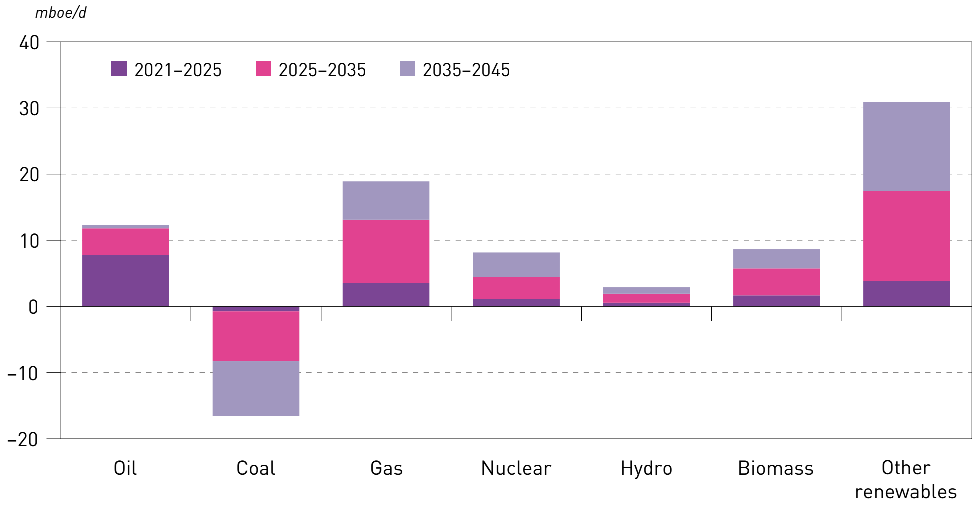
Finally, demand for **hydropower** is expected to increase by around 3 mboe/d between 2021 and 2045, reaching 10.4 mboe/d at the end of the outlook period. The increase comes mostly from developing countries, including China, as those regions still have large unutilized potential.

In total, accounting for the drop in coal demand, primary energy demand for fossil fuels increases by almost 15 mboe/d between 2021 and 2045. At the same time, demand for lower carbon fuels, including nuclear and renewables, sees a gain of more than 50 mboe/d (Figure 2.2) in the Reference Case. Despite this strong growth in lower carbon energy sources, however, the share of fossil fuels only declines by around 10 pp to 69.5% by 2045. For oil and gas alone, their combined market share in the global primary energy mix is expected to remain above 50% throughout the outlook period.

The Outlook shows different regional trends, as exhibited in Table 2.2. Long-term energy demand growth comes exclusively from non-OECD regions, notably China and India, as well as other developing countries in Asia, Middle East and Africa, supported by demographic and economic growth. Increasing energy access and a reduction in energy poverty also plays an important role in rising energy demand in these regions. In total, non-OECD demand growth between 2021 and 2045 is estimated at almost 69 mboe/d.

The country with the highest energy demand growth in the outlook period is India (Figure 2.3), where demand is projected to increase from 18.6 mboe/d in 2021 to 37.7 mboe/d in 2045, equating to average demand growth of 3% p.a. India alone accounts for around 28% of the total non-OECD energy demand growth to 2045. At the same time, China's energy demand is estimated at 77.5 mboe/d in 2045, up by around 8 mboe/d compared to 2021. As China is projected to experience a slowdown in economic growth and significantly reduce its coal demand to replace it largely with renewables, overall primary energy demand growth is much lower relative to India.

Figure 2.2
Growth in primary energy demand by fuel type, 2021–2045



Source: OPEC.

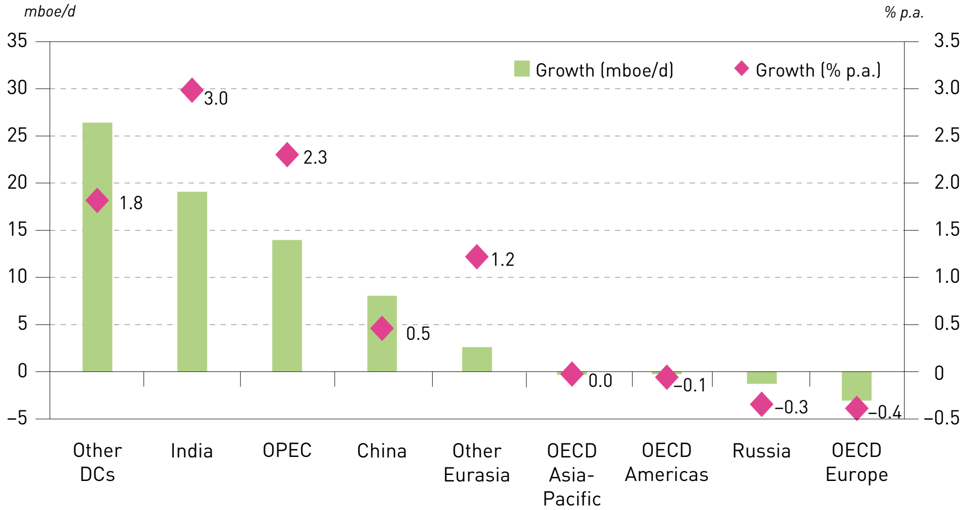
Table 2.2
Total primary energy demand by region, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
OECD Americas	54.0	55.8	55.5	54.9	54.2	53.7	–0.3	0.0	18.9	15.3
OECD Europe	34.4	34.9	34.0	33.1	32.2	31.4	–3.1	–0.4	12.0	8.9
OECD Asia-Pacific	17.4	17.8	17.8	17.6	17.5	17.2	–0.2	–0.1	6.1	4.9
OECD	**105.8**	**108.5**	**107.3**	**105.7**	**103.9**	**102.2**	**–3.6**	**–0.1**	**37.0**	**29.1**
China	69.4	73.9	76.6	77.3	77.0	77.5	8.1	0.5	24.3	22.1
India	18.6	21.7	25.8	30.1	34.2	37.7	19.1	3.0	6.5	10.7
OPEC	19.2	22.0	25.2	28.3	31.2	33.2	14.0	2.3	6.7	9.5
Other DCs	48.9	54.3	60.6	66.5	72.7	75.3	26.4	1.8	17.1	21.5
Russia	16.0	15.0	15.0	14.9	14.8	14.7	–1.3	–0.3	5.6	4.2
Other Eurasia	7.8	8.1	8.5	9.1	9.7	10.4	2.6	1.2	2.7	3.0
Non-OECD	**179.9**	**195.0**	**211.6**	**226.2**	**239.8**	**248.8**	**68.9**	**1.4**	**63.0**	**70.9**
World	**285.7**	**303.4**	**318.9**	**331.9**	**343.6**	**351.0**	**65.3**	**0.9**	**100.0**	**100.0**

Source: OPEC.

OPEC countries are also set to see a large expansion in energy demand, with a gain of 14 mboe/d between 2021 and 2045. Economic and demographic developments, as well as the availability of affordable energy resources, favour this growth. Other non-OECD countries, including a large number of developing countries in Asia, Africa and Latin America, are expected to see energy demand expand by almost 26.5 mboe/d in the

Figure 2.3
Growth in primary energy demand by region, 2021–2045



Source: OPEC.

outlook period. Consequently, the share of non-OECD countries in total primary energy demand increases from 63% in 2021 to almost 71% in 2045.

OECD long-term energy demand is expected to gradually decline, driven by slower economic growth, rising energy efficiency and the partial substitution of fossil fuels by renewables. In total, OECD primary energy demand is projected to decline by 3.6 mboe/d between 2021 and 2045. OECD Europe accounts for 3.1 mboe/d of this decline, while OECD Americas and OECD Asia-Pacific drop only marginally.

2.2 Energy demand by major regions

This section focuses on the regional details related to primary energy demand. It explains the energy mix developments in the context of economic development and major energy policies.

As shown in Table 2.3, OECD primary energy demand increases modestly in the medium-term, part of which is accounted for by the post-pandemic recovery. Demand increases from 105.8 mboe/d in 2021 to a peak of 108.5 mboe/d in 2025, which means that demand will not reach its pre-pandemic levels. In the long-term, demand is likely to decline gradually to levels just above 102 mboe/d in 2045, down by 3.6 mboe/d relative to 2021. This is largely due to energy policies and a slowdown in economic growth, as well as a higher share of other renewables with low transformation losses in the mix. The largest share of this decline can be attributed to OECD Europe, with a modest decline in OECD Americas and a minor one in OECD Asia-Pacific. The WOO maintains the view that the policy push to reduce fossil fuels consumption will be the strongest in OECD Europe, followed by OECD Americas and OECD Asia-Pacific. Subsequently, the share of OECD in global primary demand drops from 37% in 2021 to 29% in 2045.

Demand for all fossil fuels in the OECD is set to witness a drop, mostly through coal and oil, but also a marginal decline in gas. Oil demand in the OECD declines by almost

Table 2.3
OECD primary energy demand by fuel type, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
Oil	38.5	40.3	38.1	35.0	31.8	28.8	–9.7	–1.2	36.4	28.1
Coal	14.4	12.9	10.8	9.1	7.7	6.5	–7.9	–3.3	13.6	6.4
Gas	29.7	30.0	29.9	29.9	29.6	29.0	–0.7	–0.1	28.1	28.4
Nuclear	10.4	10.4	10.7	11.0	11.3	11.5	1.1	0.4	9.8	11.3
Hydro	2.5	2.6	2.7	2.8	2.8	2.9	0.5	0.7	2.3	2.9
Biomass	6.9	7.4	8.0	8.7	9.3	10.0	3.1	1.6	6.5	9.8
Other renewables	3.5	4.9	7.1	9.2	11.3	13.5	10.0	5.8	3.3	13.2
Total	**105.8**	**108.5**	**107.3**	**105.7**	**103.9**	**102.2**	**–3.6**	**–0.1**	**100.0**	**100.0**

Source: OPEC.

10 mboe/d between 2021 and 2045. This is the result of strict policies in the transportation sector focused on replacing oil, as well increasing the efficiency of oil use. According to EU proposals, all new vehicle sales (cars and vans) will be zero-emission vehicles from 2035, thus eliminating new petrol or diesel car sales. In the US, the current target is to reach a 50% share of zero-emission vehicles in new sales by 2030. Countries in OECD Asia-Pacific, such as Japan, have adopted similar policies. This, in combination with further efficiency gains in conventional cars, is the major reason for the oil demand drop.

Coal demand is projected to decline by almost 8 mboe/d between 2021 and 2045, in line with the phase-out commitments of major OECD countries. Earlier this year, G7 countries committed to phase out unabated coal power generation and achieve predominantly decarbonized power generation by 2035. OECD governments emphasized that their long-term targets on coal should not be jeopardized by the temporary comeback of coal-based power generation in most OECD region in 2022/23 due to gas supply issues. Nevertheless, target deferrals in the short- and medium-term are possible.

The demand for natural gas in the OECD is expected to inch down from levels witnessed in 2021. However, sub-regional differences are significant. European gas demand is expected to decline by some 1.7 mboe/d between 2021 and 2045. This is not only because of current geopolitical developments, but also due to a policy push for more renewables, such as wind and solar, as well as more hydrogen and biogas. Gas demand in OECD Americas is projected to increase by around 1 mboe/d in the period to 2045. The availability of relatively cheap gas resources is likely help to replace coal in this region's power generation sector.

Demand for other renewables is set to increase by 10 mboe/d in the OECD between 2021 and 2045, in line with policy support to expand wind and solar power generation. This increase will more than offset the reduction in coal-based power generation. The combined demand for nuclear, hydro and biomass is forecast to rise by almost 5 mboe/d in the same period. This increase is accounted for by the additional usage of biomass for biofuel and biogas production.

These changes in the OECD energy mix will lead to a declining share of fossil fuels in the energy mix, dropping from 78% in 2021 to just below 63% in 2045. On the other hand, the share of other renewables, increases from only 3.3% in 2021 to above 13% in 2045.

In non-OECD (Table 2.4), energy demand is projected to increase from 180 mboe/d in 2021 to nearly 249 mboe/d in 2045, an increase of almost 69 mboe/d. The major contributions come from India (+19.1 mboe/d), China (+8.1 mboe/d), OPEC (+14 mboe/d) and Other Developing countries (+26.4 mboe/d). Non-OECD demand for oil and gas is set to expand strongly in the long-term with oil growing by 22 mboe/d and gas by 19.5 mboe/d, supported by economic development and increasing energy access. At the same time, demand for coal is expected to decline by 8.6 mboe/d, which reflects the policies of several countries to reduce coal usage for power and heat generation, including China.

Table 2.4
Non-OECD primary energy demand by fuel type, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2021	**2025**	**2030**	**2035**	**2040**	**2045**	**2021–2045**	**2021–2045**	**2021**	**2045**
Oil	49.8	55.8	60.8	65.1	68.7	71.9	22.0	1.5	27.7	28.9
Coal	60.3	61.1	59.9	57.3	54.4	51.7	–8.6	–0.6	33.5	20.8
Gas	36.7	40.0	45.0	49.6	53.5	56.3	19.6	1.8	20.4	22.6
Nuclear	4.8	5.8	7.1	8.6	10.3	11.8	7.0	3.8	2.7	4.7
Hydro	5.0	5.5	6.1	6.7	7.3	7.5	2.4	1.7	2.8	3.0
Biomass	19.4	20.5	22.0	23.3	24.4	24.9	5.5	1.0	10.8	10.0
Other renewables	4.0	6.3	10.7	15.6	21.2	24.9	20.9	7.9	2.2	10.0
Total	**179.9**	**195.0**	**211.6**	**226.2**	**239.8**	**248.8**	**68.9**	**1.4**	**100.0**	**100.0**

Source: OPEC.

Furthermore, demand for all other fuels is expected to increase as well. Other renewables are forecast to gain almost 21 mboe/d between 2021 and 2045. More than 40% of this increase is set to come from China, where policies give strong support to the renewable sector. Nuclear energy is seen at almost 12 mboe/d in 2045, which is 7 mboe/d higher relative to 2021. Many countries in Asia are expected to expand their nuclear capacity, including China, India and several Middle Eastern countries.

The use of biomass is set to increase, gaining 5.5 mboe/d in the outlook period. Similarly to the OECD, a large part of this increase is due to higher demand for the advanced use of biomass, such as biofuel and biogas production. Finally, hydropower is also expected to increase, rising by nearly 2.5 mboe/d, given there are still unutilized capacities in developing countries.

The overall share of fossil fuels in the non-OECD is expected to decline from 81.6% in 2021 to 72.3% in 2045, which is mostly due to the drop in coal use. The share of oil and gas in the energy mix alone is expected to increase to above 51% in 2045. At the same time, the share of low-carbon fuels increases significantly, mostly due to the expansion of other renewables. The share of other renewables increases from just above 2% in 2021 to 10% in 2045, due to large expansions in China and OPEC (mostly Middle East).

Table 2.5 shows China's primary energy demand by fuel over the outlook period. In total, energy demand is projected to increase by 8.1 mboe/d, with a significant drop-off in growth after 2030. One of the reasons for this is a slowdown in population and economic growth, but also rising energy efficiency (in transformation and final use). In addition, China's official target is to hit peak CO_2 emissions by 2030, which will shape the future energy mix.

Table 2.5
China primary energy demand by fuel type, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
Oil	14.2	15.7	16.2	16.6	16.6	16.5	2.3	0.6	20.5	21.3
Coal	40.3	39.8	37.0	33.0	29.1	26.1	–14.2	–1.8	58.0	33.6
Gas	5.5	6.6	7.9	8.9	9.6	9.9	4.4	2.5	7.9	12.7
Nuclear	2.3	3.1	3.9	4.9	5.9	6.9	4.6	4.7	3.3	8.9
Hydro	2.3	2.4	2.6	2.7	2.8	2.9	0.7	1.1	3.3	3.8
Biomass	2.7	3.0	3.4	3.8	4.0	4.2	1.5	1.9	3.9	5.4
Other renewables	2.3	3.4	5.5	7.4	9.0	11.0	8.8	6.8	3.3	14.2
Total	**69.4**	**73.9**	**76.6**	**77.3**	**77.0**	**77.5**	**8.1**	**0.5**	**100.0**	**100.0**

Source: OPEC.

Consequently, the 14th Five-Year Plan (FYP) foresees 'strict control' of coal usage until 2025 and a gradual phase down thereafter. Retrofitting coal plants will also help to increase transformation efficiency and, in turn, reduce primary fuel usage. This is why China is forecast to see a drop in its coal demand of a huge 14.2 mboe/d between 2021 and 2045. This would bring coal share's down in the primary energy mix by almost 25 pp to 33.6% by 2045.

At the same time, natural gas demand is expected to increase by 4.4 mboe/d, partly replacing some of the phased out coal capacity. This growth is partly linked to the deployment of China's domestic gas resources, as emphasized by official targets. Chinese oil demand is set to witness a significant slowdown after 2030, which is in line with an expected rising share of EVs in the country. At the same time, China's demand for other renewables will increase by almost 9 mboe/d, mostly attributed to the increase in solar and wind capacity. The 14th FYP and the renewable energy plan for the period to 2035 sees a strong increase in renewable power generation. Nuclear energy is also expected to see strong growth. The FYP foresees an increase in nuclear capacity to around 70 GW by 2025, up from 53 GW in early 2022. In the long-term, around 4.5 mboe/d of nuclear energy is expected to be added by 2045 in the Reference Case, which is an increase of 200% from current levels.

Table 2.6 shows the energy demand projection for India, which is by far the single most important country for global energy and oil demand growth over the forecast period. India's energy consumption is seen to more than double from 18.6 mboe/d in 2021 to almost 38 mboe/d in 2045. All energy sources are expected to expand, supported by strong demographic and economic expansion.

Table 2.6
India primary energy demand by fuel type, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Fuel share *%*	
	2021	**2025**	**2030**	**2035**	**2040**	**2045**	**2021–2045**	**2021–2045**	**2021**	**2045**
Oil	4.8	5.8	7.1	8.3	9.6	11.0	6.2	3.5	25.7	29.2
Coal	8.0	9.2	10.7	12.1	13.1	13.1	5.1	2.1	43.1	34.8
Gas	1.1	1.4	1.9	2.6	3.2	3.8	2.7	5.2	6.0	10.2
Nuclear	0.3	0.4	0.6	0.8	1.1	1.4	1.1	6.7	1.6	3.7
Hydro	0.3	0.4	0.5	0.6	0.7	0.7	0.4	3.4	1.7	1.9
Biomass	3.8	3.9	4.0	4.1	4.1	4.1	0.3	0.4	20.2	10.9
Other renewables	0.3	0.6	1.0	1.6	2.4	3.5	3.2	10.9	1.6	9.3
Total	**18.6**	**21.7**	**25.8**	**30.1**	**34.2**	**37.7**	**19.1**	**3.0**	**100.0**	**100.0**

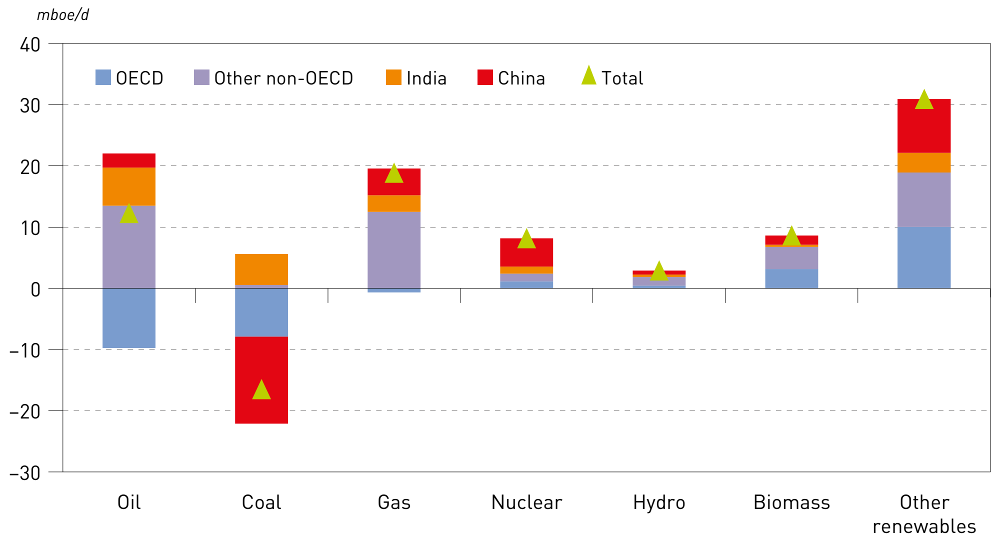
Source: OPEC.

Oil demand is forecast to increase by 6.2 mboe/d, reaching 11 mboe/d in 2045, driven by the transportation and petrochemical sectors. Higher electricity demand will result in higher coal demand, which is expected to increase by more than 5 mboe/d to 13.1 mboe/d in 2045. However, the Reference Case sees a peak in India's coal demand growth in 2040, which is due to efforts to reduce its usage. India's gas demand is set to increase from 1.1 mboe/d in 2021 to 3.8 mboe/d in 2045, attributed mostly to the power generation sector and the rising degree of gasification. India's target is to increase its share of gas in its energy mix far above current levels of 6% in 2021.

Demand for other renewables in the Reference Case is forecast to increase to 3.5 mboe/d in 2045, an increase of more than 1,000% relative to 2021. India has committed itself to increase renewable power generation capacity to 500 GW (including hydro) by 2030, up from around 150 GW in 2021. India is also expected to increase its nuclear power generation. Demand between 2021 and 2045 is set to almost triple, reaching 1.1 mboe/d at the end of the outlook period.

Figure 2.4 shows regional demand movements by fuel, and by major region. It illustrates the importance of China and India in the energy demand evolution, especially related to the development of coal demand. While the OECD plays an important role, the incremental demand for renewables remains significantly lower compared to non-OECD.

Figure 2.4
Growth in energy demand by fuel type and region, 2021–2045



Source: OPEC.

2.3 Energy demand by fuel

2.3.1 Oil

Global oil demand experienced strong growth during 2021. Measured on an energy content basis, demand increased by 5.2 mboe/d, compared to the much depressed 2020 levels due to the pandemic. This strong growth was primarily driven by an economic recovery in most parts of the world and easing COVID-19 related restrictions that improved mobility, despite the fact that some local and regional lockdowns re-emerged during the course of the year.

Nonetheless, even with this extraordinary demand increase in 2021, demand recovery represented just slightly above 60% of the losses witnessed in 2020. This provided ample room for a continuation of the recovery and another strong increase in 2022. These prospects, however, have been hampered significantly by increased geopolitical tensions at the beginning of 2022, with energy prices drifting significantly higher, as well as inflationary concerns and supply chain issues that have affected global economic growth prospects. Indeed, GDP growth projections are at 3.5% p.a. compared to 5.8% growth observed in 2021.

The combined effect of these factors is set to result in significant demand growth in the period to 2025, estimated to be a net increase of 7.8 mboe/d compared to the base year of 2021 (Table 2.7). More than two-thirds of this growth is projected for the non-OECD (+6 mboe/d), while China and India combined will account for 2.5 mboe/d of this increase.

Table 2.7
Oil demand by region, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
OECD Americas	20.1	21.5	20.6	19.1	17.5	15.9	–4.2	–1.0	22.8	15.8
OECD Europe	11.6	11.9	11.1	10.1	9.1	8.2	–3.4	–1.4	13.1	8.1
OECD Asia-Pacific	6.9	6.9	6.4	5.8	5.2	4.6	–2.2	–1.6	7.8	4.6
OECD	**38.5**	**40.3**	**38.1**	**35.0**	**31.8**	**28.8**	**–9.7**	**–1.2**	**43.6**	**28.6**
China	14.2	15.7	16.2	16.6	16.6	16.5	2.3	0.6	16.1	16.4
India	4.8	5.8	7.1	8.3	9.6	11.0	6.2	3.5	5.4	11.0
OPEC	7.9	9.1	10.1	11.0	11.6	11.9	4.0	1.7	9.0	11.9
Other DCs	17.6	19.8	21.8	23.5	25.2	26.8	9.1	1.8	19.9	26.6
Russia	3.4	3.4	3.5	3.6	3.6	3.5	0.1	0.2	3.8	3.5
Other Eurasia	1.9	1.9	2.0	2.1	2.1	2.1	0.2	0.5	2.1	2.1
Non-OECD	**49.8**	**55.8**	**60.8**	**65.1**	**68.7**	**71.9**	**22.0**	**1.5**	**56.4**	**71.4**
World	**88.3**	**96.1**	**98.9**	**100.1**	**100.5**	**100.6**	**12.3**	**0.5**	**100.0**	**100.0**

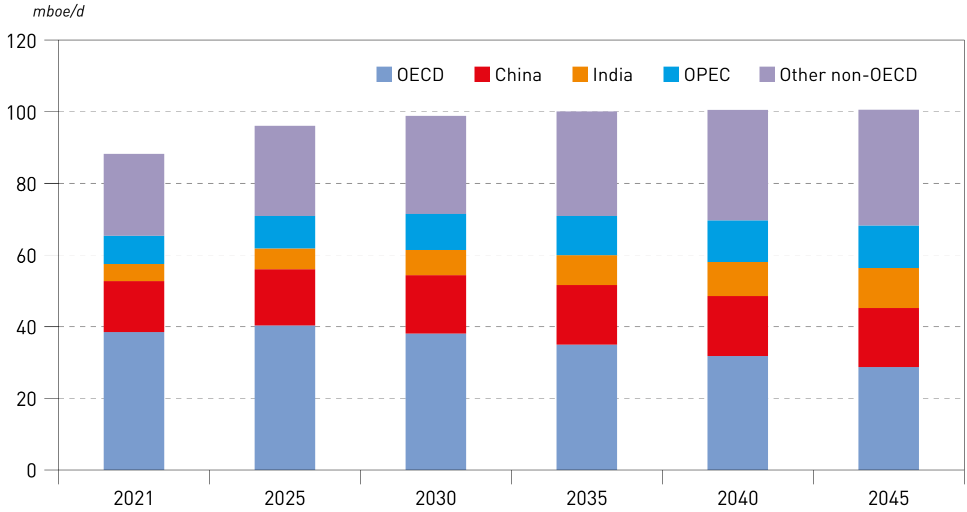
Source: OPEC.

However, this pattern will change significantly in the period beyond 2025. Global oil demand growth is set to decelerate quite considerably, already in the period from 2025 to 2030, growing by less than 3 mboe/d over these five years. A plateauing demand is projected at the end of the forecast period on the back of oil substitution, mainly by natural gas and electricity, efficiency improvements across all sectors and a significant penetration of EVs in road transportation. More details on these factors are provided in Chapter 3.

It is important to note that the figures shown in this Chapter are not directly comparable with those shown in others. There are two main reasons for this. Firstly, Chapter 2 uses energy equivalent units (mboe/d) to allow for a comparison between the different fuel types. In other chapters, however, oil is expressed in volumetric units (mb/d). Secondly, the definition of oil in Chapter 2 is different from that used in Chapters 3 through to 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 Chapters 4–6). Moreover, a gradual demand structure shift towards lighter products leads to higher volumes, even without increasing demand, if measured on an energy content basis.

Figure 2.5 and Figure 2.6 summarize these trends in respect to major regions. Overall, primary oil demand is projected to increase from 88.3 mboe/d in 2021 to almost 99 mboe/d in 2030 and then further to 100.6 mboe/d in 2045. This represents an increase of more than 12 mboe/d over the forecast period. However, this steady growth in global oil demand at the global level masks significant differences in regional prospects for the OECD and non-OECD. While demand in non-OECD countries is set to grow by 22 mboe/d between 2021 and 2045, a large part of this demand increase will be offset by a demand drop in the OECD. The decline is projected to be in the range of 10 mboe/d over the same period.

Figure 2.5
Oil demand by region, 2021–2045

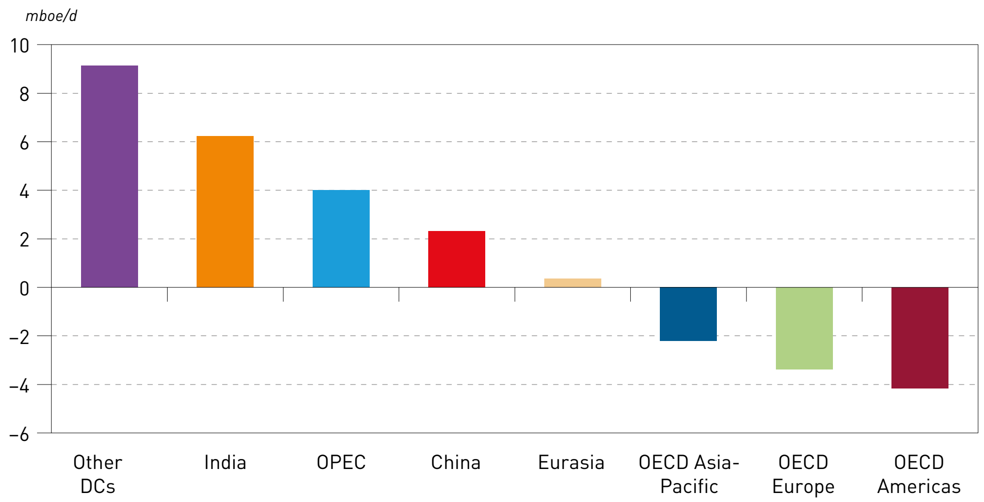


Source: OPEC.

Within the non-OECD, strong demand growth in China during the period to 2025 is projected to slow and even plateau in the period thereafter, leading to an overall increase of 2.3 mboe/d. A similar pattern is also projected for the group of OPEC Member Countries where incremental demand is expected to be in the range of 4 mboe/d.

Contrary to these regions, sustained demand growth is projected for India and most countries included in the group of Other Developing countries. This is forecast to be driven by relatively high GDP growth, further urbanization and industrialization, as well as a related expansion of the middle class and higher vehicle ownership. As a result,

Figure 2.6
Incremental oil demand by region, 2021–2045



Source: OPEC.

primary oil demand is set to increase by more than 6 mboe/d and 9 mboe/d in India and Other Developing countries, respectively.

Long-term prospects for OECD countries emphasize a slow, but steady decline in oil demand. With the exception of the first few years of the forecast period (2021–2024) when oil demand growth will still be impacted by the recovery from the depressed levels of 2020, the remaining part of the forecast period will be marked by a number of other issues. This includes a continuing penetration of EVs into the passenger car fleet, a push for oil displacement from industry and residential sectors, as well as technology driven efficiency improvements. The largest demand decline over the entire forecast period is projected for OECD Americas (–4.2 mboe/d), followed by OECD Europe (–3.4 mboe/d) and OECD Asia-Pacific (–2.2 mboe/d). In terms of energy content, the decline will be from 38.5 mboe/d in 2021 to less than 29 mboe/d in 2045.

Despite decelerating oil demand growth in the second part of the forecast period and strong growth in other energy sources, such as other renewables, gas and nuclear energy, oil is set to retain the highest share in the global energy mix during the entire period. In 2021, oil accounted for 31% of global energy requirements. Alongside the recovery in oil demand, the share of oil is expected to gradually increase to almost 32% by 2025 before it starts declining over the long-term to reach around 29% by 2045.

2.3.2 Coal

Coal is currently the second-largest source of primary energy demand, accounting for approximately 26% of the total, equivalent to almost 75 mboe/d in 2021. It is also the largest source of energy for electricity generation. While being generally considered an accessible and a low-cost base load fuel, demand for coal has come under pressure, mainly due to environmental and climate change policies aimed at phasing out coal for cleaner sources of energy. Additionally, increased competitiveness from other fuels and the increased penetration rate of renewables has also contributed to its decline in recent years. So far, this trend has been visible mostly in advanced economies, such as OECD Europe and OECD Americas. At the same time, coal demand growth in emerging and developing nations has been increasing, where economic development, industrialization and electrification growth is driving energy demand, including for coal.

After a drop of around 4.5% in 2020, coal demand increased in 2021 by almost 3%, driven by stronger electricity demand in the post-pandemic recovery. Furthermore, rising gas prices during 2021 incentivized a gas-to-coal switch in the electricity sector in many regions, including OECD Americas and OECD Europe. This trend has continued in 2022 and even intensified since the start of the conflict in Eastern Europe.

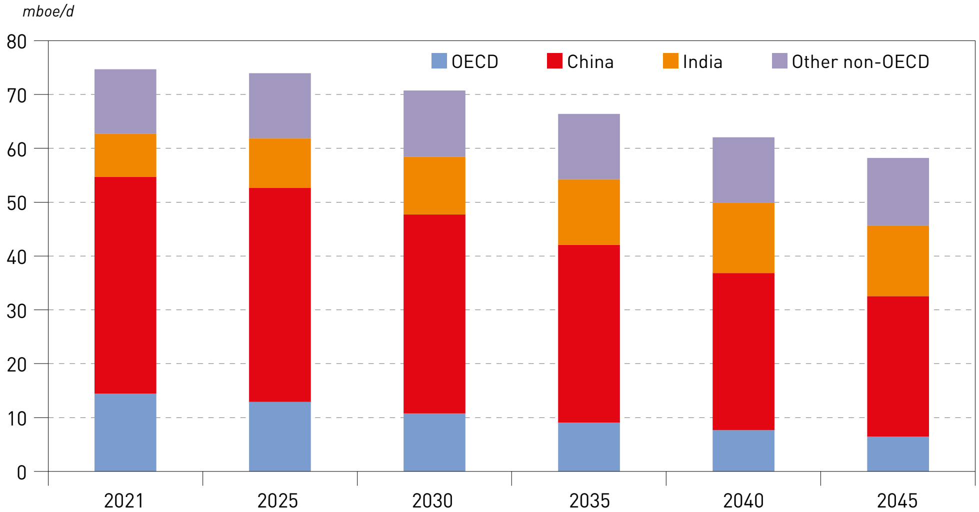
With soaring gas prices and possible gas supply shortages, many European countries are increasingly turning back to coal-based electricity generation. Germany is likely to restart (only to 2024) more than 10 GW of mostly coal-fired power plants to help avoid possible electricity shortages this coming winter. Higher coal usage has been registered in North America, as well as Asia during 2022, also supported by lower hydropower generation due to continuous droughts. This could possibly lead to higher coal consumption in the short-term, thus increasing the uncertainty of the outlook.

The Reference Case assumption is that the situation in the energy market will stabilize in the medium-term, with a rising focus on long-term energy and climate targets. Governments of major consumers are seemingly committed to their medium- and long-term targets related to coal consumption with a continued support for emission reductions and, the retirement of coal-fired plants in favour of less carbon-dense alternatives. In November 2021, Parties of the COP26, including India and China, agreed to accelerate their efforts to phasedown unabated coal power. In early 2022, G7 countries also committed themselves to "significantly curb the use of coal and other fossil fuels in electricity production." This is a major reason behind the expected significant decline of coal demand in the long-term.

As shown in Figure 2.7 and Table 2.8, coal demand is expected to decline from almost 75 mboe/d in 2021 to around 58 mboe/d in 2045, which is an average annual decline of roughly 1% p.a. Coal is the only fuel that declines in the outlook period at the global level. All OECD regions show significant coal demand reductions, with an average annual decline rate of 3.3% p.a. in the OECD. The initial version of the 'Fit For 55' plan in the EU saw a fast decline in coal use. At the national level, some countries have set ambitious targets, such as the recent decision by the new German government to accelerate coal's phase out from 2038 to 2030. The current geopolitical crisis and possible gas shortages, however, have forced European policy makers to accept possible higher generation from coal in the short- to medium-term than initially envisaged. Nevertheless, despite the current challenges, the EU sees its long-term goals as still achievable.

In OECD Americas, US coal-fired generation is anticipated to decline fast due to the pressure to reduce emissions and competition from competitive natural gas supplies. Up to 28 GW of coal generation capacity could be closed by 2028, due to the ageing fleet and a tightening of environmental regulations, including those on coal ash disposal. In a recent blow to the current US Administration, however, the Supreme Court limited the capability

Figure 2.7
Coal demand by region, 2021–2045



Source: OPEC.

Table 2.8
Coal demand by region, 2021–2045

	Levels *mboe/d*						Growth *mboe/d*	Growth *% p.a.*	Share *%*	
	2021	**2025**	**2030**	**2035**	**2040**	**2045**	**2021–2045**	**2021–2045**	**2021**	**2045**
OECD Americas	5.7	5.0	4.2	3.5	2.9	2.4	–3.4	–3.6	7.7	4.1
OECD Europe	4.1	3.5	2.5	1.8	1.3	0.9	–3.2	–6.0	5.5	1.6
OECD Asia-Pacific	4.6	4.4	4.1	3.8	3.5	3.2	–1.3	–1.4	6.1	5.5
OECD	**14.4**	**12.9**	**10.8**	**9.1**	**7.7**	**6.5**	**–7.9**	**–3.3**	**19.3**	**11.2**
China	40.3	39.8	37.0	33.0	29.1	26.1	–14.2	–1.8	53.9	44.8
India	8.0	9.2	10.7	12.1	13.1	13.1	5.1	2.1	10.8	22.5
OPEC	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1
Other DCs	7.8	8.1	8.6	8.6	8.9	9.5	1.8	0.9	10.4	16.4
Russia	2.5	2.2	2.0	1.9	1.7	1.5	–1.0	–2.2	3.4	2.5
Other Eurasia	1.7	1.7	1.6	1.6	1.5	1.4	–0.2	–0.6	2.2	2.5
Non-OECD	**60.3**	**61.1**	**59.9**	**57.3**	**54.4**	**51.7**	**–8.6**	**–0.6**	**80.7**	**88.8**
World	**74.7**	**74.0**	**70.7**	**66.4**	**62.1**	**58.2**	**–16.5**	**–1.0**	**100.0**	**100.0**

Source: OPEC.

of governmental agencies to regulate and set limits to CO_2 emissions from power plants, which was one of the important tools in implementing climate change policies.

In OECD Asia-Pacific, the decline in coal-fired generation will likely occur at a more moderate pace. South Korea and Japan are heavily dependent on coal for power generation, with the two countries relying on coal to meet the challenge of tight seasonal energy demand in recent years. Japan has announced the phase out of 'inefficient' coal plants by 2030, while keeping more efficient units such as ultra-super critical plants. In Australia, the new government detailed earlier this year a more ambitious target on emissions reductions, thus targeting coal-fired plants.

China is the world's largest producer and consumer of coal, and it is considered to be the major force in the global coal market. In addition to the power sector, coal is pivotal in supporting China's wider economic activities, such as industry and heat generation. Coal makes up about 58% of its total energy demand, equivalent to about 40 mboe/d in 2021. However, the Reference Case sees a strong long-term decline in coal demand. Coal-fired generation should be gradually phased-out after 2026, according to official statements , which is in line with a target to reach a carbon emission peak by 2030. The decline in primary fuel demand is also attributed to more efficient units, which are likely to replace older plants and thus reduce transformation losses. Furthermore, the strong expansion of renewables, gas and nuclear will substitute for coal-fired generation in the long-term. Consequently, it is expected that coal demand will drop from more than 40 mboe/d in 2021 to almost 26 mboe/d in 2045, a decline of 35%.

By comparison, long-term coal demand in India is seen to increase, from around 8 mboe/d in 2021 to just above 13 mboe/d in 2040, after which it remains stable. The slowdown is the result of the increasing substitution of coal by other fuels, such as nuclear, gas and renewables. However, while India made a commitment to phase-down coal at COP26, the government has highlighted prioritizing its multiple developmental goals of energy access, improved livelihoods and poverty reduction. This is why new build coal plants are expected to continue alongside the diversification of India's energy portfolio.

In Other Developing Countries, coal consumption is expected to increase by 1.7 mboe/d to 9.5 mboe/d in 2045, driven by economic development. Many countries have pledged to reduce coal usage, including Vietnam and Indonesia. However, the necessity of technology transfer and investments from developed rich countries are viewed as a prerequisite to such a move. Finally, coal demand in Russia is expected to decline by around 1 mboe/d in the outlook period, in line with the retirement of old plants and the replacement of coal by gas in the power generation and industry sectors.

2.3.3 Natural gas

After the drop in 2020, global gas demand recovered strongly in 2021 to above pre-COVID-19 levels, driven by the economic recovery and rising electricity generation. However, rising spot gas prices during 2021 have led to increasing gas-to-coal switching in the power mix in many countries, including OECD Europe, and despite relatively high EU Emissions Trading Scheme (ETS) prices.

The gas market situation changed fundamentally with the start of the Russia-Ukraine conflict in February 2022. Amid rising volatility, spot gas prices spiked to all-time highs with large uncertainties related to gas pipeline supplies from Russia to Europe. Already in March 2022, the Dutch Title Transfer Facility (TTF) hub spot price hit levels around $60 per million British thermal units (Mbtu). Market tightness and reduced flows of Russian gas to Europe led to TTF spot price spiking to levels around $95/Mbtu in August 2022, an all-time high gas price in Europe and worldwide. Prices decreased somewhat in September 2022, but remained elevated. TTF mostly was outperforming Asian spot LNG prices, which led to higher LNG inflows into Europe.

Since the start of the conflict, Russia has stopped gas deliveries to several countries, such as Poland, Bulgaria and Denmark as these countries did not comply with newly introduced Russian Government payment terms. As a reaction to the conflict in Ukraine and possible gas outages, the EU has proposed a plan to reduce its reliance on Russian gas in the coming years with a possible phase out by 2027. These measures will be accompanied by additional gas imports from alternative routes, including LNG and pipeline imports from Norway and North Africa. Given the tightness in the global gas market, additional measures will be needed, such as savings through energy efficiency measures and increasing supplies of other fuels including renewables, but also coal (highlighted earlier), if this plan is to be fulfilled.

Thus, the short- and medium-term outlook remain highly uncertain with possible market shocks in the coming years. Given the relatively high price elasticity of gas demand, a high gas price may lead to temporarily lower demand, especially in the power generation sector. Shocks in the European market will have significant effects on the global gas market, with tight LNG markets and reduced availability for consumers in developing countries.

As of June 2022, more than 150 billion cubic metre (bcm) of new LNG liquefaction capacity is under construction, including large projects in Qatar, the US and Mozambique. Most of these projects are expected to come online by 2026. Given, the current tightness and price levels, further additions are possible. This should help to reduce the gas shortage in the coming years.

The Reference Case assumes that the gas market will stabilize in the coming years given the sufficient availability of gas resources and the favourable role of gas in reducing CO_2 emissions. Nevertheless, lasting consequences, especially in Europe, are possible.

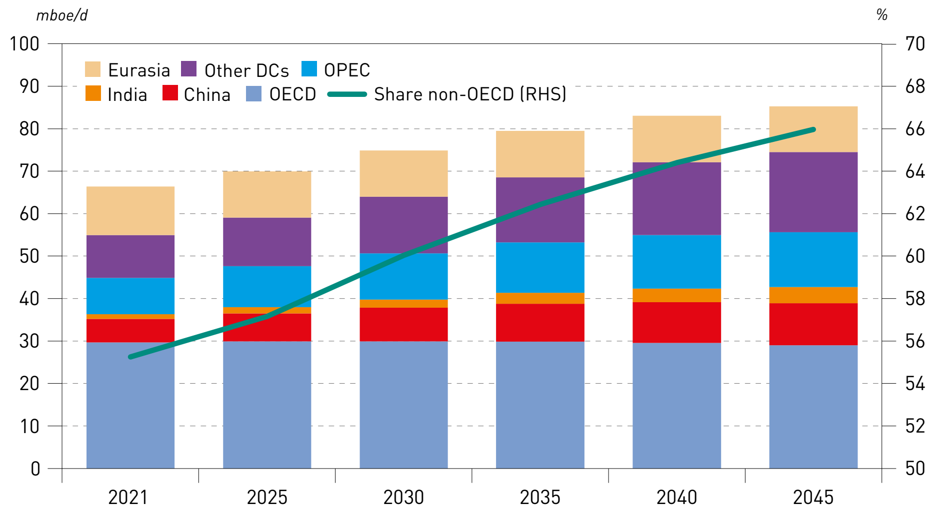
Looking to the long-term, the Reference Case projects gas demand to grow from 66.4 mboe/d in 2021 to above 85 mboe/d in 2045 (Figure 2.8 and Table 2.9). With growth of nearly 19 mboe/d in the outlook period, natural gas becomes the second largest fuel in the mix after 2030. Gas demand profits from climate change policies in various countries and the increasing availability of gas.

The growth comes almost exclusively from non-OECD countries, led by China, India and OPEC Member Countries. In total, non-OECD gas demand is projected to increase by 19.6 mboe/d to 56.3 mboe/d in 2045. This leads to the share of non-OECD in total gas demand rising to 66% in 2045, up from 55% in 2021.

In China, gas demand is set to increase by around 4.5 mboe/d, in line with country's aspirations to see peak CO_2 emissions by 2030. Gas will replace some of the retired coal-fired capacity in the power generation sector, support growing intermittent renewable generation, as well as contribute further to industry. However, gas demand growth is expected to slowdown towards the end of the forecast period, in line with a higher penetration of renewables and nuclear energy.

India's gas demand is projected to grow by 2.7 mboe/d to 3.8 mboe/d in 2045. This is in line with the official targets to increase the share of gas in the energy mix,

Figure 2.8
Natural gas demand by region, 2021–2045



Source: IAEA.

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Table 2.9
Natural gas demand by region, 2021–2045

	Levels mboe/d						Growth mboe/d	Growth % p.a.	Share %	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
OECD Americas	17.7	18.2	18.4	18.7	18.8	18.8	1.1	0.2	26.7	22.1
OECD Europe	8.4	8.2	8.0	7.7	7.2	6.7	–1.7	–0.9	12.7	7.9
OECD Asia-Pacific	3.6	3.5	3.5	3.5	3.5	3.5	–0.1	–0.1	5.4	4.1
OECD	**29.7**	**30.0**	**29.9**	**29.9**	**29.6**	**29.0**	**–0.7**	**–0.1**	**44.7**	**34.0**
China	5.5	6.6	7.9	8.9	9.6	9.9	4.4	2.5	8.3	11.6
India	1.1	1.4	1.9	2.6	3.2	3.8	2.7	5.2	1.7	4.5
OPEC	8.5	9.7	10.9	11.9	12.6	12.9	4.4	1.7	12.9	15.1
Other DCs	10.1	11.4	13.3	15.3	17.2	18.9	8.8	2.7	15.2	22.1
Russia	8.4	7.6	7.5	7.3	7.1	6.8	–1.6	–0.9	12.6	7.9
Other Eurasia	3.1	3.2	3.4	3.7	3.9	4.0	0.9	1.1	4.6	4.7
Non-OECD	**36.7**	**40.0**	**45.0**	**49.6**	**53.5**	**56.3**	**19.6**	**1.8**	**55.3**	**66.0**
World	**66.4**	**69.9**	**74.9**	**79.5**	**83.0**	**85.3**	**18.9**	**1.0**	**100.0**	**100.0**

Source: OPEC.

encompassing rising levels of gasification for households and a higher share of gas in power generation. Retail CNG will also help to increase demand in India.

OPEC is another region with expected strong gas demand growth, increasing to almost 13 mboe/d in 2045, up from 8.5 mboe/d in 2021. Many OPEC Member Countries see gas as a suitable replacement for oil in the power generation sector, which would free up additional crude oil volumes for export. This trend is also favoured by the availability of cheap resources in most OPEC Member Countries. Some countries such as the UAE and Saudi Arabia are also exploring the potential of blue hydrogen, for which the development of natural gas resources will be crucial.

The group of Other Developing Countries is also likely to see a significant increase in gas demand, almost 9 mboe/d over the outlook period. The largest share of the growth comes from Asian countries where energy demand growth combined with a slowdown in coal consumption calls for more gas demand, especially in the power generation sector. Gas will also have an important role in the expansion of access to modern energy, especially in Africa, and thus reduce the traditional use of biomass for cooking and heating.

In the OECD, gas demand shows different sub-regional trends. In OECD Europe, gas demand is expected to decline throughout the period to a level around 6.7 mboe/d in 2045, down from 8.4 mboe/d in 2021. This is mostly due to long-term EU targets related to emissions reductions. These foresee an increase in energy efficiency, as well as the substitution of gas by biogas and possibly hydrogen. These trends are reinforced by the current uncertainty related to gas supplies from Russia.

In OECD Americas, gas demand is seen to expand by around 1.1 mboe/d in the long-term, mostly replacing coal in the power generation sector. Declining coal-fired generation in the US will result in additional gas consumption. This is also supported by access to sufficient and competitive gas resources in the US.

In OECD Asia-Pacific, gas demand is set to remain relatively stable. This is the result of opposite trends in the power generation sector, where coal generation declines, while nuclear generation is set to increase. As these trends largely offset each other, this leaves gas demand generally hovering around 3.5 mboe/d over the forecast period.

2.3.4 Nuclear

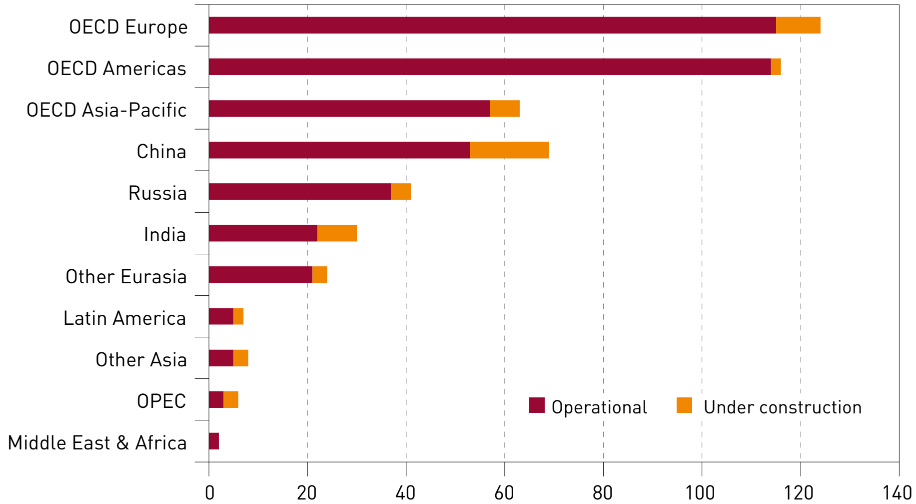
Nuclear energy will likely play an increasingly important role amid the efforts to reduce CO_2 emissions, mostly by cutting into the use of coal-fired generation. There are visible policy shifts in the recent past, which favour the expansion of nuclear capacity in the medium- and long-term.

The expansion of nuclear power is based not only on favourable policy support, but also developing technology. Emerging technologies such as small modular reactors (SMRs) can increase the acceptance of nuclear power due to lower costs and increased safety standards.

In 2021, according to the International Atomic Energy Agency (IAEA), there were 434 reactors in operation globally with a total capacity of around 390 GW (Figure 2.9), providing about 10% of the world's electricity. The majority are installed in OECD Europe, OECD Americas and Far East Asia (including China and Japan). During 2021, nine reactors were shut down permanently, mainly in Germany and the UK. By the end of 2021, all but three of Germany's nuclear power plants had been shut down and the remainder are scheduled to go offline by late 2022.

Furthermore, there were 56 reactors with a total capacity of around 58 GW under construction in late 2021 as seen in Figure 2.9. In the OECD region, OECD Europe has nine units under construction, including those in Turkey, UK and Slovakia. Six reactors were under construction in OECD Asia-Pacific, with only two in OECD Americas.

Figure 2.9
Number of nuclear reactors by region, 2021



Source: IAEA.

In the non-OECD, the largest additions are expected in China (16 new units), which is in line with the government's targets to reach 70 GW by 2025, according to the 14th FYP. India has eight reactors under construction, followed by smaller additions in other regions.

In this year's outlook, global nuclear demand (Table 2.10 and Figure 2.10) is projected to expand from 15.2 mboe/d in 2021 to 23.3 mboe/d in 2045, reflecting an average annual growth rate of 1.8% p.a.

Nuclear energy in the OECD is expected to increase by only 1.1 mboe/d to 11.5 mboe/d in 2045, led by OECD Asia-Pacific. At the same time, nuclear energy in OECD Europe and OECD Americas is expected to remain largely stable throughout the period. This stability is the result of two opposite trends – retirement of old plants and new capacity additions.

The EU is seemingly experiencing a shift in nuclear polices given the energy-shortage concerns in 2021/22, as well as the increased urgency to meet climate targets. The EU Commission has also included nuclear energy in its Taxonomy Regulation, thus classifying it as a 'transitional' source of energy. This decision was also supported by the EU Parliament.

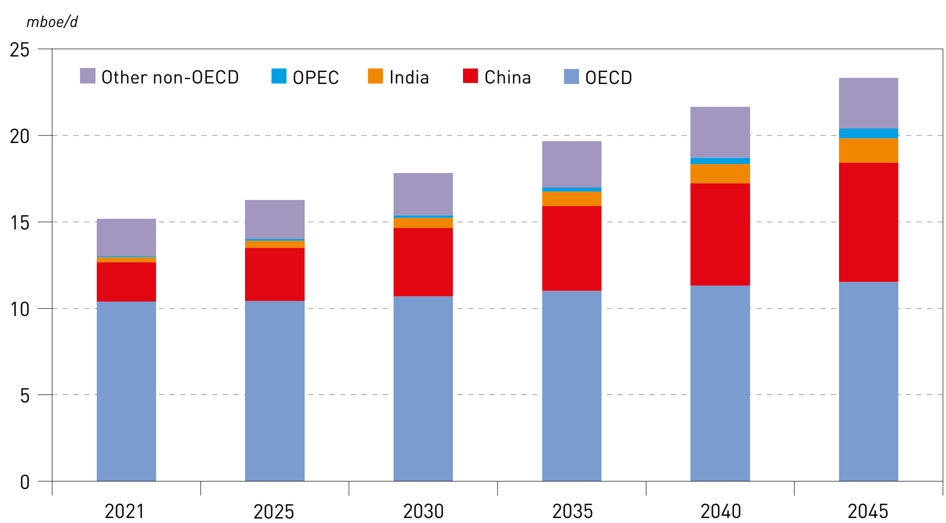
At the national level, France announced its decision in February 2022 to restart the building of new nuclear power plants (up to 14 new nuclear reactors), and to develop SMRs. This marks a major shift from the previous policy, which aimed to reduce the weight of nuclear power in France from 75% to 50% of its power generation mix by 2035. Similarly, it indicated that hydrogen produced from nuclear would be a primary asset for

Table 2.10
Nuclear demand by region, 2021–2045

	Levels mboe/d						Growth mboe/d	Growth % p.a.	Share %	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
OECD Americas	5.0	4.8	4.8	4.9	4.9	5.0	0.0	0.0	32.7	21.4
OECD Europe	4.2	4.2	4.2	4.2	4.2	4.3	0.0	0.0	28.0	18.3
OECD Asia-Pacific	1.2	1.5	1.7	2.0	2.2	2.3	1.1	2.7	7.9	9.7
OECD	**10.4**	**10.4**	**10.7**	**11.0**	**11.3**	**11.5**	**1.1**	**0.4**	**68.5**	**49.5**
China	2.3	3.1	3.9	4.9	5.9	6.9	4.6	4.7	14.9	29.5
India	0.3	0.4	0.6	0.8	1.1	1.4	1.1	6.7	1.9	6.0
OPEC	0.1	0.1	0.2	0.2	0.4	0.6	0.5	10.2	0.4	2.5
Other DCs	0.4	0.5	0.5	0.6	0.6	0.3	–0.1	–1.4	2.8	1.3
Russia	1.1	1.1	1.2	1.3	1.4	1.6	0.4	1.4	7.3	6.7
Other Eurasia	0.6	0.7	0.7	0.8	0.9	1.1	0.4	2.3	4.1	4.5
Non-OECD	**4.8**	**5.8**	**7.1**	**8.6**	**10.3**	**11.8**	**7.0**	**3.8**	**31.5**	**50.5**
World	**15.2**	**16.3**	**17.8**	**19.6**	**21.7**	**23.3**	**8.1**	**1.8**	**100.0**	**100.0**

Source: OPEC.

Figure 2.10
Nuclear energy demand by region, 2021–2045



Source: OPEC.

the country, as part of a €30 billion industrial revival plan that links nuclear, hydrogen and renewable energy.

In 2022, the UK government announced plans for a major acceleration of home-grown nuclear power, highlighting the need to boost long-term energy independence and security with plans to increase nuclear generation capacity by up to 24 GW by 2050 with an aim for it to provide about 25% of its electricity.

In the US, the commitment to nuclear power as part of its long-term energy strategy continues mainly in the form of research and technology advancement projects, rather than large commercial projects. The current focus of projects is on advancing the technology and applications of SMRs and advanced nuclear reactors. In 2021, the US Department of Energy started the first phase of its initiative that was first announced in 2020, which aims to invest about $600 million as part of its Advanced Reactor Concepts programme. Furthermore, the US is also focused on developing industrial-scale production of hydrogen using the heat and electricity from nuclear energy systems.

In OECD Asia-Pacific, nuclear power is likely to witness a revival. In South Korea, the newly elected government pledged an energy policy overhaul in March 2022 in a bid for the country to reach its climate targets. It indicated that nuclear energy would be added to South Korea's taxonomy at some point this year. The new government has declared that it would scrap the policy of phasing out nuclear energy that was introduced by its predecessor in 2017. In Japan, the current nuclear target for 2030 is to reach a 20% nuclear share in the electricity mix. This includes not only constructing new units, but also restarting some of the units that were closed after the Fukushima disaster. However, Japan still faces an issue of ageing units and negative public opinion. In recent statements, the Japanese government has proposed developing "next-generation nuclear rectors equipped with new safety mechanisms."

China has by far the largest number of nuclear reactors under construction. Over the course of 2021, China revealed the extensive scope of its plans for nuclear ahead of the COP26 Summit in Glasgow. With 16 reactors currently under construction, China is planning at least 150 new reactors in the next 15 years. China sees nuclear power as one of the ways to reduce coal consumption and shrink CO_2 emissions. In total, China's nuclear demand is expected to triple between 2021 and 2045, reaching levels of almost 7 mboe/d.

India also has an ambitious nuclear programme, which envisages 22.5 GW of capacity by 2031. Energy policy in India is supportive of nuclear energy as a low-cost, low carbon source of energy to meet its increasing demand. In the Reference Case, India's nuclear demand increases by 1.1 mboe/d to 1.4 mboe/d in 2045. Other regions, such as OPEC are also expected to increase their long-term nuclear power capacity, reaching 0.6 mboe/d in 2045, up from only 0.1 mboe/d in 2021.

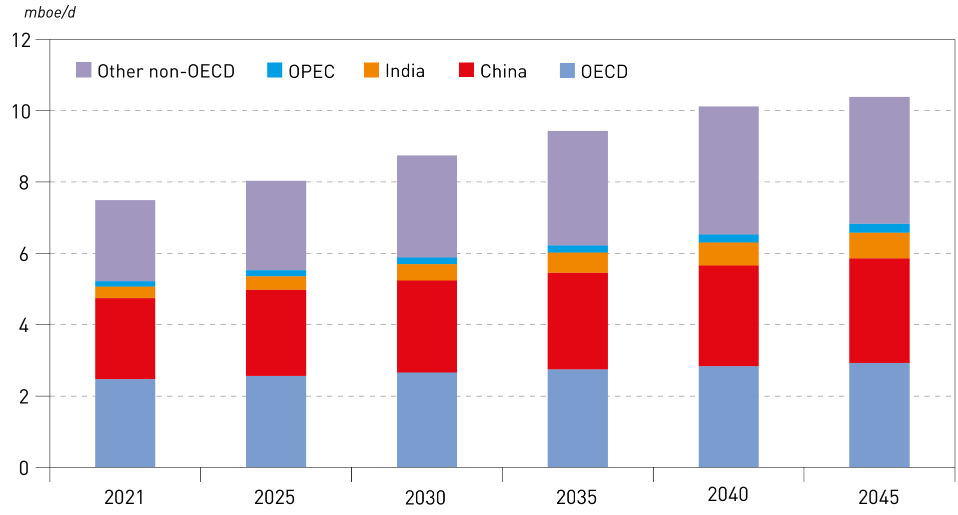
2.3.5 Hydro

Generating around 16% of the global electricity supply, hydropower is considered the largest global source of low-carbon power generation today. It provides at least 50% of total electricity supply for more than 35 countries. While operating costs are low, hydropower is considered to have significant upfront capital costs and its resources are limited, especially in developed countries.

Globally, hydropower demand is expected to grow by a relatively modest 1.4% p.a. over the forecast period. Projected demand in 2045 is 10.4 mboe/d, up from 7.5 mboe/d in 2021. Even before the pandemic, investments in hydropower have slowed in favour of other renewables, and this has been further exacerbated by construction delays in hydropower projects during the pandemic.

In the OECD region, there is no expectation for significant growth as most of the potential for hydropower has been explored. Demand in the OECD is set to increase from levels of 2.5 mboe/d in 2021 to 2.9 mboe/d in 2045, an increase of 0.7% p.a. (Figure 2.11). It is likely that most of the investments would go towards restoring the performance and the modernization of the ageing fleet where possible. Some additional capacity will be mostly smaller run-of-river plants.

Figure 2.11
Hydro demand by region, 2021–2045



Source: OPEC.

China, which has been investing heavily in hydropower, has been driving capacity additions in recent years, and remains the country with the highest installed hydropower capacity by far. China is expected to witness growth of 1.2% p.a., with capacity increasing from 2.3 mboe/d to 2.9 mboe/d over the forecast period. By the end of 2022, China's Baihetan hydropower project will be fully operational, adding up to 16 GW of capacity and making it the second largest hydropower project globally. Despite having a few large-scale hydropower projects in the pipeline, growth in China's hydropower demand is expected to slow due to it having explored most of its viable hydro potential, as well as due to environmental concerns.

India starts from a much lower base and sees significant growth of 3.4% p.a. This is mainly due to governmental support and newly announced incentives for hydropower projects that are aimed to increase energy security and the diversification of its energy portfolio. Growth is also strong within Other Developing Countries where demand for hydropower is set to grow by 2.1% p.a. to reach 2.9 mboe/d by 2045, from the current base of 1.7 mboe/d. (Table 2.11). Rising energy demand and the availability of untapped hydropower potential are the drivers of this growth.

Table 2.11
Hydro demand by region, 2021–2045

	Levels mboe/d						Growth mboe/d	Growth % p.a.	Share %	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
OECD Americas	1.3	1.3	1.4	1.4	1.5	1.6	0.3	0.9	16.8	15.1
OECD Europe	1.0	1.0	1.1	1.1	1.1	1.1	0.1	0.4	13.3	10.6
OECD Asia-Pacific	0.2	0.2	0.2	0.2	0.2	0.3	0.0	0.6	2.9	2.4
OECD	**2.5**	**2.6**	**2.7**	**2.8**	**2.8**	**2.9**	**0.5**	**0.7**	**33.0**	**28.2**
China	2.3	2.4	2.6	2.7	2.8	2.9	0.7	1.1	30.3	28.2
India	0.3	0.4	0.5	0.6	0.7	0.7	0.4	3.4	4.3	6.9
OPEC	0.2	0.2	0.2	0.2	0.2	0.3	0.1	2.0	2.1	2.4
Other DCs	1.7	2.0	2.3	2.6	2.9	2.9	1.1	2.1	23.2	27.5
Russia	0.3	0.4	0.4	0.4	0.4	0.4	0.1	1.0	4.6	4.2
Other Eurasia	0.2	0.2	0.2	0.2	0.2	0.3	0.1	1.4	2.5	2.5
Non-OECD	**5.0**	**5.5**	**6.1**	**6.7**	**7.3**	**7.5**	**2.4**	**1.7**	**67.0**	**71.8**
World	**7.5**	**8.0**	**8.7**	**9.4**	**10.1**	**10.4**	**2.9**	**1.4**	**100.0**	**100.0**

Source: OPEC.

2.3.6 Biomass

The share of biomass in the primary energy mix was estimated at around 9% in 2021. A large part of this consumption is still accounted for by the traditional use of biomass for heating and cooking, especially in developing countries and regions, such as South Asia and Sub-Saharan Africa. At the same time, biomass and its derivatives are used for electricity generation, as well as for biofuel/biogas production, mostly in the developed world. This is the result of energy market regulation and continuous subsidies.

Global biomass demand is set to grow at 1.2% p.a. over the forecast period to reach almost 35 mboe/d (Table 2.12). This represents a 10% share of the world's primary energy demand by 2045. Both the OECD and non-OECD deploy biomass as part of low-carbon energy initiatives, as well as for energy supply security.

Figure 2.12 depicts the evolving biomass trends and regional distribution. It is expected that non-OECD biomass demand will expand to almost 25 mboe/d by 2045, at a growth rate of 1% p.a. in the outlook period. China has adopted a wide variety of policies to stimulate bioenergy development, and its 14th FYP includes the development of bioenergy for energy security and as a vital component to reach its emission reductions targets. China's demand is expected to grow by 1.5 mboe/d during the outlook period, with the share of biomass in its energy mix increasing from 3.9% in 2021 to 5.4 % by 2045.

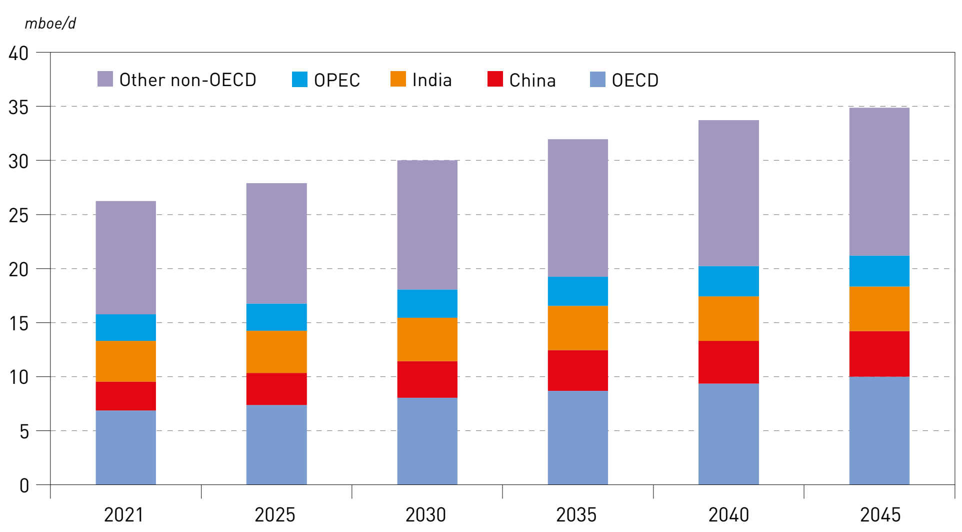
While demand for biomass in India constituted almost 20% of its total primary energy demand in 2021, growth is expected to be modest, at only 0.4 mboe/d by 2045. Consequently the share of biomass in India's energy mix is projected to drop to only 11% by 2045. India's traditional use of biomass is expected to decline due to rising access to more modern energy, such as through gasification and rising share of renewables. At

Table 2.12
Biomass demand by region, 2021–2045

	Levels mboe/d						Growth mboe/d	Growth % p.a.	Share %	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
OECD Americas	2.9	3.1	3.3	3.6	3.8	4.1	1.2	1.5	11.1	11.9
OECD Europe	3.4	3.6	4.0	4.4	4.7	5.0	1.7	1.7	12.8	14.4
OECD Asia-Pacific	0.6	0.6	0.7	0.8	0.8	0.8	0.3	1.5	2.2	2.4
OECD	**6.9**	**7.4**	**8.0**	**8.7**	**9.3**	**10.0**	**3.1**	**1.6**	**26.2**	**28.7**
China	2.7	3.0	3.4	3.8	4.0	4.2	1.5	1.9	10.2	12.1
India	3.8	3.9	4.0	4.1	4.1	4.1	0.3	0.4	14.4	11.8
OPEC	2.4	2.5	2.6	2.7	2.8	2.9	0.4	0.7	9.3	8.2
Other DCs	10.0	10.6	11.3	12.0	12.7	12.7	2.8	1.0	38.0	36.5
Russia	0.2	0.2	0.3	0.3	0.4	0.4	0.2	2.9	0.8	1.2
Other Eurasia	0.3	0.3	0.4	0.4	0.4	0.5	0.2	2.2	1.1	1.4
Non-OECD	**19.4**	**20.5**	**22.0**	**23.3**	**24.4**	**24.9**	**5.5**	**1.0**	**73.8**	**71.3**
World	**26.2**	**27.9**	**30.0**	**32.0**	**33.7**	**34.9**	**8.6**	**1.2**	**100.0**	**100.0**

Source: OPEC.

Figure 2.12
Biomass demand by region, 2021–2045



Source: OPEC.

the same time, the modern use of biomass is expected to increase. This includes already practiced biomass co-firing in coal thermal plants. Furthermore, India has introduced a mandate to blend 20% of ethanol into gasoline from 2025, which was brought further from the previous target set for 2030.

Another leading nation in the production of biofuels is Brazil. Its national biofuel policy, 'RenovaBio', targets a 10% reduction in carbon emissions by 2028. The policy classifies biofuels according to their GHG emissions profiles while introducing a tradable carbon credit system to create a cost advantage for biofuels.

In the OECD, biomass already plays an important role, predominantly in the production of liquids biofuels. With policy targets, biomass will become even more important. In OECD Europe, biomass demand is projected to increase by 1.7 mboe/d to 5 mboe/d in 2045. This includes the production of biofuels, including SAF. Furthermore, biomass is projected to be increasingly used for biogas production that will consequently partly replace natural gas. Under the EU's sustainable finance taxonomy – a system that determines which economic activities and investments can be classified as green – biomass and bioenergy were included and labelled as such. While this may encourage further investments in the sector, the inclusion of biomass in the taxonomy scheme has led to opposition from several countries due to growing concerns of environmental impacts such as deforestation, as well as unaccounted emissions along the value chain.

In OECD Americas, biomass demand is set to increase by around 1.2 mboe/d, reaching 4.1 mboe/d in 2045. On top of ethanol production, the US Administration is supporting efforts to increase SAF from biomass to reach a production level of 3 million gallons by 2030.

2.3.7 Other Renewables

In this Outlook, other renewables refer to a number of energy sources, including solar, wind, geothermal and tidal. The COVID-19 pandemic has stalled many renewable energy projects globally, disturbing supply chains for different project components due to the global lockdowns. Solar power plant projects were particularly affected by these disruptions, as many parts are imported from China. However, the upward trend for global investment in renewables continued during 2020 and 2021 despite the pandemic, with record high capacity additions.

During 2021, around 130 GW of solar capacity was installed, with China alone adding more than 52 GW. At the same time, Europe added around 22 GW and North American capacity grew by 20 GW. A similar picture can be viewed in the wind sector. Total installed wind capacity in 2021 was around 92 GW, of which 47 GW was added in China. Other large additions were seen in Europe and the US.

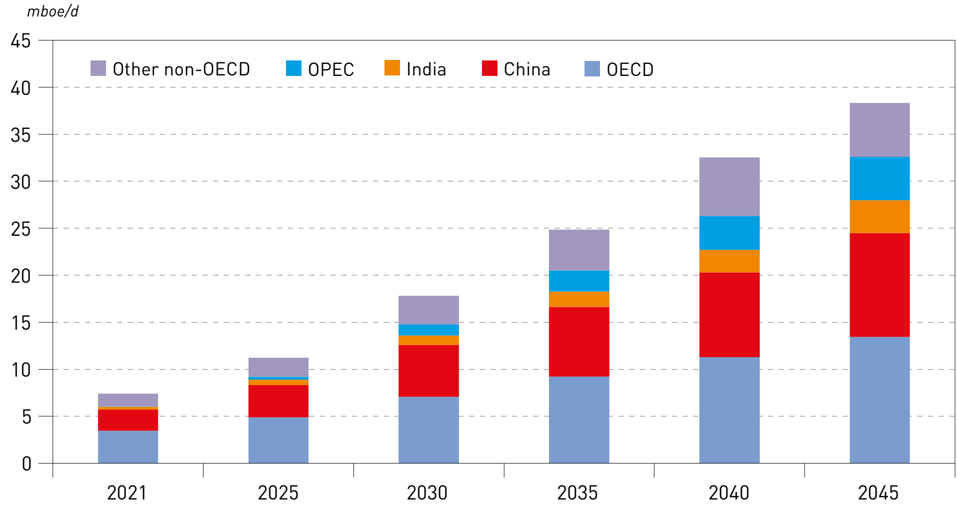
The cost competitiveness of other renewables, particular wind and solar, have been steadily improving in recent years, driven by research and technological advancements, economies of scale, improved efficiencies and supportive policies and strategies. However, rising energy and commodity prices, in combination with supply chain problems, has led to rising costs for renewable energy for the first time in a decade. In addition, capital costs have increased too, pushing investment costs even higher. It is also assumed that the overall system costs of renewables will start increasing in line with the rising share of intermittent power in the generation mix, due to the increasing need for balancing and storage.

However, this could be partly offset by further technological advancements and economies of scale in the medium- and long-term. For instance, the capacity and efficiency of wind installations has been continuously increasing. One of the largest wind turbines today has a nominal generation capacity of 14 MW, a significant increase relative to the capacity of wind turbines only several years ago.

The Reference Case assumes continuous growth of other renewables in the long-term. It is projected that other renewables will increase from around 7.4 mboe/d in 2021 to above 38 mboe/d in 2045. With growth of nearly 31 mboe/d in the outlook period, other renewables are the largest addition relative to other fuels. Due to its low base, the average annual growth rate is calculated at 7.1% p.a., also far above any other fuel in the energy mix.

Figure 2.13 and Table 2.13 show the long-term outlook for other renewables by major region. Demand in all regions is forecast to grow. The OECD region is expected to add 10 mboe/d, supported by energy policies and emission reductions targets. The EU's 'Fit for 55' policy already has a strong emissions reduction target for 2030, which requires a significant increase in renewable generation. Following the start of the conflict in Eastern Europe, the EU has presented its REPowerEU plan, which foresees the even faster deployment of renewable energy. Europe is focusing on wind power, especially in the North Sea, with several large projects coming online in the years ahead. Many oil and gas majors are investing in North Sea wind parks, including Eni, Equinor and BP.

Figure 2.13
'Other renewables' demand by region, 2021–2045



Source: OPEC.

In the US, the Administration has called for 80% of 'clean' power by 2030. In 2021, low-carbon sources (renewables and nuclear) make up just under 40% of the total generation mix. OECD Asia-Pacific is set to see the largest expansion in the OECD region, at 7.3% p.a. Japan intends to increase the share of renewables in its energy mix to 36–38% by 2030, up from around 23% currently. This includes large investments in offshore wind and solar.

Table 2.13
'Other renewables' demand by region, 2021–2045

	Levels mboe/d						Growth mboe/d	Growth % p.a.	Share %	
	2021	2025	2030	2035	2040	2045	2021–2045	2021–2045	2021	2045
OECD Americas	1.3	1.8	2.7	3.7	4.7	5.8	4.6	6.6	17.0	15.2
OECD Europe	1.7	2.4	3.2	3.9	4.5	5.1	3.4	4.6	23.3	13.3
OECD Asia-Pacific	0.5	0.7	1.2	1.6	2.1	2.5	2.0	7.3	6.3	6.5
OECD	**3.5**	**4.9**	**7.1**	**9.2**	**11.3**	**13.5**	**10.0**	**5.8**	**46.5**	**35.1**
China	2.3	3.4	5.5	7.4	9.0	11.0	8.8	6.8	30.4	28.8
India	0.3	0.6	1.0	1.6	2.4	3.5	3.2	10.9	4.0	9.1
OPEC	0.0	0.3	1.2	2.2	3.6	4.6	4.6	23.4	0.4	12.0
Other DCs	1.3	1.9	2.8	3.9	5.3	4.3	2.9	5.0	18.0	11.1
Russia	0.0	0.0	0.1	0.2	0.3	0.5	0.5	18.3	0.1	1.3
Other Eurasia	0.0	0.1	0.2	0.3	0.6	1.0	0.9	13.6	0.6	2.6
Non-OECD	**4.0**	**6.3**	**10.7**	**15.6**	**21.2**	**24.9**	**20.9**	**7.9**	**53.5**	**64.9**
World	**7.4**	**11.2**	**17.8**	**24.9**	**32.5**	**38.3**	**30.9**	**7.1**	**100.0**	**100.0**

Source: OPEC.

In recent years, China has become the single largest producer of wind and solar energy. This is set to continue in the Reference Case, with China expanding other renewables by almost 9 mboe/d by 2045, almost fourfold the current demand. Renewables expansion in China in the coming decades is backed by government support in order to achieve the country's long-term carbon neutrality plan and increase energy security. Wind power is booming in China, and is set to be the key driver in the growth of other renewables in the country. In 2021, the China Development Bank (CDB) announced the issuing of 100 billion CNY loans to support offshore wind and solar PV power generation projects.

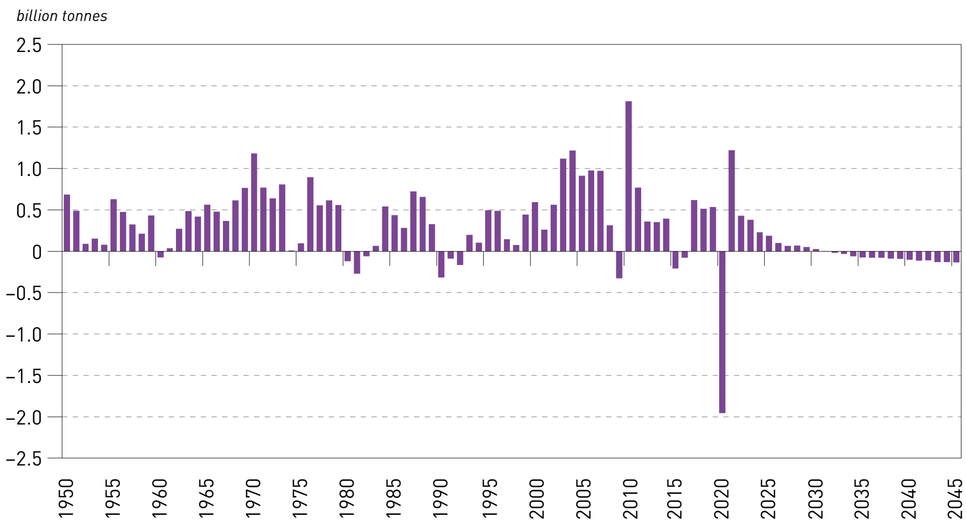
Other renewables in India are expected to increase from only 0.3 mboe/d in 2021 to 3.5 mboe/d in 2045. Challenges related to air-quality and emission reduction targets will support the expansion of renewables in the country. India has pledged to increase renewable capacity (including hydro) to 500 GW by 2030.

Given abundant solar power potential, some OPEC Member Countries have also invested heavily in other renewables in recent years. This includes mostly solar and to some extent wind, which aims to support electricity demand growth resulting from population and economic growth, as well as increasing needs for water desalination. It is expected that demand for other renewables will expand at a rate of 23.4% p.a. from 2021 to 2045, bringing total demand to 4.6 mboe/d from its current modest levels (Table 2.13). Under its National Renewable Energy Program, Saudi Arabia inaugurated its first utility-scale renewable energy project in April 2021, expecting to add approximately 3 GW of solar PV by the end of 2022. During COP26 in Glasgow in 2021, Saudi Arabia and the UAE also pledged to invest $340 billion into renewable energy, energy storage, hydrogen and CCUS projects.

2.4 Energy related CO_2 emissions

As expected, the partial recovery in global energy demand during 2021 and 2022 resulted in higher energy-related CO_2 emissions. Indeed, as presented in Figure 2.14, global CO_2 emissions in 2021 increased by more than 1 billion tonnes (bt) compared to 2020 on the back of a strong recovery in economic activity and increasing mobility in most countries. This figure also demonstrates that an increase in overall CO_2 emissions is to be expected for the rest of the current decade, despite various efforts to minimize them. A positive signal is that global CO_2 emissions will likely stabilize over the medium-term and are projected to begin a declining trajectory at some point at the beginning of the next decade, albeit dropping at lower rates than required by the Paris Agreement.

Figure 2.14
Annual change in energy related CO_2 emissions, 1950–2045



Source: OPEC.

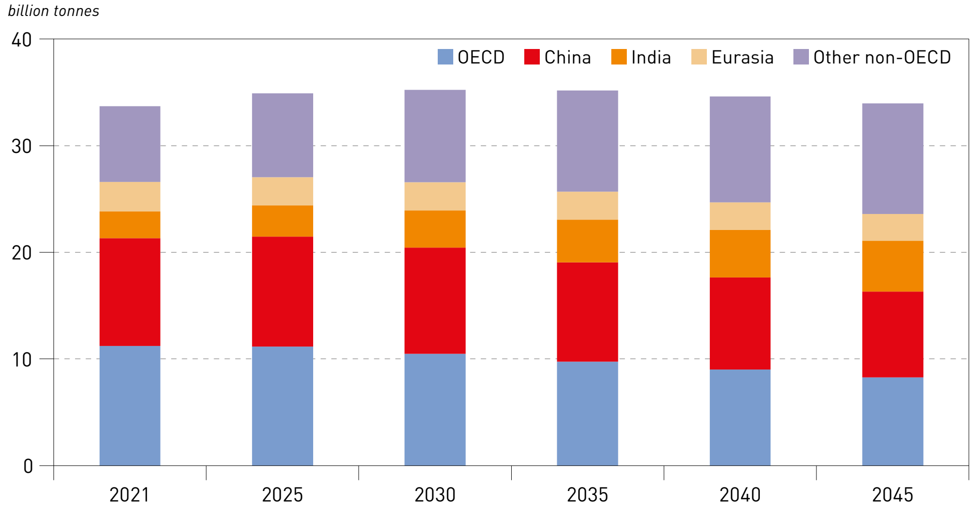
Figure 2.15 provides a regional perspective on future developments in energy related emissions. Clearly, these trends reflect significant changes in the level and composition of regional energy demand that are projected to take place over the forecast period.

Starting with the OECD, CO_2 emissions in this region are set to decline by 3 bt between 2021 and 2045. Except for a few initial years (2021–2023), emissions in this region will steadily decline driven by a continued drop in coal and oil demand as already noted.

A similar pattern in overall CO_2 emissions is also projected for China. These are set to marginally grow from current levels until around 2025 when they are forecast to peak at around 10.3 bt before gradually declining for the rest of the forecast period to reach 8 bt by 2045. The net effect is a decline of more than 2 bt of CO_2 by 2045, compared to 2021.

Some reduction in annual CO_2 emissions, in the range of 0.3 bt, is also projected for Eurasia. This is mainly associated to a projected decline in energy demand in Russia, while other countries in the region will likely see a minor increase in CO_2 emissions over the forecast period.

Figure 2.15
Energy-related annual CO_2 emissions by region, 2021–2045



Source: OPEC.

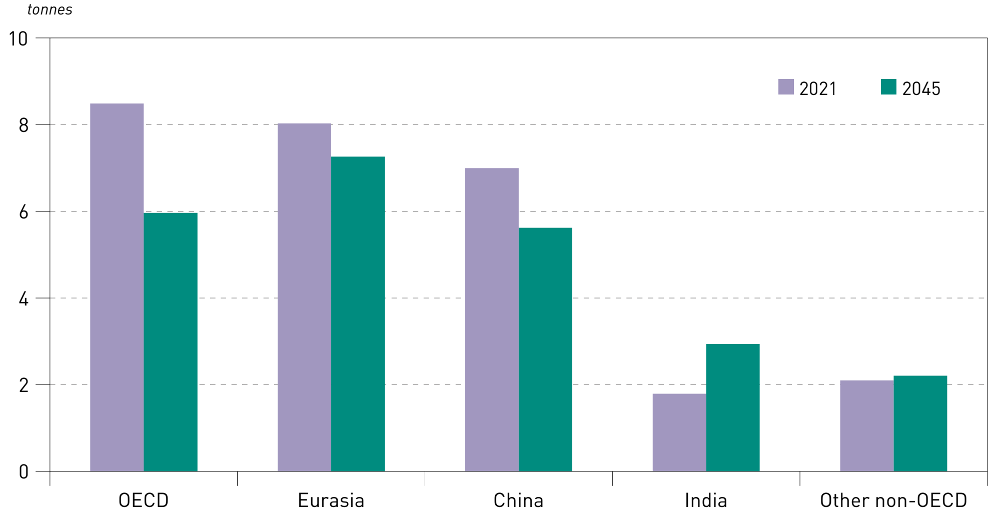
Contrary to these regions, energy-related emissions will continue to grow in most developing countries. Projected strong energy demand growth in India will lead to a rise in CO_2 emissions, from 2.5 bt in 2021 to a projected 4.8 bt in 2045. Similarly, growing energy needs in the remaining non-OECD countries will likely result in an increase in annual CO_2 emissions of around 3 bt during the forecast period, despite significant renewable energy growth in these countries.

It is important to note, however, that the strong growth in annual CO_2 emissions in developing countries, when expressed in absolute terms, is just one side of the coin. A different perspective is provided in Figure 2.16, which looks at these trends on a per capita basis. In this case, the pattern changes dramatically. Per capita emissions in OECD countries and Eurasia in 2021 were around four times higher than those in India and in 'Other non-OECD' countries. Moreover, despite a decline in per capita CO_2 emissions in OECD, Eurasia and China over the forecast period, the corresponding levels in most of the other countries will remain far below those in developed countries.

The disproportional share in the contribution to global CO_2 emissions between developed and developing countries is also demonstrated in Figure 2.17, which presents cumulative CO_2 emissions of Annex I and Non-Annex I countries since 1900. It shows that there is a substantial gap in cumulative emissions that has evolved between these two groups of countries since 1900.

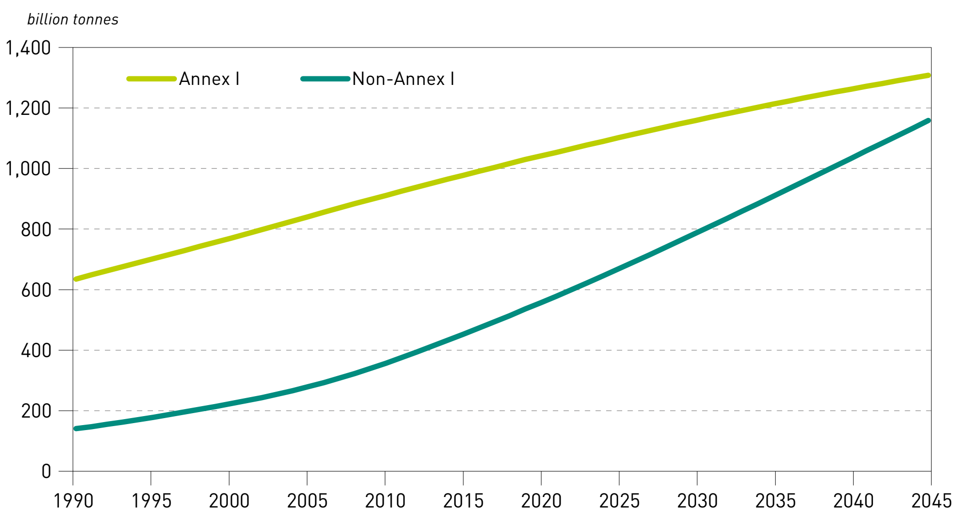
In 1990, cumulative emissions from Annex I countries were at around 635 bt, 4.5 times higher than those from Non-Annex I that stood at around 140 bt. This gap has started to narrow since then on the back of rapid energy demand growth in many developing countries. It was reduced to around two-fold in 2020 and this trend is expected to continue over the forecast period. Nevertheless, even by 2045, historical cumulative emissions by Annex I countries will remain above those generated by Non-Annex I countries.

Figure 2.16
Per capita CO_2 emissions by region, 2021 and 2045



Source: OPEC.

Figure 2.17
Cumulative CO_2 emissions since 1900, 1990–2045



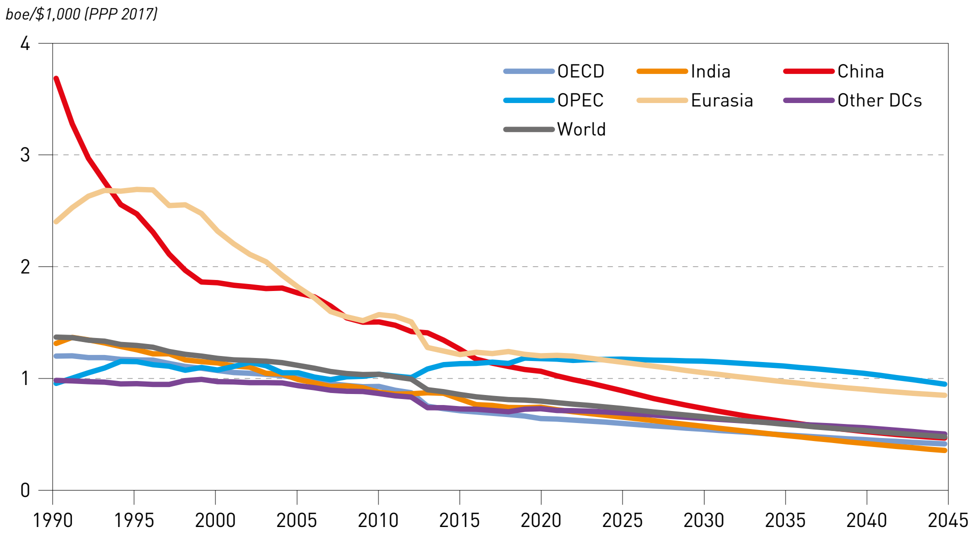
Source: OPEC.

2.5 Energy intensity and consumption per capita

Energy intensity expresses the ratio of energy consumption per unit of GDP, while the inverted energy intensity is usually employed as a measure of energy efficiency. In other words, if the energy efficiency increases, the energy intensity declines and *vice versa*. The energy intensity varies at a regional and country level due to several factors. These factors include the structure of the economy, population, technology, polices and infrastructure.

Figure 2.18 shows the historical and projected energy intensity in major regions. Energy intensity has declined strongly in the last 30 years, especially in developing countries, such as China and India. Rising energy efficiency in combination with less energy intensive economy sectors has contributed greatly to this development. This trend is expected to continue in the future, in line with further technological developments and rising energy efficiency, including a rising share of renewables with high transformation efficiency.

Figure 2.18
Evolution and projections of energy intensity in major world regions, 1990–2045



Source: OPEC.

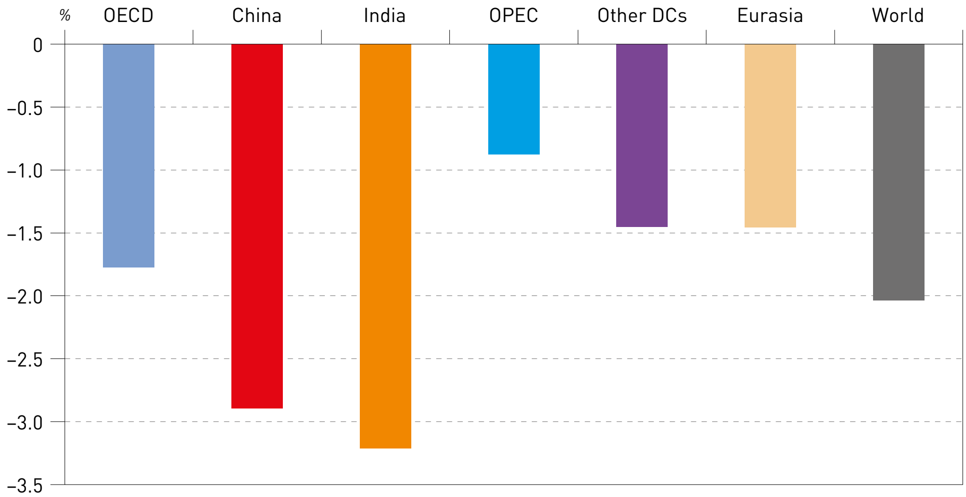
In the long-term it is expected that the energy intensity of most regions will converge. In particular, China is forecast to continue to see significant further improvements in their energy intensity over the projected period. Due to the slowdown in energy demand, China's energy intensity is likely to decline strongly, approaching much closer to OECD levels.

Figure 2.19 shows projections for improvements in the global and regional energy intensity in the period 2021–2045, which is the expression of the energy efficiency performance across the major regions. The largest gains are visible for India and China, where the slowdown and decline in coal use, as well as the more efficient use of energy, are the major contributors to this trend. The reduction in energy intensity in India and China is calculated at 3.2% p.a. and 2.9% p.a. on average, respectively.

Other regions are also expected to reduce their energy intensity. The OECD's intensity is projected to decline by 1.8% p.a. Many OECD countries already use energy efficiently and the space for improvement is limited relative to China and India. At the global level, the average energy intensity reduction is estimated at around 2% p.a.

This section also addresses the issue of energy poverty and the importance of access to modern energy services. In recent years, the general trend has been an increase in

Figure 2.19
Average annual rate of improvement in global and regional energy intensity, 2021–2045



Source: OPEC.

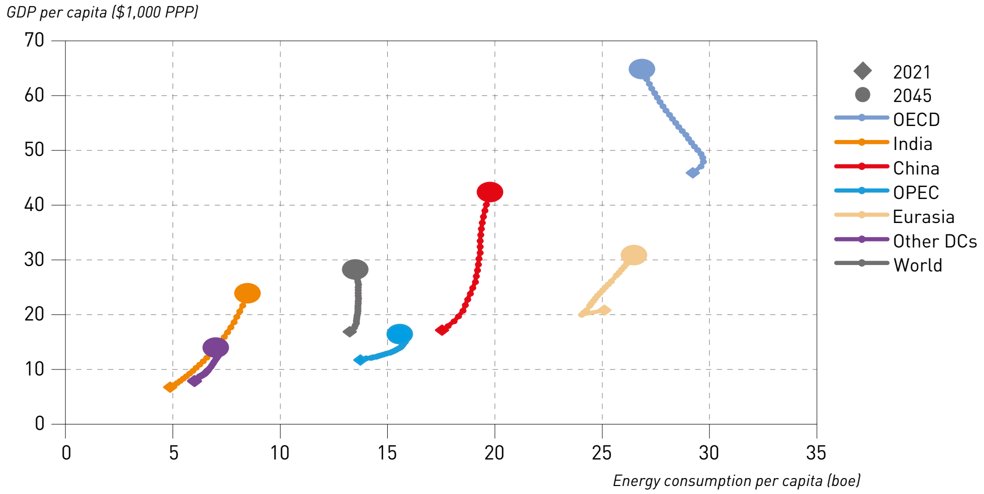
energy access and a continuous reduction of energy poverty. Rapid economic expansion in the developing world, particularly in developing Asia, has helped lift millions of people out of poverty, expanding the middle class, and enabling an increase in energy access. In 2015, average energy consumption in non-OECD countries had almost tripled compared to 1970 levels and the gap with the OECD had lessened. Nevertheless, the gap is still wide and energy poverty remains an extremely important and urgent global issue for policymakers to resolve.

However, current geopolitical turmoil and energy market prices could potentially lead to an increase in energy poverty, as many developing countries cannot afford energy at current price levels. This once again illustrates the importance of energy affordability, mentioned in the introduction to this Chapter.

Figure 2.20 shows energy demand per capita in relation to GDP per capita for major regions. The Reference Case sees the gap between energy consumption per capita in the OECD and non-OECD regions narrowing slightly in the long-term. Energy consumption per capita in the OECD declines from around 29 barrels of oil equivalent (boe) in 2021 to 27 boe in 2045. In Eurasia, energy consumption per capita is expected at similar levels to OECD in 2045, despite lower GDP per capita. China is expected to see an improvement with per capita consumption expected to increase from 17.5 boe in 2021 to almost 20 boe in 2045.

Other regions, despite strong economic and energy demand growth in the period to 2045, remain far below the OECD in terms of energy consumption per capita. For instance, the average energy consumption per capita in Other developing countries climbs to only 7 boe in 2045, which is less than one third of the OECD level in 2045. India is set to advance from 5 boe in 2021 to 8.5 boe in 2045.

Figure 2.20
Energy consumption per capita *versus* GDP at PPP per capita, 2021–2045



Source: OPEC.

Box 2.1

The role of natural gas in Africa

prepared by the Gas Exporting Countries Forum (GECF) Secretariat

The UN projects that global population will increase from 7.8 billion in 2021 to 9.7 billion in 2050. Of this growth, Africa is set to represent more than 60%, with the continent's population almost doubling from around 1.3 billion in 2021 to nearly 2.5 billion in 2050. As a result, Africa's percentage of the world population is forecast to rise from 17% to 26%.

The share of Africa's urban population is also set to increase, from 44% in 2021 to almost 60% in 2050. Although this urbanization offers great opportunities, it also poses significant challenges alongside the region's huge overall population expansion, and may put pressure on existing infrastructure. For instance, weak coverage of basic services, access to reliable and affordable energy, clean water, and a dependable supply of electricity.

Around 600 million people lacked access to electricity in Africa in 2021, and 900 million people in sub-Saharan Africa did not have access to clean cooking. In light of that, Africa's energy security concerns should not only be viewed in terms of sustained and affordable energy supplies, but also in the wider context of being an essential driver for the 17 UN SDGs.

Africa's long-term economic outlook is positive and bright. The continent has an abundance of natural resources to provide all of the energy needed for its development. The continent boasts over 125 billion barrels of oil proven reserves and around 13 trillion cubic metres (tcm) of proven gas reserves.

Natural gas is assumed to be Africa's greatest opportunity as a long-term energy supply solution to help alleviate energy poverty and enhance the quality of life, specifically in sub-Saharan Africa. As a fuel for sustainable development, natural gas can provide accessibility, affordability and reliability to African nations. Furthermore, on the back of proven technology, natural gas can also increase the rate of energy efficiency and, in combination with CCS/CCUS, with a limited carbon footprint.

Accelerated economic activity and a rising urban population will be the key drivers in the robust increase in Africa's energy needs. Over the next three decades, primary energy demand in the region is expected to almost double. Natural gas is set to make the most significant inroads into the energy mix, given the availability of ample gas reserves and a series of recent discoveries in the region. A number of countries, both established gas producers and emerging ones with significant resource potential, for example, Mozambique, Tanzania, Senegal, and Mauritania, have firm plans for production startups, as well as pipeline construction and network development that will help stimulate local consumption.

There is a huge scope for natural gas to meet the continent's substantial power deficit, especially in sub-Saharan Africa. Moreover, there is significant potential to penetrate the residential segment, helping populations move away from the use of traditional biomass for cooking. In turn, this will reduce air pollution and deforestation.

Increased gas availability will also encourage consumption by gas-based industries, such as petrochemicals, methanol and fertilisers, with the latter contributing to the productivity of the agricultural sector and food security.

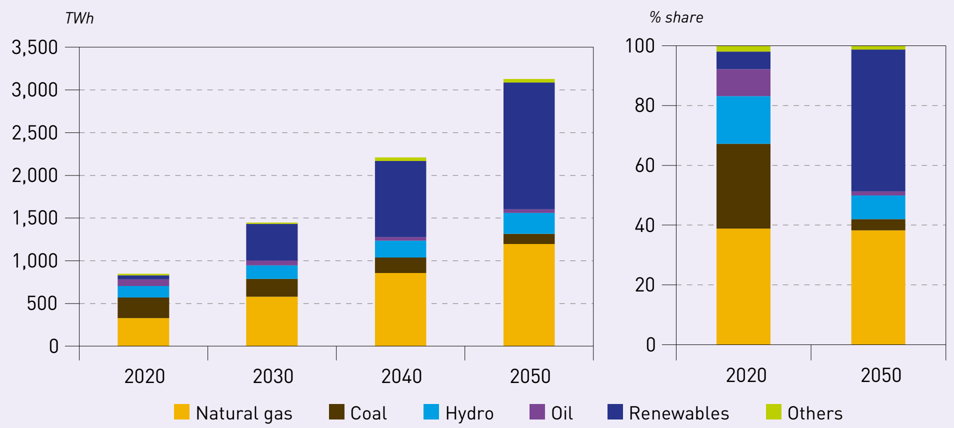
Currently, the role of gas varies across the continent. In North Africa, gas meets around half of the sub-region's energy mix and this fuel is expected to remain dominant in the long-term. At the same time, however, the share of gas in sub-Saharan Africa accounts for just 5%, yet this sub-region is expected to witness remarkable progress in the coming decades due to the push for industrial and social development. According to GECF's estimations, natural gas demand in Africa is expected to rise significantly from about 155 bcm in 2020 to almost 400 bcm by 2050, with the majority of this growth coming from sub-Saharan Africa.

From a sectoral perspective, the power generation sector is anticipated to provide the bulk of the increase, accounting for around 220 bcm, or 75%, of the total additional volumes in Africa. Simultaneously, options such as gas-by-wire within the same regional power pool and the development of LNG-to-power projects could create additional sources of demand, allowing African nations to monetize locally-produced gas and intensify intra-region integration.

Natural gas will likely be the preferred fuel in power generation to enable accelerated electrification across the continent. Likewise, natural gas is considered a suitable partner for renewables, which are projected to grow rapidly, given the scale of the electrification required, as well as countries' plans and supportive policies.

Overall, electricity generation in Africa is expected to rise from 850 terrawatt hour (TWh) in 2020 to 3,130 TWh in 2050. Natural gas is expected to cover 38% of the total rise in electricity supply and provide a stable 38-39% share of the power generation mix over the outlook period. (Figure 1).

Figure 1
Africa power generation by fuel and fuel shares



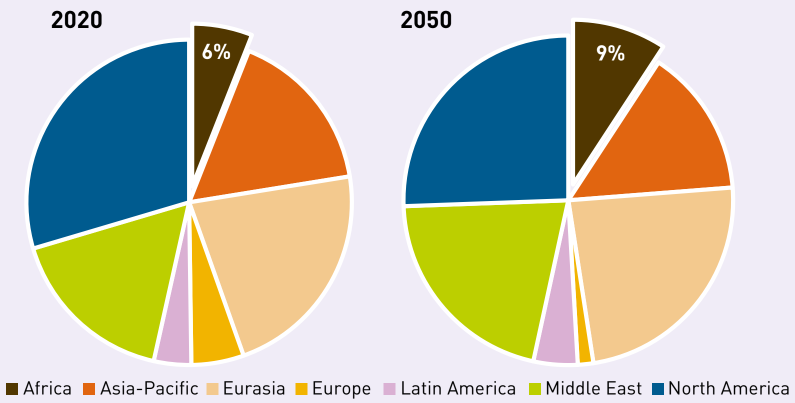
Note: Others include bioenergy, nuclear and hydrogen.
Source: GECF Secretariat based on data from the GECF GGM.

Since 2020, Africa has stepped up discovery and exploration activities despite an overall global downturn in investment in oil and gas developments. The continent is the fastest-growing region for natural gas production. Much of the recent expansion is sourced from developments for LNG exports in Mozambique's offshore Rovuma basins, Nigeria's LNG Train 7 project, the joint offshore development in Mauritania and Senegal, as well as a massive new gas discovery reported by Sonatrach in Algeria's Sahara Desert with the potential for 0.34 tcm of reserves. This is in addition to production from other North African countries, such as Egypt, to support domestic market growth.

It is forecasted that Africa's gas production will increase by an average growth rate of 2.8% p.a., from about 230 bcm in 2020 to around 520 bcm in 2050. This enormous expansion will enhance the role of Africa in global natural gas supplies and increase the region's meaningful share in global gas production. It is expected that Africa will be the source of more than 9% of the natural gas supply worldwide in 2050, compared to 6% in 2020 (Figure 2).

Presently, almost one-third of Africa's gas output is from associated gas production, which indicates the natural gas system's intricate dependence on the oil

Figure 2
Regional share in global natural gas production



Source: GECF Secretariat based on data from the GECF GGM.

industry. However, this share is forecast to reduce as more gas projects are developed in the continent.

Deep water natural gas resources are also one of Africa's untapped potentials that could see expansion in the future. In this case, technology advancement in the upstream sector is one of the critical drivers.

Nevertheless, massive investments are required across the upstream, midstream and downstream gas sectors in Africa. The GECF's Global Gas Outlook (GGO) estimates that between 2020 and 2050, turning reserves into supply will require more than $1.6 trillion of investment in the upstream sector alone.

In 2020, Africa exported around 82 bcm of natural gas to other regions. Almost 70% of this volume – 41 million tonnes (57 bcm) – was exported in the form of LNG, mostly from GECF countries, including Nigeria, Algeria, Angola and Egypt, in order of significance. Pipeline exports are mainly from Algeria and Libya to Europe. In addition, there was also some intra-regional trade in the form of pipelines, such as from Algeria to Tunisia and Morocco, and from Mozambique to South Africa.

The future for LNG exports in Africa is promising. Currently, Africa comprises about 71.1 million tonnes per annum (mtpa) of LNG liquefaction capacity located in Algeria, Angola, Cameroon, Egypt, Equatorial Guinea and Nigeria. There are also under-construction projects amounting to 18.8 mtpa in Mauritania, Mozambique and Senegal, 9 mtpa with a Final Investment Decision (FID) in Congo and Nigeria, and 26.4 mtpa that are in different stages of Front End Engineering Design (FEED) around the continent. Furthermore, proposed projects amount to 64 mtpa and there are 41.2 mtpa of potential and stalled projects.

Among the projects, Mozambique holds over 90 mtpa of LNG liquefaction projects in different development stages, including the Rovuma LNG and the Mozambique LNG projects. Meanwhile, the $7 billion Coral Sul floating LNG (FLNG) project is currently under construction by the Area 4 concessionaires in the Rovuma Basin of Mozambique. The project envisions producing gas from the southern part of the Coral Sul reservoir and using an FLNG plant with a capacity of 3.4 mtpa. Eni have announced that this project is on track to deliver its first LNG cargo in the 2H22, adding Mozambique to the list of LNG-producing countries.

The $30 billion Rovuma LNG project, led by Eni and ExxonMobil, includes the construction of two trains with a capacity of 15.2 mtpa from three reservoirs in the same Area 4 of the Rovuma Basin. This project is expected to come on stream around 2030.

Finally, the $20 billion Mozambique LNG project is the country's first onshore LNG project. Currently, it has two trains that will have a production capacity of 12.88 mtpa. It should be noted that the project could expand up to 43 mtpa. According to TotalEnergies, the project is on track to deliver its first LNG cargo in 2024.

Senegal and Mauritania are also set to join LNG exporters in 2023 when the first phase of a 2.5 mtpa FLNG that utilizes the Great Tortue gas resources begins to produce LNG. The project has the potential to expand to 10 mtpa in later phases. The area's coastline between Mauritania and Senegal features over 22 mtpa of proposed projects in BirAllah, Yakaar Teranga and Greater Tortue. These projects are estimated to materialize between 2034 and 2039.

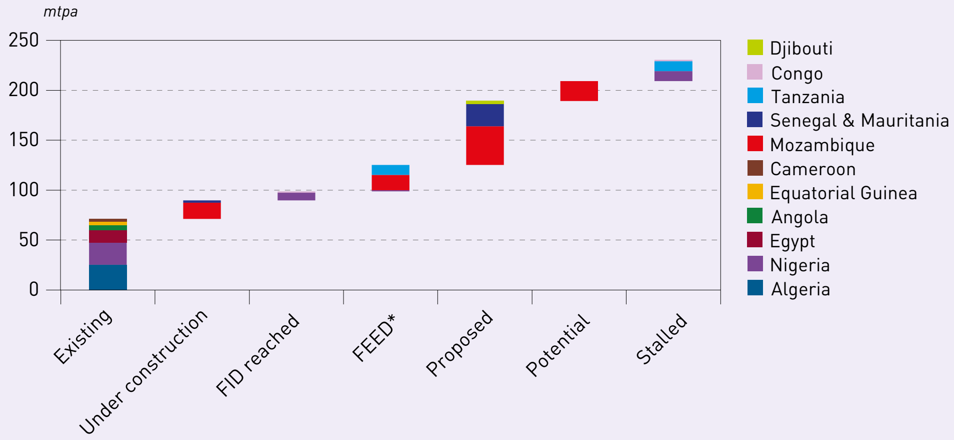
Tanzania is another gas-rich country that sees LNG exports as a way to help transform its economy. The $30 billion Tanzania LNG project aims to reach FID in 2025 and there is a hoped-for start to operations by 2030. Additionally, two trains, each with a capacity of 5 mtpa, are in the pre-FEED status.

Overall, it is estimated that the total onstream liquefaction capacity of the region in 2050 will reach around 144.8 mtpa, more than double Africa's existing export capacity. Accordingly, LNG exports are forecast to increase to about 117 bcm (85 mt) by 2050, positioning the region as a major LNG hub over the long-term.

Investment in the exploration of vast untapped gas resources in Africa will bring various benefits to the continent. The fossil fuel is set to substitute for dirty biomass stoves to aid almost 900 million people and it can provide electricity for 600 million people without access. Therefore, natural gas can revolutionize the clean energy supply transition and eliminate the dominant picture of poverty in energy access.

Meanwhile, the potential for intra-regional trade via pipeline and inter-regional export through LNG can help bring substantial economic benefits to the African people. The level of income from LNG can also drive other technological developments and enhance infrastructure in all other sectors and, as a result, has the potential to significantly reduce poverty.

Figure 3
Africa LNG liquefaction capacity



Note: FEED includes, pre-FEED and FEED completed project status.
The Figure reflects all the probable (beyond 2050) LNG liquefaction capacity projects in Africa.
Source: GECF Secretariat based on data from the GECF GGM.

Natural gas, as the cleanest hydrocarbon, is a perfect regional solution in Africa in the fight against climate change, as well as poverty, and one of the best solutions for sustainability.

Oil demand

Key takeaways

- Global oil demand is projected to reach a level of almost 107 mb/d in 2027, representing an increase of 10 mb/d compared to 2021.
- The large majority of this demand increase will materialize in the non-OECD region, which will account for 8.6 mb/d of the growth over the medium-term. Of this, however, more than 5 mb/d will be realized in the period to 2024.
- OECD oil demand is expected to increase by 1.4 mb/d in the period to 2027 with part of the increase in the period to 2024 (+2.4 mb/d compared to 2021) being offset by a decline of 1 mb/d during the rest of the medium-term.
- Annual oil demand growth is forecast at 2.1 mb/d on average during the period to 2025. Growth is then expected to slow to 0.6 mb/d between 2025 and 2030 and even more to 0.2 mb/d during the 2030–2035 period. After that, projections indicate a relatively long period of plateauing oil demand at the global level.
- Between 2021 and 2045, global oil demand is expected to increase by close to 13 mb/d, rising from 96.9 mb/d in 2021 to 109.8 mb/d in 2045.
- OECD oil demand will be on a declining trajectory after 2024, approaching the level of 34 mb/d by the end of the forecast period. This represents an overall demand decline of almost 11 mb/d between 2021 and 2045.
- Non-OECD demand is expected to increase by 23.6 mb/d between 2021 and 2045. In the initial years of the forecast period, this growth will be driven by China. In the later period, India will take over the leading role while demand growth in China will slow significantly and even turn to a marginal decline during the last five years of the forecast period.
- The aviation, road transportation and petrochemical sectors will be the main contributors to future incremental oil demand, each adding around 4 mb/d between 2021 and 2045.
- The total vehicle fleet is expected to reach 2.5 billion by 2045, increasing by almost 1 billion from 2021 levels. The EV fleet approaches 540 million vehicles by 2045, representing more than 22% of the global fleet.
- After initial years of growth, oil demand in the road transportation sector is expected to stay in a very narrow range of 46.5 mb/d to 46.7 mb/d as developments in the passenger car segment will have offsetting effects on those in the commercial vehicles segment.
- For refined products, major long-term demand growth is expected for jet/kerosene (+3.8 mb/d) followed by ethane/liquefied petroleum gas (LPG) (+2.6 mb/d), diesel/gasoil (+2.4 mb/d), naphtha (+2 mb/d) and gasoline (+1.9 mb/d).

While 2020 will go down in history as the year with the largest annual oil demand drop in living memory, the oil industry will also remember 2021 as the year with the highest demand increase. The latter came on the back of a strong economic recovery from the much depressed levels during 2020 and the easing of mobility restrictions enabled by progressive increases in COVID-19 vaccination rates in 2021.

On the economic front, global GDP increased by 5.8% in 2021, providing a strong impetus to the oil demand recovery. This was combined with a mobility return as lockdowns in a number of countries were eased, albeit they did not fully disappear from the daily life of millions of people. As a result, global oil demand increased by 5.7 mb/d.

Despite this impressive growth, 2021 was far from a year of smooth recovery. Rather, it was a year of ups and downs with re-emerging regional lockdowns, tightening and easing pandemic restrictions, price fluctuations, differing regional developments and a build-up of inflationary pressure. Moreover, 2021 was a year when policymakers and the entire energy and oil industries intensified their efforts in seeking ways to accelerate the transition to cleaner fuels in the run-up to and during the COP26 meeting in Glasgow, UK. A clear reflection of these efforts were the announced intentions of a number of countries to achieve net-zero emissions sometime around 2050.

This sentiment, however, is shifting somewhat in 2022. In the midst of increasing energy prices, rising inflation and omnipresent COVID-19 concerns, the beginning of the year was marked by the Russia-Ukraine conflict. This has brought an additional large element of uncertainty to oil markets. Gas prices in Europe skyrocketed and oil prices increased during a period of unprecedented volatility. Prospects for economic growth were significantly revised downwards, which also impacted the outlook for oil demand.

Moreover, the number of uncertainties has increased, including mounting geopolitical challenges; shifting trade patterns for oil and gas; the effectiveness of various policy measures to lower inflation; changing consumer behaviour; the pace of technology development; as well as the shifting attention of policymakers to energy security issues.

3.1 Oil demand outlook by region

Following an unprecedented decline of 9 mb/d in 2020, global oil demand began to recover in 2021 and rose by 5.7 mb/d. The main part of this growth materialized in non-OECD countries (+3.1 mb/d), led by an extraordinary demand increase in China of 1.1 mb/d. This was supported by Other Asia (+0.5 mb/d), India, the Middle East and Latin America, each rising by around 0.3 mb/d. Despite this impressive growth, the recovery rate from the demand collapse in 2020 was in the range of 50% to 60% in most regions (other than China and Eurasia), hence leaving ample potential for continued strong growth in 2022. A similar observation holds for the OECD with 2021. Oil demand in this region grew by 2.6 mb/d, of which 1.7 mb/d took place in OECD Americas. This represented almost 60% of the demand decline in 2020. However, demand in the other two sub-regions, OECD Europe and OECD Asia-Pacific, recovered by a mere 34% each during the same year.

As a result, 2022 started with an expectation for another year of strong demand growth on the back of prospects for robust global economic growth and a mobility return in major regions as COVID-19 vaccination rates were steadily rising.

However, this positive sentiment from the beginning of the year started to erode somewhat during the 1H22. The impact of the COVID-19 pandemic continued to negatively affect oil markets and the easing of COVID-19-related restrictions was slower than originally anticipated in several regions. Moreover, the reappearance of infections in China led to lockdowns in several locations, thus bringing mobility almost to a standstill. Moreover, economic activity was increasingly impacted by higher energy prices, which contributed to inflationary pressures not seen in the past two decades. On top of this, the Russia-Ukraine conflict, with western countries imposing sanctions on Russia, added yet another element of uncertainty to already complex and rather turbulent markets.

As a result, demand projections for 2022 were gradually trending downward during the 1H22. In July 2022, the OPEC Monthly Oil Market Report estimated that global oil demand would grow by 3.4 mb/d during the year, reaching the level of 100.3 mb/d, which is just marginally higher compared to pre-pandemic demand in 2019. As presented in Table 3.1 and Figure 3.1, this demand growth is primarily driven by the continued strong recovery in OECD countries (+1.8 mb/d compared to 2021). Nonetheless, despite this relatively high increase, OECD oil demand in 2022 will still remain more than 1 mb/d below its 2019 level.

In non-OECD countries, demand growth in 2022 is projected at just around half that of 2021. This is partly due to the fact that a large part of the 2020 demand decline in these

Table 3.1
Medium-term oil demand in the Reference Case

mb/d

	2021	2022	2023	2024	2025	2026	2027	Growth 2021–2027
OECD Americas	24.3	25.3	25.7	26.0	26.0	25.9	25.7	1.5
OECD Europe	13.1	13.7	13.8	13.7	13.5	13.4	13.2	0.1
OECD Asia-Pacific	7.4	7.6	7.6	7.6	7.5	7.4	7.3	–0.1
OECD	**44.8**	**46.6**	**47.2**	**47.2**	**47.0**	**46.6**	**46.2**	**1.4**
China	14.9	15.3	16.0	16.4	16.6	16.8	16.9	2.0
India	4.8	5.1	5.4	5.6	5.8	6.1	6.3	1.6
Other Asia	8.6	9.1	9.5	9.8	10.0	10.2	10.4	1.8
Latin America	6.2	6.4	6.5	6.6	6.7	6.8	6.9	0.7
Middle East	7.8	8.1	8.4	8.7	8.9	9.1	9.3	1.5
Africa	4.2	4.4	4.5	4.7	4.8	5.0	5.1	0.9
Russia	3.6	3.5	3.6	3.6	3.7	3.7	3.7	0.1
Other Eurasia	1.2	1.2	1.2	1.2	1.2	1.3	1.3	0.1
Other Europe	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.0
Non-OECD	**52.2**	**53.7**	**55.8**	**57.3**	**58.5**	**59.6**	**60.7**	**8.6**
World	**96.9**	**100.3**	**103.0**	**104.4**	**105.5**	**106.3**	**106.9**	**10.0**

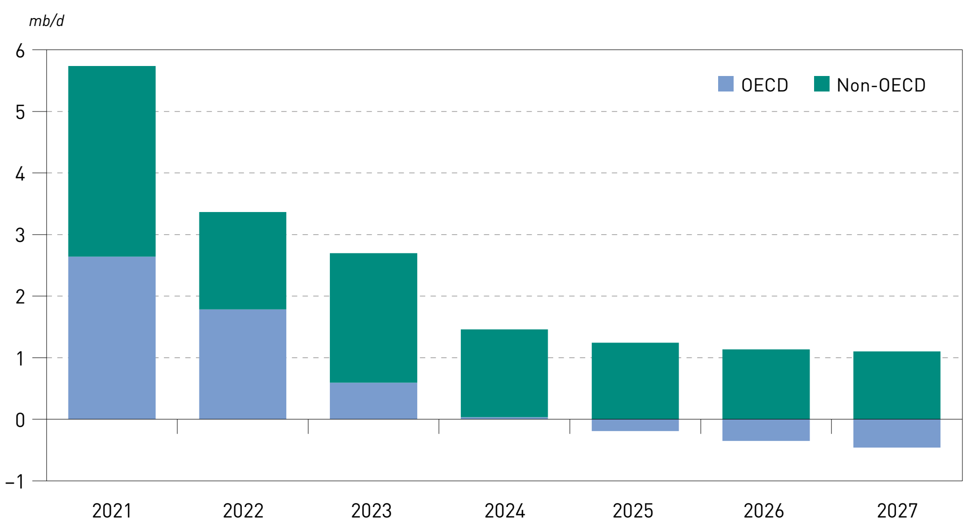
Source: OPEC.

countries was recovered in 2021, which provides less room for stronger growth in 2022. Moreover, 2022 demand in China is significantly impacted by continued regional lockdowns, while demand is even estimated to slightly decline in Russia and Other Eurasia on the back of the conflict.

All these factors indicate that oil demand will likely continue growing at robust levels in 2023 before shifting to much lower levels during the rest of the medium-term horizon. Indeed, 2023 is seen as the year when remaining parts of the demand loss incurred by the COVID-19 pandemic measures will be recovered, especially in the still-lagging aviation sector. This will be supported by a partial demand 'catch-up' of lost growth during the previous two years under an assumption that the COVID-19 pandemic will be contained by then, geopolitical tensions will ease, and the policy focus will emphasize energy security issues.

This 'catching-up' process will likely be most visible in the transport sector. A high rate of personal savings and travel restrictions imposed during the pandemic years should result in a propensity to travel more and fly longer distances, hence supporting demand growth beyond the standard link to economic activity. This will likely be supported by the return of investment decisions across all sectors, which were often postponed in the past two years. Accordingly, global oil demand is projected to grow by 2.7 mb/d in 2023 with demand growth shifting back to non-OECD countries (+2.1 mb/d). By contrast, demand growth in OECD countries will start to decelerate, especially in OECD Asia-Pacific and OECD Europe.

Figure 3.1
Annual incremental oil demand by region, 2021–2027



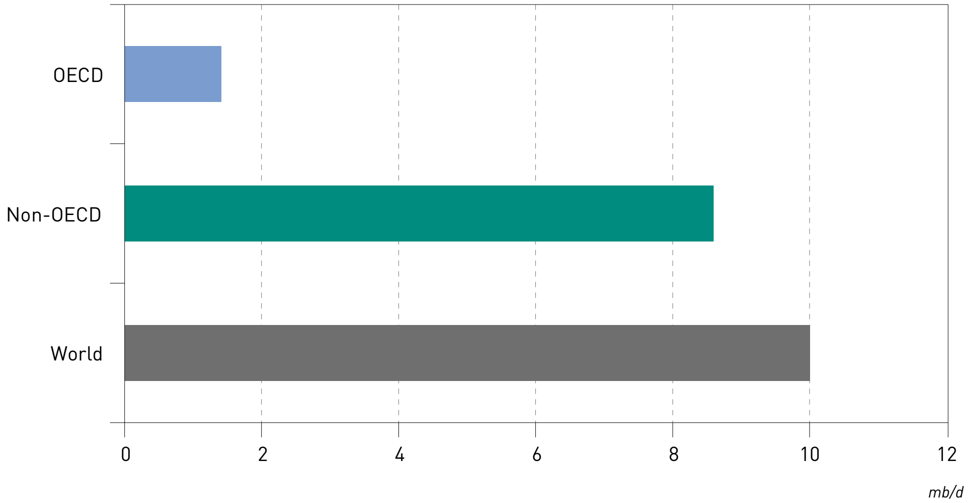
Source: OPEC.

This decelerating trend in annual oil demand growth in both the OECD and non-OECD will be even more pronounced during the second half of the medium-term. During this period, annual GDP growth is expected to remain in a fairly narrow range of 3.1% to 3.2%. Besides lower GDP growth, increasing sales of new EVs – especially in China, Europe and the US – will start to have a material impact on oil demand as the share of EVs will grow to the level of 3% to 4% of the global passenger car fleet. This will be supplemented by ongoing efficiency improvements, changing consumer behaviour and further structural shifts in the GDP composition towards less energy- and oil-intensive sectors in a number of countries.

The combined effect of all these factors, with varying impacts at the regional level, will be that annual demand increments will decline to a range of 1.5 mb/d in 2024 and further to just 0.6 mb/d by the end of the medium-term. This is primarily due to the fact that OECD demand will turn to negative growth after 2024. Despite this decline, global oil demand is projected to reach the level of almost 107 mb/d in 2027, representing an impressive increase of 10 mb/d compared to 2021.

As presented in Figure 3.2, the overwhelming majority of this demand increase over the medium-term will materialize in the non-OECD, which will account for 8.6 mb/d of the growth. Of this, however, more than 5 mb/d will be realized in the period to 2024. In the case of the OECD, oil demand is expected to increase by 1.4 mb/d in the period to 2027 as part of the increase in the period to 2024 (+2.4 mb/d compared to 2021) will be offset by a decline of 1 mb/d during the rest of the medium-term. The overall effect is that oil demand in the OECD will likely stay below its 2019 levels over the entire forecast period.

Figure 3.2
Incremental oil demand by region, 2021–2027



Source: OPEC.

It is worth noting that oil demand projections included in this Outlook represent an upward revision of almost 2 mb/d by the end of the medium-term compared with the WOO 2021. The gap starts building in 2021 and accelerates during the period to 2024, reflecting current market dynamics, surprisingly robust growth in 2022 and 2023, as well as a strong focus on energy security issues leading to slower oil substitution – especially by natural gas – compared to past outlooks. Needless to say, this will likely have some lasting implications for the long-term outlook too.

Turning to long-term demand prospects, these are summarized in Table 3.2. Between 2021 and 2045, global oil demand is expected to increase by close to 13 mb/d, rising from 96.9 mb/d in 2021 to 109.8 mb/d in 2045. This table also shows a contrasting picture between continued demand growth in the non-OECD region and a decline in the OECD. As noted earlier, this trend will begin during the medium-term period and strengthen over the longer-term. Indeed, OECD demand is projected to grow to 47.2 mb/d in the period to 2024 before starting a longer-term decline towards 34 mb/d by 2045. This is almost 11 mb/d lower than observed demand in 2021.

The main reasons for this declining trend in the OECD are efficiency improvements across all sectors of consumption and the substitution of oil by gas and renewable energy. This includes the significant penetration of EVs in the road transportation sector, ongoing electrification of residential and industrial sectors, and the penetration of alternative fuels in the marine and aviation sectors, among others. Part of this picture includes a static (and ageing) population and low economic growth, with less oil-intensive industry, especially in the second part of the forecast period.

Table 3.2
Long-term oil demand by region

mb/d

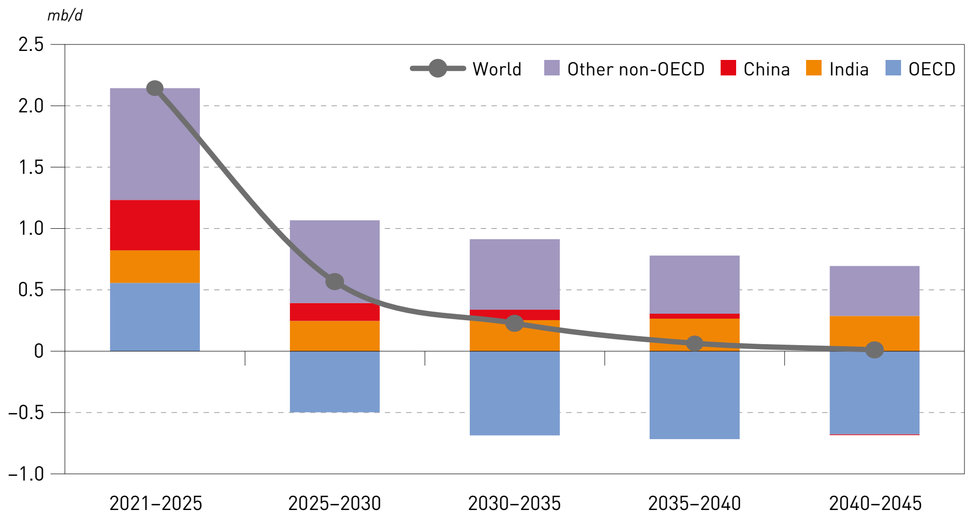
	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	24.3	26.0	25.0	23.3	21.4	19.6	–4.7
OECD Europe	13.1	13.5	12.6	11.5	10.4	9.4	–3.7
OECD Asia-Pacific	7.4	7.5	6.9	6.3	5.7	5.1	–2.3
OECD	**44.8**	**47.0**	**44.5**	**41.1**	**37.5**	**34.1**	**–10.7**
China	14.9	16.6	17.3	17.7	17.9	17.9	3.0
India	4.8	5.8	7.1	8.3	9.7	11.1	6.3
Other Asia	8.6	10.0	10.9	11.8	12.6	13.3	4.7
Latin America	6.2	6.7	7.2	7.6	7.8	8.1	1.9
Middle East	7.8	8.9	9.9	10.7	11.2	11.5	3.7
Africa	4.2	4.8	5.5	6.3	7.0	7.8	3.6
Russia	3.6	3.7	3.8	3.9	3.9	3.8	0.2
Other Eurasia	1.2	1.2	1.3	1.4	1.5	1.5	0.3
Other Europe	0.8	0.8	0.8	0.8	0.8	0.7	–0.1
Non-OECD	**52.2**	**58.5**	**63.8**	**68.4**	**72.3**	**75.7**	**23.6**
World	**96.9**	**105.5**	**108.3**	**109.5**	**109.8**	**109.8**	**12.9**

Source: OPEC.

Prospects for continued strong demand growth in the non-OECD stands in stark contrast to the OECD outlook. Driven by an expanding middle class, high population growth rates and stronger economic growth potential, non-OECD demand is expected to increase by 23.6 mb/d between 2021 and 2045. In the initial years of the forecast period, this growth will be driven by China, which is set to add around 0.4 mb/d on average to non-OECD demand. In the later period, however, India will take over the leading role, contributing close to 0.3 mb/d each year (Figure 3.3) while demand growth in China will significantly slow and turn even to a marginal decline during the last five years of the forecast period.

Figure 3.3 also demonstrates a distinct picture between demand growth during the current decade and the remaining part of the forecast period. Driven mainly by the recovery process from COVID-19, annual oil demand growth is forecast at 2.1 mb/d on average during the period to 2025. Growth is then expected to slow to 0.6 mb/d between 2025 and 2030 and even more to 0.2 mb/d during the 2030–2035 period. After that, projections indicate virtually no growth, hinting to a relatively long period of plateauing oil demand at the global level. As noted earlier in this chapter, this will be a period when demand declines in the OECD will broadly offset growth in the non-OECD. This is driven by both energy policies and technology development, which will play an increasing role in diversifying the future energy mix.

Figure 3.3
Average annual oil demand increments by region, 2021–2045



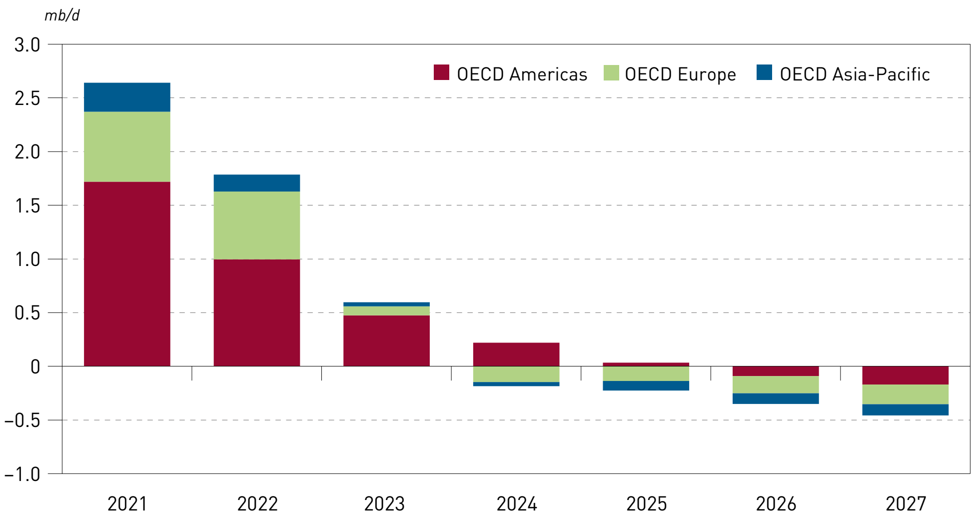
Source: OPEC.

Similar to the medium-term period, long-term oil demand projections represent an upward revision compared to the WOO 2021. However, the pattern of these revisions reverses from a growing gap during the medium-term (reaching almost 2 mb/d by 2027) to a declining difference at the global level over the long-term. Nevertheless, even though part of this higher demand will be eliminated over the long-term as a reflection of tightening policy measures aimed at reducing energy-related emissions and an upward revision to the penetration of EVs, global oil demand is still projected to be around 1.6 mb/d higher by 2045, compared to last year's WOO.

3.1.1 OECD

OECD oil demand was affected most during the pandemic year of 2020 when it declined by 5.7 mb/d, representing more than 60% of the global demand drop during the year. Almost half of this demand loss was recovered during 2021 when lockdowns eased, mobility partly recovered and OECD economies returned to a growth trajectory. Strong demand growth in this region is expected to continue in 2022, adding another 1.8 mb/d (Figure 3.4). This is mainly due to the improved pandemic situation as conditions have further normalized and economic growth remains at relatively high levels, in the range of 3% for OECD Americas and Europe and a still robust 2.4% in OECD Asia-Pacific.

Figure 3.4
Annual oil demand growth in the OECD, 2021–2027



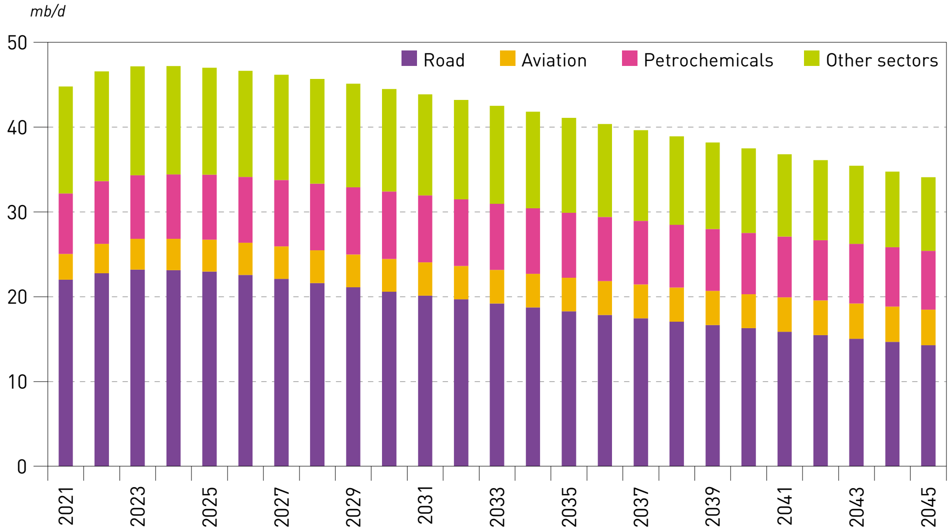
Source: OPEC.

However, this is expected to change in the next several years. GDP growth is set to decelerate to the range of 2% p.a. in OECD Americas, 1.4% to 1.8% p.a. in OECD Europe and stay in an even lower range of 1.3% p.a. in OECD Asia-Pacific. Moreover, the potential for demand recovery due to pandemic measures will mostly be exhausted during 2023 (with a possible exception of the aviation sector), new EV sales will progress further, and policy measures and technology advances will continue to support efficiency improvements and oil substitution.

Therefore, OECD demand will expand by just 0.6 mb/d in 2023 and is expected to be below 0.1 mb/d in 2024, before it turns to negative growth for the rest of the forecast period. This reversal will take place in 2023 in the case of OECD Europe and OECD Asia-Pacific. The net effect is that OECD oil demand will increase by 1.4 mb/d between 2021 and 2027 to reach the level of 46.2 mb/d by the end of the medium-term.

Beyond the medium-term, oil demand will be on a declining trajectory, approaching the level of 34 mb/d by the end of the forecast period. This represents an overall demand decline of almost 11 mb/d between 2021 and 2045. As presented in Figure 3.5, the main sector contributing to this decline is road transportation, which will account for more than 70% (7.7 mb/d) of the drop. There are two main reasons driving these projections. The first one relates to the pace of penetration of EVs into the future car fleet in OECD countries. As discussed in detail in Section 3.2.1, a gradual increase in the sales of EVs will result in having around 200 million EVs on OECD roads by 2045, which will replace more than 4 mb/d of potential gasoline and diesel demand. Another key parameter relates to efficiency improvements of vehicles with ICEs over the forecast period, driven by tightening efficiency standards set by policymakers. Despite the related time lag (or legacy effect of older cars in the fleet), the impact of these improvements on road transportation oil demand will be comparable to the penetration of EVs.

Figure 3.5
OECD oil demand by sector, 2021–2045



Source: OPEC.

Some demand decline is also projected in the industry, residential/agriculture/commercial and electricity generation sectors (shown as 'Other sectors' in Figure 1.5), primarily due to oil substitution by gas and electricity. The largest scope for demand reduction exists in the residential and industry sectors. The primary means to achieve this reduction in the residential sector include tighter building codes for newly constructed houses, replacement of oil-based heating systems in older buildings and better insulation. Emissions trading systems and the implementation of more efficient technology will have the same effect in the industrial sector. However, the overall effect on these sectors is significantly lower compared to road transportation, each contributing around 1 mb/d to the long-term total OECD demand decline.

In contrast to these sectors, oil demand in the aviation sector is projected to increase in the long-term. OECD demand in this sector has so far struggled to recover from the 2020 collapse and is unlikely to reach its pre-pandemic levels before 2025. However, once the recovery phase is over and consumers regain confidence, demand is expected to continue growing – though incremental demand in the OECD will be fairly limited. Overall demand growth is projected at 1.2 mb/d between 2021 and 2045, while the larger part of this increase is linked to outstanding demand recovery rather than to providing fuels for additional aviation activity. Similar to road transportation, efficiency improvements and alternative fuels will play a major role in limiting the potential for incremental demand in OECD.

The long-term path for OECD oil demand in the petrochemical sector will be somewhere between the road transportation and aviation sectors. OECD demand in this sector rebounded fairly quickly after dropping in 2020 and is projected to grow until around 2030. This growth will primarily be driven by favourable conditions in the US on the back of growing tight oil production and available steam-cracking capacity. This, however, will change after tight oil production peaks towards the end of the current decade and starts to decline for the rest of the forecast period.

Box 3.1

EU 'Fit for 55': Impact on oil demand

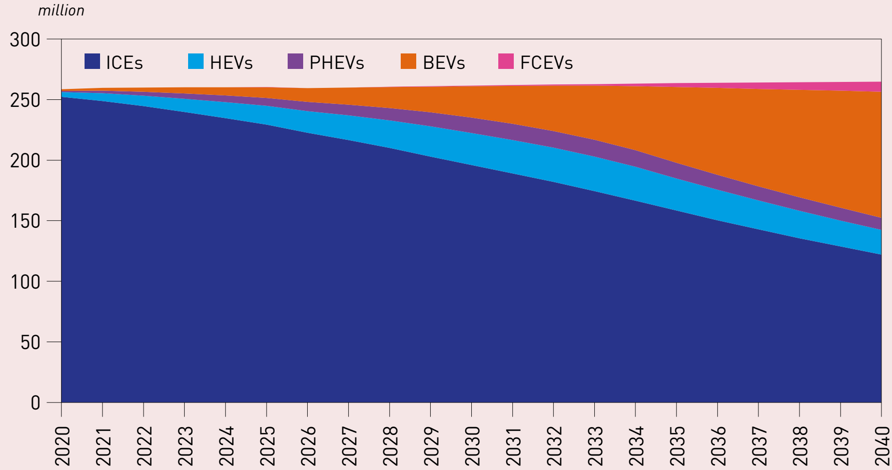
The EU's current climate ambitions, as proposed in the 'Fit for 55' package of numerous interwoven schemes, require a significant change in the bloc's energy system. Collectively, this package should enable the EU to reduce GHG emissions by 55% by 2030. These proposals are still in a very early phase and are indeed just proposals. Several steps are still needed for the package to become legally binding. In this box, the potential impact of a full implementation of the proposals on the EU's oil demand is elaborated and compared to the WOO Reference Case projections.

For the current decade, a significant reduction of coal and natural gas consumption in the EU seems feasible. However, the European Commission (EC) projects only a minor reduction of 5% in gross domestic oil consumption due to the implementation of the 'Fit for 55' package compared to its reference case. The main reason for this is the high oil demand in transport and the comparable long-lead times to implement significant changes in this sector.

For the period from 2030 to 2045, all fossil energy sources would be highly impacted by the new EU policy framework. According to the impact assessment prepared by the EC, coal would be almost completely phased out of the EU energy mix by 2045. Natural gas consumption is projected to fall by almost two-thirds compared to the EC's reference scenario without additional policy measures, while domestic oil consumption would be reduced by over 60%. Moreover, these energy sources would be replaced mainly by renewable electricity.

Oil demand in road transport, as the main consumer of oil products in the EU, would be most affected by the proposed policy measures. Stricter CO_2 standards for cars and vans, which *de facto* lead to a ban on the sale of ICE-based vehicles from 2035 onwards, the implementation of an ETS for transport and buildings and the higher taxation of gasoline and diesel (compared to biofuels and electricity) would have a significant impact on the EU's vehicle fleet composition, which will likely develop as presented in Figure 1.

Figure 1
Estimated EU-27 passenger fleet composition under 'Fit for 55', 2020–2040



Source: OPEC.

In this case, EU oil demand in road transportation is projected to be 4.4 mb/d in 2030 and 2.9 mb/d in 2040. Compared to the assessment included in this Outlook, the timely implementation of 'Fit for 55' would lead to an additional decrease in oil demand of 0.1 mb/d in 2030 and of 0.7 mb/d in 2045.

The European aviation sector will be mainly impacted by the ReFuelEU Aviation initiative, strengthened ETS and the inclusion of kerosene in the Energy Taxation Directive. ReFuelEU Aviation aims to introduce significant shares of SAFs in the form of biokerosene and renewable fuels of non-biological origin (RFNBOs) in this sector. Electricity can be considered as an option for small, short-haul aircrafts, but will be mainly used to reduce kerosene demand of aircraft parked at airports. The first small amounts of biokerosene are expected to enter the market as early as 2024. The lead time for RFNBOs is expected to be longer and the first significant amounts are expected from 2030 onwards. The EU expects biokerosene to have a share of 4.3% in 2030 and 31% in 2045. The share of RFNBOs is projected at 0.7% in 2030 and 18% in 2045. Such a transition for aviation fuel would decrease oil demand in the aviation sector by 0.05 mb/d in 2030 and by around 0.4 mb/d in 2045 compared to the WOO Reference Case.

Similar to ReFuelEU Aviation, the FuelEU Maritime initiative aims to reduce the GHG intensity of maritime fuels. LNG is considered a transition fuel, which, according to the impact assessment, is expected to peak with a 12% share in 2030. For 2045, a share of 4.7% is projected. Biofuels are projected to contribute 6% of maritime energy demand in 2030 and 43% in 2045. Bio-LNG is projected

3

to be not available in significant amounts before 2030. In 2045, a share of 13% is projected. E-fuels are expected to contribute from 2035 onwards with a share of 11% by 2045.

An increasing share of LNG as a marine fuel is already accounted for in the WOO Reference Case. Considering the full implementation of additional 'Fit for 55' measures, oil demand for maritime fuels in the WOO Reference Case would only marginally drop by 2030, but the gap could would extend to 0.3 mb/d in 2045.

Changes in oil demand in the industry sector are mainly driven by the stricter ETS and the proposed increase in energy taxes for fossil fuels. However, the 'Fit for 55' package is expected to have significant impacts on the industry sector only after 2030. It is worth mentioning that the EU's baseline scenario already projects a significantly steeper decline in oil demand compared to this Outlook. The full implementation of 'Fit for 55' would widen the gap compared to this Outlook to 0.3 mb/d in 2030 and 0.8 mb/d in 2045.

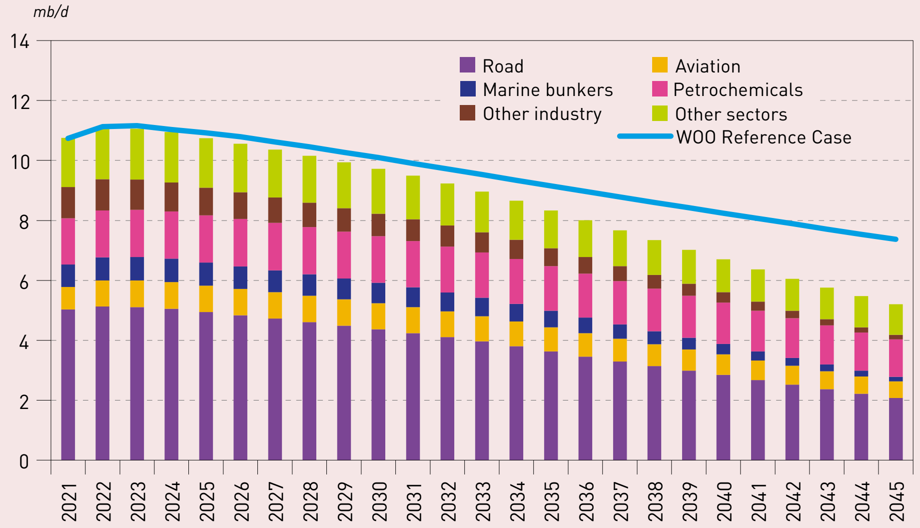
EU oil demand for electricity production is already very low and is projected to decrease continuously in the WOO Reference Case. However, the stricter ETS targets under 'Fit for 55', which also affect emissions from power plants, are projected to lead to an even steeper decline, especially during the current decade. Nevertheless, it remains to be seen to what extent these targets will be met given the current market situation and the EU's intention to reduce its dependence on Russian gas imports. In the longer-term, projections for oil demand in the power sector included in the WOO Reference Case are broadly consistent with EU targets. The same can be stated for the remaining sectors, such as residential, commercial, agriculture, rail and waterways as projections included in this Outlook show no major difference to the EU assessment.

In summary, a complete and successful implementation of the 'Fit for 55' package could potentially reduce EU oil demand by 1.3 mb/d in 2030 and by 5.8 mb/d in 2045, compared to 2022 levels. Total oil demand in the EU is projected to be 9.7 mb/d in 2030 and 5.2 mb/d in 2045 (Figure 2). A change in the EU's vehicle fleet composition and measures assumed to be implemented in the industry sector would be the main drivers of the oil demand drop. However, road transport is still projected to be the sector with the highest oil demand by 2045 due to the limited impact of these measures on commercial vehicles.

It remains to be seen to what extent the EU will be able to implement these ambitious targets in a timely manner, especially in view of the current turbulence in its energy markets. This is especially the case given the need to substantially redirect flows of oil and gas and to proceed with necessary adjustments in related infrastructure and in all sectors of consumption.

Finally, it is important to note that negotiations on the 'Fit for 55' package are still in an early phase and must still be adopted by Member States. Nevertheless, it indicates the potential for a downward revision in EU oil demand in the years to come.

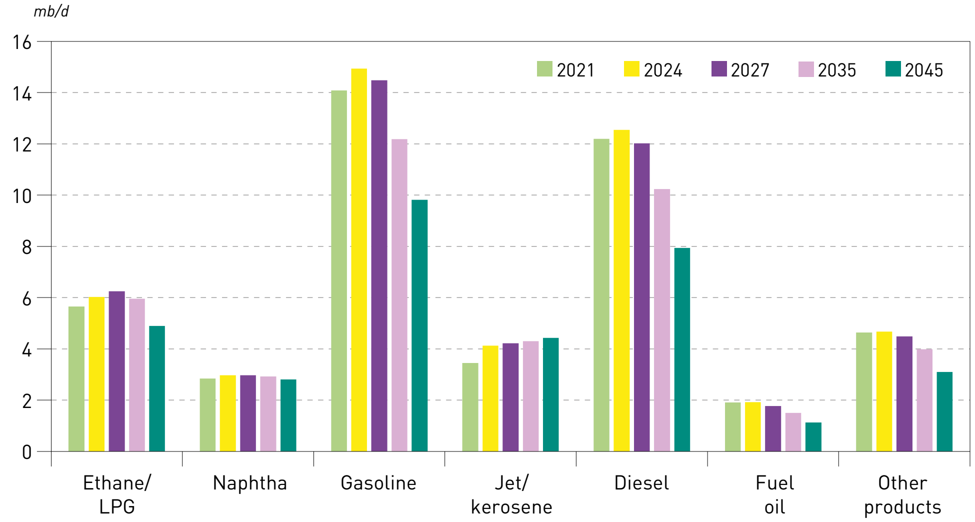
Figure 2
Oil demand in the EU-27 by sector under the assumption that the 'Fit for 55' package is fully implemented, 2021–2045



Source: OPEC.

Figure 3.6 provides some details on these prospects from the perspective of specific refined products. Driven by projected developments in the road transportation sector, the largest demand decline is projected for diesel and gasoline. OECD diesel demand is set to drop by 4.8 mb/d between 2021 and 2045. It will grow slightly during the initial years of

Figure 3.6
OECD oil demand by product, 2021–2045



Source: OPEC.

the forecast period as part of the recovery process, but the combined effect of long-term declining demand in the road transport, industry, residential and marine transport sectors will push diesel to below 7 mb/d in 2045, compared to almost 12 mb/d in 2021. A similar demand pattern is also projected for gasoline, although demand for this product is almost entirely linked to the changing fleet composition and the way passenger cars will be used.

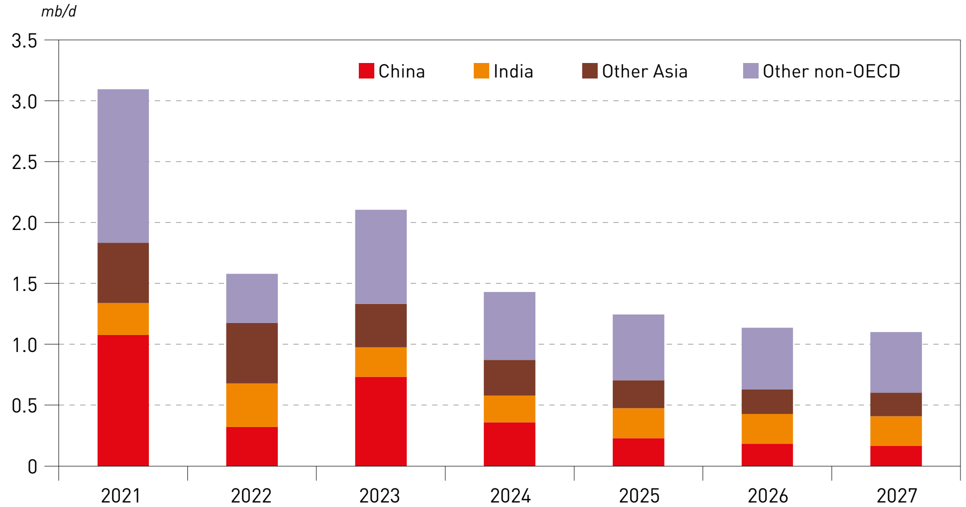
Future demand for ethane/liquefied petroleum gas (LPG) and naphtha will, to a large extent, mirror developments in the petrochemical sector. Naphtha provides a baseload for petrochemicals, hence its demand is projected to remain relatively stable during the forecast period. The use of ethane/LPG will be affected by its availability, especially in OECD Americas. The supply increase in ethane during the current decade will be absorbed by the petrochemical industry, but its availability will be reduced by declining US tight oil production sometime after 2030.

Fuel oil and 'other products' will be affected by declining demand in the industry (including lower refinery own use), power generation and marine bunkers. The overall decline for 'other products' will be around 1.5 mb/d while demand for residual fuel is projected to drop by 0.8 mb/d between 2021 and 2045. The only product with increasing demand over this period will be jet kerosene, reflecting increased traffic in the aviation sector.

3.1.2 Non-OECD

Following strong demand growth of more than 3 mb/d in 2021, non-OECD oil demand is projected to expand by just 1.6 mb/d in 2022 (Figure 3.7). The main reasons for this slower growth include lockdowns in China, declining demand in Russia and Other Eurasia (which partly offsets growth in other regions), and slower economic growth compared to 2021 on the back of the conflict in Eastern Europe, higher energy prices and disruptions in supply chains for a number of products.

Figure 3.7
Annual oil demand growth in non-OECD countries, 2021–2027



Source: OPEC.

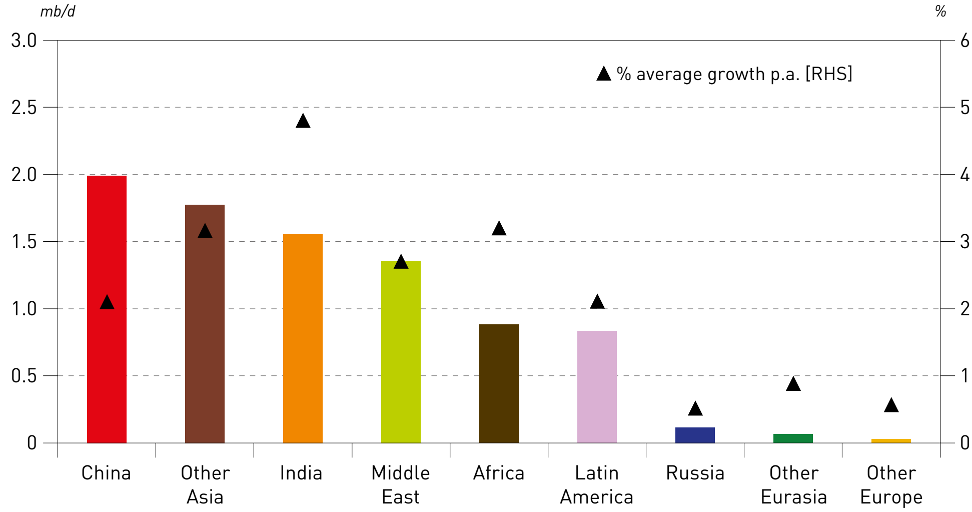
The outlook for 2023 demand seems to be more optimistic under the assumption that several of the recent challenges would be resolved. Demand growth in China is expected to resume as COVID-19-related lockdowns will likely be imposed on fewer citizens. Demand in both Russia and Other Eurasia is also expected to revert to growth, albeit only marginally. Combined with the ongoing recovery from COVID-19-induced crises in some sectors, such as aviation, these factors should result in stronger non-OECD demand growth, estimated at 2.1 mb/d in 2023.

The rest of the medium-term period will be marked by the stabilization of annual demand growth at levels slightly above 1 mb/d. The overall effect of these annual trends is that non-OECD demand will expand by 8.6 mb/d between 2021 and 2027. Figure 3.8 shows how this growth is distributed between regions, together with the corresponding average annual demand growth rates. The largest demand increase is projected for China, which will contribute 2 mb/d to non-OECD demand growth over the medium-term. This is followed by Other Asia, India and the Middle East, with each contributing between 1.4 mb/d to 1.8 mb/d to incremental demand over the medium-term.

However, this order changes when comparing the growth in relative terms. In this case, India leads the group of non-OECD countries/regions with average annual growth of 4.8% during the 2021–2027 period. Other Asia and Africa follow, each growing by 3.2% p.a. on average. Relatively fast growth is also projected for the Middle East, Latin America and China, all expanding more than 2% p.a. on average while much lower growth rates, less than 1% p.a., are projected for Eurasia and Other Europe.

Turning to the long-term, non-OECD demand prospects are marked by continued growth. Indeed, annual demand increments in this region are projected to stay in the 1 mb/d range for another five years beyond the medium-term and gradually decline to

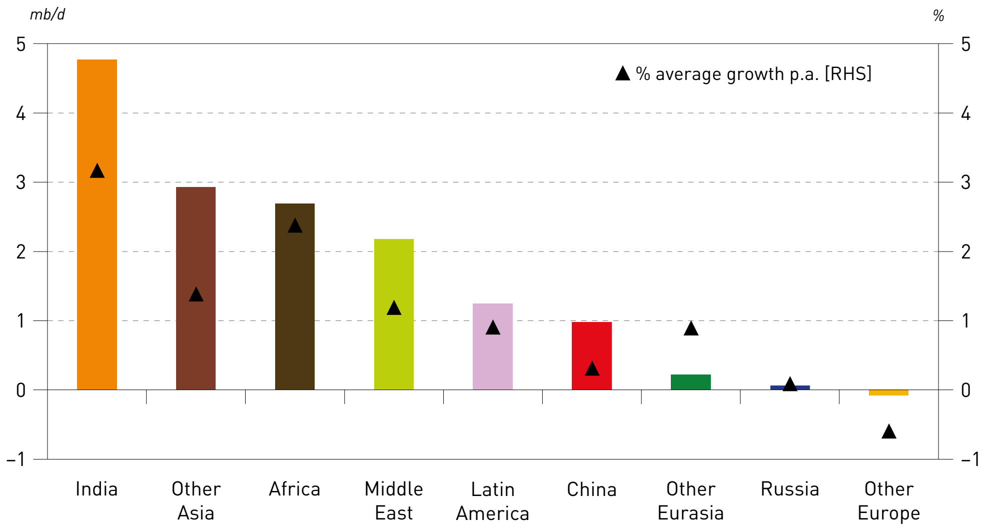
Figure 3.8
Non-OECD regional oil demand growth, 2021–2027



Source: OPEC.

0.7 mb/d towards the end of the forecast period. As presented in Figure 3.9, this growth will be led by India and Africa where economic progress, urbanization, industrialization and the expansion of the vehicle fleet will be fastest among all regions. This will result in a respective demand increase of almost 5 mb/d and 3 mb/d, respectively, during the 2027–2045 period. Even by 2045, oil demand will still grow at the rate of more than 2% p.a. in these two regions.

Figure 3.9
Non-OECD regional oil demand growth, 2027–2045



Source: OPEC.

Demand growth in other non-OECD regions will be much slower. Other Asia, the Middle East, Latin America and Other Eurasia are projected to be in the range of 1% p.a. on average. Among these regions, oil demand in Other Asia and the Middle East will have much higher base demand in 2027 (more than 10 mb/d and 9 mb/d, respectively) compared to Latin America and Other Eurasia, where respective demand will be just 7 mb/d and slightly above 1 mb/d. Therefore, incremental demand in Other Asia and the Middle East will be significantly higher compared to the other two regions.

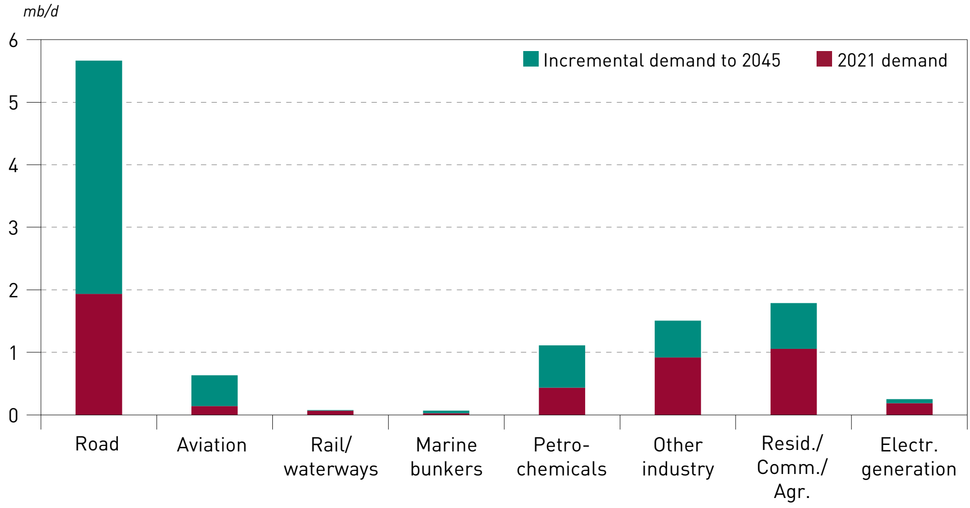
Oil demand in the remaining non-OECD regions, including China, will mature in the second part of the forecast period, plateau during the next decade and even decline marginally towards the end of the forecast period. Of these regions, China will be the only one with a noticeable demand increase, in the range of 1 mb/d, while demand growth in Russia and Other Europe fluctuates in a fairly narrow range of around 0.1 mb/d. One noticeable effect of all these trends is that the future centre of gravity of global oil demand will shift significantly towards non-OECD Asian countries.

India

Oil demand in India is projected to increase by 6.3 mb/d during the forecast period, rising from 4.8 mb/d in 2021 to 11.1 mb/d by 2045. This means that India will be the country with the fastest demand growth and largest incremental demand over the forecast period. There are several drivers leading to this conclusion. India is, and will remain, the country with a very dynamic population growth. The population is set to increase by more than 238 million between 2021 and 2045. Strong population growth will drive economic expansion too, which is projected to grow by more than 6% p.a. on average during entire period, remaining robust (above 5% p.a.) even towards the end of the forecast period.

This strong economic growth will, in turn, generate a large middle class that in combination with urbanization and expanding infrastructure, will enable expansion of the country's vehicle fleet, including both passenger and commercial vehicles. This will go hand-in-hand with the increased use of oil in the residential and industry sectors, including petrochemicals. These trends are clearly reflected in Figure 3.10, which details oil demand growth in India from a sectoral perspective.

Figure 3.10
Oil demand in India by sector, 2021 and 2045



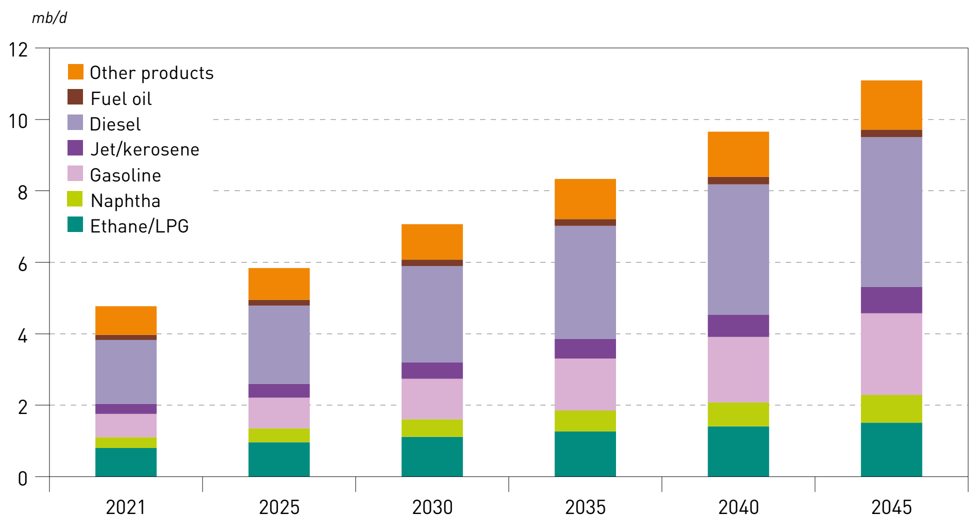
Source: OPEC.

The largest demand increase, close to 4 mb/d between 2021 and 2045, is projected in the road transportation sector as the total number of vehicles in India is projected to grow by close to 190 million between 2021 and 2045, from 54 million in 2021 to slightly above 240 million in 2045 (not including two-wheelers). This expansion includes a relatively large portion of commercial vehicles, almost 50 million, which will significantly support diesel demand. Moreover, the penetration of EVs will remain subdued compared to some other countries, such as China and the OECD countries. This will also play a role in growing gasoline demand in India.

Demand additions in other sectors are projected to be in a significantly lower range. Oil demand in the combined residential, commercial and agricultural sector faces strong competition from electricity and natural gas, which will displace part of oil demand from heating and cooking, especially wherever the gas network is expanded under the City Gas Distribution programme. The objective of this programme is to improve access to natural gas, especially in larger cities. Therefore, oil demand in this sector is anticipated to grow by just around 0.7 mb/d between 2021 and 2045. A comparable increase is projected for the petrochemical sector, also at 0.7 mb/d, followed by 'other industry' at 0.6 mb/d and the aviation sector at 0.5 mb/d.

Figure 3.11 translates these sectoral trends into demand for specific refined products. The largest demand increase is projected for diesel, which also constitutes the largest share of current demand in India. Driven by the robust growth of commercial vehicles and supported by expected developments in the industry and the agricultural sectors, demand for this product will expand by 2.4 mb/d between 2021 and 2045. Since gasoline is the preferred fuel in the growing segment of passenger cars, its demand in India is projected to increase by around 1.6 mb/d by 2045. A large part of the residential sector growth will be linked to the use of LPG, which is projected to increase by 0.7 mb/d. Growth in the aviation and petrochemical sectors will result in increased demand for jet kerosene (0.5 mb/d) and naphtha (0.5 mb/d), respectively.

Figure 3.11
Oil demand in India by product, 2021–2045



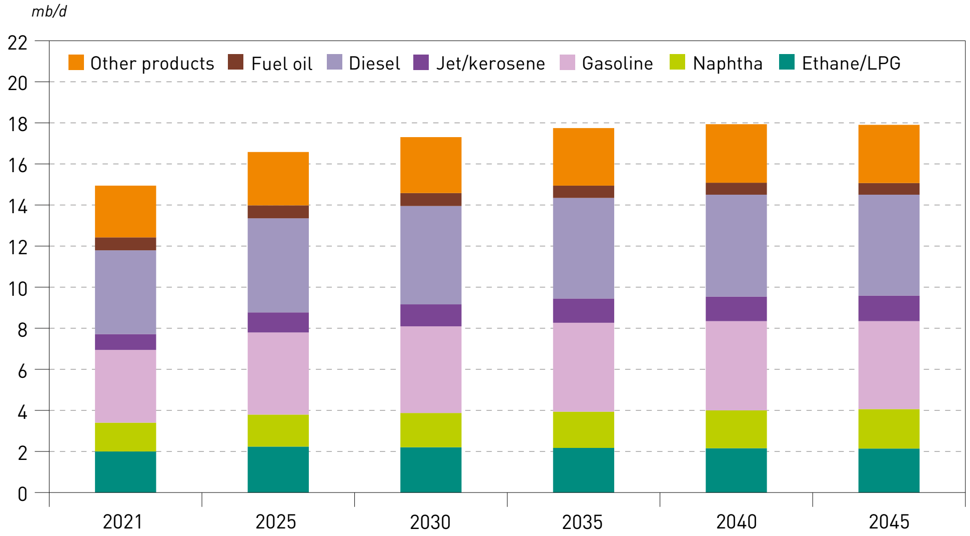
Source: OPEC.

Demand growth in the same range (0.6 mb/d) is also projected for the group of 'other products', such as bitumen, pet coke, lubes/greases 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. Finally, demand for residual fuel oil is set to remain in a narrow range of 0.1 mb/d to 0.2 mb/d during the entire forecast period, since there are no major international bunkering hubs in India and the electricity sector is dominated by the use of coal, renewables and natural gas.

China

The overall pattern for China's oil demand is characterized by strong demand growth during the medium-term period. This, however, will swiftly decelerate in the period to 2035 before plateauing and even marginally declining towards the end of the forecast period. This is present in Figure 3.12, which breaks down China's oil demand into major refining products. To complement this picture, Figure 3.13 shows its oil demand by sector.

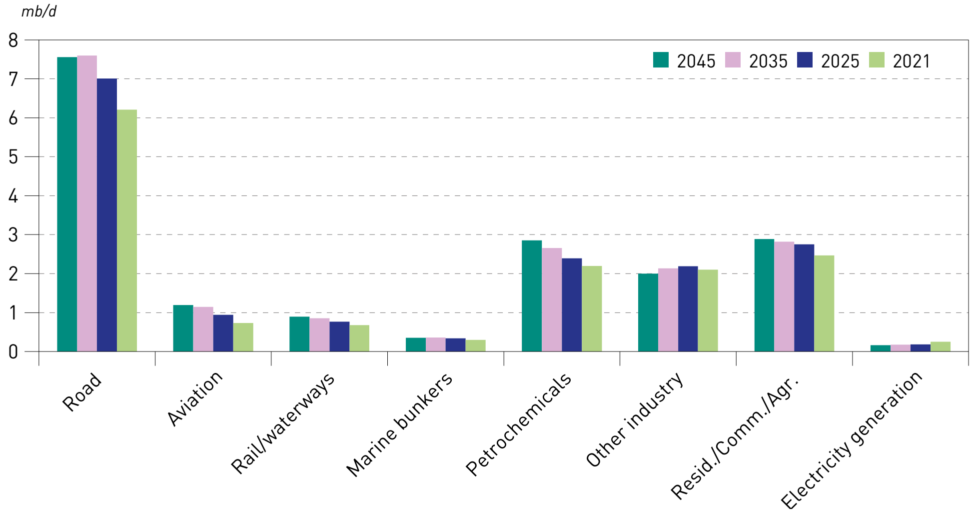
Figure 3.12
Oil demand in China by product, 2021–2045



Source: OPEC.

China's oil demand experienced surprisingly high growth in 2021, when demand increased by 1.1 mb/d. Lower growth in 2022 (mainly due to continued lockdowns) will to a large extent be compensated for in 2023, with demand projected to expand by more than 0.7 mb/d. However, China's demand will revert to a much lower incremental levels in later years. The earliest deceleration/reversal of growth is expected in electricity generation, industry (other than petrochemicals) and residential sectors on the back of oil substitution by natural gas and electricity.

Figure 3.13
Oil demand in China by sector, 2021–2045



Source: OPEC.

In the power sector, the share of oil is minimal, confined to fuelling diesel aggregates for special purposes and limited use of fuel oil, often within refinery gates. This will not change significantly in the years to come, hence keeping oil demand in this sector at around 0.2 mb/d. However, the situation is expected change quite soon in the industry sector with a progression in the use of natural gas instead of oil and coal. Moreover, a continued shift in the structure of Chinese industry, with an increasing share of lower oil- and energy-intensive segments, will contribute to the shift from expanding to declining demand prospects.

However, the main factor that will potentially affect the largest part of oil demand in China relates to changes in the future size and structure of the vehicle fleet. With new car sales of more than 26 million in 2021, China is by far the largest and most dynamic car market in the world. The size of the passenger vehicle fleet in China is projected to more than double, rising from almost 200 million cars in 2021 to around 440 million in 2045. However, a significant part of the potential demand growth resulting from this impressive increase in fleet size will be offset by improved average efficiencies, as well as fuel substitution through electrification and natural gas.

Indeed, recent estimates indicate that there will be around 150 million alternative fuel cars in China by 2045, more than one-third of the total in the country. These vehicles, mostly EVs, will increasingly displace older (and less efficient) ICE cars leading to much slower oil demand growth. Nonetheless, oil demand in the road transportation will account for around 46% of overall demand growth – 1.4 mb/d of a total 3 mb/d of incremental demand – between 2021 and 2045. It is worth noting that this accounts for a minor demand decline during the last five years of the forecast period.

The second largest contribution to China's oil demand will come from the petrochemical industry, which is estimated to grow by 0.7 mb/d over the forecast period. A large part of this expansion will be naphtha-based (+0.5 mb/d), supplemented by ethane and LPG.

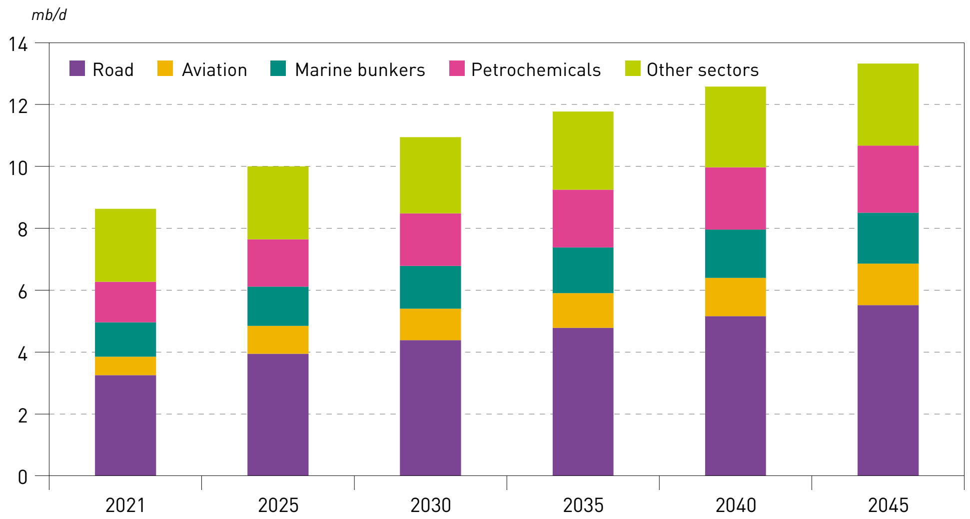
In contrast to road transportation, oil demand in this sector will continue growing throughout the forecast period, though annual increments will gradually decline to just 20 tb/d at the end of the period.

A similar pattern also applies to the aviation sector with a variance that China's demand in this sector will virtually plateau towards the end of the forecast period. Nonetheless, robust growth during the medium-term period, combined with a still-growing market over the next decade, results in an overall demand increase of 0.5 mb/d.

Other non-OECD Regions

Other Asia is the second-largest contributor to future oil demand. Consisting of several countries with high population growth (such as Indonesia, the Philippines and Vietnam), rising urbanization and an expanding middle class, this region is projected to experience robust economic growth in the period to 2045. This, in turn, provides strong support for oil demand growth, especially in the first half of the forecast period, as the road transportation, petrochemical and aviation sectors expand (Figure 3.14). The largest incremental demand is projected in road transportation (2.3 mb/d) on the back of growing numbers of both passenger cars and commercial vehicles. The petrochemical and aviation sectors are set to add another 0.9 mb/d and 0.7 mb/d, respectively.

Figure 3.14
Oil demand in 'Other Asia' by sector, 2021–2045



Source: OPEC.

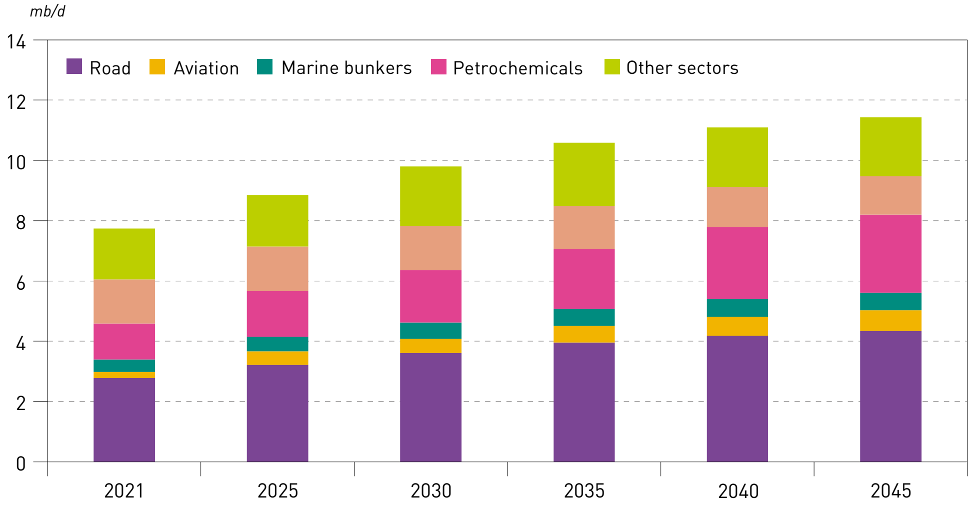
The specifics of Other Asia include a high share of marine bunkers in total demand due to the presence of large bunkering ports in the region. Projected growth in marine shipping in this region will likely offset expected efficiency improvements and some shifts to LNG, so that demand for marine bunkers increases by 0.5 mb/d.

The third largest contributor to future non-OECD incremental demand will be **Africa**. As discussed in Chapter 1, given its very dynamic demographic developments, abundant natural resources and strong potential for industrial expansion and urbanization, oil demand in this region is projected to increase by 3.6 mb/d over the forecast period. More than half of this incremental demand is linked to road transportation (+1.9 mb/d) as motorization progresses primarily with the use of ICEs.

The other half of incremental oil demand on this continent will be fairly equally split between residential/agriculture (0.5 mb/d, mainly LPG and domestic kerosene), electricity generation (0.4 mb/d), aviation (0.4 mb/d) and industry (0.3 mb/d). In contrast to other regions, where oil use for electricity generation is typically declining, it will continue to expand in Africa due to 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 around 0.1 mb/d. Although this demand will more than double over the forecast period, it will still remain below 0.3 mb/d, much lower than in other high growth regions.

The **Middle East** countries are also projected to play an important role in shaping future oil demand, adding some 3.5 mb/d to incremental demand between 2021 and 2045 (Figure 3.15). The Middle East stands out among all other regions as the one where demand growth in road transportation is almost at parity with the petrochemical industry, each accounting for 1.5 mb/d and 1.4 mb/d of the region's future demand, respectively. Strong growth in this sector already starts in the medium-term as several large petrochemical projects come on stream in Saudi Arabia, IR Iran, the UAE, Qatar and Oman. Significant demand growth is also projected in the aviation sector (+0.5 mb/d). In contrast to these sectors, part of the oil used to generate electricity will be replaced by natural gas and renewable electricity. Hence, demand in this sector is set to gradually decline.

Figure 3.15
Oil demand in the Middle East by sector, 2021–2045



Source: OPEC.

Future oil demand changes in the remaining non-OECD regions will be rather limited. In the case of **Latin America**, overall demand growth is projected at around 2 mb/d, reaching the level of 8.3 mb/d by 2045 from 6.2 mb/d in 2021. This is mainly due to sluggish GDP growth in the region, which is projected to stay in the range of 1.5% to 2.5% p.a. during the forecast period. As is the case in most regions, incremental demand is primarily driven by road transportation, which is projected to increase by 0.7 mb/d. Moderately lower demand growth is expected in the residential and agricultural sectors that combined will add another 0.4 mb/d, while the aviation and industrial sectors will grow by around 0.3 mb/d each during the forecast period.

Demand growth will be even more constrained in the remaining three non-OECD regions. Minor but steady growth is expected in **Other Eurasian** countries. The overall change is expected to be in the range of 0.3 mb/d, primarily driven by demand growth in road transportation (+0.2 mb/d). Demand in **Russia** and **Other Europe** will expand only slightly by around 2035 before it plateaus and marginally declines for the rest of the period. This trajectory will result from the offsetting effects of some growth in petrochemicals (especially in Russia) and aviation and stagnating to declining demand in other sectors.

3.2 Oil demand outlook by sector

The objective of this section is to provide an overview of key trends in future oil demand from a sectoral perspective. The high-level breakdown of global demand to major sectors is presented in Table 3.3 and, in terms of incremental demand, in Figure 3.16. Various forms of transportation are not only the main source of current demand. They also provide the largest source of future incremental demand. It needs to be mentioned, however, that part of this future demand increase still relates to a demand recovery from the sharp drop in 2020, especially in the aviation and road transportation sectors.

Amongst all transport modes, the largest demand increase, estimated at 4.1 mb/d between 2021 and 2045, comes from the aviation sector. However, considering 2021 as

Table 3.3
Sectoral oil demand, 2021–2045

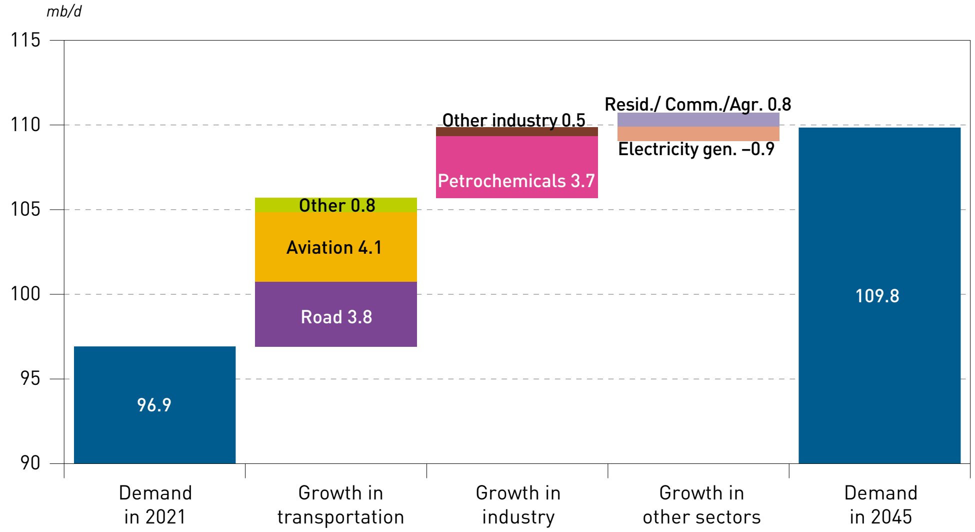
mb/d

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
Road	43.2	47.2	47.3	47.2	47.2	47.0	3.8
Aviation	5.4	7.2	7.8	8.4	8.9	9.5	4.1
Rail/waterways	1.9	2.0	2.1	2.1	2.2	2.1	0.2
Marine bunkers	4.0	4.4	4.6	4.7	4.7	4.7	0.6
Transportation	**54.5**	**60.8**	**61.8**	**62.4**	**62.9**	**63.2**	**8.8**
Petrochemicals	13.8	15.3	16.3	16.7	17.2	17.5	3.7
Other industry	12.8	13.1	13.6	13.8	13.4	13.3	0.5
Industry	**26.6**	**28.4**	**29.9**	**30.5**	**30.6**	**30.8**	**4.2**
Resid./Comm./Agr.	11.0	11.6	12.1	12.2	12.1	11.8	0.8
Electricity generation	4.9	4.7	4.5	4.4	4.2	4.1	–0.9
Other uses	**15.9**	**16.3**	**16.6**	**16.6**	**16.3**	**15.8**	**0.0**
World	**96.9**	**105.5**	**108.3**	**109.5**	**109.8**	**109.8**	**12.9**

Source: OPEC.

3

Figure 3.16
Oil demand growth by sector, 2021–2045



Source: OPEC.

a basis for comparison, more than 1 mb/d of this increase will be needed just to reach pre-pandemic levels, which will likely not be achieved before 2024 (on an annual average). Beyond the recovery period, there is an expectation for steady demand growth resulting from a combination of increased traffic, improved energy efficiency and the gradual penetration of alternative fuels.

This interplay of various factors with offsetting effects will be even more pronounced in the road transportation sector, which will likely witness distinct patterns in the passenger car and commercial vehicle segments. Both segments will grow significantly in respect to the number of vehicles. However, there is larger potential for efficiency improvements in the passenger car segment, which will also experience much faster penetration of alternative (i.e. non-ICE) vehicles, especially EVs. Contributing to the complexity of this segment are changing consumer driving habits, shifts in regional scrappage rates, as well as consumer trends in buying larger cars (e.g. SUVs). The net effect is that oil demand in this segment will continue growing during the medium-term period, but starts slowly declining thereafter.

ICE-based commercial vehicles will face much less competition. Some smaller trucks and pick-ups will certainly be replaced by EVs, but the range of penetration will be much lower (compared to passenger cars). Natural gas-driven vehicles will likely displace even heavy-duty ICE vehicles, but this will be restricted to only a few countries/regions (mainly China). Considering that the number of commercial vehicles will almost double over the forecast period, oil demand in this segment will continue growing and thus offset the decline in the passenger car segment. As a result, oil demand in the road transportation sector is set to grow from 43.2 mb/d in 2021 to above 47 mb/d in 2030 and will stay in this range for the rest of the forecast period.

Some demand growth is also projected in the industrial sector, driven by strong demand for petrochemical products, though the magnitude of this increase is much lower compared with the transportation sector. The overall demand change in the industrial sector is forecast to be 4.2 mb/d, of which 3.7 mb/d relates to petrochemical feedstock. It is worth mentioning that demand growth in the petrochemical industry represented the single-largest contributor to incremental oil demand in the last pre-COVID Outlook. Technically, this is not the case in this year's Outlook, as both the road transportation and aviation sectors are projected to grow by larger volumes. This change, however, is only due to specific developments related to COVID-19 as road transportation and aviation demand was much more affected than the petrochemical industry. Adjusting these figures for the demand decline in 2020, the petrochemical sector actually remains the largest source of incremental demand to 2045.

Oil demand in the 'other industry' sector will follow a similar pattern to the road transportation sector, though for different reasons. It is projected to grow for around another ten years before it starts to slowly decline. The overall change, at the global level, will be quite limited as demand in this sector will move within a range of 1 mb/d during the entire forecast period. This picture, however, looks different at the regional level. Demand in OECD regions is set to decline by more than 1 mb/d between 2021 and 2045 as the industrial use of oil will face strong competition from natural gas and renewable electricity, except for a few initial years of demand recovery. Moreover, during these years, paradoxically, oil could serve as a potential substitute for gas in the industry sector amid an emerging shortage of gas supplies to Europe.

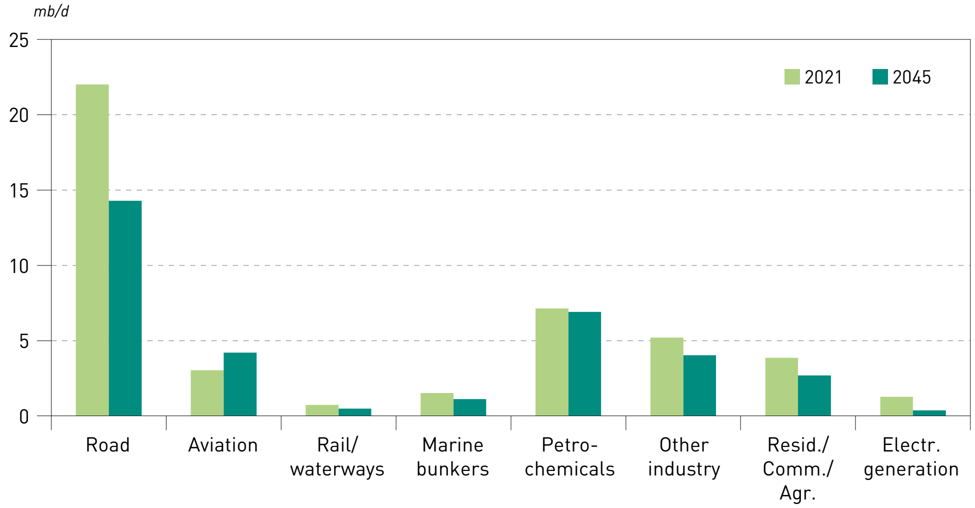
This outlook changes when non-OECD countries are considered. In this case, oil demand in 'other industry' will be driven by progressing industrialization and robust GDP growth in most of these countries. Nonetheless, efficiency improvements and competition between oil, gas and electricity is set to be partly offset potential growth linked to industrialization, especially in the second part of the forecast period when growth will be much slower. Despite this, the non-OECD demand increase is projected at 1.7 mb/d between 2021 and 2045, more than offsetting decline in OECD countries.

The next grouping with significant oil consumption consists of the combined residential, commercial and agricultural sector, which accounts for more than 10% of total oil demand. Demand in this sector is expected to grow by 1.2 mb/d in the period to around 2035 and then decline by 0.4 mb/d for the rest of the forecast period. Broadly, the demand increase in this sector will be offset by losses in the electricity generation sector, which is projected to decline by almost 1 mb/d. It is worth mentioning that electricity generation is the only sector where demand is forecast to drop at the global level.

Figure 3.17 and Figure 3.18 shed more light on these trends by providing a summary of changes in sectoral demand in the OECD and non-OECD. In the OECD case, oil demand will decline in all major sectors except for aviation, where demand will be around 1.2 mb/d higher than in 2021. The largest demand drop is projected for road transportation at 7.7 mb/d, followed by residential and 'other industry' (each declining by 1.2 mb/d), while demand in the petrochemical sector at the end of the forecast period will be comparable to 2021 levels.

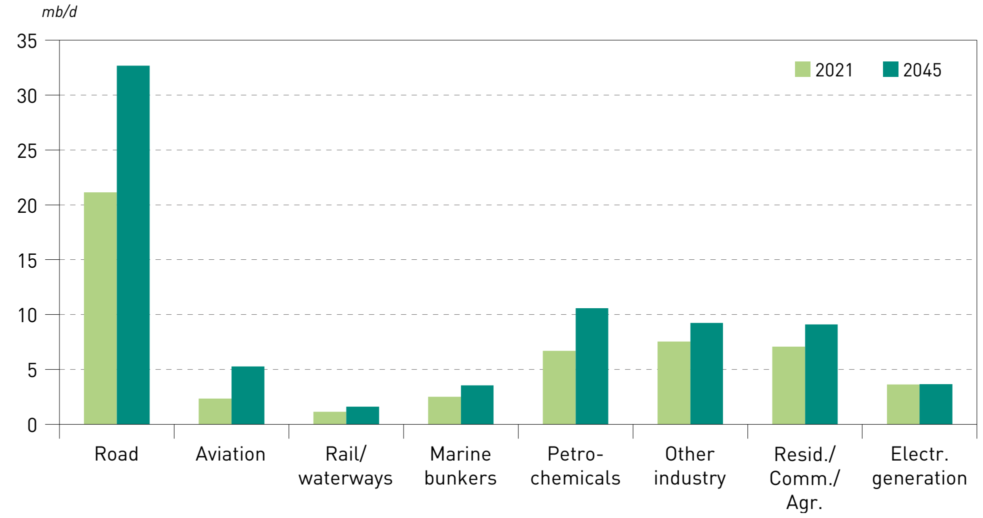
Finally, non-OECD demand is forecast to grow in all major sectors, albeit only a marginal change is projected for electricity generation. Incremental demand will be dominated by an increase in the road transportation (+11.5 mb/d). A significant increase

Figure 3.17
Sectoral oil demand in the OECD region, 2021 and 2045



Source: OPEC.

Figure 3.18
Sectoral oil demand in non-OECD countries, 2021 and 2045



Source: OPEC.

is also projected for petrochemicals where demand will grow by almost 4 mb/d between 2021 and 2045. This will be followed by aviation (+2.9 mb/d), residential (+2 mb/d) and 'other industry' (+1.7 mb/d) sectors.

3.2.1 Road transportation

The COVID-19 pandemic has had a major impact on road transportation. At the pandemic's peak, road transport activities came to a near halt in many economic centres, especially in the OECD. Although road transportation began to recover in 2021 and is on its way back to pre-pandemic levels in 2022, the re-emergence of some regional lock-downs and supply chain disruptions in vehicle manufacturing persist. These disruptions have contributed to a so-called 'chip crisis' at a time when there has been a substantial move towards more intelligent vehicles and EVs. As a result, delivery time for newly ordered vehicles has reached levels not seen for a long time. Moreover, rising inflation and alteration to global energy flows will also have an impact on road transportation.

It should be noted that electrified powertrains – including HEVs, BEVs, PHEVs and FCEVs – not only need intelligent control electronics (microchips), but also a rising number of power semiconductors. It is likely that vehicle production and, therefore, new sales will be disrupted for some time with a consequent effect on fleet development. Nevertheless, new sales have nearly recovered to pre-pandemic levels at the global level. Moreover, various incentives, mainly in Europe and China, are in place to support new EV sales, which continue to increase both in terms of the number of vehicles and the share of new vehicle registrations.

In the longer-term, it is expected that the global fleet will substantially increase during the forecast period, mainly driven by sales in developing regions where people may follow trends similar to OECD countries and acquire passenger cars as soon as economic development permits. The demand for commercial transportation, especially for transportation of goods, but also passengers in urban areas, will require an approximate doubling of commercial vehicles by 2045. Oil demand related to the commercial fleet is set to further increase and largely balance the decline in the passenger car segment. A major reason is the fact that replacing efficient diesel engines with batteries or fuel cells is far more complex than in the case of passenger cars, which can more easily shift towards electric mobility.

Another factor to be monitored relates to autonomous mobility as this may change the travel pattern of passengers and make commercial transportation far more efficient in the longer-term. In both segments, transportation services may increase and, consequently, energy demand would grow whether in the form of conventional fuels or as electricity, hydrogen and potentially synthetic fuels.

Vehicle stock

Vehicle stock development depends basically on existing stocks, new sales and scrappage of older vehicles. New sales are strongly linked to economic development, but also demographics and, increasingly, on policy measures and alternative means of transportation. Scrappage depends on the commissioning of new technologies, as well as standards that make older vehicles increasingly unattractive. High fuel prices, for example, make newer and more efficient vehicles more appealing, especially in the commercial segment.

In congested urban areas, the expansion of public transportation, Mobility as a Service (MaaS) and insufficient parking may reduce consumers' interest in passenger cars, or at least see a limit of one vehicle per family. However, replacing rarely used second vehicles with car or ride sharing may decongest roads and parking, but it does not reduce the passenger transportation load. It is likely that MaaS will require amounts of energy and fuel similar to individual passenger traffic.

The provision of satisfactory road infrastructure also has an important impact on new passenger car sales and is related to economic progress. This is especially the case in developing countries, which will drive global fleet growth significantly in the upcoming decades, except for some already densely populated areas around megacities where measures may restrict vehicle growth to reduce pollution. This will also be the case in OECD countries, which already show signs of fleet saturation, especially in parts of the US, Europe and Japan.

The COVID-19 pandemic caused new sales around the globe to decline substantially, to around 73 million in 2020 from more than 84 million in 2019. New sales broadly recovered in 2021, reaching almost 84 million vehicles. It is worth noting that EV sales grew continuously from 2019 through 2021 despite the pandemic, and this trend continued in the 1H22. Sales reached 5.7 million in 2021, compared to less than 3 million in 2019.

After a sharp decline in 2020 of about 24%, new passenger car sales in OECD Europe fell further to below 12 million in 2021, led by declines in Germany. Nonetheless, EV sales increased year-on-year and reached around 2 million in 2021, up from 1.4 million in 2020. Europe is the largest market for PHEVs, which account for around 45% of all

EV sales. However, the phase-out of PHEV subsidies in major countries like Germany may change that in the near future. Recent geopolitical developments in Europe will likely lead to an even stronger electrification of the passenger car segment to reduce the region's dependency on oil imports. The rise in EV sales has been accompanied by additional investment in charging infrastructure.

In contrast to Europe, China's new passenger vehicle sales increased by almost 4% in 2021 to more than 26 million. However, the Chinese market, in general, lost some of its momentum due to extended lockdowns in major cities in the 1H22. Nevertheless, Chinese car manufacturers have ambitions to develop their industry into a major global supplier of road vehicles based on all powertrain technologies. It remains to be seen to what extent the Chinese car industry will benefit from the fact that many important manufacturers in OECD countries are abandoning the long-term development of ICE vehicles in favour of BEVs in the passenger segment.

In OECD Americas, new vehicle registrations recovered in 2021 to almost 16 million from around 14 million in 2020. ICEs remain by far the most important segment. In contrast to other major OECD countries and especially (non-OECD) China, OECD Americas saw no major movement in new EVs sales, which remained around 0.8 million in 2021. These numbers indicate that EV sales are still largely linked to government incentives.

Turning to the outlook, Table 3.4 shows that the global passenger car fleet is projected to surpass two billion vehicles by 2045. Most of this growth will come from non-OECD regions, which will add more than 770 million passenger cars to the global fleet. Asia, in general, contributes more than 70% to the increased car fleet, with China and India outdistancing other countries and regions with a fleet increase of 242.7 and 139.9 million, respectively. While the number of passenger cars increases by around 22% in China, in

Table 3.4
Number of passenger cars, 2021–2045

millions

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	283.4	284.6	297.5	311.2	320.8	327.0	43.6
OECD Europe	259.8	265.5	265.5	265.2	263.5	261.2	1.5
OECD Asia-Pacific	94.3	94.2	93.7	92.9	91.8	90.5	–3.8
OECD	**637.4**	**644.3**	**656.7**	**669.4**	**676.1**	**678.7**	**41.3**
China	198.1	246.8	311.9	368.1	408.0	440.9	242.7
India	34.8	48.1	71.5	102.4	138.8	174.7	139.9
Other Asia	83.5	102.1	137.0	175.5	215.5	254.5	170.9
Russia	38.3	37.8	38.6	38.9	38.7	38.5	0.2
Other non-OECD	232.8	262.5	304.1	348.9	397.5	450.4	217.6
Non-OECD	**587.5**	**697.3**	**863.1**	**1,033.8**	**1,198.4**	**1,358.9**	**771.5**
World	**1,224.9**	**1,341.6**	**1,519.8**	**1,703.2**	**1,874.4**	**2,037.6**	**812.7**

Source: OPEC.

India around five times the number of passenger cars will be on the road as compared to 2021. This impressive increase is closely linked to the country's expected population and GDP growth in the upcoming decades. 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 non-OECD', which covers Africa and Latin America, will basically see the size of its fleet double by 2045 and become an increasingly important consumer of oil in the road transportation sector, comparable to China.

The OECD, on the other hand, sees a smaller increase in the passenger car fleet of only 41.3 million. The existing high level of car ownership and demographic projections are the main reasons for this trend, as is the case in the near-term in OECD Asia-Pacific and somewhat later in OECD Europe as its population starts to decrease. OECD Americas sees an overall fleet increase of 15% between 2021 and 2045.

The global commercial fleet is projected to nearly double from 257.4 million in 2021 to 492.1 million in 2045, as presented in Table 3.5. The commercial fleet in the OECD region will increase by 37%, which is substantially above the 6.5% increase in the passenger car fleet. It is interesting to see that OECD Europe is expected to surpass OECD Americas, both in the size of the fleet and growth until 2045.

However, the non-OECD shows a far stronger dynamic with the commercial fleet growing by more than 130%, from 148.2 million commercial vehicles in 2021 to 342.6 million in 2045. India's fleet will basically equal that of China's by 2045 with more than 66 million vehicles each, corresponding to fleet growth of 254% and 116%, respectively. The largest fleet increase is projected for 'Other non-OECD', which includes a large group of rapidly growing countries, with the fleet expanding by 77.7 million vehicles, from 62.3 million in 2021 to 140 million in 2045.

Table 3.5
Number of commercial vehicles, 2021–2045

millions

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	40.9	42.7	46.8	51.5	55.6	59.2	18.3
OECD Europe	42.9	47.1	51.2	55.6	60.0	64.4	21.6
OECD Asia-Pacific	25.4	25.7	25.8	25.9	25.9	25.9	0.5
OECD	**109.2**	**115.5**	**123.9**	**132.9**	**141.5**	**149.6**	**40.4**
China	30.8	35.3	42.9	51.1	59.3	66.4	35.6
India	18.9	23.9	31.8	41.8	54.4	66.9	48.1
Other Asia	30.1	33.9	41.5	48.9	56.3	63.5	33.4
Russia	6.1	5.9	5.8	5.7	5.7	5.6	–0.4
Other non-OECD	62.3	71.6	84.7	100.3	119.4	140.0	77.7
Non-OECD	**148.2**	**170.7**	**206.8**	**247.8**	**295.0**	**342.6**	**194.4**
World	**257.4**	**286.2**	**330.6**	**380.8**	**436.6**	**492.1**	**234.7**

Source: OPEC.

This rapid expansion of the commercial vehicle stock in developing countries reflects expected trade, urbanization and promising GDP growth, which play a significant role in the expansion of commercial activities and correspondingly, vehicles. China, India, the Middle East and Africa are expanding their commercial vehicle fleets at a much faster rate than in the OECD region. This trend is particularly the case for minivan delivery vehicles and freight trucks. Infrastructure expansion in Other Asia and Africa will in particular encourage interregional trade and the exchange of goods and services.

Vehicle fleet composition

Investments to encourage the uptake of electric powertrains are considered a means to help recover from the COVID-19 economic downturn, especially in Europe and China. Efforts to tighten emissions regulations and additional policy measures are contributing to the solid growth of electric mobility in a number of countries. Consequently, there has been an acceleration in the sale and fleet penetration of EVs, although from a very low level. Electrification is largely considered the silver bullet for decarbonizing road transportation, although several alternatives exist. With the increasing penetration of BEVs, related subsidies will need to be phased out to avoid overloading public budgets. China has been at the forefront of reducing subsidies, which has pressured Chinese BEV manufacturers to become more competitive in view of both EV prices and range. Both price and range are the main factors customers consider when comparing BEVs and ICEs.

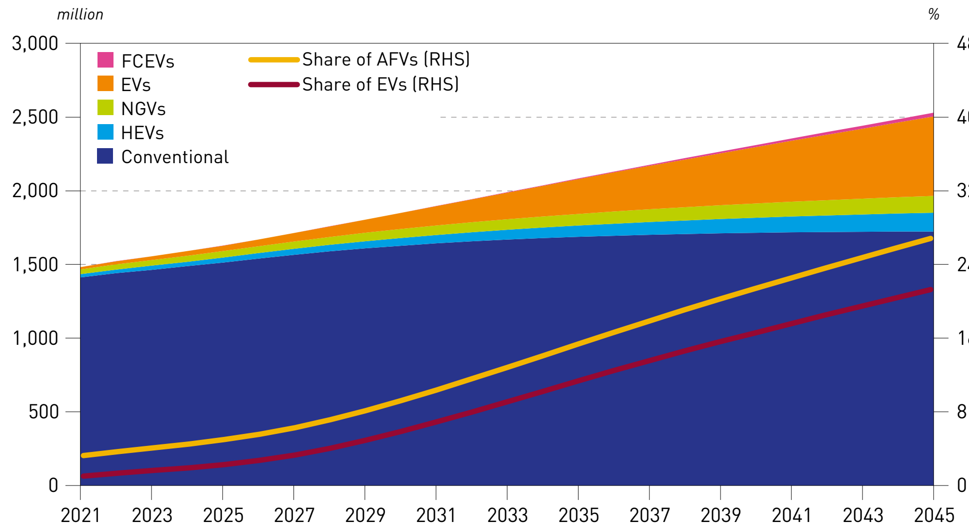
EVs play an increasingly important role in China and Europe with 2021 EV sales of around three million and 2.5 million, respectively. All other regions, including the US, play a far less important role and accounted for only one million new sales in 2021. Nevertheless, even in these three important EV markets, conventional sales are still dominant.

In developing regions, ICEs are basically the only passenger cars sold and sales of EVs are negligible. The fleet composition in these regions will be dominated largely by ICEs for the foreseeable future. Because hybridization has become a competitive way to increase the fuel efficiency of ICEs, the regional penetration of HEVs grows proportionally to ICEs.

Commercial vehicles have substantially different market requirements, not least because they must provide competitive services for their owners. While customers' personal preferences play an important role in the case of passenger cars, operators of trucks and buses strongly prefer cost-effective options. Additionally, range and refuelling (or in the case of commercial BEVs, recharging networks) play an important role. Therefore, the penetration of EVs in the commercial sector is currently restricted to urban buses and last-mile delivery solutions where emission and noise are important aspects, and the operators are typically either state-owned or operating in a *de facto* competition-free environment. Electric trucks are currently limited to delivery and short-distance vehicles with daily ranges of not more than 200 km and a mandatory daily return to a (recharging) base. Nevertheless, both segments will grow in the future.

Figure 3.19 presents the expected long-term composition of the global passenger and commercial vehicle fleets. This figure takes into consideration the implications of current and assumed future vehicle sales based on the powertrain shift and deployment. It is noticeable that the structural change in fleet composition is proceeding rather gradually due to a large base of conventional vehicles in the global fleet. Hence, the transition

Figure 3.19
Global fleet composition, 2021–2045



Source: OPEC.

to alternative powertrains will take decades, even if new vehicle registrations advance at a higher rate.

This figure also shows that EVs are set to become the fastest-growing alternative powertrain and will account for the largest share of fleet additions in the long-term. NGVs also expand, but at a far lower pace than EVs, which will overtake NGVs in the course of this decade. Ambitious electrification programmes result in a 10% fleet share of EVs around 2035 and approximately 20% by 2045, equivalent to about 540 million vehicles. It should be noted that the share of EV sales at the global level will be around 40% in 2045. These numbers indicate the time lag between changes in the global fleet structure and the composition of new vehicle sales.

Moreover, EVs become important much more quickly in the passenger car segment and to a far larger extent than in the case of commercial vehicles. Range and economic reasons (heavy and large batteries reduce payload and increase electric truck operation costs accordingly) slow EV penetration in the commercial segment. Solid-state batteries, which are expected sometime after 2030, will ease this disadvantage, but still represent a major weight and volume issue. Although fewer charging points are required for electric long-haul trucks than for passenger BEVs, charging infrastructure and operations still represent a substantial challenge compared to conventional (mainly diesel) vehicles.

Hydrogen fuel cell vehicles are increasingly attracting the attention of policymakers, especially in Japan, China, Europe and the US. However, their share in the global fleet is projected to remain relatively low due to cost, technology readiness and the availability of hydrogen. It should be noted, however, that China allocates funds for fuel cell vehicle research, including the strategic development of new hydrogen infrastructure framework.

The natural gas vehicle fleet is projected to more than triple in size, rising from 33 million vehicles in 2021 to 115 million in 2045. However, starting from a relatively low base in 2021, this represents a global increase in the range of 80 million during the forecast period. LNG and CNG can be used by conventional ICE-based vehicles with few adaptations, thus reducing CO_2 emissions by one-third compared to diesel or gasoline due to the higher hydrogen content. LNG and CNG may succeed in a limited manner in the commercial sector, but NGVs are expected to remain below 5% of the global fleet. LNG is penetrating the heavy-duty commercial vehicle segment in India and China and can contribute quickly to reductions in GHG emissions with minimal investment compared to electrification.

In summary, projections show that ICEs will retain the leading role with a global fleet share of more than 73% in 2045. In the passenger car segment, the fleet share of conventional vehicles decreases to 70%, and in the commercial vehicle segment to 90% over the same period. Because of the growing global fleet – primarily sustained by fleet size increases in developing regions – the absolute number of conventional vehicles still rises from 1.4 billion vehicles in 2021 to almost 1.9 billion in 2045.

In the case of commercial vehicles, in particular, the absolute number of ICE vehicles (including HEVs) jumps from 252 million to 425 million in the same period. Commercial vehicles, especially large and heavy trucks, consume far more fuel than passenger cars. This has an important impact on oil demand despite the continuously improving fuel efficiency of ICEs. Combining these figures with NGVs, which commonly employ an ICE for propelling purposes, projections suggest that a total of close to two billion vehicles on the road will still use an ICE by 2045.

Outlook for oil demand in road transportation

Vehicle fleet growth, changes in fleet composition and expected efficiency improvements in ICEs are the key factors determining future global oil demand in this sector. In addition, there are a number of other factors that will play a role through their impact on the distances travelled by each vehicle. These include changing consumer habits, extension of home working concepts, growth in MaaS, especially in urban regions, and advances in autonomous driving technology, among others.

Considering the likely impact of all these parameters, Table 3.6 presents projected oil demand in the road transportation sector by major regions. In the OECD, demand growth is curtailed by the penetration of alternative fuel vehicles (AFVs) and improved efficiencies, resulting in a decline of 7.7 mb/d between 2021 and 2045. On the other hand, sustained demand growth in non-OECD regions will be supported by an expansion of the vehicle fleet and increasing economic activity, adding up to 11.5 mb/d of incremental demand between 2021 and 2045. This Outlook, therefore, expects a net increase in global oil demand in the road transportation sector of 3.8 mb/d by 2045.

India stands out with demand tripling from 1.9 mb/d in 2021 to 5.7 mb/d in 2045. Africa also experiences strong growth, with demand projected to double from 1.9 mb/d in 2021 to 3.8 mb/d in 2045. In terms of the largest incremental demand, Other Asia follows India with an increase of 2.3 mb/d through the end of the forecast period.

Oil demand in China shows signs of stagnation at the beginning of the next decade with demand plateauing at 7.6 mb/d after 2035. Strong policy support for EV expansion and fuel-switching, especially in the long-haul trucking sector, is anticipated to be the major

Table 3.6
Oil demand in the road transportation sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	13.3	14.2	12.8	11.5	10.5	9.6	–3.7
OECD Europe	6.2	6.3	5.6	4.9	4.2	3.5	–2.6
OECD Asia-Pacific	2.6	2.5	2.2	1.9	1.5	1.1	–1.4
OECD	**22.0**	**23.0**	**20.6**	**18.3**	**16.3**	**14.3**	**–7.7**
China	6.2	7.0	7.4	7.6	7.6	7.6	1.4
India	1.9	2.5	3.2	3.9	4.7	5.7	3.7
Other Asia	3.3	3.9	4.4	4.8	5.2	5.5	2.3
Latin America	3.0	3.2	3.3	3.4	3.5	3.6	0.7
Middle East	2.8	3.2	3.6	4.0	4.2	4.3	1.6
Africa	1.9	2.2	2.6	3.0	3.4	3.8	1.9
Russia	1.2	1.1	1.2	1.2	1.1	1.1	–0.1
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	0.3	0.0
Non-OECD	**21.1**	**24.2**	**26.7**	**28.9**	**30.9**	**32.7**	**11.5**
World	**43.2**	**47.2**	**47.3**	**47.2**	**47.2**	**47.0**	**3.8**

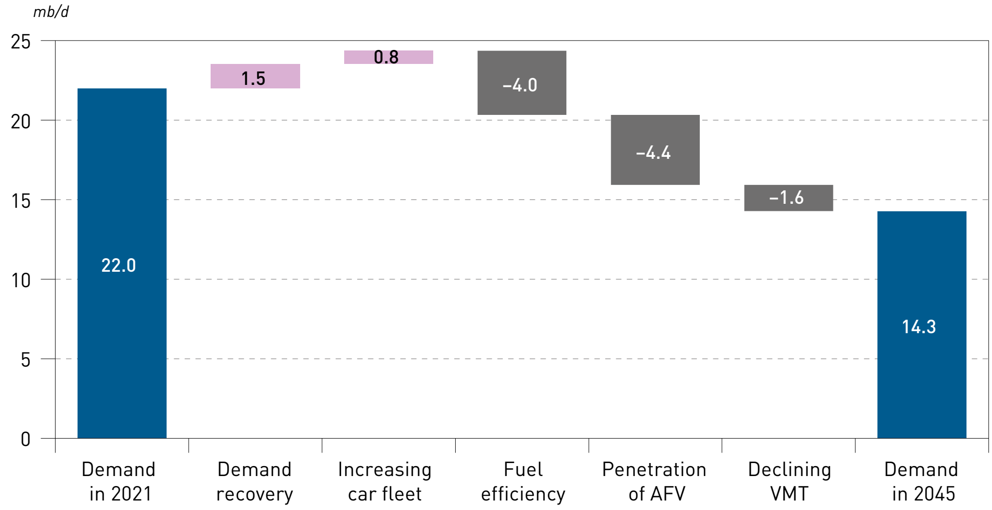
Source: OPEC.

reason for this development. Nevertheless, China will remain by far the most important oil consumer in Asia in the road transport sector, and globally, it will be second to OECD Americas.

Figures 3.20 and 3.21 highlight the key reasons for distinct demand prospects between the OECD and non-OECD in the road transportation sector. Oil demand in OECD countries is set to decline by 7.7 mb/d during the forecast period. The largest part of this decline is associated with the progressing penetration of AFVs, which will substitute for around 4.4 mb/d of potential demand. A comparable volume will be eliminated by improving efficiencies (–4 mb/d) while projected changes in the vehicle miles travelled (VMT) will lower future demand by another 1.6 mb/d.

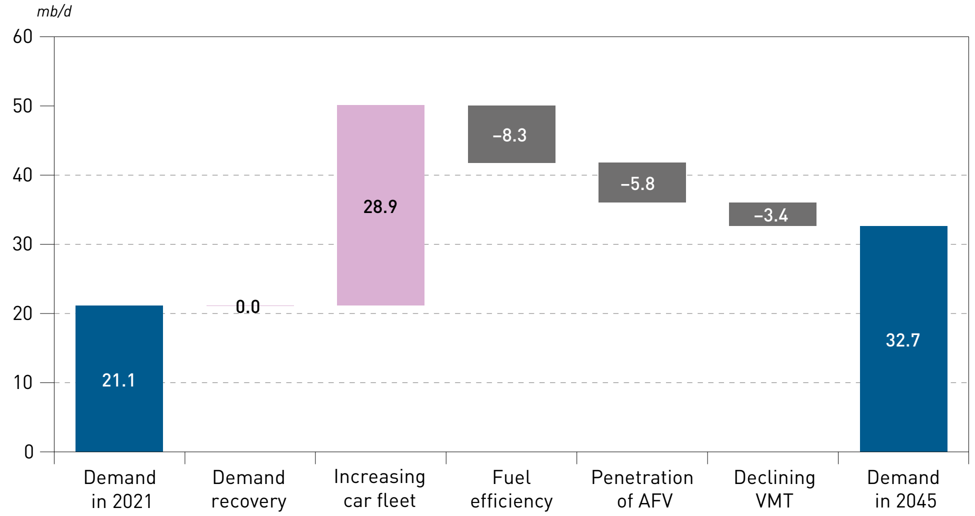
In the non-OECD, the impact of these parameters on future oil demand is different. The dominant factor in this region will be the expansion of the vehicle fleet to over one billion vehicles between 2021 and 2045. Assuming all other parameters being equal, this would result in a demand increase of 28.9 mb/d between 2021 and 2045. Compared to 2021, part of this potential future demand, around 8.3 mb/d, will be eliminated by improved efficiency. Even though the impact is much lower than in the other two cases, the penetration of AFVs offsets the demand increase by another –5.8 mb/d. VMT is also expected to decline in the future because the growing fleet means fewer people will rely on one vehicle. The corresponding effect amounts to –3.4 mb/d by 2045.

Figure 3.20
Demand in road transportation in OECD countries, 2021 and 2045



Source: OPEC.

Figure 3.21
Demand in road transportation in non-OECD countries, 2021 and 2045



Source: OPEC.

3.2.2 Aviation

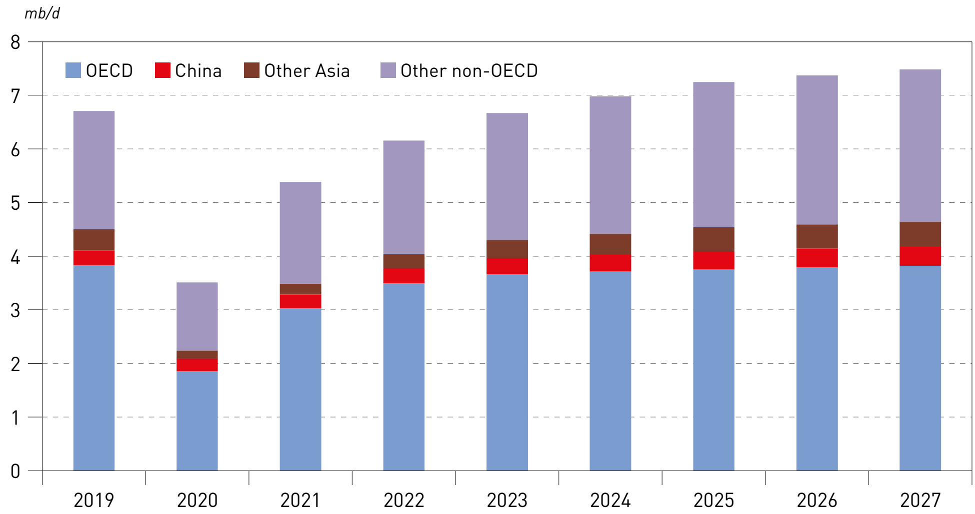
The aviation sector has gone through turbulent times since the outbreak of the COVID-19 pandemic. It experienced its worst period during the 2Q20, when a large number of aircraft were grounded for weeks and oil demand in the sector collapsed. A partial recovery started later in the year and continued in 2021, but re-emerging waves of regional travel restrictions, especially for international and long-haul flights, put a cap on both aviation traffic and related oil demand.

In 2022, the willingness of passengers to travel increased further although a number of restrictions remained in place, causing consumers to continue to be more cautious. Estimates by the IATA indicate that 2022 passenger journeys will reach around 80% of 2019 traffic levels. However, this recovery is far from smooth for airlines which, at the same time as lower traffic and income, face higher fuel prices and a shortage of manpower combined with higher labour costs. Moreover, geopolitical conflicts are a further challenge for the aviation sector. Additionally, airlines mothballed many planes to cope with the COVID-19 effects on air transportation. It can be expected that they will reactivate the more modern planes with lower fuel consumption first which, in turn, may lead to passenger numbers increasing faster than fuel consumption as air traffic recovers.

It is expected that the number of passengers will further increase in 2023 and beyond, resulting in a steady growth over the next several years. Bearing in mind these uncertainties, oil demand in the aviation sector is projected to continue recovering in the coming years to move above 2019 levels sometime in 2024 (Figure 3.22) and to reach 7.5 mb/d in 2027. From a regional perspective, the recovery process will be somewhat faster in non-OECD countries (compared to OECD). Faster growth in the non-OECD will result in a diminishing difference in oil demand between these two major regions over the medium-term period. In 2019, aviation demand in the OECD was almost 1 mb/d higher than in the non-OECD. However, oil demand in these two regions will be close to parity in 2029.

Long-term aviation demand will be shaped by a number of additional challenges. A growing population and expanding middle class resulting from solid economic growth in developing countries is expected to provide support to future oil demand. Moreover, growing inter-regional trade will also have a positive effect. Part of this potential growth, however, will be offset by improved efficiency and measures aimed at reducing the sector's emissions. These measures are set by the ICAO and IATA and are centred around

Figure 3.22
Oil demand in the aviation sector, 2019–2027



Source: OPEC.

the two leading targets: a cap on net aviation CO_2 emissions (carbon-neutral growth) at 2019 levels and a reduction in net aviation CO_2 emissions of 50% by 2050 (compared to 2005 levels).

These ambitious targets are supposed to be achieved through a combination of efforts. Part of the emission reduction should be achieved through the improved efficiency of all related processes ,including higher load factors, route optimization, improved aerodynamic properties and reduced weight of aircraft, as well as better engine fuel economies. These measures will be supplemented by oil substitution with SAF and, to a lesser extent, electricity. 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 during the forecast period of this Outlook. However, SAF has the potential to play a more prominent role subject to reducing production costs and resolving some technical obstacles. Another important element in this sector's strategy to reduce its emissions footprint will be efforts to offset emissions in various ways, such as reforestation and land restoration.

Considering all these factors, aviation oil demand is projected to increase from 5.4 mb/d in 2021 to 9.5 mb/d in 2045, thus growing by more than 4 mb/d over the forecast period. Table 3.7 presents a regional breakdown of this global trend. It shows that the larger part of this incremental demand will occur in non-OECD countries (+2.9 mb/d), while total OECD will expand by 1.2 mb/d.

Table 3.7
Oil demand in the aviation sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	1.5	1.9	2.0	2.0	2.0	2.1	0.6
OECD Europe	1.1	1.3	1.3	1.4	1.4	1.4	0.3
OECD Asia-Pacific	0.4	0.5	0.6	0.6	0.6	0.7	0.2
OECD	**3.0**	**3.8**	**3.9**	**4.0**	**4.0**	**4.2**	**1.2**
China	0.7	0.9	1.0	1.1	1.2	1.2	0.5
India	0.1	0.2	0.3	0.4	0.5	0.6	0.5
Other Asia	0.6	0.9	1.0	1.1	1.2	1.3	0.7
Latin America	0.3	0.3	0.4	0.5	0.5	0.5	0.3
Middle East	0.2	0.4	0.5	0.6	0.6	0.7	0.5
Africa	0.2	0.3	0.3	0.4	0.5	0.5	0.3
Russia	0.2	0.2	0.2	0.2	0.2	0.2	0.1
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	**2.4**	**3.5**	**3.9**	**4.4**	**4.9**	**5.3**	**2.9**
World	**5.4**	**7.2**	**7.8**	**8.4**	**8.9**	**9.5**	**4.1**

Source: OPEC.

The largest demand increase at the regional level will come from Other Asia, at 0.7 mb/d, between 2021 and 2045 and China, India and the Middle East will add some 0.5 mb/d each to future demand in this sector, with more than half of this growth taking place in the period to 2030. Nonetheless, growth will continue beyond the medium-term (albeit at a slower rate), amplifying the importance of these regions for long-term demand growth in this sector.

Significant demand additions are also projected in the OECD, which is set to grow by 1.2 mb/d between 2021 and 2045, out of which half will be added in OECD Americas. However, almost 1 mb/d of this growth will materialize in the period to 2030 while demand is set to plateau 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 industry was one of the few sectors where oil demand recovered very swiftly from the drop experienced in 2020. Already in 2021, oil demand in this sector was close to pre-pandemic levels in almost all regions and even higher demand was observed in China. Nevertheless, the pandemic years had some impact on consumer behaviour with implications for the composition of major petrochemical building blocks. A decline in construction and car manufacturing lowered demand for specific products such as benzene, toluene and butadiene. On the flip side, increased consumption of certain types of plastics used in households and in the healthcare sector, including single-use plastics, resulted in demand growth for ethylene and propylene.

Besides these shifts, the petrochemical industry also faces headwinds due to environmental concerns and regulations, such as efforts to reduce emissions, single-use plastics and the push for increased recycling. These will increasingly play an important role in shaping long-term prospects by adding another layer of uncertainty and potential disruption to future demand growth. However, technology developments and innovative approaches could support the extended use of oil in this sector. Options include CCUS and a possibility to use electrically heated steam crackers, such as a project being developed by BASF, Sabic and Linde, which could significantly reduce CO_2 emissions related to petrochemical operations.

Taking into account all these factors, Table 3.8 presents the assessment of oil demand prospects in this sector. At the global level, it is projected to increase by 3.7 mb/d during the forecast period, rising from 13.8 mb/d in 2021 to 17.5 mb/d in 2045. The overwhelming majority of this growth will come from Asian countries and the Middle East. Minor growth is also projected for Latin America, Africa and Russia. Meanwhile, OECD oil use for petrochemicals at the end of the forecast period will be lower than in 2021, despite some temporary growth during the current decade.

The largest incremental demand is projected for the Middle East, estimated at 1.4 mb/d between 2021 and 2045. This region will benefit from competitive costs, primarily using locally available ethane and LPG. Ethane-cracking projects are currently under development in IR Iran, the United Arab Emirates (UAE) and Qatar. A world-scale steam cracker is also expected to be constructed in Oman as a joint venture of OQ and SABIC. In Saudi Arabia, Saudi Aramco and SABIC will proceed with the first crude oil-to-chemicals

Table 3.8
Oil demand in the petrochemical sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	3.4	3.8	4.2	4.0	3.7	3.6	0.2
OECD Europe	1.8	1.8	1.8	1.7	1.5	1.4	–0.4
OECD Asia-Pacific	2.0	2.1	2.0	2.0	2.0	2.0	0.0
OECD	**7.1**	**7.7**	**8.0**	**7.6**	**7.2**	**6.9**	**–0.2**
China	2.2	2.4	2.5	2.7	2.7	2.9	0.7
India	0.4	0.5	0.7	0.8	1.0	1.1	0.7
Other Asia	1.3	1.5	1.7	1.9	2.0	2.2	0.9
Latin America	0.3	0.4	0.4	0.4	0.4	0.4	0.1
Middle East	1.2	1.5	1.7	2.0	2.4	2.6	1.4
Africa	0.1	0.2	0.2	0.2	0.2	0.3	0.1
Russia	1.0	1.0	1.1	1.1	1.1	1.1	0.1
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	**6.7**	**7.6**	**8.4**	**9.1**	**9.9**	**10.6**	**3.9**
World	**13.8**	**15.3**	**16.3**	**16.7**	**17.2**	**17.5**	**3.7**

Source: OPEC.

(COTC) petrochemical plant in Yanbu, which will be integrated with the existing refinery to increase resilience and flexibility in a dynamic refinery business. These projects will support the region's oil demand for petrochemicals during the medium-term period. Moreover, a continuation of this trend is expected during the long-term too.

Strong demand growth is also expected in all non-OECD Asian regions. Other Asia, China and India will add between 0.7 mb/d to 0.9 mb/d each to future petrochemical demand with a combined addition of 2.2 mb/d. The importance of the petrochemical industry in this region is clearly visible in the long list of potential medium-term projects. Most of them will focus on using naphtha and other liquid feedstock, including COTC technology. However, non-conventional technologies – such as coal-to-olefins and methanol-to-olefins – are also expected to be developed, despite some rising environmental concerns.

Other non-OECD regions – Russia, Latin America and Africa – are expected to witness only a slight demand increase, in the range of 0.1 mb/d each, with no significant impact on the sector's overall demand. Given its recent demand drop, Russia has suspended several petrochemical projects that were part of its ambitious plan for capacity expansion. It is possible, however, that these will be revived beyond the medium-term period.

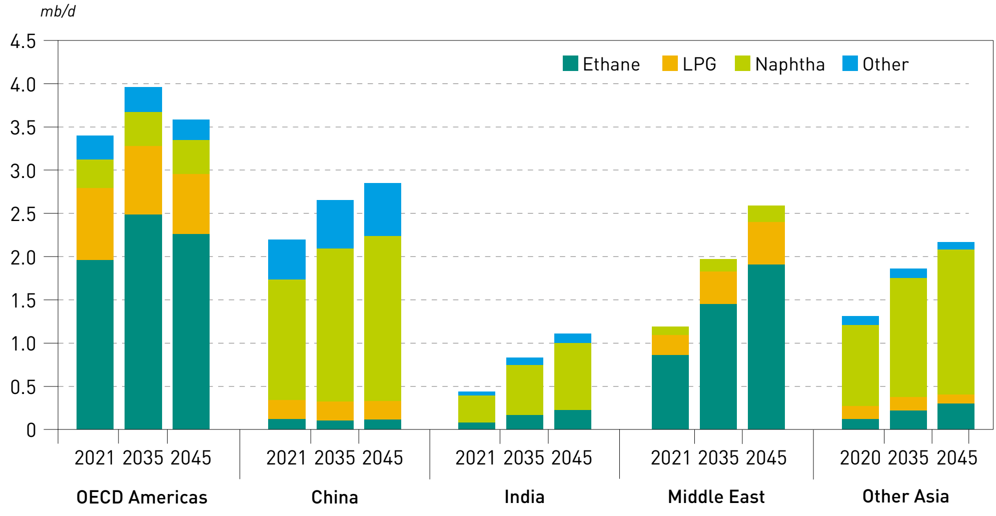
Turning to OECD regions, OECD Americas will likely see a considerable demand increase of 0.8 mb/d between 2021 and 2030, driven by developments in the US. Most of the additional capacity coming on stream benefits from a cheap ethane supply, such as the Exxon-SABIC ethane-based cracker project in Corpus Christi, Texas, with a capacity of 1.8 million tonnes a year (mt/y), which began operating in January 2022, and the almost completed Shell cracker in Monaca, Pennsylvania, with a capacity of 1.6 mt/y. Another boost to the US petrochemical industry could be provided by a joint venture project between Chevron Phillips Chemical and Qatar Petrochemical, which are looking to build the single largest cracker in the world with a capacity of 1.9 mt/y.

However, this boom will likely come to an end in the longer-term as the ethane supply dwindles and naphtha cracking potentially returns to a competitive trajectory in the US. This is also reflected in the projection that oil demand in the OECD Americas petrochemical sector will decline by around 0.6 mb/d between 2030 and 2045.

As for other OECD regions, the demand outlook in the petrochemical sector is less promising as it is unlikely that both OECD Europe and OECD Asia-Pacific will be able to sustain increased competition. One exception to this trend is South Korea, where the implementation of several projects, such as the Lotte-Hyundai Cracker in Daesan and GS Caltex Cracker in Yeosu, are expected to come online by 2023 and will support demand growth in the country. In fact, some demand growth in South Korea will likely offset demand losses elsewhere in the region so that the net effect will be relative stable oil demand in the range of 2 mb/d during the entire forecast period. Maturing demand and domestic constraints in OECD Europe will likely trigger sectoral rationalization with a demand decline of 0.4 mb/d between 2021 and 2045.

Figure 3.23 provides a different perspective on these trends by presenting a breakdown of regional demand in the petrochemical industry to major product categories (accounting for both feedstocks and sectoral energy consumption). Firstly, it demonstrates that petrochemical demand in OECD Americas and in the Middle East is dominated by ethane, while all Asian regions primarily use naphtha.

Figure 3.23
Regional demand in the petrochemical sector by product, 2021–2045



Source: OPEC.

Secondly, it shows a distinct demand pattern for periods before and after 2035. In the first period (2021–2035), demand for all major products in the petrochemical sector increases at the global level while growth in ethane (+1.2 mb/d), of which 0.6 mb/d and 0.5 mb/d is for the Middle East and OECD Americas, respectively, is broadly on parity with naphtha (+1.3 mb/d), mostly in the three major Asian regions, with each adding between 0.3 mb/d to 0.4 mb/d.

Demand for naphtha is set to continue growing during the last ten years of the forecast period, although with decelerated growth. The overall demand increase for this product will be in the range of 0.7 mb/d, again fairly equally split between the three Asian regions. However, ethane demand will continue growing in the Middle East only (+0.5 mb/d), while it will decline by almost 0.3 mb/d in the OECD regions.

3.2.4 Other sectors

Oil demand in the global **residential, commercial and agricultural** grouping is projected to increase steadily during the current decade, plateau around the level of 12 mb/d in the following decade and slowly decline for the rest of the forecast period. The overall demand change is not large, below 1 mb/d. This, however, results from larger changes at the regional level with offsetting trends between the OECD and developing countries.

This can be observed in Table 3.9, which shows that oil demand in the non-OECD will increase by 2 mb/d between 2021 and 2045 while OECD demand is set to decrease by more than 1 mb/d during the same period.

OECD oil demand in this sector is set to remain relatively stable over the current decade, potentially even slightly increasing in the next few years as oil substitution by gas, especially in Europe, will likely be slower. In the short-term, an opposite trend could even take place due to a shortage of gas and high gas prices. In the later period, however, the expected accelerated energy transition will likely lead to more oil substitution by electricity amid the faster penetration of heat pumps, PV technology, district heating and more energy-efficient appliances, especially in the residential sector. However, oil use in agriculture will likely be more resilient to such changes.

Building codes that promote energy efficiency are an important component in efforts to reduce energy demand in the commercial and residential sectors. As shown in Box 3.1, plans to reduce energy 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' plan in the EU. Similar regulations exist in other OECD regions.

Clearly, these regulations are also present in non-OECD countries. However, the impact of population growth, urbanization and a rising middle class in this region will more than offset energy savings resulting from these regulations. Consequently, non-OECD oil use in this sector is projected to grow steadily over the forecast period. This includes fuel-switching from solid biomass to oil-based products, mainly in sub-Saharan Africa, India and parts of Southeast Asia, and the use of oil products for off-grid electricity generation in remote rural settlements for household lighting, heating and cooling.

Considering these trends, non-OECD oil demand in the combined residential, commercial and agricultural sector will grow by 2 mb/d, rising from 7.1 mb/d in 2021 to

Table 3.9
Oil demand in the residential/commercial/agricultural sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	1.6	1.7	1.8	1.8	1.6	1.1	–0.4
OECD Europe	1.5	1.6	1.5	1.3	1.1	1.1	–0.4
OECD Asia-Pacific	0.8	0.8	0.8	0.6	0.6	0.5	–0.3
OECD	**3.9**	**4.0**	**4.0**	**3.7**	**3.3**	**2.7**	**–1.2**
China	2.5	2.8	2.8	2.8	2.9	2.9	0.4
India	1.1	1.2	1.4	1.6	1.7	1.8	0.7
Other Asia	0.9	0.8	0.8	0.9	0.9	0.9	0.0
Latin America	0.8	0.8	1.0	1.1	1.1	1.2	0.4
Middle East	0.5	0.5	0.6	0.6	0.5	0.5	0.0
Africa	0.6	0.7	0.8	0.9	1.0	1.1	0.5
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	**7.1**	**7.5**	**8.1**	**8.5**	**8.8**	**9.1**	**2.0**
World	**11.0**	**11.6**	**12.1**	**12.2**	**12.1**	**11.8**	**0.8**

Source: OPEC.

9.1 mb/d in 2045. The largest demand increases in this sector are expected from India (+0.7 mb/d), Africa (+0.5 mb/d), Latin America and China (each adding 0.4 mb/d). From the product perspective, the largest part of the demand increase will be for LPG used in the residential sector and for diesel used in agriculture and for electricity generation.

Maritime trade will be another 'battle ground' where growing trade, a push for efficiency improvements and fuel substitution will interact with and shape related oil demand. Indeed, driven primarily by assumed GDP growth, shipping activity is set to increase, though the link between economic growth and maritime trade will likely weaken. With respect to efficiency, of particular importance are IMO targets aiming to achieve 30% efficiency improvements by 2025 for all new ships compared to ships built in 2014. The main tools to enforce the regulation are the Energy Efficiency Design Index (EEDI), mandatory for new ships, and the Ship Energy Efficiency Management Plan, mandatory for all ships. In the long-term, the IMO aims to achieve a 50% reduction in overall GHG emissions from marine transport by 2050, compared with 2008 levels. This is a challenging target, which, if achieved, would have significant implications for future oil demand in the sector.

It is clear that technology will contribute to efficiency improvements for ICEs used in maritime transport, though current engines are already quite efficient. One method to improve fuel efficiency is the use of waste heat recovery units, which have been widely available on the market for two decades, but have hardly been used because of economic reasons. Apart from the required investment, payload tonnage and space is reduced, which may affect economic performance of the vessel. Some improvements could be achieved through reduced internal friction, eliminating losses caused by scavenging and other fluid flows, as well as improved combustion processes. Another option is slow steaming that become popular in the aftermath of the financial crisis a decade or so ago.

However, the aforementioned measures will not be sufficient to achieve the required emissions reductions. As a result, oil substitution by other energy sources will be needed and the shipping industry is currently at a technology crossroads in its search for alternative powertrains.

The most likely alternative is LNG as it reduces CO_2 emission and offers a higher degree of efficiency improvement. The availability of LNG bunkering facilities has increased significantly in recent years and LNG engines constitute more than a 10% of the share of order books for new-build vessels. Other alternatives include the use of hydrogen, ammonia and electricity as energy sources for maritime transport. Prototype vessels for each of these alternative powertrains already exist, demonstrating their advantages, but also their disadvantages. However, it is unlikely that a significant penetration of these engines would be reached before 2045.

Table 3.10 translates the impact of these factors on future marine bunker demand to 2045. The overall change between 2021 and 2045 is limited to only 0.6 mb/d, with demand increasing mostly in the period to 2030. This growth is partly related to offsetting the 2020 demand decline, with the rest driven by expanding international trade

Table 3.10
Oil demand in the marine bunkers sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	0.5	0.5	0.5	0.5	0.4	0.4	–0.1
OECD Europe	0.7	0.8	0.7	0.7	0.6	0.6	–0.2
OECD Asia-Pacific	0.3	0.2	0.2	0.2	0.2	0.2	–0.1
OECD	**1.5**	**1.5**	**1.5**	**1.4**	**1.2**	**1.1**	**–0.4**
China	0.3	0.3	0.4	0.4	0.4	0.4	0.1
India	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Other Asia	1.1	1.3	1.4	1.5	1.6	1.6	0.5
Latin America	0.3	0.3	0.4	0.4	0.4	0.4	0.1
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-OECD	**2.5**	**2.8**	**3.1**	**3.3**	**3.4**	**3.6**	**1.0**
World	**4.0**	**4.4**	**4.6**	**4.7**	**4.7**	**4.7**	**0.6**

Source: OPEC.

on the back of robust economic growth in developing countries. Demand for marine bunkers is projected to remain virtually flat after 2030. During this period, LNG vessels are expected to achieve sufficient penetration and, combined with the higher efficiency of oil-based vessels, this will counterbalance the still-growing trade.

Looking at these trends from a regional perspective, OECD demand in this sector is projected to stay at around 1.5 mb/d during the current decade before starting to decline in the second part of the forecast period. This reflects an expectation that growth in international trade will increasingly shift to non-OECD regions and the penetration of non-oil-based vessels will start biting into oil demand.

However, demand growth will continue in the non-OECD during the entire forecast period, with regional incremental demand of 1 mb/d. The largest demand increases are projected in Other Asia (+0.5 mb/d) and the Middle East (+0.2 mb/d), which are home to the largest bunkering ports. In contrast, combined incremental demand for marine bunker fuels in other non-OECD regions is projected to be just 0.3 mb/d between 2021 and 2045.

Even lower global incremental demand is projected for the '**other industry**' and the 'rail and domestic waterways' sectors. Demand prospects for 'other industry' (which includes a wide range of sub-sectors with often diverging demand trends such as iron and steel, glass and cement production, construction and mining and internal refinery use) are presented in Table 3.11. It shows that the fastest demand growth is projected in regions with the largest industrialization potential, which typically supports the

Table 3.11
Oil demand in the 'other industry' sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	3.0	3.1	3.0	2.9	2.5	2.3	–0.7
OECD Europe	1.4	1.4	1.3	1.3	1.2	1.2	–0.2
OECD Asia-Pacific	0.8	0.8	0.7	0.7	0.6	0.5	–0.3
OECD	**5.2**	**5.3**	**5.1**	**4.9**	**4.3**	**4.0**	**–1.2**
China	2.1	2.2	2.2	2.1	2.1	2.0	–0.1
India	0.9	1.0	1.1	1.2	1.4	1.5	0.6
Other Asia	0.9	1.0	1.1	1.1	1.2	1.2	0.3
Latin America	0.9	1.0	1.1	1.1	1.1	1.2	0.3
Middle East	1.2	1.2	1.4	1.5	1.5	1.4	0.3
Africa	0.6	0.6	0.7	0.8	0.8	0.9	0.3
Russia	0.5	0.5	0.5	0.6	0.6	0.6	0.1
Other Eurasia	0.2	0.2	0.3	0.3	0.3	0.3	0.1
Other Europe	0.2	0.2	0.2	0.2	0.2	0.1	0.0
Non-OECD	**7.6**	**7.9**	**8.5**	**8.9**	**9.1**	**9.2**	**1.7**
World	**12.8**	**13.1**	**13.6**	**13.8**	**13.4**	**13.3**	**0.5**

Source: OPEC.

consumption of diesel, residual fuel and LPG. This is particularly the case in India where demand growth in this sector will be in the range of 0.6 mb/d between 2021 and 2045. Other Asia, Latin America, the Middle East and Africa will also follow suit, each growing by around 0.3 mb/d. Some demand growth is also projected for Russia and Other Eurasia, though demand changes in these two regions are minimal.

Remaining regions, including China and the OECD, will see stable to declining oil demand in this sector, especially in the long-term. This is because oil-intensive parts of industrial production will gradually decline in these regions and options for oil substitution will increase, strongly supported by adopted policy measures. Therefore, except for the initial years of the forecast period still affected by the recovery from 2020 demand drop, OECD oil demand in the 'other industry' sector will steadily decline over the forecast period to reach the level of 4 mb/d by 2045, from 5.2 mb/d observed in 2021. The overall demand change in China will be much less, just 0.1 mb/d, but a declining trajectory during the second part of the forecast period is obvious.

Oil use in **rail and domestic waterways** is the lowest among all sectors considered in this Outlook. Global demand in this sector was just below 2 mb/d in 2021 and is projected to move in a very narrow band around 2 mb/d over the forecast period. Moreover, more than half of this demand is currently concentrated in only two regions, OECD Americas and China (Table 3.12). In the case of OECD Americas, the majority of the demand is linked to diesel used for rail transport. This is also the case for all other regions, with the exception of China, where a larger part of demand relates to domestic waterways.

Table 3.12
Oil demand in the rail and domestic waterways sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	0.5	0.5	0.5	0.5	0.4	0.3	–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**	**0.6**	**0.6**	**0.5**	**–0.3**
China	0.7	0.8	0.8	0.9	0.9	0.9	0.2
India	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Other Asia	0.1	0.2	0.2	0.2	0.2	0.2	0.1
Latin America	0.1	0.1	0.1	0.2	0.2	0.2	0.1
Middle East	0.1	0.1	0.1	0.1	0.1	0.1	0.0
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	0.1
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	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.6**	**0.5**
World	**1.9**	**2.0**	**2.1**	**2.1**	**2.2**	**2.1**	**0.2**

Source: OPEC.

In fact, it is the expansion of domestic waterways in China that will be the single biggest source of incremental demand in this sector. This view is well supported by an ambitious plan to expand the country's navigable inland waterways network by 25,000 km in the period to 2035 . If successfully implemented, China will have by far the longest waterways network in the world consisting of more than 200,000 km. With expanding passenger and freight traffic on this system, even after accounting for better future efficiencies, oil demand (and diesel, in particular) is set to grow. However, part of this potential growth will be offset by the growing electrification of the railway system so that the country's combined rail and waterways demand is estimated to grow by 0.2 mb/d between 2021 and 2045.

The situation in the second largest-market in this sector, the US, is not expected to change significantly over the forecast period, as no major extension nor a substantial change in electrification of the railway system is expected. Broadly, the same can be stated for inland waterways, even though a few expansion projects are being developed, such as establishing a new container facility network along the Mississippi River. Therefore, OECD Americas oil demand in this sector will remain relatively stable during the next ten to 15 years. However, a material, though still minor, decline is projected during the last ten years on the back of improved efficiencies and some oil substitution.

Demand in other regions is projected to oscillate around their current levels. Even in regions with some visible demand growth, such as Latin America, Other Asia and Russia, related increments are below 0.1 mb/d over the entire forecast period.

Table 3.13
Oil demand in the electricity generation sector by region, 2021–2045 *mb/d*

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
OECD Americas	0.5	0.3	0.2	0.2	0.1	0.1	–0.4
OECD Europe	0.3	0.3	0.2	0.2	0.2	0.1	–0.1
OECD Asia-Pacific	0.5	0.4	0.3	0.3	0.2	0.2	–0.4
OECD	**1.3**	**1.0**	**0.8**	**0.7**	**0.5**	**0.4**	**–0.9**
China	0.3	0.2	0.2	0.2	0.2	0.2	–0.1
India	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Other Asia	0.4	0.4	0.4	0.4	0.4	0.4	–0.1
Latin America	0.5	0.5	0.6	0.5	0.5	0.5	0.0
Middle East	1.5	1.5	1.5	1.4	1.3	1.3	–0.2
Africa	0.6	0.6	0.7	0.8	0.9	0.9	0.4
Russia	0.2	0.2	0.2	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	**3.6**	**3.7**	**3.7**	**3.7**	**3.7**	**0.0**	**0.0**
World	**4.9**	**4.7**	**4.5**	**4.4**	**4.2**	**4.1**	**–0.9**

Source: OPEC.

The last major consumption sector considered in this Outlook is **electricity generation**. This is projected to be the only sector where global oil demand declines over the forecast period. The main reason for this decline will be the almost complete displacement of oil in the OECD from this sector, driven by the rapid expansion of renewable electricity and the increased use of gas, despite the current gas shortages in OECD Europe. This, however, is considered a temporary issue and is expected to be resolved over the next several years. As presented in Table 3.13, the overall OECD demand decline in this sector is projected at 0.9 mb/d, which will push regional demand as low as 0.4 mb/d in 2045, compared to 1.3 mb/d in 2021.

Some demand decline, especially in the long-term, but at a much lower scale, is also projected for several non-OECD regions, including the Middle East, China, Other Asia and Latin America. These demand losses will be broadly compensated by growing oil demand in Africa and India where oil will help to improve access to electricity and provide a back-up to on-grid electricity. Consequently, oil demand for electricity generation in non-OECD regions will remain at a fairly stable level of 3.7 mb/d over the entire forecast period.

3.3 Oil demand outlook by product

This section provides a brief overview of the demand outlook from the perspective of major refined products. In fact, demand for specific products largely reflects major trends at the regional and sectoral levels as there are direct links between demand for several products and sectors. For example, gasoline demand is closely linked to road transportation, naphtha 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.

Table 3.14 and Figure 3.24 provide a summary of projections on global product demand over the forecast period. They show that incremental demand will be almost equally split between light products and middle distillates, while virtually no growth is projected for the heavy end of the refined barrel.

The largest demand increase in the category of light products is projected for ethane/LPG, which is set to grow by 2.6 mb/d over the forecast period. LPG is mostly consumed in the residential and industry sectors while the largest part of ethane serves as petrochemical feedstock. Accordingly, demand for these products will grow quite significantly during the current decade (as presented in Figure 3.25), but this growth will slow in the second part of the forecast period. It should be noted, however, that an important element of decelerating demand growth in the long-term relates to declining ethane availability due to a drop in US tight oil supply. This is also partly the reason why demand for naphtha continues in the long-term.

Demand for naphtha follows developments in the petrochemical sector, especially in Asian markets, Europe and Latin America. Since this industry is projected to grow over the entire forecast period (except in Europe), incremental demand for naphtha in the long-term will be even higher than in the medium-term period. From a regional perspective, incremental demand for naphtha will be concentrated in Asian countries, with the largest increments projected for Other Asia (+1.2 mb/d), India (+0.6 mb/d) and Latin America (+0.5 mb/d).

Table 3.14
Global oil demand by product, 2021–2045

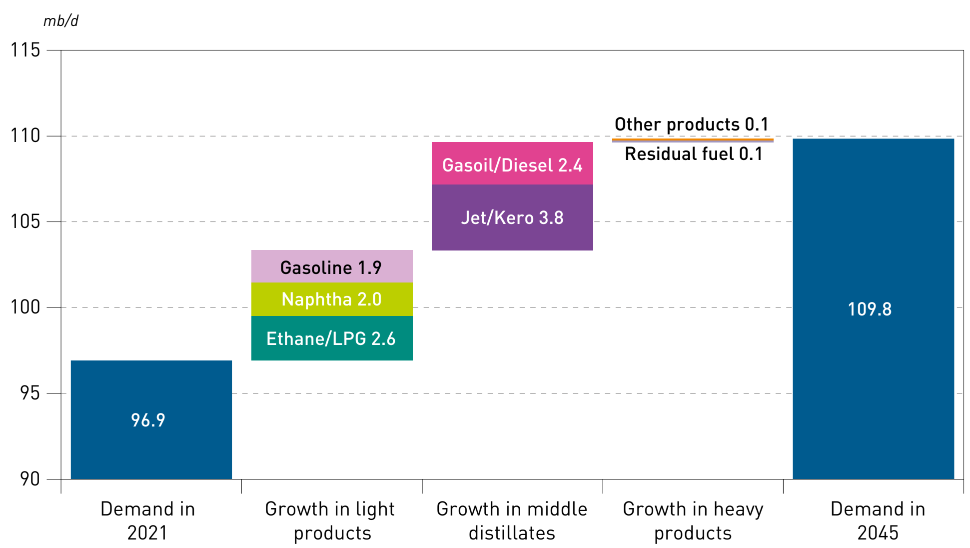
mb/d

	2021	2025	2030	2035	2040	2045	Growth 2021–2045
Ethane/LPG	12.8	14.1	15.0	15.2	15.4	15.4	2.6
Naphtha	6.4	7.0	7.4	7.7	8.1	8.4	2.0
Gasoline	25.7	28.1	28.2	27.9	27.8	27.6	1.9
Light products	**44.8**	**49.2**	**50.7**	**50.9**	**51.3**	**51.3**	**6.4**
Jet/kero	6.2	8.1	8.6	9.1	9.5	10.1	3.8
Gasoil/diesel	27.6	29.6	30.0	30.2	30.1	30.1	2.4
Middle distillates	**33.9**	**37.6**	**38.6**	**39.4**	**39.7**	**40.2**	**6.3**
Residual fuel	7.0	7.2	7.4	7.4	7.3	7.1	0.1
Other products	11.2	11.4	11.7	11.7	11.5	11.3	0.1
Heavy products	**18.2**	**18.6**	**19.1**	**19.2**	**18.8**	**18.4**	**0.2**
World	**96.9**	**105.5**	**108.3**	**109.5**	**109.8**	**109.8**	**12.9**

Source: OPEC.

3

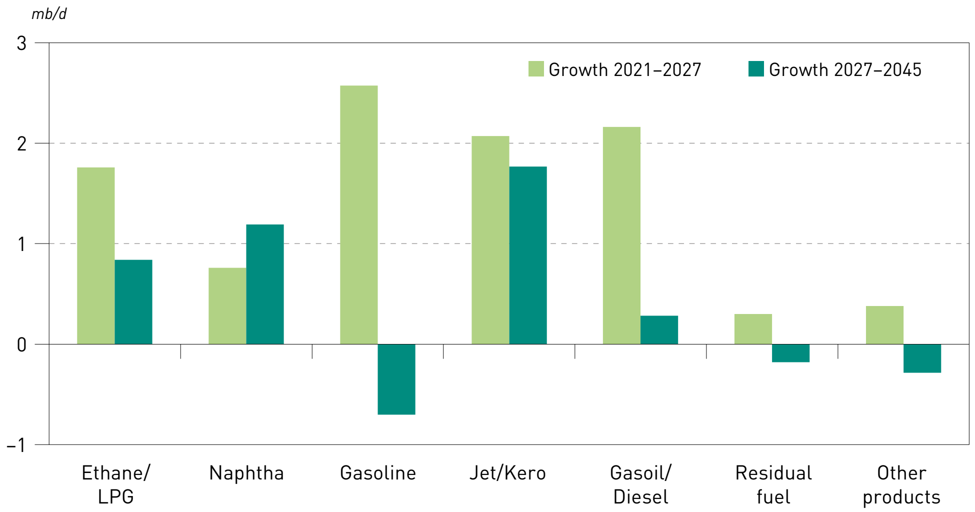
Figure 3.24
Demand growth by product category between 2021 and 2045



Source: OPEC.

Gasoline demand (including ethanol) accounts for the largest share among light products with current consumption estimated at more than 26 mb/d. Moreover, demand for this product will increase by almost 2.6 mb/d between 2021 and 2027. There are two main reasons underlying this expectation. The primary reason relates to the continued expansion of the passenger car fleet, the details of which were described earlier. Since

Figure 3.25
Growth in global oil demand by product



Source: OPEC.

a large share of these vehicles will be gasoline-based, this will drive gasoline demand. Moreover, part of the incremental medium-term demand will be linked to the ongoing recovery from COVID-19-induced mobility restrictions, which will support gasoline demand in 2022 and 2023, in particular.

Demand for gasoline, however, is projected to peak sometime around the end of the medium-term when improving fuel efficiencies and the increasing penetration of AFVs, primarily EVs, will start to offset the potential demand increase resulting from an expansion in the number of vehicles. This change will be relatively slow, but steady, leading to a gradual drop in gasoline demand for the rest of the forecast period. As a result, gasoline demand is projected to decline by around 0.7 mb/d between 2027 and 2045 to reach the level of 27.6 mb/d by 2045.

Turning to middle distillates, demand for jet/kerosene will be determined by developments in the aviation sector. Strong potential for growing jet fuel demand exists, especially over the medium-term, as the aviation sector recovers from the hard landing it suffered because of COVID-19-related mobility restrictions. Moreover, demand in the aviation sector is expected to continue rising in the long-term. Therefore, the overall demand increase for jet/kerosene will be 3.8 mb/d between 2021 and 2045. This is slightly lower than overall demand in the aviation sector. This is because demand for domestic kerosene will slightly decline, hence, part of the kerosene volume will 'shift' from the residential sector to aviation. In the case of diesel/gasoil, strong demand growth is projected during the medium-term, but this growth is set to decelerate thereafter and is expected to peak sometime around 2035, before declining over the last ten years of the forecast period. Nonetheless, the overall demand increase will be 2.4 mb/d.

For the remaining part of petroleum products, primarily the heavy part of the refined barrel, projected changes are minimal. Generally, some growth during the medium-term period, in the range of 0.3 mb/d to 0.4 mb/d each for residual fuel oil and 'other products', will be largely offset over the long-term, ending the forecast period at slightly higher levels than recorded in 2021.

Liquids supply

Key takeaways

- Non-OPEC liquids supply will continue its post-pandemic rebound and is projected to grow from 63.6 mb/d in 2021 to 71.4 mb/d in 2027, under the assumption of a strong recovery in demand and on the back of supportive fundamentals.

- The US will remain the leading medium-term source of non-OPEC liquids supply growth, providing 3.9 mb/d or 50% of incremental output. Crude oil supply in the US has clawed back much of the shut-in volumes related to the COVID-19 pandemic outbreak, and rising activity, favourable economics and growing investment indicate a return to healthy growth in coming years.

- Other major sources of medium-term non-OPEC supply growth are Brazil (+1.2 mb/d), Guyana (+0.8 mb/d), Canada (+0.5 mb/d) and Norway (+0.4 mb/d). By contrast, geopolitical tensions as a consequence of the Russia-Ukraine conflict are set to result in Russian liquids supply declining by 0.7 mb/d in the medium-term.

- Major risks to the economic outlook, high inflation, energy policy goals being confronted with energy security challenges and questions regarding a perceived shortfall in upstream investment, all coupled with persisting and new geopolitical risks, mean that significant uncertainty regarding the longer-term liquids supply outlook remains.

- US tight oil will provide much of the medium-term supply growth, until resource constraints see US tight oil peak at just over 16 mb/d around 2030. Thereafter, supply growth continues in Guyana, Canada, Kazakhstan, Brazil and Qatar, but is insufficient to offset non-OPEC decline elsewhere. Thus total non-OPEC liquids supply declines again from the early 2030s, to average 67.5 mb/d in 2045, still up by 3.9 mb/d from 2021.

- Non-crude liquids supply growth offsets crude oil's longer-term decline. Besides NGLs, biofuels and other liquids, including Canadian oil sands, and increasingly, synthetic aviation fuel are also important sources of new barrels, and increasingly supported by energy policies, mandates and technology advances.

- OPEC liquids are set to recover strongly in 2022, growing from 31.6 mb/d to 36 mb/d and holding steady around this level throughout the medium-term. After non-OPEC supply peaks around 2030, OPEC liquids are set to increase again, rising to 42.4 mb/d by 2045. Thus, OPEC's share of global liquids supply is projected to increase from 33% in 2021 to 39% in 2045.

- Cumulative oil-related investment requirements are projected at $12.1 trillion over the entire 2022–2045 period (in 2022 US dollars). This is slightly higher than assessed in WOO 2021, as higher-revised demand projections and assumed cost inflation in the short- and medium-term more than offset the forecast period being one year shorter. Upstream needs make up $9.5 trillion, while downstream and midstream requirements are $1.6 trillion and $1 trillion, respectively.

This chapter describes the outlook for liquids supply from 2021–2045. As in previous WOOs, the medium-term projections for 2021–2027 and the longer-term outlook are discussed separately, due to the different methodologies employed. The medium-term view relies upon 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 upon an assessment of the available resource base and other factors. US tight oil is also modelled and discussed separately, as are non-crude liquids.

4.1 Global liquids supply outlook

Global liquids supply continued its recovery following the huge shock to demand stemming from the fallout of the COVID-19 pandemic, and the resulting voluntary and involuntary production adjustments taken by many producers. Not least due to the rapid and historically large action taken by OPEC and non-OPEC partners in the DoC, oil markets subsequently regained a modicum of stability throughout 2021, allowing for recovering oil demand to be met by rising supply.

Table 4.1
Long-term global liquids supply outlook

mb/d

	2021	2025	2030	2035	2040	2045	Change 2021–2045
Americas	25.2	29.0	29.2	27.9	26.5	25.2	0.0
of which US	*17.8*	*21.3*	*21.3*	*19.9*	*18.5*	*17.2*	*–0.5*
Europe	3.8	4.1	4.2	4.1	4.1	4.1	0.3
Asia-Pacific	0.5	0.5	0.6	0.5	0.5	0.4	–0.1
OECD	**29.4**	**33.6**	**34.0**	**32.5**	**31.0**	**29.7**	**0.3**
China	4.3	4.6	4.5	4.4	4.3	4.2	–0.2
India	0.8	0.8	0.8	0.8	0.8	0.8	0.0
Other Asia	2.4	2.3	2.2	2.1	2.0	1.8	–0.6
Latin America	6.0	7.3	8.8	9.0	8.9	8.7	2.8
Middle East	3.2	3.5	3.8	3.8	3.8	3.8	0.5
Africa	1.3	1.5	1.8	1.7	1.6	1.6	0.2
Russia	10.8	10.2	10.4	10.5	10.5	10.4	–0.4
Other Eurasia	2.9	3.2	3.3	3.3	3.3	3.2	0.3
Other Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Non-OECD	**31.9**	**33.4**	**35.6**	**35.8**	**35.3**	**34.6**	**2.8**
Non-OPEC production	61.3	67.0	69.6	68.3	66.3	64.3	3.0
Processing gains	2.3	2.6	2.8	2.9	3.0	3.2	0.9
Non-OPEC liquids	**63.6**	**69.6**	**72.4**	**71.2**	**69.3**	**67.5**	**3.9**
OPEC liquids	**31.6**	**36.1**	**36.1**	**38.3**	**40.4**	**42.4**	**10.7**
World*	**95.2**	**105.7**	**108.4**	**109.5**	**109.8**	**109.8**	**14.6**

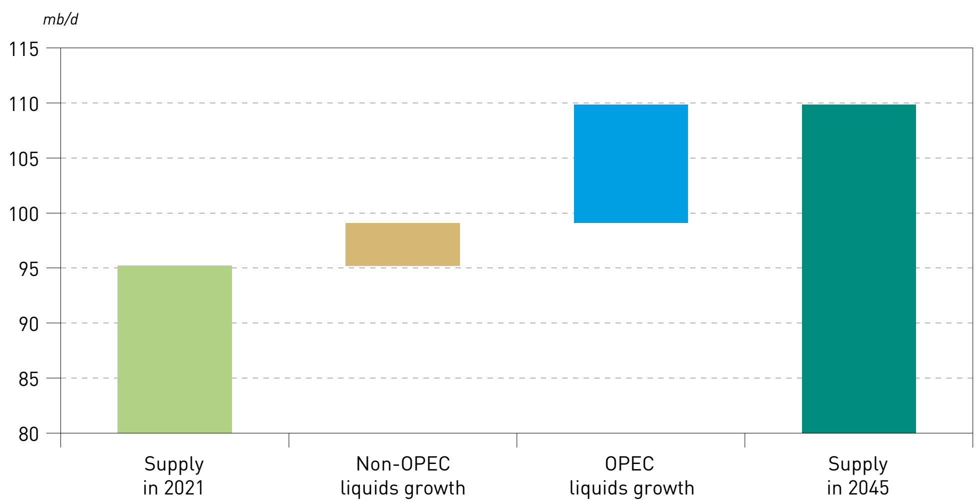
** The sum of the countries/regions may not add up to the global supply total due to rounding and stock change assumptions.*
Source: OPEC.

Having said that, commodity market volatility has returned in 2022, as economic growth has become more uneven and uncertain, inflation has reached multi-decade highs, and geopolitical uncertainties have risen as a result of the Russia-Ukraine conflict. Nonetheless, as the world continues to emerge from its pandemic hibernation, supportive fundamentals are encouraging steady growth in non-OPEC supply, even as DoC producers have returned barrels to the market.

As a result, the non-OPEC supply outlook sees an expansion from 63.6 mb/d in 2021 to 71.4 mb/d in 2027, or an increase of 7.8 mb/d. Thereafter, it is projected to peak at 72.4 mb/d around 2030 and slowly decline to 67.5 mb/d by 2045 (Table 4.1). The main medium-term driver of non-OPEC liquids supply growth is the US, followed by Brazil, Guyana, Canada and Norway. In the long-term, after US supply is set to peak in the latter 2020s, the two Latin American producers are joined by Canada, Kazakhstan and Qatar as the primary sources of non-OPEC liquids supply increments.

OPEC liquids are expected to rise from 31.6 mb/d in 2021 to 42.4 mb/d in 2045, an increase of 10.7 mb/d. This means the group's collective output will see its global market share rise from 33% in 2021 to 39% in 2045.

Figure 4.1
Composition of global oil liquids supply growth, 2021–2045



Source: OPEC.

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

Non-OPEC liquids supply is projected to grow from 63.6 mb/d in 2021 to 71.4 mb/d in 2027 (Table 4.2). US liquids production, in particular, which – outside of voluntary adjustments made by DoC participants – saw the largest downturn as the COVID-19 pandemic hit in 2020, has seen a steady recovery since, and is likely to reach pre-pandemic levels again in the latter part of 2022.

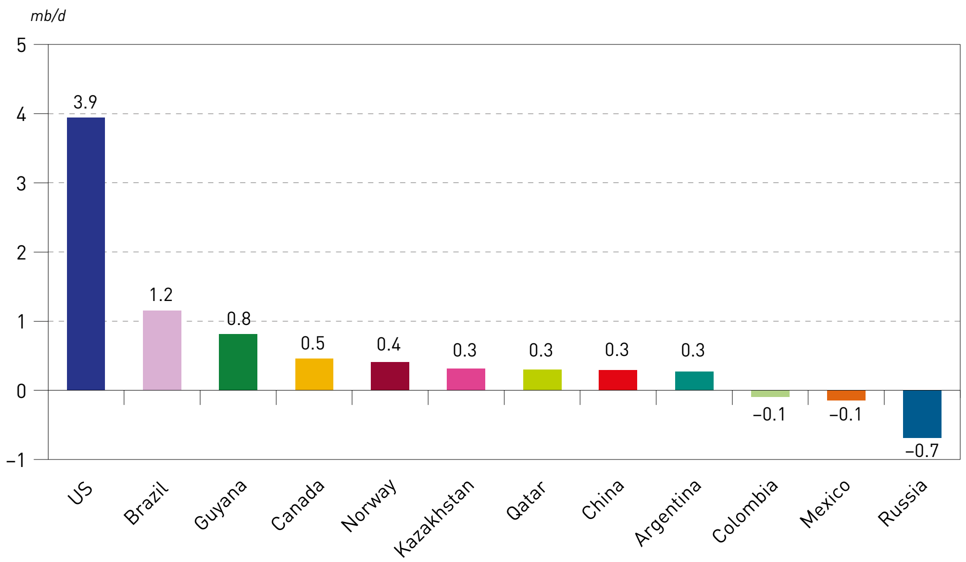
Table 4.2
Medium-term global liquids supply outlook

mb/d

	2021	2022	2023	2024	2025	2026	2027	Change 2021–2027
Americas	25.2	26.7	27.8	28.5	29.0	29.3	29.4	4.3
of which US	*17.8*	*19.0*	*20.1*	*20.8*	*21.3*	*21.6*	*21.7*	*3.9*
Europe	3.8	3.8	4.1	4.1	4.1	4.1	4.2	0.4
Asia-Pacific	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.1
OECD	**29.4**	**31.0**	**32.4**	**33.1**	**33.6**	**34.0**	**34.2**	**4.8**
China	4.3	4.5	4.5	4.6	4.6	4.6	4.6	0.3
India	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.0
Other Asia	2.4	2.4	2.3	2.3	2.3	2.2	2.2	–0.2
Latin America	6.0	6.2	6.6	6.9	7.3	7.6	8.1	2.2
Middle East	3.2	3.3	3.4	3.4	3.5	3.6	3.7	0.5
Africa	1.3	1.3	1.3	1.4	1.5	1.6	1.7	0.4
Russia	10.8	10.6	10.4	10.2	10.2	10.1	10.1	–0.7
Other Eurasia	2.9	3.1	3.1	3.2	3.2	3.1	3.2	0.2
Other Europe	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Non-OECD	**31.9**	**32.3**	**32.6**	**32.9**	**33.4**	**33.9**	**34.6**	**2.7**
Non-OPEC production	61.3	63.3	65.0	66.0	67.0	67.9	68.8	7.5
Processing gains	2.3	2.4	2.5	2.5	2.6	2.6	2.6	0.4
Non-OPEC liquids	**63.6**	**65.7**	**67.4**	**68.5**	**69.6**	**70.5**	**71.4**	**7.8**
OPEC liquids	**31.6**	**36.0**	**36.3**	**36.3**	**36.1**	**35.9**	**35.6**	**4.0**
World*	**95.2**	**101.7**	**103.8**	**104.8**	**105.7**	**106.5**	**107.1**	**11.9**

* *The sum of the countries/regions may not add up to the global supply total due to rounding and stock change assumptions.*
Source: OPEC.

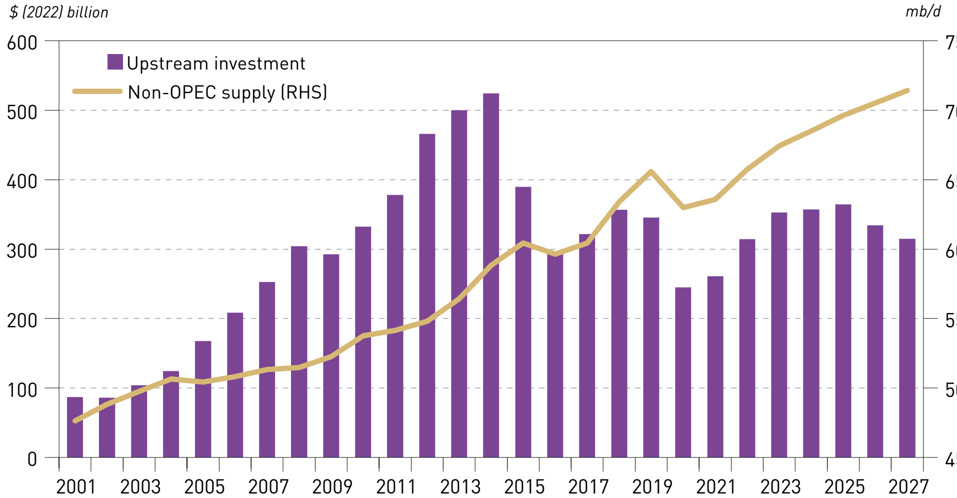
Figure 4.2
Select contributors to non-OPEC total liquids change, 2021–2027



Source: OPEC.

Elsewhere, a backlog of upstream projects delayed by lockdowns and waves of COVID infections is beginning to clear, leading to a steady stream of new fields coming online in countries and regions such as Brazil, the US Gulf of Mexico (GoM), the North Sea and Kazakhstan, even as output in newcomers Guyana, Senegal and Uganda ramps up. Post-pandemic catch-up and recovery is also being stimulated by supportive fundamentals, with demand rebounding and markets clamouring for crude. While upstream investment fell by a sharp 29% in 2020 and only grew by 6% in 2021, estimations are for a healthier rise of just over 20% in 2022 and modest increases in 2023–2025 (Figure 4.3). However, levels are expected to remain well below those witnessed in 2014. The need for consistent and stable investment in the entire oil value chain will remain crucial to prevent volatility in oil markets and provide a stable supply of oil to the market.

Figure 4.3
Global upstream capital expenditure (oil only)



Source: Rystad Energy, OPEC.

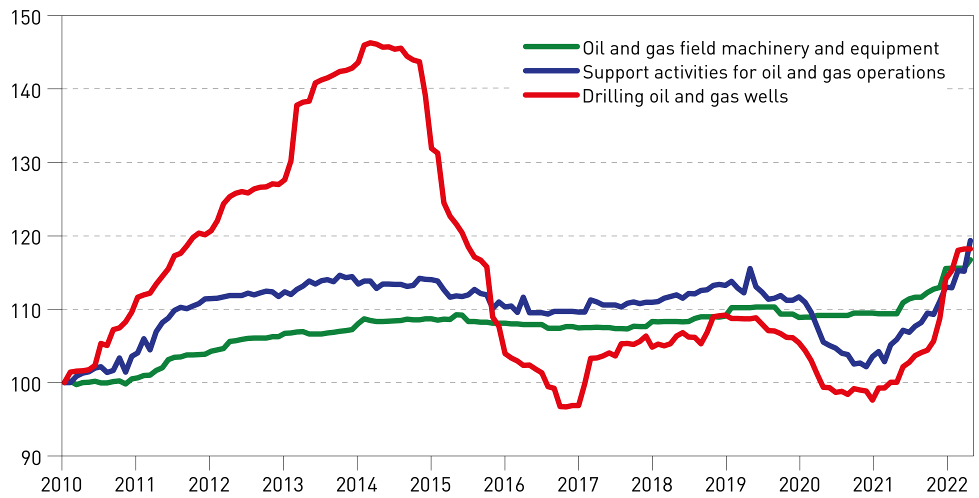
Inflation in general, and cost inflation in the oil upstream sector, in particular, are also eating into capital expenditure. Based on the US upstream sector, producer costs fell sharply in 2015–2016 and remained relatively steady until late 2021, since when they have risen by over 10% (Figure 4.4). Higher costs are likely to prevail for a while yet, amid tightness in labour markets, supply chain bottlenecks, and higher input prices (including energy). At the same time, technological and efficiency improvements continue, not least in the US tight oil sector, to some extent offsetting higher costs.

At the same time, exploration is beginning to pick up again, with new discoveries of oil and gas announced in 1Q22 totalling 2.3 billion boe, according to Rystad Energy, and up sharply from a disappointing 2021.

The other major challenge that has emerged in the upstream sector concerns a heightening of geopolitical tensions due to the Russia-Ukraine conflict. Combined with economic uncertainties as markets emerge post-pandemic, embargos, self-sanctioning by buyers of Russian oil and supply chain issues have led to significant dislocations.

This has impacted trade flows of crude and products into Europe, with knock-on global consequences. The outlook for Russian liquids supply has also been revised down as a result.

Figure 4.4
US producer cost indices (January 2010 = 100)



Source: US Bureau of Labor Statistics.

Amid all of this, OPEC and non-OPEC participants in the DoC have played a stabilizing role, by adjusting supply in line with market needs, and thus helping reduce volatility.

As a result of all these factors, the outlook for non-OPEC liquids supply growth over the medium-term has been revised modestly higher, and is now projected to rise by 7.8 mb/d, from 63.6 mb/d in 2021 to 71.4 mb/d in 2027. While the initial years are slightly lower than in the outlook published in last year's WOO, 2027 has been nudged higher largely as a result of expectations for stronger North American supply.

In the long-term, despite challenges with regard to upstream investment, and uncertainty and pressure resulting from the outlook for energy policies, the forecast for non-OPEC liquids supply has been adjusted around 1.7 mb/d on average higher p.a. for the period 2030–2045.

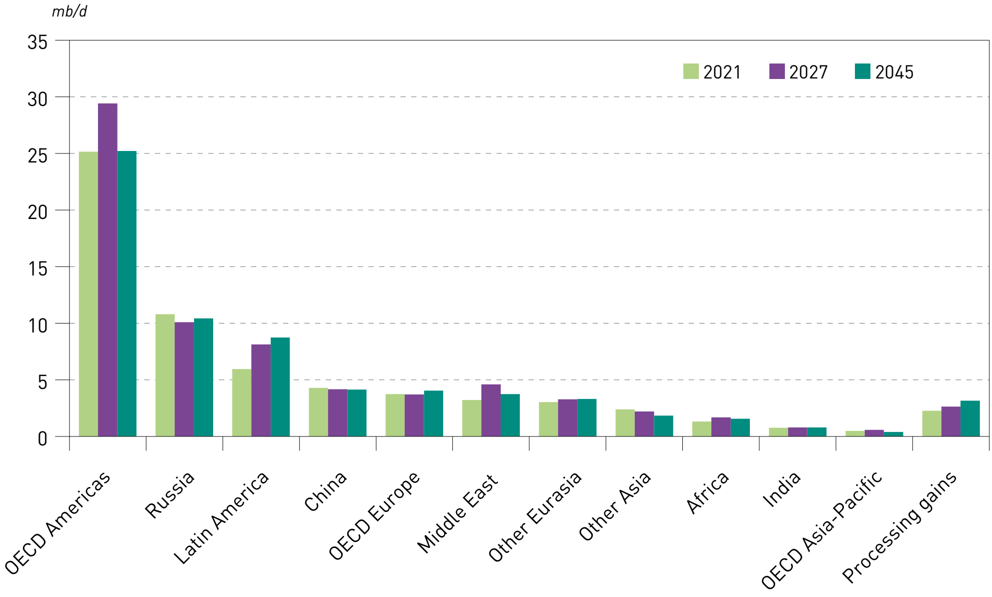
In this report's Reference Case, while far from all climate-related pledges are implemented, the need to address energy poverty and ensure energy security remains of utmost importance, resulting in a need for continued investment in new upstream capacity. Moreover, given increasingly ambitious mandate proposals in some key regions, projected volumes of biofuels and other non-crude liquids supply have been revised higher (Section 4.4 and Box 4.1).

In the long-term, non-OPEC liquids supply is set to grow from 63.6 mb/d in 2021 to a peak of 72.4 mb/d around 2030, before declining again to average 67.5 mb/d in 2045.

4.3 Breakdown of liquids supply outlook by main regions

Regionally, the areas with significant medium-term supply growth are the OECD Americas, and Latin America, both in the medium- and long-term. Together with some modest growth in the Middle East and Other Eurasia, they contribute nearly all of the incremental non-OPEC liquids supply within the timeframe of this WOO (Figure 4.5). Refinery processing gains are also projected to increase in the long-term. By contrast, liquids supply is projected to decline, albeit modestly, in Russia, China and Other Asia. Output will remain broadly flat in Africa, India and OECD Asia-Pacific.

Figure 4.5
Non-OPEC liquids supply outlook by region



Source: OPEC.

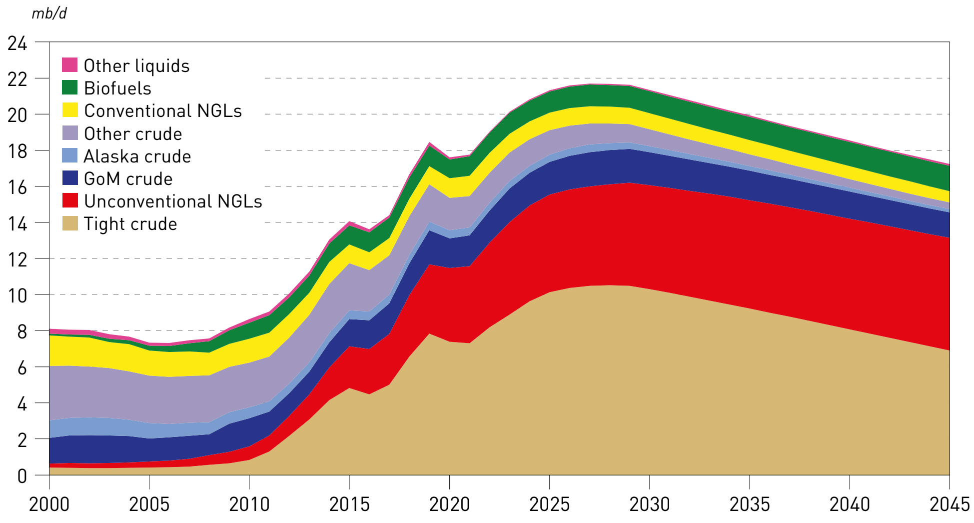
4.3.1 Major countries

US

Liquids supply in the US, which experienced the largest single downturn in the course of the COVID-19 pandemic, has since witnessed a gradual recovery and has likely regained pre-pandemic production levels in the latter half of 2022. Tight crude is generally the most responsive form of liquids supply, and rig counts, drilling and completion activity all fell sharply in 2Q20, before stabilizing in 2H20 and increasing steadily since. Several weather incidents including GoM hurricanes and severe winter storms in Texas in early 2021 caused pronounced, but temporary shut-ins.

Looking ahead, the continued rise in rig counts and drilling activity, the still-low well-head breakeven prices, against a favourable fundamentals background, are expected to lead to continued investment, and steady growth in supply – if not as fast as pre-pandemic record levels. US tight crude, especially from the Permian Basin (US tight crude will be discussed in more detail in Section 4.5.2), NGLs associated with continued strong gas supply growth, and other sources of crude oil and liquids supply are expected to see growth, especially in the medium-term (Figure 4.6).

Figure 4.6
US total liquids supply outlook



Source: OPEC.

While onshore crude (excluding tight oil) is expected to remain in decline, including in Alaska, due to maturity and a lack of new upstream projects, GoM crude oil supply is set to see modest medium-term growth, rising from 1.7 mb/d to 1.9 mb/d in 2027, as sizeable new project start-ups continue their ramp-up phase. These include Phase 2 of BP's Mad Dog, which commenced production in 2022, as well as Shell's Vito and Whale, due in 2023 and 2024, respectively. Chevron is expected to bring its Anchor and Ballymore projects onstream in 2024 and 2026, respectively. All of these projects are in the 80–120 tb/d capacity range.

Viewed over the long-term, NGLs production is anticipated to grow the most, adding 1.5 mb/d to reach 6.9 mb/d, driven by unconventional supply. Total crude supply is set to grow until the late 2020s, after which US tight crude is projected to peak, and with declining supply from conventional mature areas, overall supply will be down, declining by a total of 2.3 mb/d from 2021–2045. US biofuels and other liquids, including synthetic aviation fuel, are likely to see modest growth. In sum, US total liquids is expected to decline modestly over the long-term, from 17.8 mb/d in 2021 to 17.2 mb/d in 2045, or a drop of 0.5 mb/d (Table 4.3).

Policy deliberations continue to have a potential short- and long-term impact on US liquids supply. Earlier in the Biden Administration, a moratorium was imposed on the leasing of federal lands for oil and gas development, raising concerns among oil companies active in the US. The moratorium was overturned in April 2022, however, and most consider it only had a very modest effect on leasing. This is due to the huge inventory of acreage held by most producers, the relatively lower attractiveness of acreage available on federal lands, and reduced interest in acquiring new acreage during the pandemic-related downturn.

Table 4.3
US total liquids supply, 2021–2045

mb/d

	2021	2025	2030	2035	2040	2045	Change 2021–2045
US tight oil	11.6	15.5	16.1	15.2	14.2	13.1	1.6
of which: tight crude	*7.3*	*10.1*	*10.3*	*9.2*	*8.1*	*6.9*	*–0.4*
of which: unconventional NGLs	*4.3*	*5.4*	*5.8*	*6.0*	*6.1*	*6.2*	*2.0*
US Gulf of Mexico crude	1.7	1.8	1.8	1.6	1.5	1.4	–0.3
US Alaska crude	0.4	0.4	0.3	0.3	0.2	0.2	–0.3
US other crude	1.8	1.4	0.9	0.7	0.5	0.4	–1.4
US other NGLs	1.1	1.0	0.9	0.8	0.7	0.6	–0.5
US biofuels	1.1	1.2	1.2	1.3	1.3	1.4	0.3
US other liquids	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Memo item: US total crude	*11.2*	*13.7*	*13.4*	*11.8*	*10.3*	*8.9*	*–2.3*
Memo item: US total NGLs	*5.4*	*6.4*	*6.7*	*6.8*	*6.8*	*6.9*	*1.5*
Total US liquids production	**17.8**	**21.3**	**21.3**	**19.9**	**18.5**	**17.2**	**–0.5**

Source: OPEC.

4

In April 2022, however, the Biden Administration also reduced the amount of acreage it will offer in future lease sales in the National Petroleum Reserve Alaska ('NPR-Alaska'), reversing the previous administration's initiative to open this area up for more drilling. Again, given limited interest by companies in acquiring options to drill in Alaska – a mature, and relatively high-cost producing region compared to the Permian, for instance – this may not have much of an impact. Having said that, uncertainty related to the degree to which future acreage in the GoM will become or remain available may be key to determining whether this region remains an area of potential further growth or not, and adds to the widespread US oil and gas industry perception that the current administration views it critically.

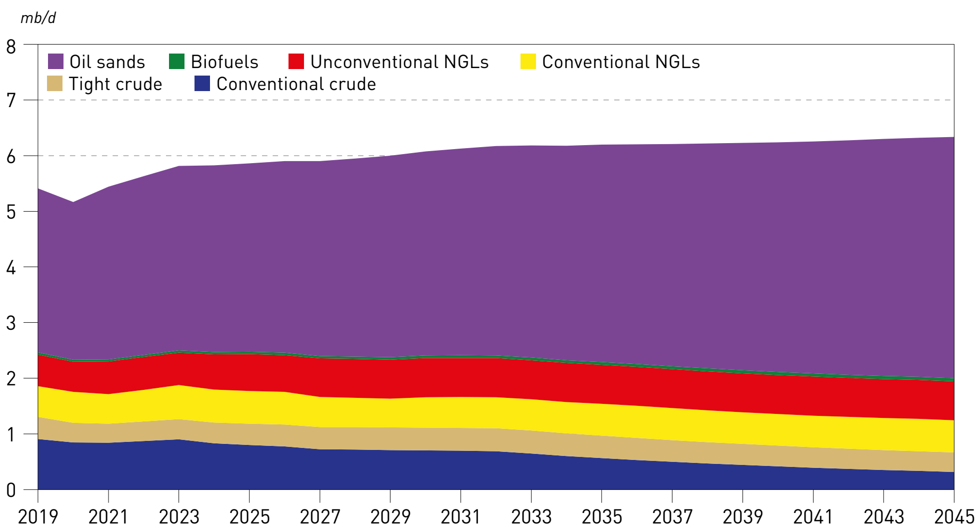
Then in the summer of 2022, the IRA was passed, which in a careful calibration of short- and long-term priorities, included several provisions to shake up and formalize the permitting and leasing process on federal lands and in the GoM, even while making available significant funding for non-fossil energy and climate programmes (for more detail, see Section 7.2.1 on US energy policies).

Canada

Canada's liquids production, having recovered from a pandemic-induced downturn in 2020, is expected to see modest, albeit steady medium-term growth, rising from 5.4

mb/d in 2021 to 5.9 mb/d in 2027. This would mark a slowdown from supply growth in the preceding five years, in which total liquids supply grew by 1 mb/d (from 2016–2021). In particular, this reflects the relatively high cost of Canadian oil sands, as well as some environmental concerns that have seen some international oil companies (IOCs) rebalancing their portfolio by exiting Canada. In the medium-term, liquids supply growth is overwhelmingly driven by rising oil sands output, while conventional crude is projected to decline modestly, due to maturity and a scarcity of new upstream projects. West White Rose offshore the East Coast is expected to add 80 tb/d from 2025, while the larger Bay du Nord project should come online from 2028, adding 150 tb/d.

Figure 4.7
Canada total liquids supply outlook



Source: OPEC.

Beyond 2027, projections are for further slow, albeit steady growth, adding another 0.4 mb/d from 2027–2045. Again, this assumes gradual increases largely in oil sands capacity, which rises to 4.3 mb/d by 2045, taking total Canadian liquids supply to 6.3 mb/d (Figure 4.7). Question marks about the environmental sustainability of oil sands, and related CO_2 emissions may have been somewhat abated by the creation of the 'Oil Sands Pathway to Net Zero' consortium in 2021. Initiated by the current administration, this group brings together all major producers active in the oil sands patch, and aims to essentially build a CO_2 gathering and sequestration infrastructure with a view to reduce emissions related to oil sands production.

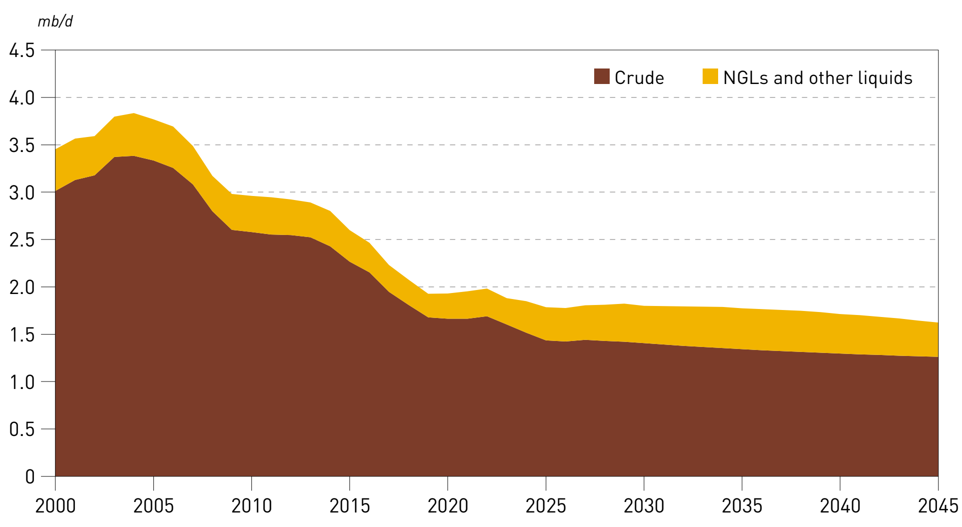
Another long-standing challenge to further growth in Canadian liquids production is export infrastructure bottlenecks. However, this has been somewhat eased after the Enbridge Line 3 replacement project doubled the capacity of this key pipeline to 760 tb/d in late 2021. Stretching from Alberta's oil sands to Superior, Wisconsin in the US, this additional capacity has helped to reduce export capacity tightness, not least due to the earlier cancellation of the Keystone XL pipeline by the Biden

Administration. Furthermore, in late 2021/early 2022, the Capline Pipeline from St. James, Louisiana, to Patoka, Illinois, was reversed, adding another 200 tb/d to capacity to send Canadian or other crude south. Meanwhile, the further expansion of the Trans-Mountain pipeline to Canada's West Coast remains somewhat uncertain after cost overruns.

Mexico

Mexico's liquids supply is projected to continue its slow decline, dipping from 2 mb/d in 2021 to 1.8 mb/d in 2027, even as a slug of new projects as a result of the 2013 market opening comes online or ramps up output. The medium-term period will likely see the start-up of new capacity at the Area 1 cluster of fields, at Ayatsil-Tekel, Hokchi and the Ixachi expansion, among others. Even larger-capacity benefits of the market opening – subsequently effectively reversed – are expected to come online towards the end of the medium-term period. Around 2026, the 120 tb/d Zama field should come online, while 2027 should see first oil from the 80 tb/d Trion project. Thereafter, Mexican liquids supply is projected to plateau for most of the 2030s and decline modestly to average 1.6 mb/d in 2045 (Figure 4.8).

Figure 4.8
Mexico total liquids supply outlook



Source: OPEC.

Norway

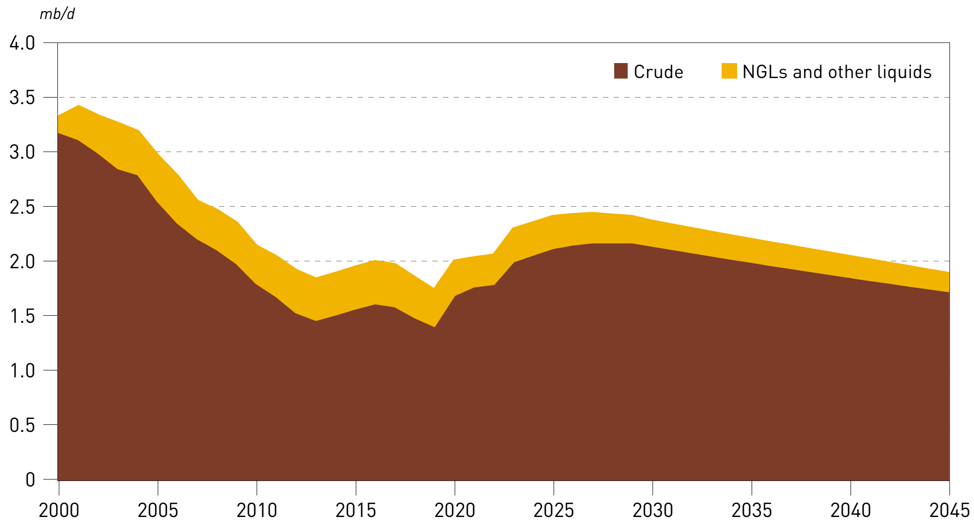
Norway's liquids supply was not greatly affected by the pandemic. It continued to grow throughout 2020–2021, generally on the back of expanding output from the large Johan Sverdrup field, and it is expected to continue to rise in the medium-term, growing from 2 mb/d in 2021 to 2.4 mb/d in 2027. After Phase 2 expansions at Johan Sverdrup, the latter part of the medium-term period will see the start-up of output at the 200 tb/d Johan Castberg field – now delayed to 2024 after COVID-related lockdowns at shipyards. The period 2024–2025 is also expected to see the start-up of the Grane expansion project, which will add 45 tb/d.

Thereafter, in the absence of large new upstream additions, liquids supply in Norway is expected to plateau and ultimately drop again, returning to its long-term pattern of decline after peaking in the late 1990s. The decline trend was only recently offset by the discovery and addition of Johan Sverdrup, which is likely to achieve peak capacity of around 750 tb/d when fully developed by around 2024.

In late June 2022, concerned about Europe's relatively high degree of import dependence, the EU and the Norwegian government agreed to enhance cooperation in energy, with Deputy President of the European Commission, Frans Timmermans, vocally supporting "further exploration and investment to bring oil and gas to the European market". Such support could help to provide a framework conducive to long-term and large-scale investments in energy infrastructure, in particular, including new terminals and pipelines from Norway to other European countries.

This report projects that Norway's liquids supply will plateau and decline slowly, averaging 1.9 mb/d by 2045 (Figure 4.9).

Figure 4.9
Norway total liquids supply outlook



Source: OPEC.

UK

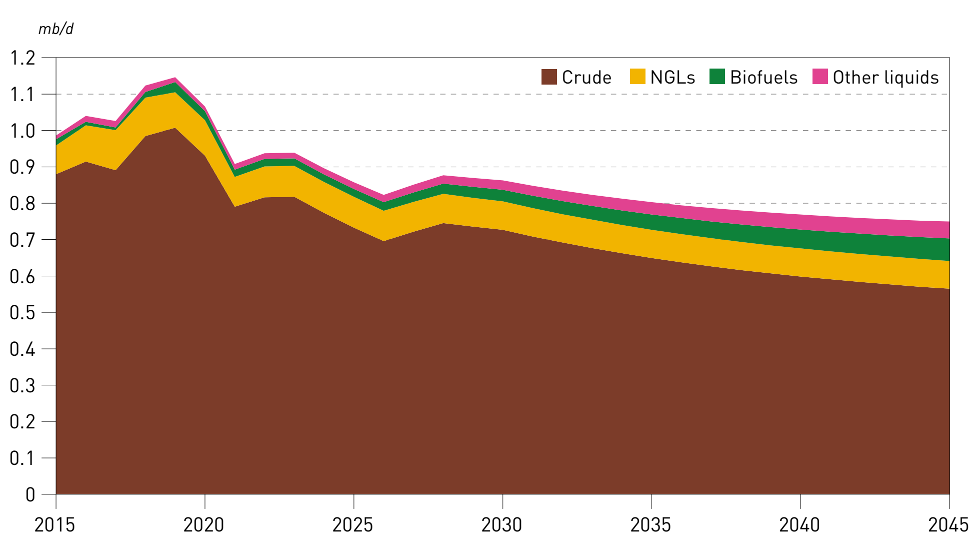
The UK is set to continue to experience a slow, but steady decline in liquids supply. A relatively modest slate of small-to-medium sized upstream projects is expected to come online in the coming years, but this will fail to offset natural declines in what is by now a relatively mature producing region. The Penguins redevelopment project and new field start-up Seagull should each add around 30–35 tb/d from 2023, and Galapagos another 35 tb/d from 2025.

At the same time, the push and pull of an ongoing debate between a government perceived as wishing to limit new upstream developments due to climate change commitments, and wanting to develop domestic production further in order to enhance energy security, is apparent (though the advent of the new Liz Truss government from September 2022 may change this).

A new round of upstream licensing seems likely to go ahead in the course of 2022, following a two-year absence. A vociferous campaign around the time of COP26 in late 2021 shelved development of the Cambo field, with a potential 50 tb/d. In May 2022, the government also imposed a 25% windfall tax on oil and gas companies operating in the UK, raising concerns this might limit future upstream investment. At the time of writing, Equinor has announced it would nonetheless proceed with sanctioning Rosebank, a 60 tb/d project west of Shetland, possibly to start production in 2027, after redesigning the project scope, including lower nameplate capacity and a new floating production, storage and offloading (FPSO) vessel.

The UK is expected, however, to see a modest increase in biofuels and synthetic aviation fuel, stimulated by ambitious mandates. In sum, UK total liquids is set to decline from 0.9 mb/d in 2021 to 0.7 mb/d by 2045 (Figure 4.10).

Figure 4.10
UK total liquids supply outlook



Source: OPEC.

Brazil

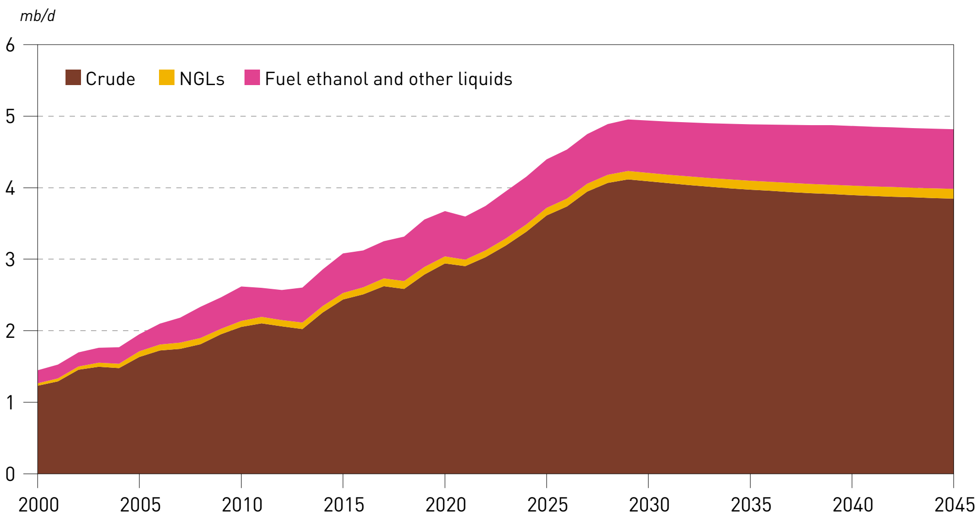
Brazil remains the second-largest source of non-OPEC liquids supply growth in the medium-term, with output projected to increase from 3.6 mb/d in 2021 to 4.8 mb/d in 2027. This is based upon continued growth in the country's highly proficient ultra-deepwater pre-salt acreage, which has already provided the lion's share of Brazil's production increase of around 1 mb/d over the past decade.

During the COVID-19 pandemic, infection clusters and lockdowns caused delays to the completion of several FPSO vessels, which are typically moored above large Brazilian offshore fields to facilitate production and exports – thus, in turn postponing the start-up of various large new fields. Now that the backlog has been reduced, a string of large new projects is due to come onstream in the coming years.

These include Mero 2, 3 and 4, the next three developmental stages of the large Mero project, part of the Libra block, following first oil produced at Mero 1 in May 2022. Each FPSO will have a nameplate capacity of 180 tb/d, thus adding some 0.7 mb/d collectively. Other notable large projects include Buzios 5–10, again each with a large FPSO with average capacity around 190 tb/d and scheduled to start-up over the course of the 2021–2027 period. Itapu, Bacalhau, Jubarte and Sergipe-Alagoas are other projects due to come online in the coming years. Thus, even with relatively high natural decline rates that are typical for the pre-salt areas, Brazilian liquids supply is set for strong growth.

Even after the medium-term, Brazilian oil production is set to increase, with total liquids supply expected to peak at 5 mb/d around 2030. Thereafter, projections are for output to essentially plateau in the long-term, with expected new discoveries brought online, and production declining slightly to 4.8 mb/d by 2045 (Figure 4.11).

Figure 4.11
Brazil total liquids supply outlook

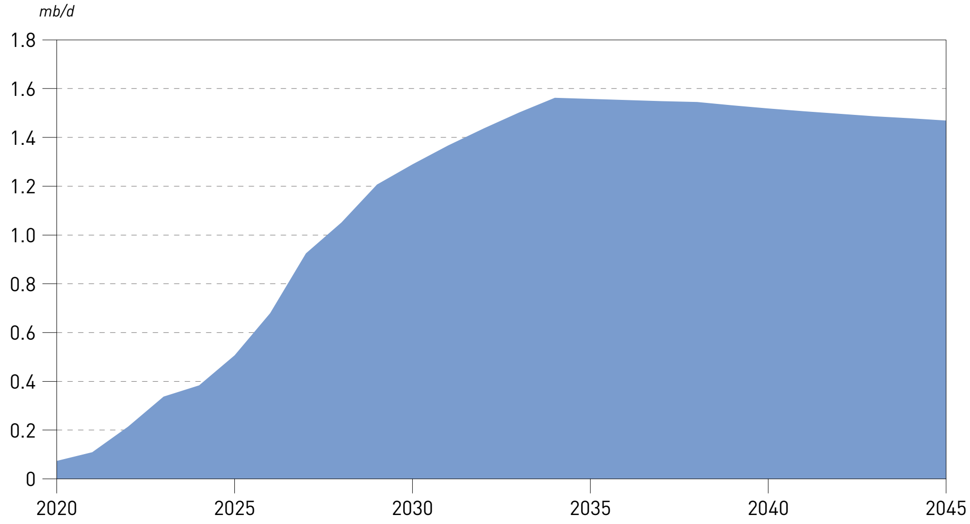


Source: OPEC.

Guyana

Similarly to Brazil, newcomer Guyana is projected to see a significant ramp-up in production, with liquids supply growing from 0.1 mb/d in 2021 to 0.9 mb/d in 2027. Following the start-up of the 220 tb/d Liza Phase 2 in early 2022, the Payara and Yellowtail projects are set to follow in 2024 and 2025, adding another 220 tb/d and 240 tb/d nameplate capacity, respectively. Over the course of the medium-term, north of an estimated 1 mb/d of net new upstream capacity is expected to be added. Based upon the bountiful list of announced discoveries, projections are for further increases in liquids supply thereafter, eventually rising to 1.6 mb/d in the mid-2030s and with clear upside potential (Figure 4.12).

Figure 4.12
Guyana total liquids supply outlook



Source: OPEC.

Colombia

Colombia's liquids supply is projected to continue its decline from a peak of around 1 mb/d in the early 2010s. This report's Reference Case is for output to fall from 0.8 mb/d in 2021 to 0.7 mb/d in 2027 and then as low as 0.4 mb/d in the long-term (Figure 4.13). However, significant uncertainties surround the country's supply outlook. While Colombia's conventional crude reserves are quite low at around 2 billion barrels (according to the BP Statistical Review 2022), the country is known to have significant unconventional liquids resources, including tight oil, which have so far remained largely undeveloped.

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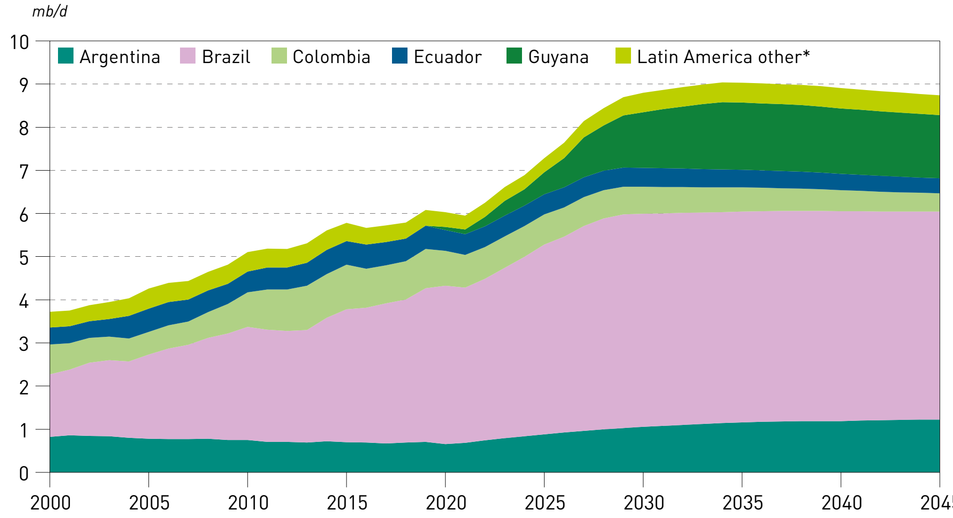
Figure 4.13
Latin America total liquids supply outlook



* *Latin America other includes Bolivia, Cuba, Peru, Trinidad & Tobago and smaller producers, but excludes OPEC Member Venezuela.*
Source: OPEC.

In mid-2022, a regional court gave the green light for national oil company Ecopetrol to continue with a pilot fracking project, dependent upon an environmental licence that had still to be granted. However, the June 2022 election of President Gustavo Petro, who ran on a platform of banning fracking, put a stop to the awarding of new oil exploration rights and halted hydrocarbon exports. This put the further development of unconventional and offshore resources in doubt (Ecopetrol has two exploration ventures in the Caribbean). Without tapping new resources, however, a further decline in liquids supply seems inevitable.

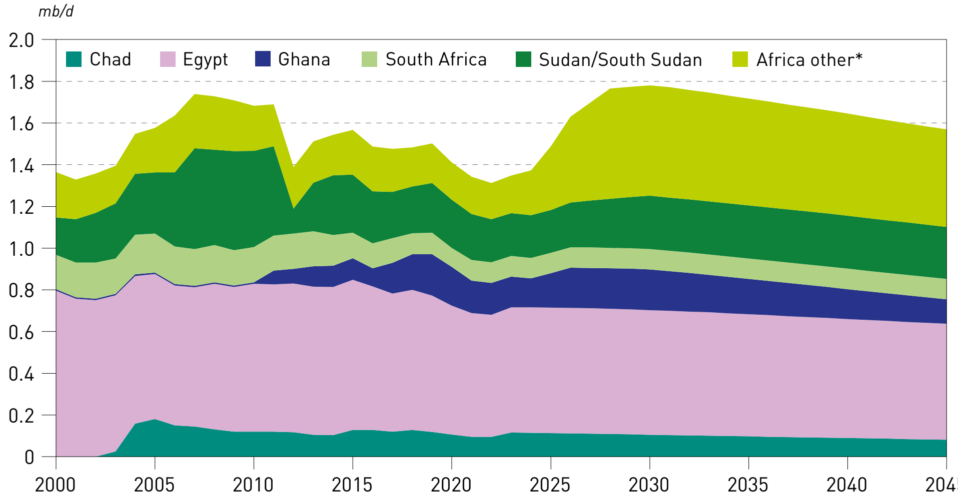
Africa

Non-OPEC Africa's liquids supply is set to experience a resurgence, as production commences at a number of new producers. Sangomar Phase 1 is set to start up offshore Senegal from 2024, with nameplate capacity of 100 tb/d, marking the country's first oil production. A second phase may follow in the latter part of the 2020s. In Uganda, liquids production is expected to commence in the Lake Albert area, with the Tilenga field developed by TotalEnergies starting up in 2025. In 2026, the CNOOC-operated Kingfisher field is set to be added, with the two fields together having a nameplate capacity of around 230 tb/d.

Eni hopes to fast-track its Baleine discovery in offshore Ivory Coast, though at the time of writing, the project has not yet received a FID. The recent discovery in Namibia of what could be sub-Saharan Africa's largest-ever offshore deposit, Venus, may allow for production there by operator TotalEnergies later in the decade.

In sum, liquids production in Africa (ex-OPEC) is set to grow from 1.3 mb/d in 2021 to 1.7 mb/d in 2027, a level last seen around 2010. Production is projected to remain at these higher levels throughout most of the 2030s, and could rise higher if the above-mentioned large new discoveries are developed (Figure 4.14).

Figure 4.14
Africa total liquids supply outlook



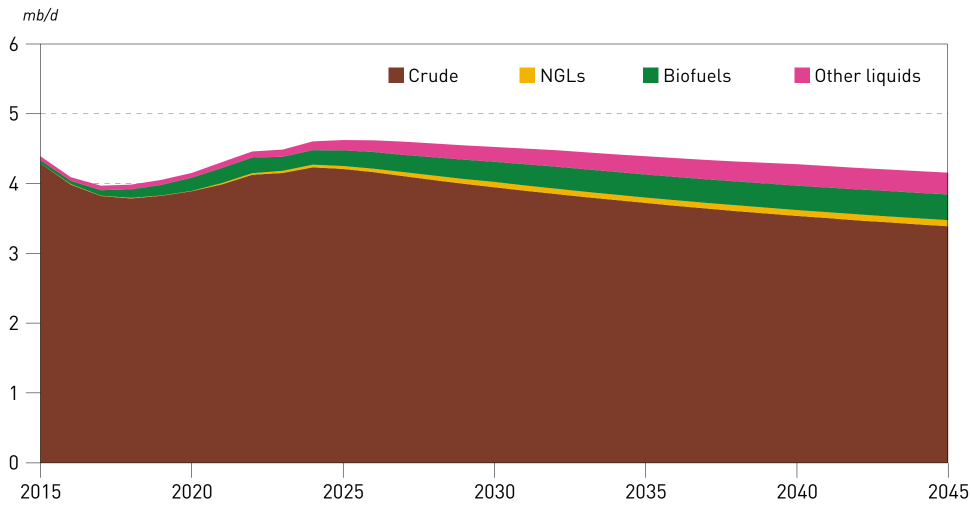
* *Africa other includes Cameroon, Senegal, Tunisia, Uganda and smaller producers, but excludes African OPEC producers.*

Source: OPEC.

China

China's total liquids supply is projected to continue to grow modestly in the medium-term, rising from 4.3 mb/d in 2021 to 4.6 mb/d in 2027. A string of moderate-sized new fields is expected to come onstream in this period, including at the Penglai, Qinhuangdao, Luda, Caofeidian and Jinhuazhen complexes. According to the government's 14th FYP, crude oil production is to be kept at around 4 mb/d for the next few years. From the late 2020s, while conventional crude supplies are projected to start declining again, tight crude, biofuels and other liquids, including CTLs and synthetic aviation fuel, will continue to grow, rising to 150 tb/d, 310 tb/d and 370 tb/d, respectively in the long-term. In sum, Chinese liquids supply will decline again to 4.2 mb/d by 2045.

Figure 4.15
China total liquids supply outlook



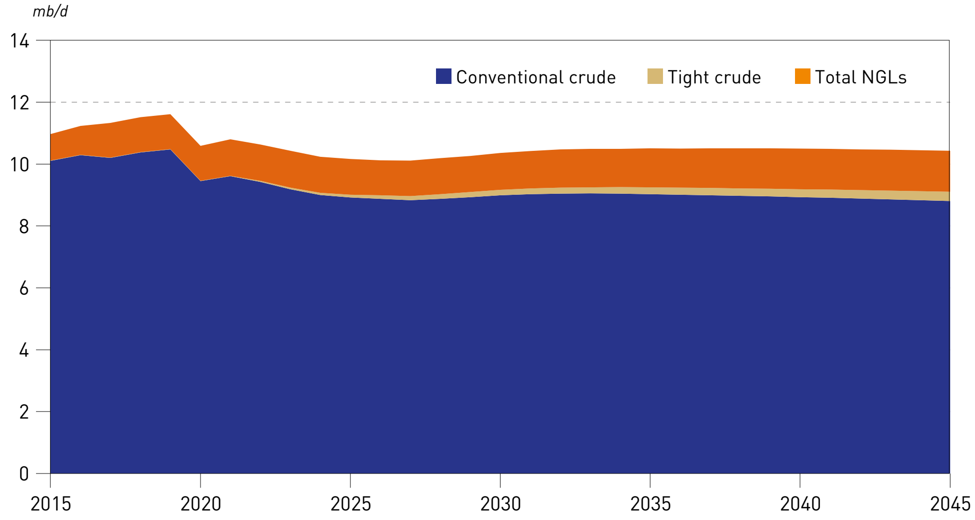
Source: OPEC.

Russia

Russian liquids supply is projected to decline in the short- and medium-term, as a consequence of the Russia-Ukraine conflict, and a resulting combination of weaker domestic demand, embargos and self-sanctioning by purchasers of the country's oil. Most importantly, a near-full ban on imports of Russian crude into EU countries (exceptions will remain in place for some pipeline imports into Eastern Europe), to be implemented around the end of 2022, and concurrent limitations on insurance, shipping and commodity trade finance, are likely to have a meaningful impact. Many IOCs active in Russia's upstream have also announced divestments or a halt to activities, raising questions about continued investment and, in some cases, technology transfer.

As a result, Russian liquids supply is expected to decline from 10.8 mb/d in 2021 to 10.1 mb/d by 2027. Thereafter, expectations are for a gradual and partial recovery in output, as domestic investment picks up, notably in the large Vostok project in Eastern Siberia, which groups existing and some future fields into a new mega-complex. As a result, production levels are set to rise again to around 10.5 mb/d by the early 2030s, and are projected to average 10.4 mb/d by 2045 (Figure 4.16).

Figure 4.16
Russia total liquids supply outlook

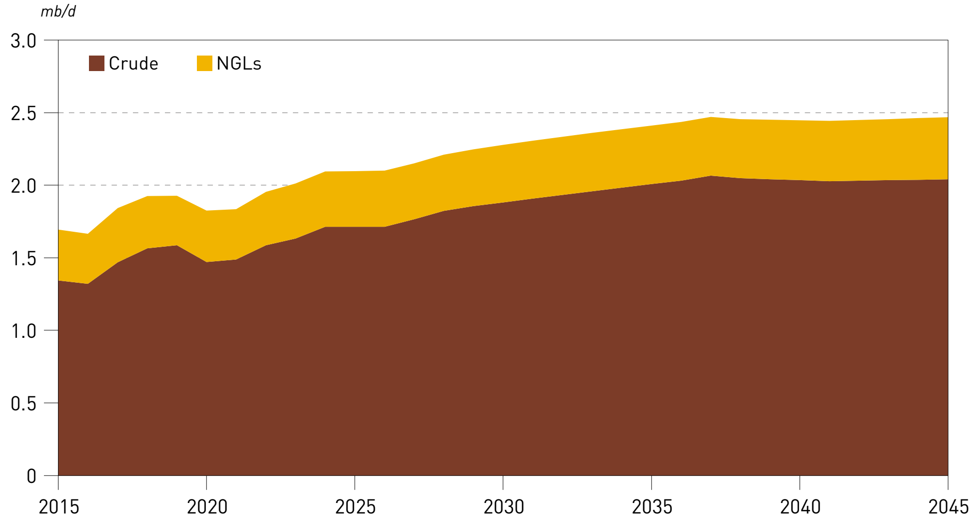


Source: OPEC.

Kazakhstan

Kazakhstan is projected to see steady growth over the entire forecast period; indeed, it is one of the few sources of non-OPEC liquids supply to experience this. The Future Growth Project at the giant Tengiz field, though delayed in its ramp-up due to pandemic-related setbacks, is set to increase output by 260 tb/d over the course of the coming

Figure 4.17
Kazakhstan total liquids supply outlook



Source: OPEC.

years. Concurrently, a gas re-injection project at the Kashagan field is set to increase nameplate capacity there by a further 100 tb/d. Smaller increments should come online at the Karachaganak and Kalamkas-More fields.

In the long-term, the WOO assumes further growth at the country's large field complexes, especially Kashagan, based upon the large resource base, and despite challenging conditions. As a result, Kazakhstan's total liquids supply is set to rise from 1.8 mb/d in 2021 to 2.2 mb/d in 2027, and then further to plateau at 2.5 mb/d from the mid-2030s (Figure 4.17).

4.4 Breakdown of liquids supply by type

Broken down by type of liquid, the medium-term sees non-OPEC liquids supply growth dominated by crude oil, which makes up 4.7 mb/d, or 60% of the projected 7.9 mb/d growth in the 2021–2027 horizon. NGLs make up another 1.7 mb/d, or just over 20%, and combined biofuels, refinery processing gains and 'other liquids' make up another 1.4 mb/d, also close to 20%.

In the long-term, crude oil's trend is reversed, with crude supply from non-OPEC producers declining by 3.3 mb/d, as fields increasingly mature, and as US tight crude, in particular, sees a peak. At the same time, other non-crude liquids evidence fairly strong growth in the 2021–2045 period, more than offsetting crude oil's decline and enabling a total increment in non-OPEC liquids of 3.9 mb/d by 2045. Thus, NGLs increase by 2.7 mb/d on the back of continued natural gas growth (Table 4.4).

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Table 4.4
Long-term non-OPEC liquids supply outlook by type *mb/d*

	2021	2025	2030	2035	2040	2045	Change 2021–2045
Crude	43.3	46.9	48.0	45.5	42.6	40.0	–3.3
NGLs	11.6	13.0	13.7	14.1	14.2	14.3	2.7
Global biofuels	2.5	2.9	3.3	3.7	4.2	4.4	1.9
Other liquids	4.0	4.3	4.7	5.0	5.3	5.6	1.6
Processing gains	2.3	2.6	2.8	2.9	3.0	3.2	0.9
Non-OPEC	**63.6**	**69.6**	**72.4**	**71.2**	**69.3**	**67.5**	**3.9**

Source: OPEC.

With regard to other liquids, Canadian oil sands will also likely continue to see quite strong growth, rising from 3.1 mb/d in 2021 to 4.3 mb/d in 2045. Under the assumption that not all proposed mandates are put into law, or are realized, the Reference Case is for growth from virtually zero synthetic aviation fuel today, to 0.4 mb/d in 2045, in addition to some biojet/biokerosene included in the 'biodiesel' category. By contrast, GTLs, CTLs and others (largely refinery additives) is set to stay flat, due to unattractive economics (Table 4.5).

Table 4.5
Long-term non-OPEC biofuels and other liquids supply outlook *mb/d*

	2021	2025	2030	2035	2040	2045	Change 2021–2045
Fuel ethanol	1.7	1.9	2.1	2.3	2.5	2.6	0.9
Biodiesel	0.8	0.9	1.2	1.4	1.6	1.8	1.0
Global biofuels	**2.5**	**2.9**	**3.3**	**3.7**	**4.2**	**4.4**	**1.9**
Canadian oil sands	3.1	3.4	3.7	3.9	4.1	4.3	1.2
Gas-to-liquids (GTLs)	0.2	0.3	0.3	0.3	0.3	0.3	0.0
Coal-to-liquids (CTLs)	0.3	0.3	0.4	0.4	0.4	0.4	0.1
Synthetic aviation fuel	0.0	0.0	0.1	0.1	0.2	0.4	0.4
Other*	0.3	0.3	0.3	0.3	0.3	0.3	–0.1
Total 'Other liquids'	**4.0**	**4.3**	**4.7**	**5.0**	**5.3**	**5.6**	**1.6**
Non-OPEC	**6.5**	**7.1**	**8.0**	**8.7**	**9.5**	**10.0**	**3.6**

** Including oil shale (kerogen), extra-heavy crude, MTBE and other refinery additives.*
Source: OPEC.

Box 4.1

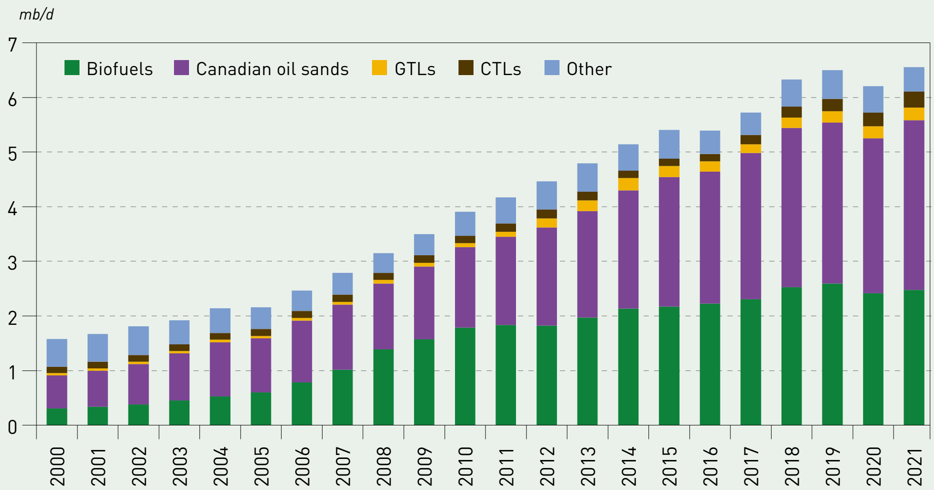
Non-crudes on the rise

Non-crude liquids have emerged as a pivotal complement to crude oil in recent decades. In 1980, global total liquids supply totalled 64 mb/d, of which non-crude liquids accounted for 3.9 mb/d, or 6%, the bulk being NGLs, with other non-crude liquids amounting to only 260 tb/d. By 2021, however, total non-crude liquids amounted to nearly 25% of global supply, and 7% when excluding NGLs.

Non-crude liquids comprise NGLs, fuel ethanol and biodiesel, oil sands, GTLs, CTLs, small volumes of refinery additives, extra-heavy oil and oil shale (kerogen). While NGLs emerged essentially as a by-product of expanding natural gas supply, some other sources of non-crude liquids benefited mainly from government support. This was with a view towards substituting expensive or difficult-to-source crude oil, as the result of a desire to monetize stranded assets including gas and coal, and benefitting from technological advances.

The major contribution of non-crude liquids towards the global market for 'oil' is set to continue its rise, with WOO projections seeing their share increase to around 30%, or nearly 32 mb/d by 2045. Stripping out NGLs, the share of biofuels, Canadian oil sands and other unconventional liquids is expected to rise to 10 mb/d, or nearly 10% of global liquids supply, in the long-term, with potential to the upside, especially for biofuels and synthetic aviation fuel. This feature box specifically focuses on non-crude liquids, outside of NGLs.

Figure 1
Historical global growth of non-crude-liquids (excluding NGLs)



Source: OPEC.

Historically, a desire to find alternatives to crude oil, as well as stranded assets and energy security concerns, has motivated the development of alternatives, including GTLs and CTLs.

For instance, the emergence in recent decades of GTLs as a commercially-viable industry has offered market diversification and an alternative to natural gas. However, the increasing popularity of LNG has largely replaced this drive. Thus, GTLs supply is forecast to grow only marginally in the coming years, with one new plant in Uzbekistan starting up recently, and some organic growth at existing projects expected elsewhere. GTLs supply is expected to expand from 230 tb/d to reach 270 tb/d by 2045.

Similarly, CTLs, first developed on a large scale by South Africa, and since taken up by China, have contributed to other liquids supply growth over the past decade or so. In the long-term, it is projected that CTLs also rise modestly, to 0.4 mb/d by 2045.

The story for biofuels is different. Biofuels largely emerged as an alternative to fossil fuel-based liquids as a result of government policy, with a view towards reducing emissions and making fuels more sustainable. The US led the way with its Renewable Fuel Standard (RFS) implemented in 2005–2007. This established blending mandates and has today resulted in the production of around 1 mb/d of fuel ethanol as part of the US's liquids fuel mix.

Biofuels have also been strongly pushed by the EU, which recently updated a directive concerned with the use of biofuels in the transport sector. The Renewable Energy Directive (RED-II) requires fuel suppliers in EU Member States to supply renewable fuels for at least 14% of the energy consumed in the road and rail transport sector, including a minimum share of 3.5% for advanced biofuels. EU countries are also required to set out an obligation on fuel suppliers that ensures the achievement of this target.

China has ambitions for non-crude liquids too, which are set out in its national 14th FYP. Similarly, India is gradually reducing petroleum-based fuels with the introduction of its National Policy on Biofuels. The policy seeks to promote the use of biofuels in the transport sector by mandating 20% blending of ethanol in gasoline and 5% blending of biodiesel in diesel by 2030.

Biofuels and synthetic fuel technology continues to advance, in some cases also aided by the conversion of non-economical conventional refineries into biorefineries. Recently there has been an increased focus on moving beyond road fuels with a view towards providing alternatives to oil-based jet aviation fuel, given the inherent difficulties to electrify this sector. Taking into account proposed mandates in this sphere, this outlook projects that total supplies of non-fossil aviation fuel (including both of biological origin and synthetic fuels), is set to rise from around 120 tb/d in 2021 to double that by 2030. It could then move as high as 620 tb/d by 2045, or around a 7% share of global jet fuel demand at that point. With greater political support, particularly if current ambitious plans for even higher blending mandates were realized, this share could be much greater, potentially making up more than 25% of the global jet fuel market by 2045.

The share of non-crude liquids in the global supply mix remains on an upward trend. They are a vital component of supply, with the potential for further growth in the years and decades ahead.

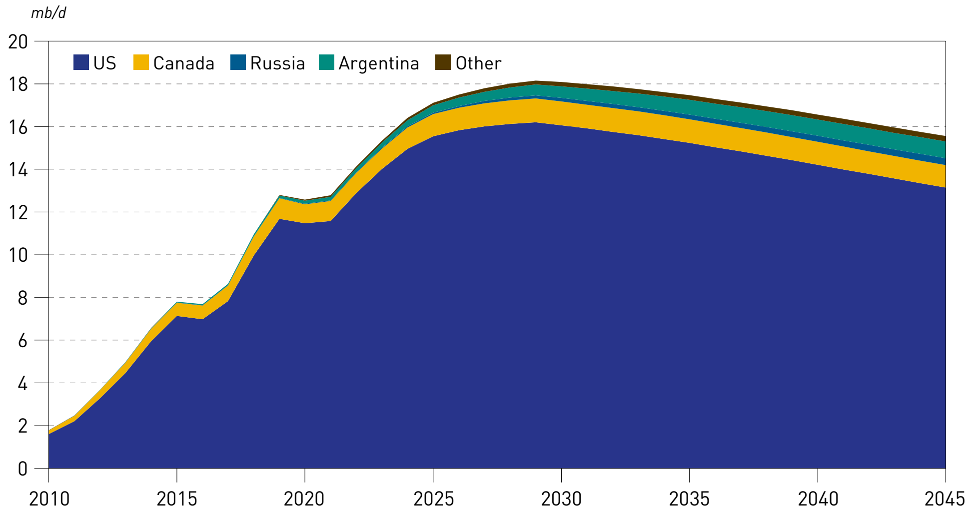
4.5 Tight oil: US and other countries

4.5.1 Global tight oil supply outlook

Global tight oil, including tight crude and unconventional NGLs, is set to rise from 12.8 mb/d in 2021, or around 20% of total non-OPEC liquids supply, to a peak of 18 mb/d, or 25%, around 2030. After US tight oil peaks and goes into decline, global supplies are expected to drop again to 15.6 mb/d, or 23% of non-OPEC liquids supply by 2045 (Figure 4.18).

US tight oil is expected to continue to make up the bulk of global tight supplies, rising to a peak production of just over 16 mb/d in the late 2020s. Supplies from other producers, which made up 1.2 mb/d in 2021, are set to rise to 2 mb/d in sum by 2030, and then a higher 2.4 mb/d by 2045. Canada, already with a sizeable production of 0.9 mb/d, as well as Argentina and to a lesser extent Russia, are likely to emerge as meaningful long-term tight oil producers. The outlook for tight oil supply in Argentina has been revised higher on strong recent performance. Supportive fundamentals and new offtake capacity from the landlocked Neuquén province have helped to boost production in the Vaca Muerta basin. The country's total tight oil supply is projected to rise from 0.2 mb/d in 2021 to 0.8 mb/d in the long-term, with potential to the upside.

Figure 4.18
Global tight oil supply outlook



Source: OPEC.

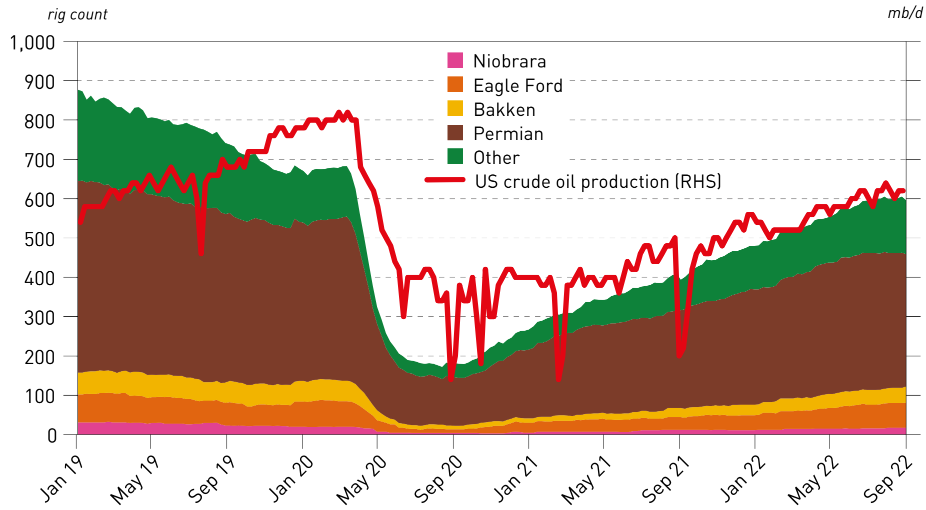
4.5.2 US tight oil outlook

Despite experiencing a sharp downturn as a result of lower drilling and completion activity during the pandemic, US tight liquids supply began to recover in the course of 2021 and is projected to return to strong growth in the medium-term. Total US tight oil, including tight crude and unconventional NGLs, is set to grow from 11.6 mb/d in 2021 to 16 mb/d by 2027, an increase of 4.4 mb/d. Of this, tight crude is expected to see an increase of 3.2 mb/d, and unconventional NGLs an increment of 1.2 mb/d. Supply is expected to plateau at this level for several years before declining again throughout the 2030s and beyond, to average 13.1 mb/d by 2045 – still higher than in 2021.

US tight oil is widely considered to be one of the most price-elastic sources of supply. This is largely due to how it is produced; essentially rather more a manufacturing or industrial process when compared with conventional oil, with output largely defined by how efficiently processes, including drilling, fracking and completion can be managed, which are themselves dependent upon efficiently marshalling resources, equipment and labour. As a result, tight oil is broadly considered 'short-cycle', in other words it has a shorter lead time than conventional resources, which can take several years from discovery to first oil being produced.

Thus, given the current and projected overwhelmingly supportive outlook for fundamentals, the question is to what extent and at what pace US tight oil will recover and grow again in the coming years.

Figure 4.19
US oil rig count and crude oil production



Source: GE/Baker Hughes, Energy Information Agency.

Much continues to be made about oil companies' reluctance to reinvest in new production capacity, despite record-high cash flows – insisting on so-called 'capital discipline'. CEOs of publicly-held tight oil producers are often quoted as wanting to cap annual growth at around 5%, while rewarding investors with generous dividends and large share buybacks. At the same time, less constrained by a desire to reward investors, it has been widely noted that privately-held shale operators have been re-investing more in growth, looking to benefit from supportive fundamentals and the generally strong demand outlook.

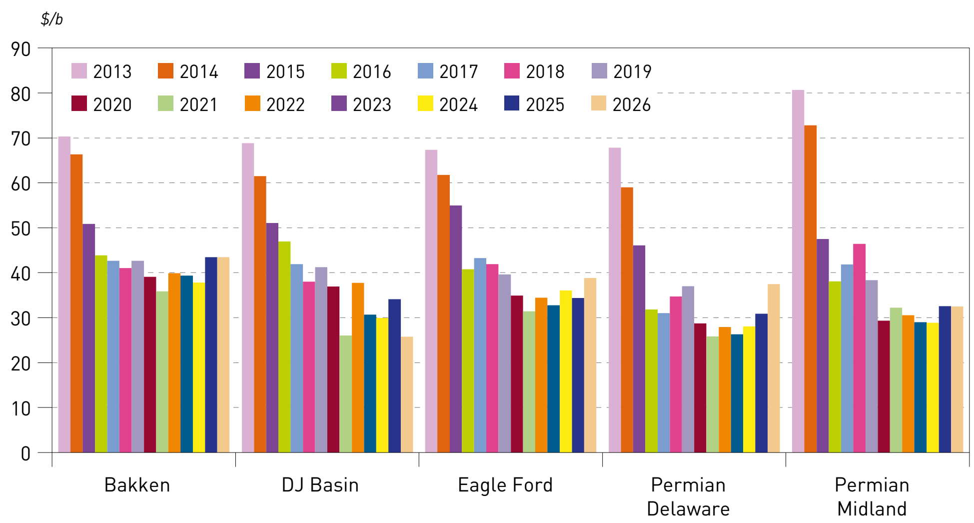
Some also quote infrastructural constraints as putting a cap on stronger growth in US tight oil production. These include supply chain issues and thus difficulties to source steel, oil rigs, frac crews, fracking chemicals, labour, and even high fuel costs. At the same time, the evidence appears to show that efficiency gains are offsetting some of these costs, including in such measures as time to drill wells, frac wells, the length of horizontal wells and laterals. US service companies, in statements, are pointing towards what they see as a cyclical upswing, with for example Schlumberger expecting a 20% increase in domestic spending in the US upstream.

At the same time, according to the widely-regarded Dallas Fed survey of oil industry executives in the US's key producing areas, executives have noted rising upstream costs in 2Q22 (June 2022 survey), with the index for oilfield services reporting a record-high reading. Executives surveyed also complained about mixed messaging from the US Administration, which on the one hand is calling for domestic (and foreign) oil production to be raised, while also calling for the phasing out of fossil fuel use in the long-term. The latter, in particular, is seen as a risk to upstream investment, with uncertainty as to how supportive policies will be given ESG pressures and ambitions to accelerate the energy transition away from fossil fuels.

However, the Dallas Fed survey also noted that business activity rose to its highest reading ever in 2Q22, with executives expecting continued strong fundamentals for the remainder of 2022 and, as a result, continued liquids supply growth. Moreover, forward indicators, such as rigs deployed in key shale basins, show slow, but steady growth, rising to around 600 rigs, compared to an average just below 700 before the pandemic hit (Figure 4.19).

Well-head breakeven prices for US tight crude definitely look favourable, with thresholds expected to hover in a $28–45/b range in the medium-term, and perhaps most significantly, even below that in the most prolific tight crude parts of the Permian Basin (Figure 4.20).

Figure 4.20
Evolution of US tight oil wellhead breakeven prices by basin



Source: Rystad Energy.

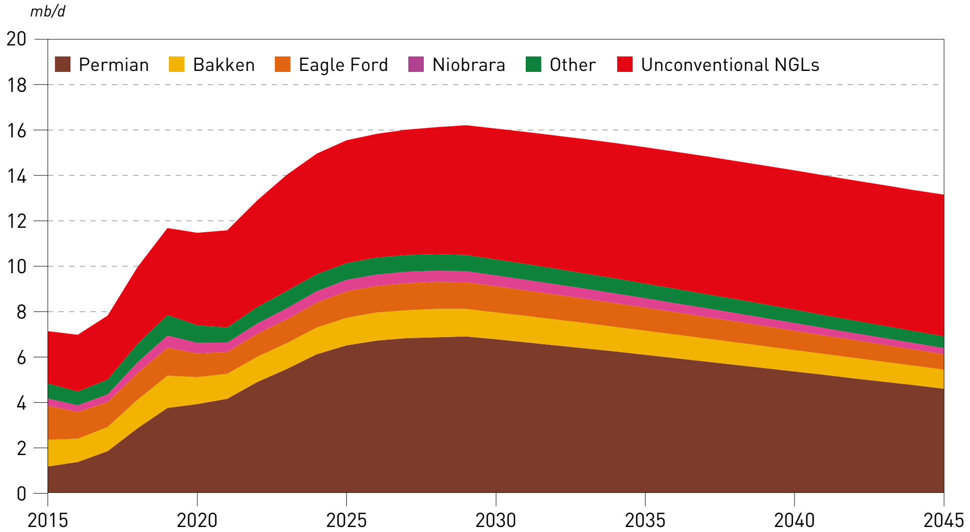
The bottom line is that a return to growth is taking time, with tight crude output in the US essentially flat (as was total crude oil supply) in 2021. However, the pick-up in activity and other indicators lead the WOO to project growth of 0.9 mb/d in 2022, followed by average annual growth of 0.5 mb/d in the subsequent 2023–2027 period, albeit slowing over the timeframe. In the same time period, unconventional NGLs, which never stopped growing during the pandemic (on an annual basis), are also set to continue to rise on the back of surging natural gas output. Thus, combined, US tight oil is projected to increase by 4.4 mb/d in the medium-term, from 11.6 mb/d in 2021, to 16 mb/d in 2027.

Thereafter, output is expected to plateau for several years, as basins exhaust their most proficient acreage and successively peak.

On a basin-by-basin basis, medium-term supply growth is projected for all major producing areas. However, with the exception of the Permian, none of them is expected to regain pre-pandemic levels. Indeed, the Eagle Ford in southern Texas likely saw production peak at 1.5 mb/d in 2015, before the recent slowdown. The Permian Basin, already by far the prolific producing area in the US, did not see output decline in 2020, and it is projected to grow from 4.2 mb/d in 2021 to 6.8 mb/d in 2027, a new peak.

Around that time, however, resource constraints kick in, and the Permian too sees output plateau in the late 2020s, after which it declines. With the other producing basins having peaked slightly earlier, total tight crude supply declines from a peak of 10.5 mb/d to 6.9 mb/d in 2045. Combined with unconventional NGLs, total US tight oil rises from 11.6 mb/d in 2021 to 16 mb/d in the late 2020s, before falling again to average 13.1 mb/d in 2045 (Figure 4.21).

Figure 4.21
US tight oil supply outlook



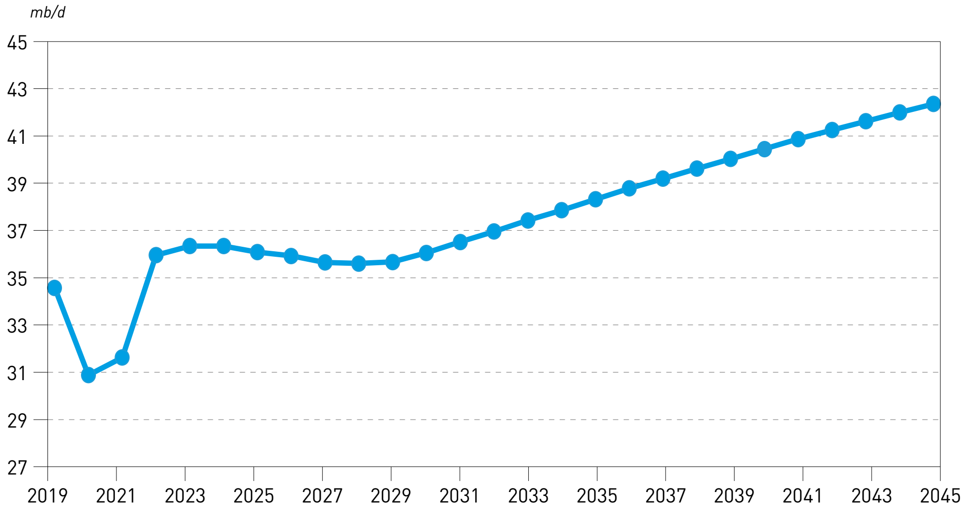
Source: OPEC.

4.6 OPEC liquids supply

OPEC liquids supply, which declined sharply in the course of the pandemic-induced demand slump, as a result of production adjustments decided by Member Countries and their partners in the DoC, is projected to increase again in the medium- and long-term.

From 31.6 mb/d in 2021, demand recovery will enable OPEC liquids to grow, rising to 35.6 mb/d by 2027, albeit most of that growth will take place in 2022–2023 as market dynamics stabilize. After US tight oil peaks in the late 2030s and later declines, and with the few other sources of non-OPEC supply growth unable to offset declines elsewhere, OPEC liquids are set to grow steadily, rising to 42.4 mb/d by 2045. As such, OPEC's total market share rises from 33% in 2021 to 39% by 2045 (Figure 4.22).

Figure 4.22
OPEC total liquids supply



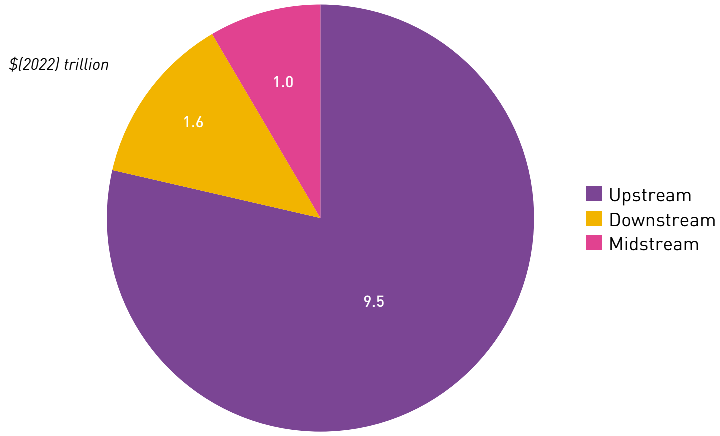
Source: OPEC.

4.7 Upstream investment requirements

The need for continued investment in oil is clear. Based upon this report's Reference Case for projected demand growth of nearly 13 mb/d in the 2021–2045 period, and given natural decline in existing oil fields, significant commitments to sustain net new production and processing capacity in the sector's up-, mid- and downstream will be needed.

Estimated costs for total oil-related investment needs in the long-term are assessed at $12.1 trillion (in 2022 US dollar terms). Of this, $9.5 trillion will be required in the upstream, $1.6 trillion in the downstream, and $1 trillion in the midstream (Figure 4.23). This total is

Figure 4.23
Cumulative oil-related investment requirements by sector, 2022–2045

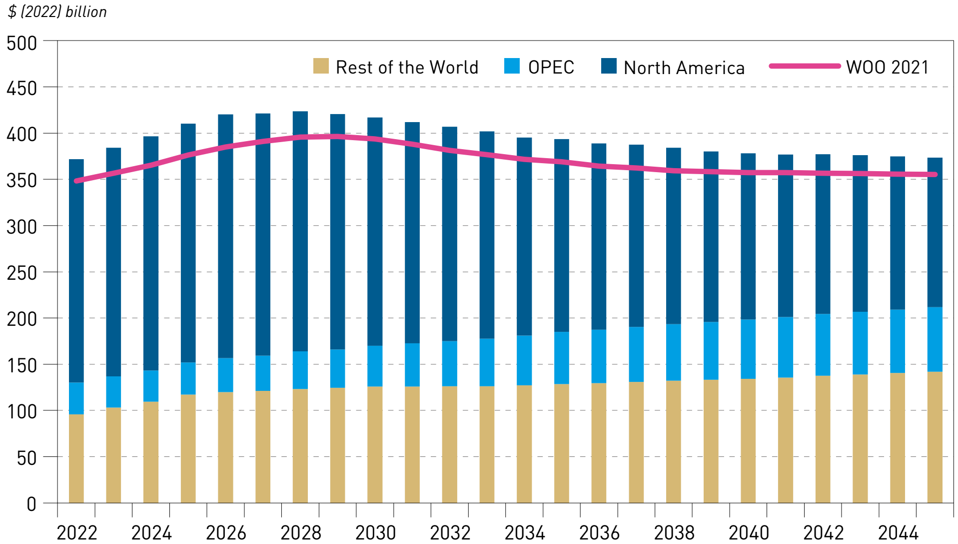


Source: OPEC.

higher than estimated in the WOO 2021 as, even though the period in question is one year shorter, some cost inflation is expected, especially in the short- and medium-term. The outlook for oil demand has also been lifted higher in the long-term, and on the supply side, a shift towards higher production from higher-cost countries is assumed.

With regard to upstream investment needs, the overwhelming share remains projected for North America, albeit one that declines over time. This reflects once again the relative importance of US liquids, and in particular, US tight oil in contributing towards short- and medium-term non-OPEC liquids supply growth, as well as the relatively higher costs in the US, as well as in Canadian oil sands. Total North American upstream investment requirements are projected to rise from $241 billion p.a. for 2022 to a peak of $260 billion p.a. in 2028, before US tight oil is expected to peak. Then, requirements and North America's share of total investments declines again, from 65% in 2022 to 43% in 2045 (Figure 4.24).

Figure 4.24
Annual upstream investment requirements for capacity additions, 2022–2045



Source: OPEC.

Refining outlook

Key takeaways

- The downstream market has tightened significantly over the last year. Strong oil demand growth, a decline in available refining capacity and geopolitical uncertainties have been the main drivers.

- During the medium-term (2022–2027) around 7.3 mb/d of refining capacity additions are expected, most of which is expected in the Asia-Pacific (3.6 mb/d), the Middle East (1.6 mb/d) and Africa (1.2 mb/d). Refining capacity additions in other regions are minor and mostly limited to the expansion of existing refineries.

- In the long-term (2022–2045) global refining additions are projected at 15.5 mb/d. Expected additions are front-loaded, with a significant slowdown in the rate of additions towards the end of the projection period. Almost 90% of additions are located in the Asia-Pacific, the Middle East and Africa.

- The medium-term balance points to a tightening downstream market relative to 2021. The estimated deficit of potential refining capacity relative to required refining capacity is set to peak around 2.7 mb/d in 2023 and 2024. Due to the demand growth slowdown and continuous capacity additions, the deficit is set to decline to around 1.4 mb/d in 2027.

- Global utilization rates are projected to increase to almost 80% in 2022, which is close to pre-pandemic levels. Between 2023 and 2025, the utilization rate is projected to increase to above 81.5% due to both strong demand growth and refinery closures.

- In the long-term, refinery runs are expected to increase to a peak of around 86.5 mb/d in 2035, after which it is likely to inch down towards 86.2 mb/d in 2045. Throughputs in the US & Canada and Europe, as well as developed Asia-Pacific, are forecast to decline from 2025 onwards. However, this is more than offset by increases in developing regions, especially in Other Asia-Pacific, Africa and the Middle East.

- In 2020 and 2021, around 3 mb/d of refining capacity was closed, mostly in developed countries. Another 2.6 mb/d of refinery shutdowns are expected between 2022 and 2027. Due to the current market tightness, however, it is possible that some of these closures will be postponed.

- Long-term secondary capacity additions are significant with around 15.8 mb/d of desulphurization capacities, 8 mb/d of conversion capacities and 5.7 mb/d of octane units.

- Total required downstream sector investments are projected at above $1.5 trillion. Around $530 billion is required for refinery capacity expansions, while $1 trillion is calculated for continuous maintenance and replacement.

This chapter presents the oil downstream sector outlook for the period 2022–2045. It is fully consistent with Reference Case projections on demand (Chapter 3) and oil supply (Chapter 4). It examines how different factors are expected to influence the future global refining sector, highlighting the challenges, uncertainties and opportunities. Similar to Chapter 3 and 4, the analysis is conducted in two different timeframes – the medium-term (2022–2027) and long-term (2022–2045).

The initial focus is on recent refining sector developments, including the effects of the COVID 19 pandemic and the post-pandemic recovery. It also looks at the possible consequences related to the Russia–Ukraine conflict on the downstream market. This is followed by an updated assessment of current 'base' capacity by region (as of January 2022), which is the basis for medium- and long-term projections.

These projections are based on two steps. First, the medium-term refining capacity additions are assessed, based on the review of current refinery projects and their progress. Second, based on global and regional oil demand trends, long-term refining capacity additions are projected. Moreover, the analysis in this chapter shows how the downstream market balance is anticipated to evolve in the medium-term, which provides insights into regional market balances and utilization rates.

Recent and near-term refinery closures are also discussed and projected. In the medium-term, projections are based on announcements (firm closures) and an assessment of potential closures by 2027. Beyond 2027, the Reference Case makes no explicit projections on closures, but provides an indication on required refinery closures based on the projected regional utilization rates.

This chapter also examines secondary capacity additions in the medium- and long-term. This includes projections for upgrading capacity fluid catalytic cracking (FCC), coking and hydrocracking) and desulphurization capacity, as well as 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 projects 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

The situation in the global downstream market has changed fundamentally over the last year. From a relatively loose market in the pre-pandemic period to a depressed market in 2020 and 2021, the downstream market became extremely tight in mid-2022 with record high product cracks and refinery margins. There are several reasons for this – strong demand growth in the post-pandemic recovery period, geopolitical uncertainties related to crude and product flows, tightening available refining capacity amid a high level of recent refinery closures, delays in refinery additions, as well as escalating refining costs.

As was underscored in the WOO 2021, the COVID-19 pandemic had a severe impact on the refining sector. Following the sudden demand decline in early 2020, many refiners had to reduce their throughputs during the year in the midst of dropping refinery margins. The situation improved somewhat during 2021 and utilization rates increased in most regions, however, they were still below pre-pandemic levels. Consequently, refinery downtime was significant throughout the pandemic, which also triggered decisions to close a significant number of refineries. Nevertheless, as lockdown measures were relaxed in many parts of the world, particularly in the 2H21 and into 2022, oil demand growth surged with a significant increase in refinery throughputs.

Low refinery margins in combination with the bleak market outlook led to numerous refinery shutdowns in 2020 and 2021. It should also be noted that another supporting factor for the shutdowns was the strong shift in energy policy away from fossil fuels, especially in developed countries. Consequently, around 3 mb/d of refining capacity was closed in 2020 and 2021. Further closures of close to 1.3 mb/d were announced for 2022. More than 60% of refinery closures in the period 2020–2022 occurred in developed countries in Europe, North America and the Asia-Pacific (e.g. Australia, New Zealand and Japan). Given increased demand levels in 2022, the shutdowns impacted capacity margins, with those in developed countries dropping significantly.

At the same time, due to the pandemic-related problems and global supply chain issues, the start-up of several new refineries has been delayed, which has been another factor reducing available refining capacity during 2022. This also affected some large export-oriented projects. In addition, in markets like China, refinery throughputs declined during the first eight months of 2022 and remained lower year-on-year (y-o-y), due to lockdown measures and lower-than-expected demand growth. In addition, through restrictive export quotas, China has limited refined product exports, which has additionally tightened the global downstream market.

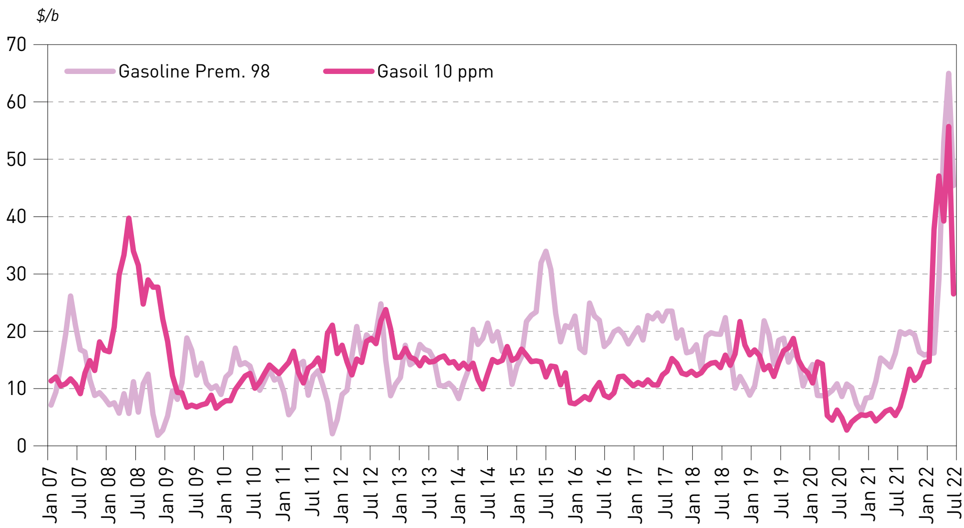
The beginning of the Russia-Ukraine conflict in February 2022 had several parallel effects in the downstream market. First, the geopolitical premium increased, not only on oil prices, but on product prices too, given that Russia is a significant product exporter, especially to Europe. Second, as a reaction to the conflict, several buyers stopped purchasing Russian crude and products. This had negative consequences on Russian refinery throughputs, which declined y-o-y by some 10% in the first months of the conflict. Consequently, this further reduced available refining capacity.

Additionally, rising energy costs, especially those related to natural gas, have proven to be an important cost factor for many refiners.

All this has led to all time high product spreads in 2022, far higher than the levels recorded in 2008 when the middle distillate market was tight. For instance, gasoline and gasoil cracks in Northwest Europe reached all time high levels of $65/b and $56/b, respectively, in June 2022 (Figure 5.1). This illustrates the extreme tightness of the downstream market in mid-2022. During the summer of 2022, product cracks plunged somewhat, partly due to rising utilization rates and a higher supply of products. Nevertheless, spreads remained higher relative to previous years.

All this creates preconditions for a structurally bullish market, with further possible product supply and price distortions in the near-term. For example, the EU's reaction to the Russia-Ukraine conflict was to introduce an embargo (with some exceptions until 2024) on Russian crude oil and products as of late 2022/2023, leaving many European

Figure 5.1
Gasoline and gasoil spreads *versus* Dated Brent in Rotterdam



Source: Argus.

refiners to replace Russian crude oil. However, this may lead to operational difficulties and suboptimal utilization in the short-run, especially related to product yields. Once EU countries discontinue imports of Russian products, further market distortions and shortages in the downstream market could be the result, especially related to middle distillates.

At the same time, oil demand growth is expected to remain strong in the short- and medium-term putting additional pressure on the global refining system. While some relief should come from refining capacity additions, projections show a tightening downstream market, especially in the period 2023-2025 (see Section 5.2.3).

While this chapter provides medium- and long-term projections it also emphasizes various uncertainties related to the global downstream market. Given that uncertainties have increased significantly in 2022, projections are much more difficult than previously.

5.1.2 Base refinery capacity in 2021

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 2021.

The 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 nameplate level, where appropriate. Overall, it should be stated that no single data source for global and regional refinery capacities can 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, primary and secondary alike, as well as for new projects and closures.

Table 5.1 provides details by region and process on the 101.5 mb/d of assessed base refinery capacity (distillation) as of January 2022. This level represents a net reduction *versus* the 101.9 mb/d listed for January 2021 in the WOO 2021. As such, it constitutes the second year in a row of reduced refining capacity, an exception to the historical trend of global capacity increases y-o-y.

As was the case for 2020, the main contributor to the base capacity reduction, compared to the previous year, was the very high level of refinery closures that occurred during 2021. Again, these were mainly a consequence of the COVID-19 pandemic and the resulting historic drop in global liquids demand. Nearly 1.4 mb/d of refinery closures occurred in 2021 (see section 5.2.4). This was similar to the closures in 2020, but far above the average annual closures of around 0.6 mb/d that had occurred in the preceding five years. It also exceeded the 0.9 mb/d of new capacity that came online in

Table 5.1
Assessed available base capacity as of January 2022 *mb/d*

	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	World
Distillation									
Crude oil (atmospheric)	19.8	7.7	3.8	15.3	7.6	10.4	17.6	19.2	101.5
Vacuum	8.9	3.4	0.9	6.6	3.1	3.0	7.0	6.0	39.0
Upgrading									
Coking	2.8	0.8	0.1	0.8	0.5	0.4	2.2	1.1	8.9
Catalytic cracking	5.6	1.6	0.2	2.2	0.9	1.1	4.2	3.6	19.5
Hydro cracking	2.5	0.2	0.2	2.3	0.8	0.9	2.4	1.7	11.0
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	0.2	0.2	1.2
Octane units									
Reforming	3.7	0.6	0.5	2.4	0.8	1.4	2.2	3.0	14.6
Isomerization	0.8	0.1	0.1	0.6	0.3	0.5	0.2	0.4	3.0
Alkylation	1.2	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	3.0	1.0	2.1	2.3	3.2	17.5
Gasoline	2.8	0.5	0.1	0.7	0.3	0.4	1.5	1.4	7.7
Middle distillates	6.5	2.4	0.8	5.8	2.4	3.1	4.7	7.0	32.7
Heavy oil/Residual fuel	3.2	0.4	0.0	1.8	0.3	0.7	1.1	3.1	10.7
Sulphur (short tons/day)	42,306	7,242	3,757	19,912	7,818	14,318	20,558	39,453	155,364
Hydrogen (million scf/d)	6,370	1,221	397	5,011	2,033	3,281	6,701	6,465	31,480

Source: OPEC.

5

2021. Together, with minor adjustments to the base capacities of individual refineries, these factors led to a net assessed capacity of 101.5 mb/d at the start of 2022.

At the regional level, the US and Europe in 2021 each lost 0.4 mb/d of distillation capacity, Other Asia-Pacific lost 0.3 mb/d, whereas China and the Middle East were the regions where capacities increased. Other regions had very little, if any, capacity change in 2021.

The changes in regional capacity underlying Table 5.1 reflect the ongoing trend that has been evident for several years, namely the capacity shift from West to East. In the five years since January 2017, refinery distillation capacity has dropped by 0.5 mb/d in the US & Canada to just under 20 mb/d, resulting in a small decline in its associated percentage of global capacity, from 20.8% in 2017 to 19.5% in 2022. This shrinkage has occurred despite large increases in domestic crude and condensate production. In the same period, Europe's capacity has declined by 1.8 mb/d, with its global share dropping from 17.6% to 15.1%, mainly through ongoing rationalization that has more than offset limited additions. Conversely, capacity in the Russia & Caspian region has risen by 0.5 mb/d and Latin America and Africa have each registered small capacity declines over the same period.

Over the past five years, the Middle East and the Asia-Pacific have been at the centre of capacity additions. Combined, the two have recorded over 6.4 mb/d of refining capacity net additions to total over 47 mb/d in January 2022. This equates to 46.5% of the global total today, up from 41.9% (40.8 mb/d) in 2017. Moreover, this shift in capacity has occurred despite – and net of – some 0.7 mb/d of closures over the period in Other Asia-Pacific, primarily Japan, Australia and Singapore. In short, beneath a relatively stable global picture lie significant regional differences in refinery capacity trends.

Secondary capacity

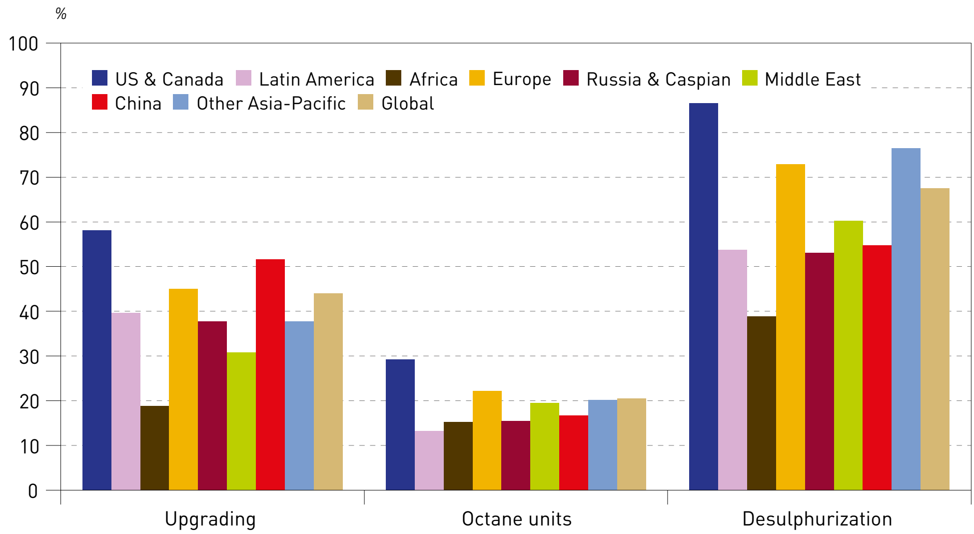
Today's refineries are increasingly complex with expanding secondary processing capacity per barrel of primary distillation capacity. This global trend is the result of a combination of the tendency to close older, simpler refineries; progressively add secondary processing at existing plants; and, generally, build new refineries at a high level of complexity from the outset. In the latter, the new refineries are increasingly designed to yield high outputs of petrochemical feedstocks.

The underlying drivers of these trends are the long-term shift towards incremental demand predominantly for light clean products, including petrochemicals, an associated steady decline in demand for residual fuel oil, and increasingly stringent fuel quality regulations. Together, these call for higher levels of upgrading, desulphurization, octane units and related supporting capacities, including hydrogen and sulphur recovery. Global vacuum distillation capacity currently stands at an average 38.4% of crude (atmospheric) distillation capacity, upgrading at 44%, gasoline octane units at 20.5% and desulphurization at 67.6%. 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 the variations in refinery complexity between regions. The US & Canada continue to hold the highest levels of upgrading, gasoline production and desulphurization relative to distillation, reflecting a traditionally very complex refining system. However, continued state-of-the-art refinery capacity additions, particularly in the Middle East and Asia, 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 greater than 58% of distillation capacity, followed by China at around 52% and Europe at 45%. All other regions show values in the 30–40% range, apart from Africa at 19%.

Figure 5.2
Secondary capacity relative to distillation capacity, January 2022



Source: OPEC.

5

In terms of upgrading, the distribution by type of unit varies significantly from region-to-region. The US & Canada, Latin America and China account for the highest levels of coking, around 25% of total upgrading in each region. They also account for two thirds of total global coking capacity. The same regions, plus Other Asia-Pacific, have the highest proportions of catalytic cracking at around 50%. All regions other than Latin America show significant proportions (22–33%) of hydrocracking in total upgrading. The distribution of mild upgrading, notably visbreaking, varies widely with significant proportions only in Africa, Europe, Russia & Caspian and the Middle East.

For octane units, the US & Canada is an outlier at over 29% of distillation capacity, which is in line with the region's exceptionally high gasoline consumption. Europe is at around 22%, illustrating the presence of installed gasoline capacity before the continent's dieselization shift that led to a gasoline surplus. At 20%, levels in the Middle East and Other Asia-Pacific are close to those in Europe, while the remaining regions – Latin America, Africa, Russian & Caspian and China – exhibit lower proportions of octane units, in the range of 13–17%.

Desulphurization levels vary widely across regions depending on their fuel standards and crude slates. The highest share of desulphurization is seen in the US & Canada at

87%, which is more than double that of the lowest region, Africa, at 39%. Refineries in the US & Canada have traditionally processed a large proportion of heavy and medium-sour crudes, mainly imported from other regions, such as Latin America and the Middle East. Related capacity, notably coking and desulphurization, nonetheless, remains in place.

Europe and Other Asia-Pacific, which includes countries such as Japan and South Korea that possess substantial amounts of residual desulphurization, also have relatively high proportions of desulphurization capacity, at 73% and 76%, respectively. The Middle East is at 60%, while in the remaining regions – Latin America, Russia & Caspian and China – the level is in the 53–55% 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 Europe, as is the case in the US & Canada, the high desulphurization ratio reflects the long-established implementation of ULS fuel standards. In Other Asia-Pacific and the Middle East, the high rising levels reflect a strong movement to ULS standards, plus a situation where large new refineries are today invariably built for elevated levels of clean fuel output to ULS standards. The same trend is under way in China.

With the continuing progressive adoption of the Euro 4/5/6 standards, reinforced by the IMO 2020 Sulphur Rule, which has been met only partially by the use of scrubbers, the trend towards higher desulphurization levels can be assumed to continue.

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

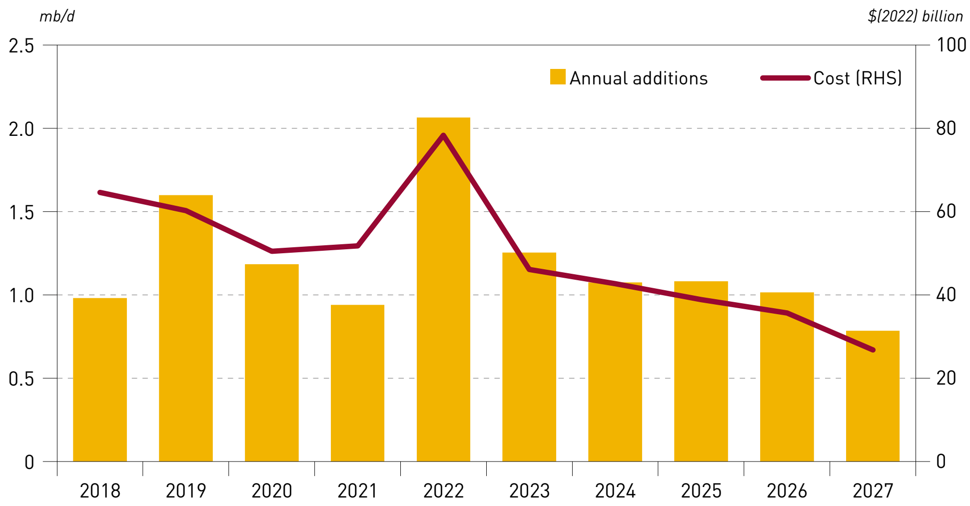
This section focuses on a review of medium-term (2022–2027) refinery capacity additions based on a careful review of announced refinery projects. It takes into account refinery projects under construction, as well as other advanced projects that are likely to come online by 2027.

The Reference Case sees refining capacity additions of around 7.3 mb/d in the medium-term. This is slightly higher relative to last year's outlook, but it includes delayed projects, such as the start-up of the Al-Zour refinery in Kuwait in 2022, originally scheduled to be online during 2021. It should be noted that this projection does not include so-called 'creep' capacity, which is aimed at refinery debottlenecking at existing refineries and is continuously added.

Similar to previous outlooks, the largest share of the capacity additions is expected in developing countries in the Asia-Pacific, Middle East and Africa. The major driver is demand growth in these regions. This year's outlook sees an increasing number of potential refinery projects, reflecting the rising certainty of investors after the demand shock caused by the COVID-19 pandemic. In addition, the current market tightness combined with record high product refinery margins is also supporting new FID.

Figure 5.3 shows annual global capacity additions, averaging around 1.2 mb/d between 2022 and 2027, which is slightly higher relative to the WOO 2021. In 2022, more than 2 mb/d of new capacity is expected to come online, including the delayed Al-Zour refinery in Kuwait (nameplate capacity of 615,000 b/d). From 2023 onwards, the rate of additions is set to decline to around 1 mb/d. At the end of the medium-term, in 2027, the addition rate is projected at 0.8 mb/d. Figure 5.3 also shows the expected investment volume related to new refining projects.

Figure 5.3
Annual distillation capacity additions and total projects investment



Source: OPEC.

As always, the uncertainty in the downstream sector remains high. This relates especially to the start-up of new plants and potential delays. Recent years have shown that many projects tend to be postponed for various reasons, including financing, technical issues, market uncertainties, delays related to the pandemic and subsequent lockdowns, and supply chain delays. Although this is generally a conservative Reference Case outlook, unforeseen delays are possible, thus potentitally pushing back some projects.

Table 5.2 and Figure 5.4 illustrate medium-term refinery additions by region. Nearly 90% of capacity (6.4 mb/d) is expected to come online in the Middle East, the Asia-Pacific and Africa, driven mostly by demand trends in these regions. The remaining medium-term capacity additions of around 0.9 mb/d is distributed across developed regions and accounts not only for new refineries, but also for capacity expansions at existing refineries. Europe is the only region where distillation capacity expansions are virtually zero, in line with expected oil demand developments in the medium- and long-term.

Some regions like Africa are heavily dependent on refined product imports, and this dependency has been rising, so new projects could help to reduce product imports. In the Middle East, the effort to increase refined product at the cost of crude exports is an important driver of capacity expansion.

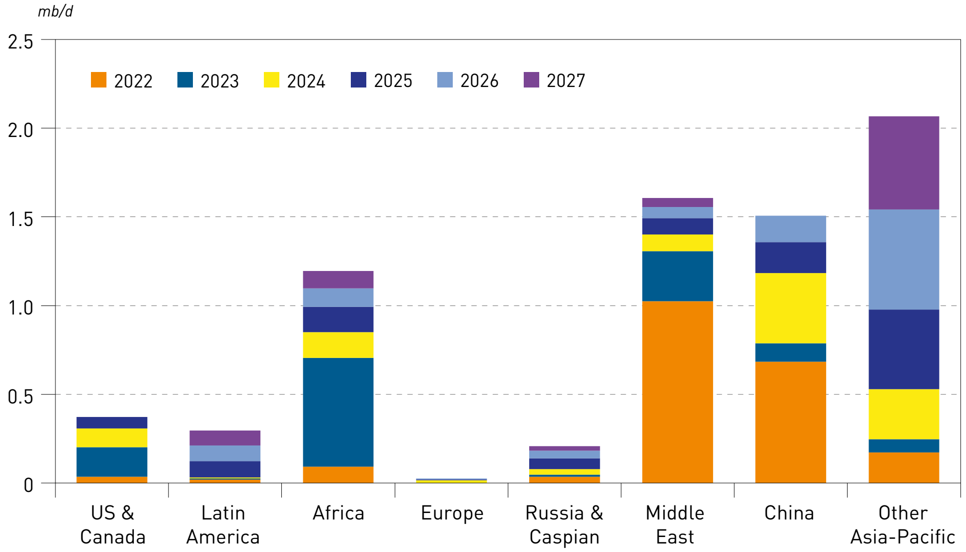
Table 5.2
Medium-term distillation capacity additions from existing projects by region *mb/d*

	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia Pacific	World
2022	0.0	0.0	0.1	0.0	0.0	1.0	0.7	0.2	2.1
2023	0.2	0.0	0.6	0.0	0.0	0.3	0.1	0.1	1.3
2024	0.1	0.0	0.1	0.0	0.0	0.1	0.4	0.3	1.1
2025	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.4	1.1
2026	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.6	1.0
2027	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.5	0.8
2022–2027	**0.4**	**0.3**	**1.2**	**0.0**	**0.2**	**1.6**	**1.5**	**2.1**	**7.3**
Share	*5.1%*	*4.1%*	*16.4%*	*0.4%*	*2.9%*	*22.1%*	*20.7%*	*28.4%*	*100.0%*

Source: OPEC.

Other Asia-Pacific is the region with the largest expected medium-term additions that reach almost 2.1 mb/d. This includes several medium-sized units in India, some of which are expansions of existing refineries. All major Indian oil companies are expected to expand their capacities, including IOC, HPCL, BPCL and Reliance. Several other refinery projects are located in other countries of the region, such as Indonesia, Vietnam, Thailand, Brunei and Bangladesh. Nevertheless, many of these projects are not yet under construction and this Outlook maintains a relatively low probability for their completion in the medium-term.

Figure 5.4
Medium-term distillation capacity additions from existing projects



Source: OPEC.

China alone is expected to increase its refining capacity by around 1.5 mb/d between 2022 and 2027, dominated by several large projects. This includes two large projects scheduled to come online this year – Jieyang (400 tb/d) and Lianyungang (320 tb/d). Furthermore, in 2024, the 400 tb/d Yulong refinery and 240 tb/d Zhenhai plants are expected to be finalized. However, the addition of the aforementioned Yulong refinery will replace some of the closures related to China's teapot plants. Total closures of teapot plants between 2020 and 2022 are estimated at around 700 tb/d.

Within the medium-term period, Middle East distillation capacity is set to expand by around 1.6 mb/d, supported not only by regional demand growth, but also efforts to increase refined product exports to international markets. The largest single project is the Al-Zour refinery in Kuwait, now scheduled to come online in 2022. In Iraq, several refineries are expected to start operating within the medium-term period, including Karbala and Kirkuk refineries (around 150 tb/d each) and several smaller additions. In Oman, the Duqm 230 tb/d refinery is projected to start operating towards the end of 2022 or in early 2023. Other countries in the region such as Bahrain, IR Iran, Saudi Arabia and the UAE are expected to see additional crude distillation or condensate splitter capacities in the medium-term.

In Africa, medium-term distillation additions are estimated at around 1.2 mb/d. More than a half of this number is accounted for by Nigeria's Dangote refinery (650 tb/d). According to recent reports, its commissioning is likely to be delayed from 2022 to 2023, partly due to financial issues. Furthermore, Nigeria is likely to see the addition of a number of small modular refineries with capacities of up to 20 tb/d over the medium-term, thus adding much needed capacity in the country. Elsewhere, a new 100 tb/d refinery is likely to be built in Soyo, Angola in 2025. In North Africa, a modest expansion is expected in Algeria (Hassi Messaoud) and Egypt (Midor and Assiut). Finally, several sub-Saharan countries, including Ghana, Guinea, Senegal and the Republic of the Congo are expected to commission new units, most of which are modular. With these expansions, the region will look to address fast growing demand, but it could also potentially reduce product imports from other regions.

In Latin America, the expected medium-term refinery capacity expansion is around 300 tb/d with one major project – Dos Bocas in Mexico. This project was officially inaugurated earlier this year following significant cost overruns. Nevertheless, the refinery is still not fully operational and commercial start-up is not likely to occur before 2024/25. In addition, minor expansions are expected in Peru and Chile between 2022 and 2027.

In the US & Canada, the medium-term distillation expansion is estimated at almost 300 tb/d. Exxon's Beaumont refinery (250 tb/d) is by far the largest project and is expected to start-up in 2023. In addition, there are several smaller projects, albeit mostly expansions of primary capacity at existing refineries. No new projects are expected in Canada.

In Europe, except for a minor distillation project in Turkey of around 30 tb/d, there are no expected medium-term projects. This is in line with the expectation of a peak in oil demand in the coming years that, in turn, could lead to further capacity closures or conversions.

It is important to emphasize that OPEC's Reference Case with 7.3 mb/d of new capacity additions between 2022 and 2027 consists of projects identified from a list of announced projects that total close to 25 mb/d. However, only a limited part of these announced projects can materialize in the medium-term. Furthermore, the total medium-term capacity additions of 7.3 mb/d are composed of projects in different stages of development. Around 3.3 mb/d of capacity is under construction or close to this stage; hence, these are the projects with the highest certainty to materialize in the medium-term. However, despite the conservative approach when assessing possible commissioning dates, it is possible that some of the projects are delayed for technical and/or financial reasons, as has been the case with several large projects in recent years. The remaining projects are mostly in the early stages of development, but still advanced enough in terms of financing and engineering to be considered 'firm' medium-term Reference Case capacity additions. Nevertheless, the uncertainty surrounding these projects is high with a potential risk that some of the projects only start beyond the medium-term horizon, or get cancelled for various reasons.

5.2.2 Long-term distillation capacity additions

This section focuses on long-term global and regional refining capacity additions. It takes into account Reference Case assumptions on global and regional oil demand (Chapter 3) and oil supply (Chapter 4), as well as medium-term refinery capacity additions (Section 5.2.1) and announced refinery closures (Section 5.2.5). Table 5.3 shows the assessed medium-term projects as already discussed and projected additions beyond the medium-term based on long-term downstream sector modelling.

As shown in Table 5.3, in addition to 7.3 mb/d of assessed projects in the medium-term, around 8.3 mb/d of generic projects will be needed at the global level between 2028 and 2045. These capacities are not linked to any specific projects, but are modelled as required capacities to meet demand for refined products. Capacity additions beyond

Table 5.3
Refinery distillation capacity additions by period *mb/d*

	Distillation capacity additions starting 2022			
	Assessed projects*	New units	Total	Annualized
2022–2025	5.5	0.2	5.7	1.4
2025–2030	1.8	2.5	4.3	0.9
2030–2035	0.0	2.9	2.9	0.6
2035–2040	0.0	1.9	1.9	0.4
2040–2045	0.0	0.7	0.7	0.1
	Cumulative distillation capacity additions			
	Assessed projects*	New units	Total	Annualized
2022–2025	5.5	0.2	5.7	1.4
2022–2030	7.3	2.8	10.0	1.1
2022–2035	7.3	5.6	12.9	0.9
2022–2040	7.3	7.6	14.8	0.8
2022–2045	7.3	8.3	15.5	0.6

* *Firm projects exclude additions resulting from capacity creep.*
Source: OPEC.

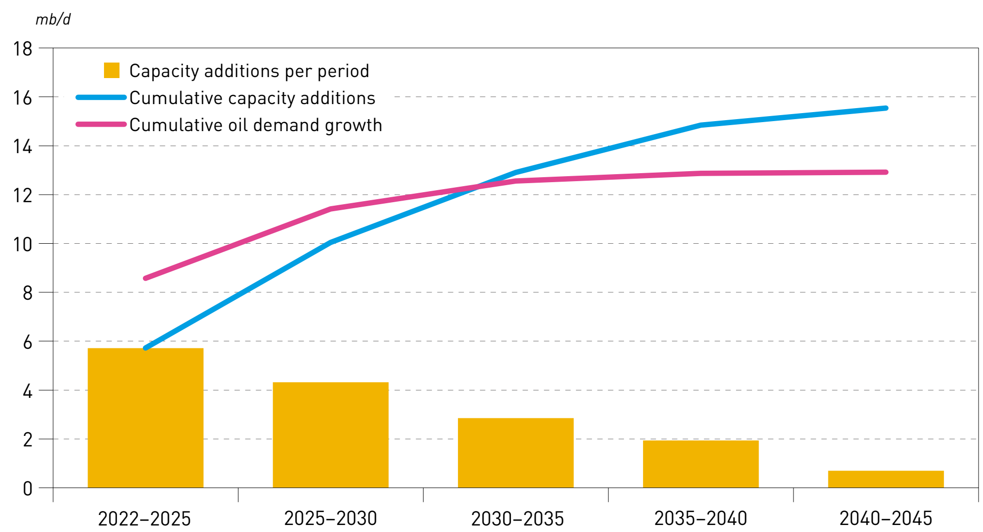
2028 also include debottlenecking additions, which are estimated at around 0.65 mb/d by 2045 and are distributed across all regions. As a result, total distillation capacity additions between 2022 and 2045 are projected at 15.5 mb/d. This is somewhat higher relative to the WOO 2021. It is driven by the upward oil demand revision, as well as the higher-than-expected refinery closures, which calls for further capacity additions in demand growth regions.

Nevertheless, the major downstream market trends remain unchanged. The rate of capacity additions is set to decline gradually. Between 2022 and 2025 around 5.7 mb/d (1.4 mb/d on an annualized basis) of new capacity is expected, followed by 4.3 mb/d (0.9 mb/d on an annualized basis) for the period 2025–2030. In the longer-term, the rate declines further with only 0.7 mb/d (0.1 mb/d on an annualized basis) of new capacity added in the period 2040–2045.

Figure 5.5 shows cumulative oil demand growth between 2021 and 2045 compared with refinery capacity additions between 2022 and 2045. It is important to mention that oil demand growth in this figure also includes demand for non-refinery products, such as NGLs, biofuels, CTLs and GTLs. The base year for this comparison is 2021 for oil demand and 2022 for refinery capacity additions. There are two distinct periods in this figure. In the period to 2030, oil demand grows faster relative to capacity additions. This is especially true for the period to 2025. While oil demand growth increases by 8.6 mb/d, refining capacity additions expand by 5.7 mb/d. The strong demand growth is partly driven by the post-COVID recovery as explained in Chapter 3.

However, as demand growth slows, it falls below cumulative refining capacity additions from 2035 onwards. In total, oil demand is expected to increase by 12.9 mb/d between 2021 and 2045, which compares to 15.5 mb/d of new refining capacity for the period 2022–2045. However, a large part of oil demand growth will be met by non-refinery

Figure 5.5
Distillation capacity additions and oil demand growth, 2022–2045



Source: OPEC.

fuels, especially in the petrochemical sector. This is why global refinery utilization rates are expected to decline from a peak of 81.6% in 2025 to just above 75% in 2045.

As already noted, oil demand growth is not equally distributed, with a concentration in developing regions, such as the Asia-Pacific, Africa and the Middle East. At the same time, developed regions such as Europe, US & Canada and developed Asian countries are likely to see a significant drop in long-term oil demand. All this has significant implications on regional refining utilization rates (see Section 5.2.3).

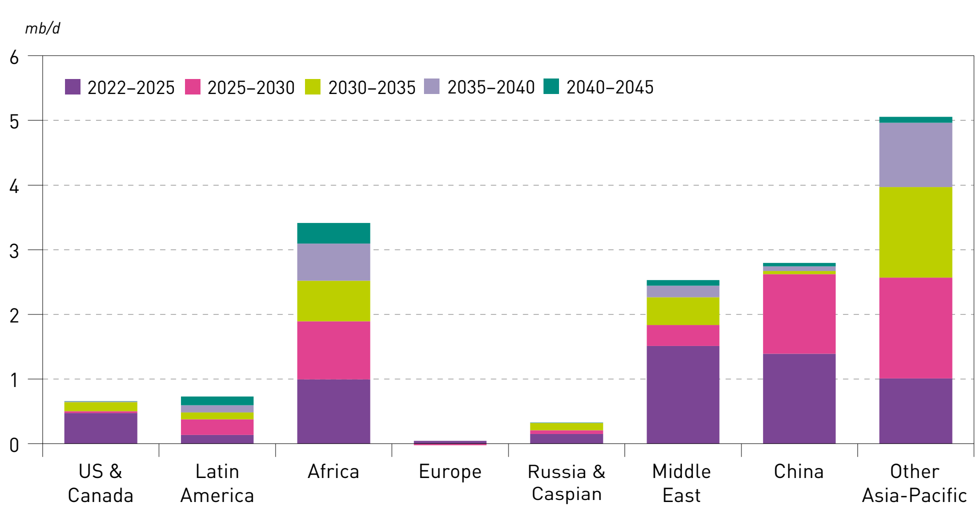
Regional additions

As mentioned, the Reference Case projects global refinery capacity additions of 15.5 mb/d between 2022 and 2045. The regional distribution of long-term refinery capacity additions is similar to medium-term trends. This means that the vast majority of long-term additions are located in developing countries in the Asia-Pacific, the Middle East and Africa. These regions are expected to see capacity additions of 13.8 mb/d, which is 89% of the total long-term additions.

Other Asia-Pacific (excluding China) is set to add around 5.1 mb/d between 2022 and 2045, supported by strong demand growth. The majority of the additions are likely to come before 2035, with a significant slowdown thereafter. After 2040, only minor additions are expected. The largest share of these additions will likely be located in India, with expected demand growth of 6.3 mb/d in the outlook period.

In China, modelling results show a total distillation capacity addition of 2.8 mb/d between 2022 and 2045. In line with an expected demand growth slowdown, the majority of the additions are expected in the period to 2030, totalling around 2.6 mb/d. Beyond 2030, refinery additions in China are limited to a total of around 0.2 mb/d. As already highlighted, some of the medium-term additions are in fact a replacement for closures of old and inefficient teapot refineries in the period 2020–2022.

Figure 5.6
Crude distillation capacity additions, 2022–2045



Source: OPEC.

In the Middle East, total distillation capacity expansion is projected at around 2.5 mb/d, and of this, 1.5 mb/d is already set to be commissioned by 2025. Additions beyond 2025 are in line with demand growth and the additional call-on-refining in several countries of the region. Similar to the Asia-Pacific, additions are minimal beyond 2035. Beyond the projected additions, further projects with a focus on product exports are possible.

In Africa, total required long-term capacity additions are estimated at 3.4 mb/d driven by the region's strong demand growth. These additions would help not only to cover demand growth, but also to reduce product imports in some countries. Continuous competition with product inflows from other markets and problems related to project financing and finalization remain the main challenges for the continent in building the required capacity on time. Any delays and/or cancellations would necessarily lead to higher product imports relative to the Reference Case.

In Latin America, capacity additions are projected at around 0.75 mb/d. The relatively limited level of additions is linked to the low utilization of existing capacity, part of which could be refurbished in the medium- and long-term. Furthermore, the proximity of the US with its competitive refining system and increasing long-term product exports is another hurdle for capacity expansions in the region.

Long-term capacity expansions in other regions (Russia & Caspian, US & Canada and Europe) are minor and mostly related to the expansion of existing plants (including debottlenecking additions). This is due to peaking oil demand in these regions and potentially lower product exports, which should lead to lower utilization rates and potentially further closures in the long-term.

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 subsections – the medium-term and long-term – which follow two different methodologies.

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 2021. The call-on-refining is based on oil demand growth and also considers the demand for non-refinery fuels such as NGLs, CTLs, GTLs and biofuels. The long-term outlook looks at modelling results over the period 2025–2045 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 discussed in Section 5.2.1, medium-term distillation capacity additions are projected at 7.3 mb/d globally. On top of these additions, modelling results suggest 'creep' capacity additions of around 0.25 mb/d by 2027, mostly in the US & Canada due to the large base of existing refineries.

Consequently, total distillation capacity additions between 2022 and 2027 are estimated at around 7.5 mb/d. As per the methodology applied, assumed refinery closures in the medium-term are not taken into account at this stage, but are discussed later.

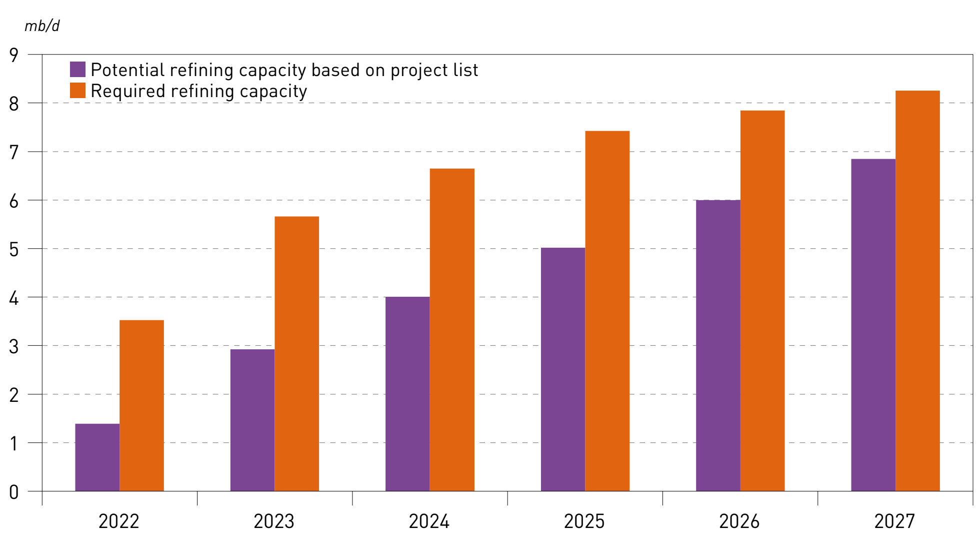
The methodology also assumes that new refining capacities may reach the maximum assumed utilization rate of 90% throughout the year. Consequently, this provides insight into the potential incremental crude runs or potential refining capacity between 2022 and 2027. Furthermore, as this outlook is done on an annual basis, this methodology tries to capture uncertainties related to the start-up 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 expected to reach levels of around 6.8 mb/d by 2027, relative to 2021.

In the following step, the cumulative required incremental crude runs 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 (e.g. NGLs used directly in the petrochemical industry), 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. 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 2021. This is a good indicator of the state of the downstream sector 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 in comparison to the required incremental product supply from refineries relative to 2021. Potential cumulative refining capacity is expected to increase gradually to around 6.8 mb/d in 2027. At the

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.

same time, the required refining capacity is increasing strongly, partly due to the post-pandemic recovery. Relative to 2021, the incremental required refining capacity is projected at 8.25 mb/d by 2027. The resulting difference is a clear indication of the downstream market tightness.

The gap between required and potential refining capacity is the highest in 2022/2023, at around 2.6 mb/d. It then declines to around 1.4 mb/d by 2027 due to demand growth slowdown. This means relative to 2021, the downstream market is expected to become tighter in the early years of the medium-term with rising refinery utilization rates. As the gap narrows, the downstream market should become less tight, albeit still considerably tighter relative to 2021. However, given possible refinery project delays, the gap between the potential and required refining capacity could be higher in the later years of the medium-term. It is important to note that this analysis does not consider announced refinery closures between 2022 and 2027. If these closures go ahead as announced/planned, the downstream market may be even tighter than that shown in Figure 5.7. Furthermore, this analysis does not consider any market distortions, such as the announced EU embargo on Russian crude oil imports from early 2023. These will be discussed separately.

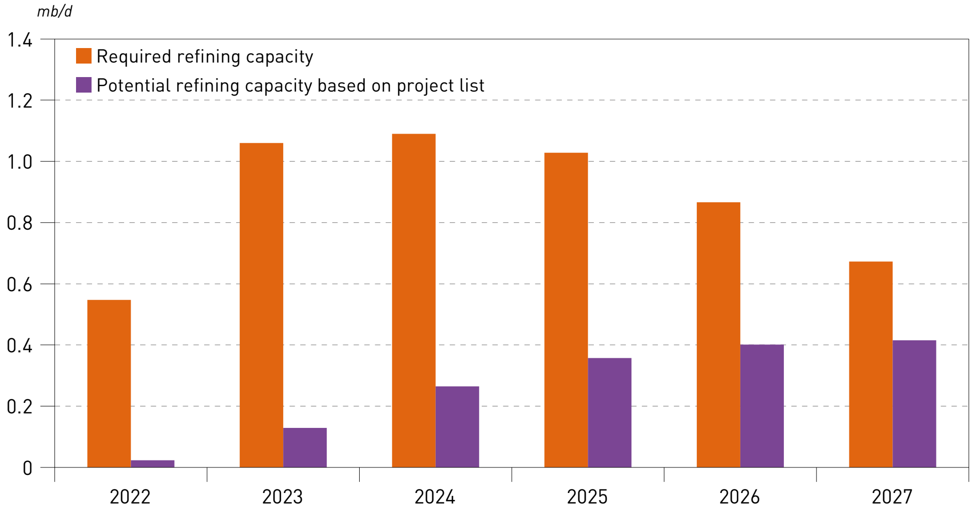
As already emphasized, Figure 5.7 provides the medium-term outlook for the global downstream market balance. However, given the different trends in oil demand growth and capacity additions, there is a wide range of regional patterns. These are discussed in the following section.

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 period 2022–2027.

Figure 5.8 shows the medium-term balance for the US & Canada. Increasing oil demand (relative to 2021) in the initial years leads to a rise in the required refining capacity that

Figure 5.8
Additional cumulative crude runs in US & Canada, potential and required

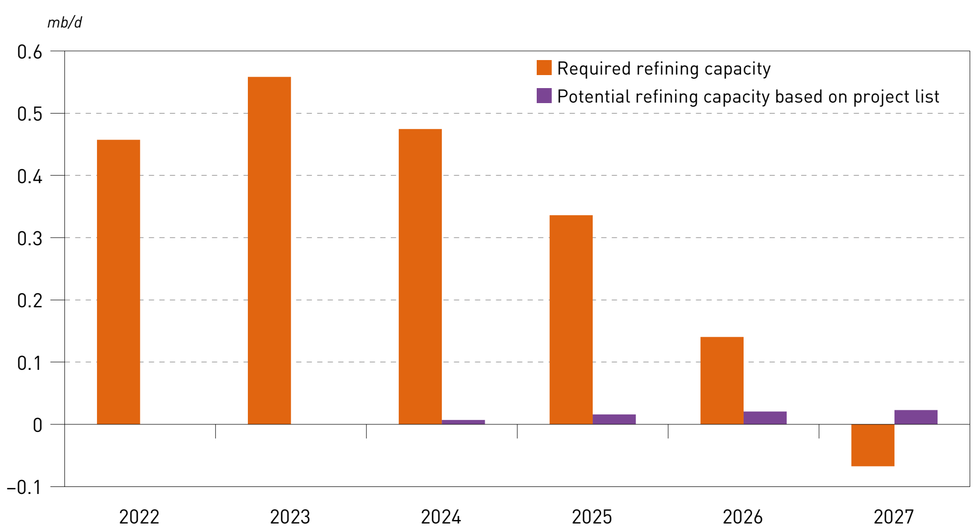


Source: OPEC.

climbs to around 1.1 mb/d in 2024. However, as demand reaches its peak, the required refining capacity declines to around 0.7 mb/d by 2027. At the same time, the potential refining capacity increases only gradually, hitting around 0.4 mb/d in 2027. The gap between the required and potential incremental capacity reaches its peak in 2023/24 at between 0.8 and 0.9 mb/d, after which it declines to around 0.25 mb/d in 2027. This points to an increasingly tight market in the short-term and a possible relaxation of this thereafter.

Europe shows a similar trend to the US & Canada as seen in Figure 5.9. In the short-term, rising demand in its post-pandemic recovery leads to higher required refining capacity, estimated at around 0.55 mb/d in 2023. However, as demand peaks and starts to decline, the required refining capacity drops to around –0.1 mb/d in 2027. At the same time, the potential refining capacity remains close to zero, as there are almost no expansions in this region except for one minor unit. Consequently, the downstream market is expected to become tighter in the short-term. As this analysis is based only on the incremental required and potential capacity relative to the base year, the potential effects of the EU embargo on Russian crude imports are not included.

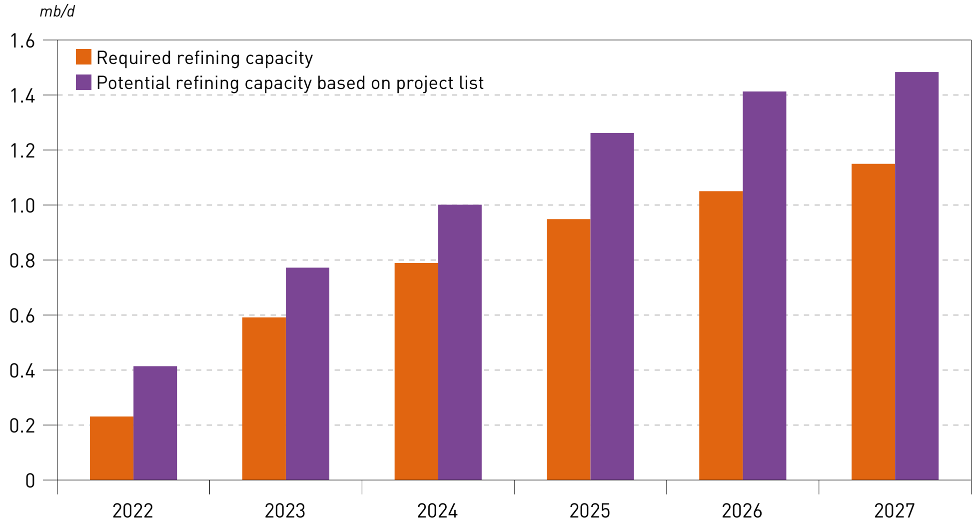
Figure 5.9
Additional cumulative crude runs in Europe, potential and required



Source: OPEC.

In China (Figure 5.10), the required refining capacity increases from around 0.2 mb/d in 2022 to 1.15 mb/d in 2027. This compares to a faster expansion of potential refining capacity, which increases from 0.4 mb/d to almost 1.5 mb/d over the same period. Consequently, the potential refining capacity shows a surplus of around 0.3 mb/d throughout the assessment period. However, it is important to note that part of the potential refining capacity increment is the 400 tb/d Yulong refinery, which is a replacement for the closure of several smaller teapot plants. If closures are taken into account, the gap between the potential and required refining capacity is minimal, thus pointing at a balanced medium-term market.

Figure 5.10
Additional cumulative crude runs in China, potential and required



Source: OPEC.

In the Asia-Pacific (excl. China), as shown in Figure 5.11, strong demand growth relative to 2021 sees required refining capacity increasing to 3 mb/d by 2027. However, the incremental potential refining capacity increases 'only' to around 1.7 mb/d over the same period. As a result, the gap between the required and potential refining capacity remains wide, peaking at around 1.8 mb/d in 2024, before gradually narrowing to 1.3 mb/d in 2027. Consequently, the Asia-Pacific (excl. China) is likely to see a significant tightening of the downstream market with rising utilization rates and possible rising product imports from other regions, such as the Middle East.

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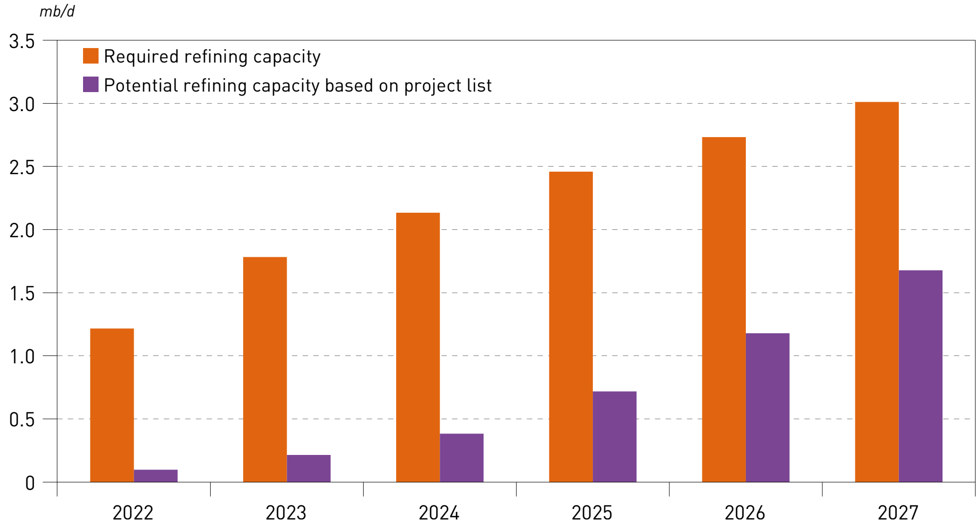
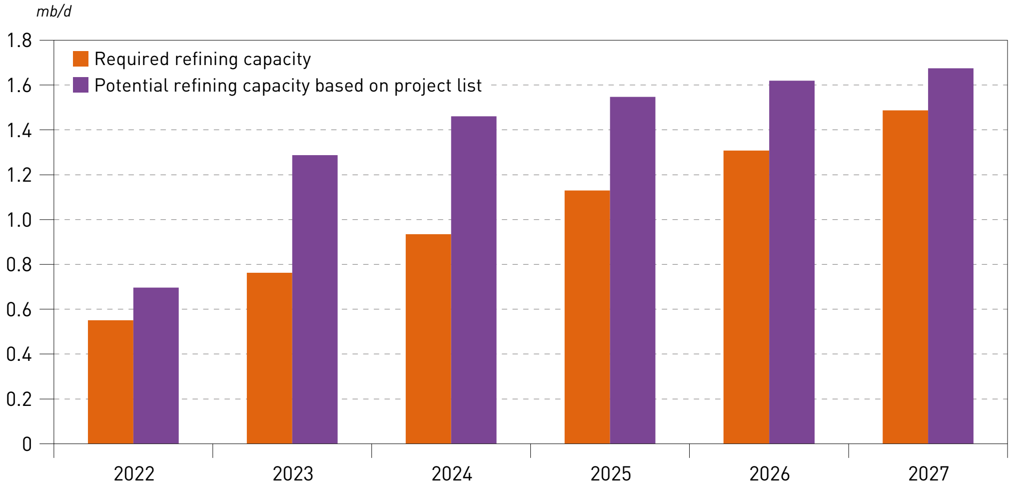
Figure 5.11
Additional cumulative crude runs in Asia-Pacific (excl. China), potential and required



Source: OPEC.

In the Middle East (Figure 5.12), the potential refining capacity is set to increase from 0.7 mb/d in 2022 to almost 1.7 mb/d in 2027, based on the significant additions described earlier. Required refining capacity increases from 0.55 mb/d in 2022 to 1.5 mb/d in 2027, thus remaining below the potential refining capacity. The surplus of potential refining capacity could lead to rising refined product exports in the short- and medium-term, mostly to the Asia-Pacific and Europe, where a tight downstream market is expected.

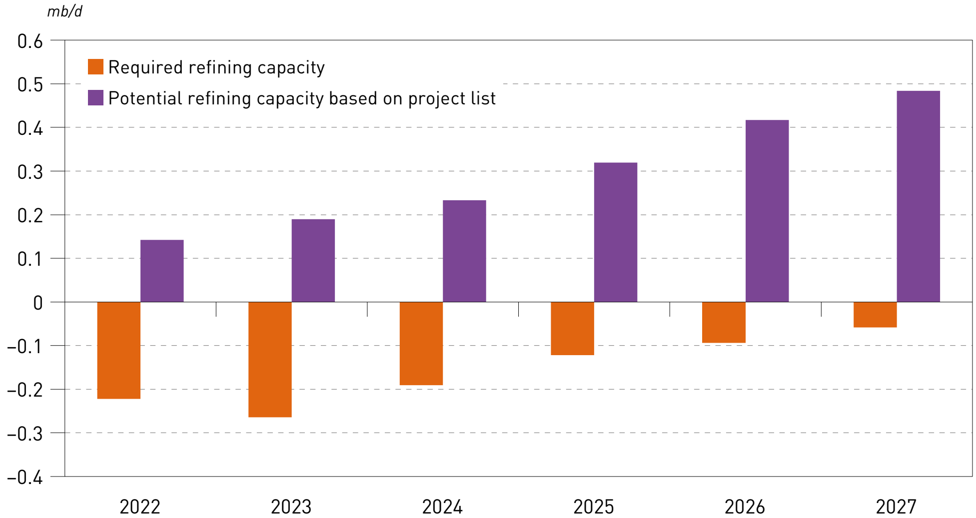
Figure 5.12
Additional cumulative crude runs in the Middle East, potential and required



Source: OPEC.

In the Russia & Caspian region, as shown in Figure 5.13, the potential refining capacity increases only marginally, reaching levels around 0.25 mb/d by 2027. Required refining capacity remains negative throughout the period, relative to 2021. This is based on the assumption that there are no significant changes in medium-term trade

Figure 5.13
Additional cumulative crude runs in the Russia & Caspian, potential and required

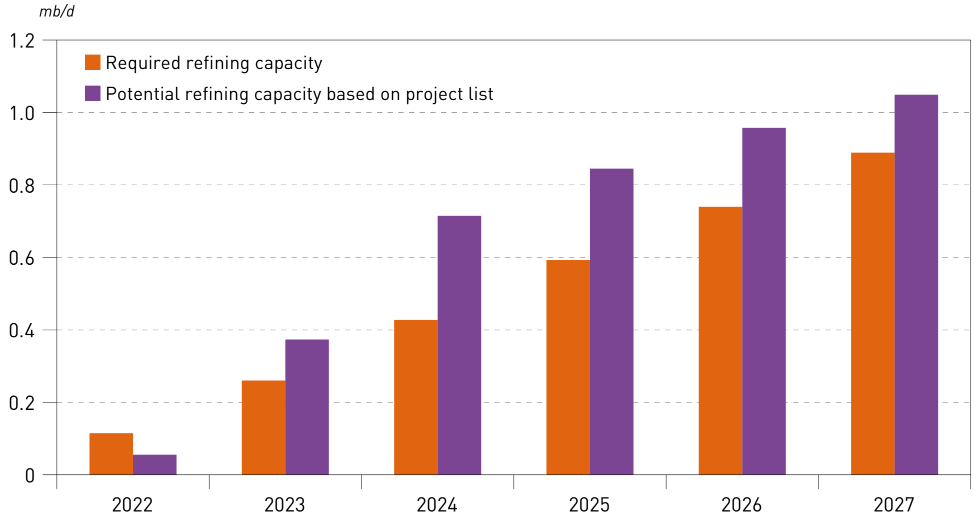


Source: OPEC.

patterns. However, as Russia has been a large product exporter, especially to the EU, the recently announced sanctions could impact the 'call-on-refining' in the Russia & Caspian region, adding significant challenges and uncertainties to this outlook.

In Africa (Figure 5.14), the potential cumulative refining capacity increases to above 1 mb/d by 2027, mostly due to announced expansions in West Africa, such as Dangote in Nigeria. The required refining capacity increases to almost 0.9 mb/d in 2027. If all refining capacity additions occur as assumed, the surplus of potential refining capacity relative to the required refining capacity is at its highest in 2024, at around 0.3 mb/d. It then drops to 0.15 mb/d at the end of the assessment period. Consequently, refinery additions will be able to cover the demand increase between 2021 and 2027. The surplus of potential refining capacity will help to reduce refined product imports from other regions.

Figure 5.14
Additional cumulative crude runs in Africa, potential and required

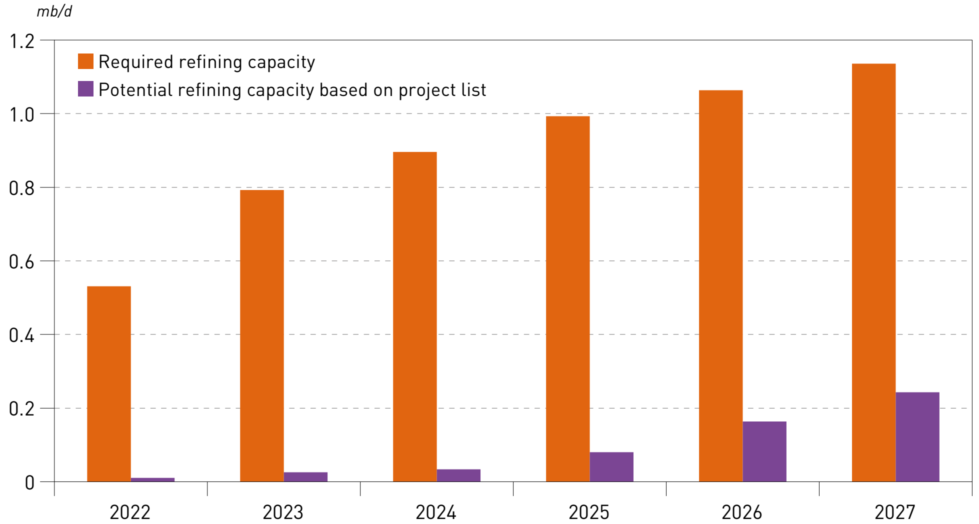


Source: OPEC.

In Latin America, as shown in Figure 5.15, cumulative potential refining capacity is set to increase only modestly, reaching levels around 0.25 mb/d in 2027. Cumulative required refining capacity is expected to increase to 1.15 mb/d by the end of the medium-term period. This means that the gap between required and potential refining capacity widens from around 0.5 mb/d in 2022 to 0.9 mb/d from 2025 onwards. The widening gap will potentially lead to the higher utilization of existing capacity, which was assessed at only 56% in 2021 and/or higher imports, especially from the US.

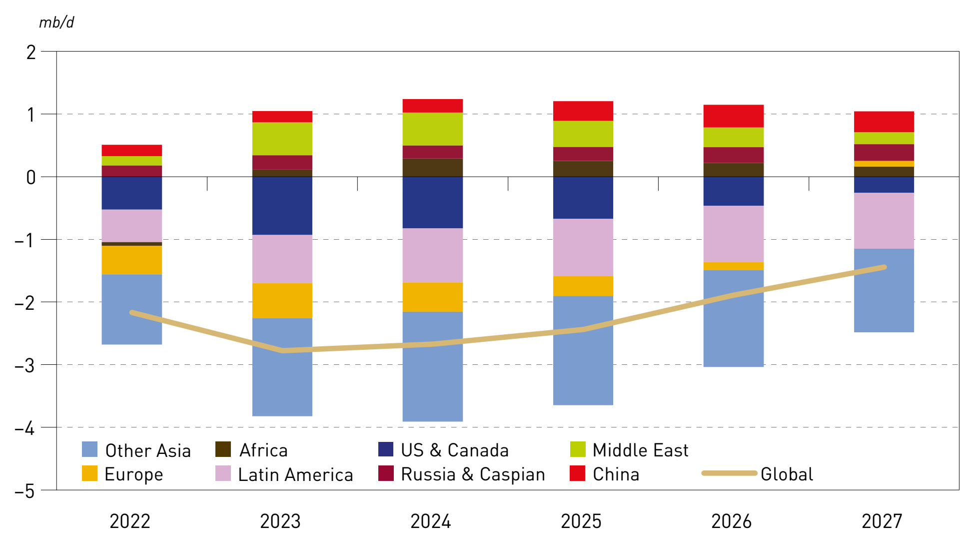
In summary, Figure 5.16 illustrates the cumulative medium-term gap between the incremental potential and required refining capacity for all major regions, as already discussed. As this outlook takes 2021 as the base year, the overall balance is negative throughout the assessment period meaning there is a deficit of potential refining capacity *versus* the requirement. This is mostly due to strong demand growth, part of which is post-pandemic recovery, especially in the short-term. This means the gap is at its widest in the period 2022–2025, where it varies between 2.2 mb/d and 2.8 mb/d. As demand growth slows towards the end of the medium-term and refinery capacity additions continue at higher rates, the gap drops to around 1.4 mb/d by 2027.

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.

It is important to note that in the medium-term period this balance does not include any assumed refinery closures. These closures are estimated at around 2.6 mb/d between 2022 and 2027, of which around 2 mb/d of capacity is likely to be closed already by the end of 2023. If all these closures materialize as expected, the market deficit by the end of the period would be even more pronounced. The implications for global utilization rates, which also includes assumptions on refinery closures are discussed later.

The largest deficit is expected in Other Asia-Pacific and Latin America. The US & Canada and Europe also show large deficits in the early medium-term years, but are projected to decrease later due to a peak and then a decline in oil demand. Several regions show a surplus of cumulative potential refining capacity, including China, Middle East and Africa and the Russia & Caspian.

Medium-term refinery utilization and throughputs outlook

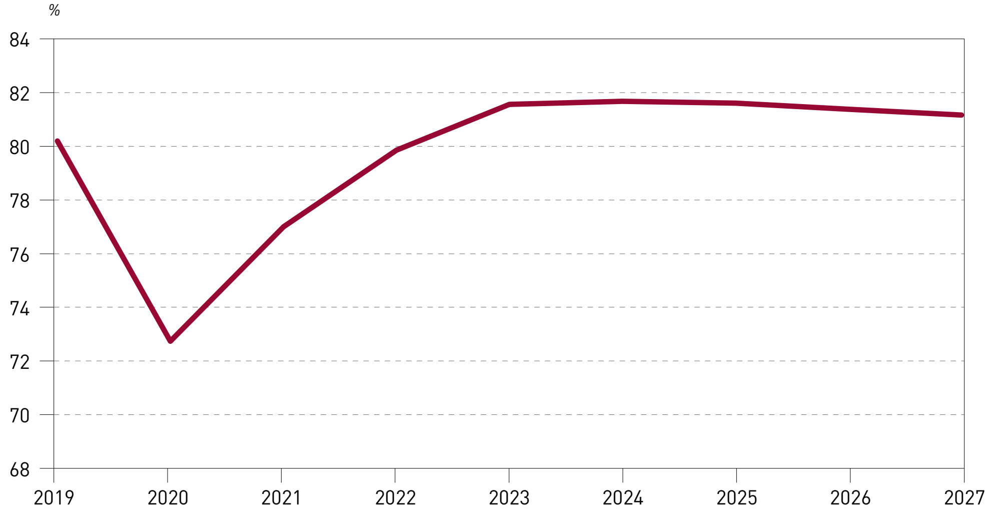
This section focuses on projected global refinery utilization rates based on assumed demand growth, refinery capacity expansions and estimated medium-term refinery closures. Furthermore, it shows the estimated crude runs, the effects of the historical and assumed closures and the so-called spare refining capacity for the medium-term.

Figure 5.17 presents global refining utilization rates between 2019 and 2027. During 2019, the global utilization rate averaged around 80.2%, which was followed by a significant drop to below 73% in 2020 due to the demand decline caused by the impact of the pandemic and related measures. The utilization rate recovered in 2021 to a level around 77%, supported by recovering demand, as well as refinery closures, some of which were the direct consequence of the pandemic. Nonetheless, the global utilization rate was still significantly lower relative to pre-pandemic levels.

During 2022, global utilization rates are expected to reach average levels of close to 80%, similar to 2019 rates. In the medium-term, rates are set to increase further, supported by continuous demand growth and additional closures to reach rates above 81.5% in 2023 and 2024. Thereafter, utilization rates are likely to decline towards 81%, in line with continued refinery additions and a slowdown in demand growth.

It is important to note that these utilization rates are calculated based on what is the assumed nominal refining capacity. However, given that refining capacities in several

Figure 5.17
Historical and projected global refinery utilization, 2019–2027



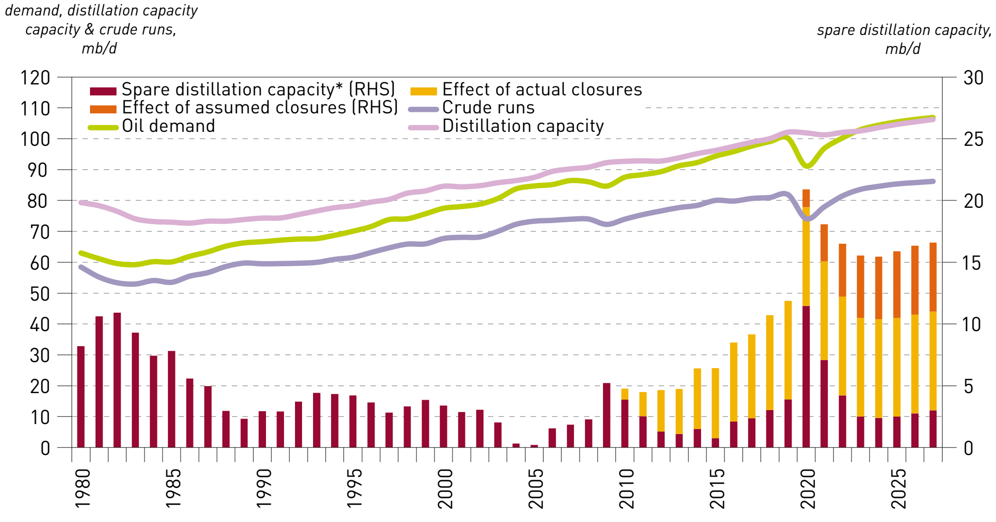
Source: OPEC.

developing countries are officially reported as available, but are practically not used, the real utilization rate could be even higher. Further upside pressure comes from the EU embargo on Russian crude and product imports expected from early 2023. Lower product imports from Russia could lead to lower utilization rates in this country, thus effectively reducing the available refining capacity, and impacting the global downstream market. Russia's throughput declined by some 0.6 mb/d in the period March–May 2022, and was around 10% lower than the respective period last year. Furthermore, EU refiners have already started replacing Russian crude with alternatives from elsewhere. In the short-term, however, the replacement of Russian crude could lead to sub-optimal operational patterns, negatively affecting the availability of refinery capacity in the EU.

Figure 5.18 highlights the evolution of oil demand, crude oil throughputs and nominal distillation capacity at the global level. The long-term trend shows a gradual convergence of oil demand and nominal distillation capacity. This is due to the increasing share of demand attributed to non-refinery fuels, such as NGLs, biofuels, CTLs and GTLs, which has reduced the share of refinery products in total oil demand. This has kept the refining capacity additions lower relative to oil demand increments.

In the medium-term, global refinery runs are set to come close to pre-pandemic levels in 2022 and are expected to continue increasing to levels around 86 mb/d at the end of the medium-term period. Figure 5.18 also shows the impact on the available refining capacity, including the consequences of recent and projected closures. Total refinery closures for the period 2020-2027 are estimated at around 5.6 mb/d. Consequently, the so-called spare refining capacity is expected to below 2.5 mb/d in 2024. This is a swift decline from the record high spare capacity levels of above 11 mb/d in 2020, which was due to the large demand drop that year. Due to the upside demand revision, the projected spare refining capacity in the medium-term is slightly lower compared to the WOO 2021.

Figure 5.18
Global oil demand, refining capacity and crude runs, 1980–2027



* *Effective 'spare' capacity estimate based on assumed 84% utilization rate, accounting for already-closed capacity.*
Source: OPEC.

5.2.4 Long-term balance for the refining sector

This section discusses projections for the long-term downstream sector, including crude throughputs and utilization rates at the global and regional level. This is based on oil demand and supply projections as shown in Chapter 3 and Chapter 4, respectively.

Table 5.4 illustrates projected refinery throughputs and utilization rates at the global level and for major regions. These projections include projected medium-term refinery closures (discussed in section 5.2.5), but no closures beyond 2027 are assumed. Global refinery throughputs are estimated at around 78 mb/d in 2021 and then increase strongly to 85.4 mb/d by 2025, in line with robust demand growth, including the post-pandemic recovery. However, global refinery throughputs increase only marginally thereafter, reaching levels close to 86.5 mb/d in 2035, after which they are expected to start inching down to 86.2 mb/d in 2045. This is due to slower demand growth, as well as a rising share of non-refinery fuels, mostly NGLs and biofuels, including SAF. At their peak in 2035, global refinery runs are only around 4.5 mb/d higher in 2035, relative to the 2019 pre-pandemic level.

Global refinery utilization rates increase in the medium-term, climbing to over 81%, which is higher relative to the 2019 level. In the long-term, however, global refinery

Table 5.4
Crude unit throughputs and utilization rates, 2021–2045

Total crude unit throughputs *mb/d*									
	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	Global
2021	17.0	4.2	1.8	11.3	7.0	7.1	14.1	15.4	78.0
2025	17.9	5.2	2.8	11.9	6.6	8.7	15.0	17.4	85.4
2030	17.7	5.3	3.7	10.9	6.4	9.0	15.3	17.8	86.1
2035	17.0	5.4	3.8	10.7	6.1	9.5	15.6	18.2	86.4
2040	16.8	5.6	4.2	9.7	6.0	9.8	15.5	18.8	86.3
2045	15.8	5.8	4.8	8.9	5.8	10.3	15.4	19.4	86.2
Crude unit utilizations *% of calendar day capacity*									
	US & Canada	Latin America	Africa	Europe	Russia & Caspian	Middle East	China	Other Asia-Pacific	Global
2021	82.6	55.9	48.6	70.5	92.1	69.7	82.9	79.9	76.4
2025	88.7	66.2	62.5	82.3	84.6	73.5	79.8	87.6	81.2
2030	87.8	66.3	69.4	76.1	82.2	74.4	76.1	83.1	78.8
2035	83.7	66.5	65.0	74.8	77.3	75.3	77.6	79.8	77.0
2040	82.6	67.6	65.0	67.7	75.8	77.1	76.6	78.9	75.7
2045	77.8	69.3	70.3	61.9	73.4	80.4	76.0	81.0	75.1

Source: OPEC.

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utilization rates are projected to decline gradually to around 75% in 2045. The major driver for falling utilization rates is the declining demand in developed regions such as Europe, US & Canada and developed Asia-Pacific.

However, global refinery throughputs and utilization rates are the combination of different regional trends. In the US & Canada, refinery throughputs are expected to decline strongly, moving from almost 18 mb/d in 2025 to below 16 mb/d in 2045, due to decreasing oil demand in this region. Refinery runs in the US & Canada receive some support from rising product exports to international markets, as the US refining system remains competitive with sufficient domestic oil supply. Utilization rates, which are expected to reach almost 89% in 2025, decline gradually to below 78% in 2045, given that there are no major long-term capacity expansions.

Europe sees a similar picture with throughputs increasing from 11.3 mb/d in 2021 to almost 12 mb/d in 2025. After an anticipated peak in 2025, throughputs are projected to drop to below 9 mb/d in 2045, in line with declining demand. This brings utilization rates from above 82% in 2025 to below 62% in 2045. Consequently, significant closures can be expected in Europe beyond the medium-term.

In Latin America, refinery throughputs are expected to rise to 5.2 mb/d in 2025 driven by rising demand. However further increases are only modest with refinery runs reaching 5.8 mb/d in 2045. The downstream sector in Latin America is exposed to competition from the US, which is expected to intensify in the long-term as the US increases its product exports to international markets. Utilization rates in Latin America are expected to increase gradually, reaching levels close to 70% in 2045, up from around 56% in 2021.

Relatively low utilization levels are the result of a large number of plants, which have not been officially closed and run at very low levels or do not run at all. For instance, Mexican nameplate capacity in early 2022 was around 1.6 mb/d, while runs in 1H22 only reached levels around 0.8 mb/d. Old and insufficient equipment and repeated industrial accidents are the main reason for this low utilization rate. Consequently, the region is expected to increase its refinery utilization rates partly by refurbishing some of the old units and increasing their throughputs.

In Africa, refinery throughputs increase from 1.8 mb/d in 2021 to 4.8 mb/d in 2045, based on strong demand growth and refining capacity additions in both the medium- and long-term. However, lower than expected refining capacity additions would likely lead to lower refinery throughputs. Refinery utilization rates are expected to increase from below 50% in 2021 to above 70% in 2045. Similarly to Latin America, Africa has a large number of non-operating refineries, some of which are undergoing refurbishment. Should the refurbishments succeed, Africa could expect even higher throughputs and utilization rates in the long-term.

Refinery throughputs in the Russia & Caspian decline throughout the period from 7 mb/d in 2021 to 5.8 mb/d in 2045. This development mirrors the expected long-term decline in product exports. Moreover, the EU oil embargo could accelerate this development in the coming years, if Russian refiners do not manage to redirect their exports to other regions. Expected utilization rates are projected to decline from 92% in 2021 to below 73.5% in 2045, which should result in closures of old and inefficient units.

Refinery runs in the Middle East are forecast to increase by more than 3 mb/d, from 7.1 mb/d in 2021 to 10.3 mb/d in 2045. Rising domestic demand is the main driver for increasing throughputs. However, this region is also focused on product exports to international markets, with several large export-oriented refineries constructed in recent years. The average utilization rate is expected to increase from below 70% in 2021 to almost 80.5% in 2045, which reflects the competitiveness of this region in the global downstream market.

China's refinery throughputs are projected to increase from 14.1 mb/d in 2021 to 15.6 mb/d in 2035, after which they are set to inch down towards 15.4 mb/d in 2045. China's downstream market is expected to reach saturation after 2030, leading to a stagnation of refinery runs in this period. Utilization rates are projected to decline gradually from 83% in 2021 to around 76% in 2045, which could lead to additional closures of smaller and inefficient teapot plants in the long-term.

Refinery runs in Other Asia-Pacific are projected to increase from 15.4 mb/d in 2021 to almost 19.5 mb/d in 2045. Post-pandemic recovery in the short-term and robust demand growth in the long-term are the major drivers of this development. Utilization rates are expected to peak at around 87.5% in 2025, followed by a decline towards more sustainable average levels around 80% in the period after 2035. Declining utilization rates are also the result of increasing competition and rising product imports from the Middle East and the US & Canada.

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 2027), 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 show recent and projected refinery closures to 2027. Between 2012 and 2019, around 6 mb/d of refining capacity was closed, mostly in the developed world and mainly simple and inefficient refineries. However, around 3 mb/d of refining capacities were closed alone in 2020 and 2021. This was, largely due to the demand shock caused by the pandemic and the related lockdown measures. More than half of these closures were located in Europe and the US & Canada. The rest is attributed to the Asia-Pacific, part of which is related to closures of old and inefficient teapot refineries in China, some of which will be replaced by new projects in the near future.

Almost 60% of the closures between 2022 and 2027 are expected in Europe and the US & Canada. This includes several relatively large refineries, such as Shell's Wesseling refinery in Germany, Eni's plant in Livorno, Italy and Repsol's refinery in Puertollano, Spain. In the US, the LyondellBasell refinery in Houston and the Philips 66 refinery in San Francisco are scheduled for closure this year.

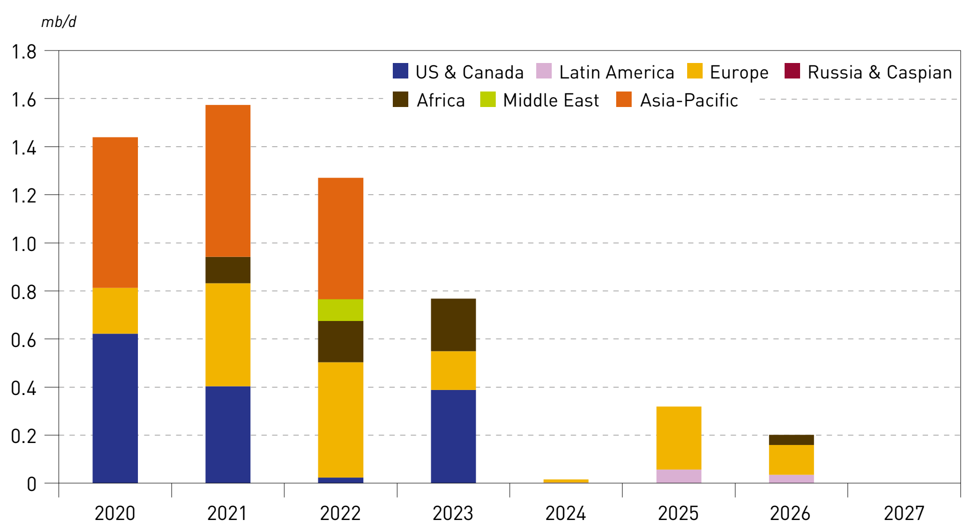
The Asia-Pacific is also projected to see significant refinery closures, totalling 0.5 mb/d between 2022 and 2027, mostly focused on developed countries in this region.

Table 5.5
Net refinery closures by region, recent and projected *mb/d*

	Total 2012–2019	2020	2021	2022	2023	2024	2025	2026	2027	Total 2020–2027
US & Canada	1.2	0.6	0.4	0.0	0.4	0.0	0.0	0.0	0.0	1.4
Latin America	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Europe	1.7	0.2	0.4	0.5	0.2	0.0	0.3	0.1	0.0	1.7
Russia & Caspian	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Africa	0.1	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.5
Middle East	0.8	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Asia-Pacific	1.7	0.6	0.6	0.5	0.0	0.0	0.0	0.0	0.0	1.8
Total	**6.0**	**1.4**	**1.6**	**1.3**	**0.8**	**0.0**	**0.3**	**0.2**	**0.0**	**5.6**

Source: OPEC.

Figure 5.19
Refinery closures by region, recent and projected



Source: OPEC.

The most significant closures are expected in Japan (Negishi and Wakajama) and New Zealand (Marsden Point). Furthermore, China is expected to continue reducing its teapot capacity with around 150 tb/d scheduled for closure in the medium-term.

Africa is also expected to see sizeable closures in the period 2022–2027, which is all related to announced closures in South Africa, including the Sapref, Durban and Sasolburg refineries.

After the closure of these refineries, however, some will be reportedly converted into biofuel and/or hydrogen plants, although at a lower nominal capacity. For example, this is the case with Eni's refinery in Livorno, which could be converted to a biofuel plant, similar to an earlier announcement of TotalEnergies conversion of its Grandpuits refinery (closed in 2020) to a biofuel and bioplastic production facility. In the US, there are several projects aimed at conversion to renewables fuels that relate to refineries closed since 2020.

Furthermore, given recent high refining margins and utilizations, it could be argued that some of the recently closed refineries could start back up; however, it is not an easy task to restart a refinery. A skilled workforce needs to be rehired and trained, deferred maintenance done, and environmental permits reauthorized, among other things. It could take several years to restart even a recently closed refinery. A more plausible response to high margins might be the delayed shutdown of refineries that are planned to close in the near future. This is especially the case for Europe and the US & Canada, as these regions planned closures and the expected reduction in Russian product imports could lead to a higher call-on-refining in these regions.

Refinery closures in the long-term

The Reference Case does not project any explicit refinery closures beyond 2027. Instead, based on the long-term modelling results, it indicates so-called implied closures at the regional level. These are back-calculated targeting the sustainable long-term average utilization rate, which is estimated at around 80%. It is important to recall that modelling cases already include assumptions on medium-term refinery closures (2.6 mb/d for the period 2022–2027). Thus, model results will indicate some level of implied closures for any region with projected average annual utilization levels below 80%.

Due to strong demand growth combined with announced refinery closures, the average global utilization rate is expected to increase to above 81% in 2025. All major refining regions have sufficient utilization rates, which do not require further closures. The only exceptions are Latin America and Africa, where the refining sector suffers from low utilization rates.

Nevertheless, global utilization rate starts declining from 2025 onwards. This is mostly in Europe, the US & Canada, developed countries in the Asia-Pacific, as well as in Russia & Caspian (Table 5.4). Although less pronounced, other regions also see weakness in refinery utilization rates, due to declining demand growth from 2030 onwards. Furthermore, utilization rates in Latin America and Africa remain below 80% despite the significant increase in the outlook period.

All this will likely lead to a further consolidation in the downstream sector, with further long-term refinery closures. It is estimated that on top of medium-term refinery closures, another 6.5 mb/d of global closures will be needed to 2045, if utilization rates are to be kept at reasonable levels.

The largest share of long-term closures are estimated in Europe, at around 2.5–3 mb/d beyond 2027. In a market with declining oil demand, many older European refineries will suffer from low utilization rates, which could be followed by permanent shutdowns. This is followed by the US & Canada where closures of around 1 mb/d are possible, especially several older and inefficient plants, such as those on the US East coast. The rate of closures in this region also depends on the level of long-term product exports and the competitiveness of the US refining sector on international markets.

The Reference Case also sees the need for closures of around 1 mb/d in the Russia & Caspian region. However, the EU oil embargo could have some negative and lasting effects on the Russian refining sector in the short-term, possible leading to earlier and an even higher level of closures.

In China, limited refinery shutdowns below 1 mb/d are possible in the long-term, especially after oil demand growth levels off, with a focus on older and inefficient teapot plants. Finally, in Africa and Latin America, limited closures are expected and it will likely only affect refineries with low or zero utilization.

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 and 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

The 7.3 mb/d of new distillation capacity from medium-term projects as shown in Table 5.2 is expected to be accompanied by around 3.8 mb/d of conversion units, 5.8 mb/d of desulphurization capacity and 1.8 mb/d of octane units (Table 5.6). Medium-term projections include several highly complex refineries (especially in the Middle East and the Asia-Pacific), which is the reason for the relatively high share of secondary additions, relative to those for distillation.

Conversion units

Figure 5.20 highlights the geographic distribution of conversion capacity additions by major unit category, such as coking/visbreaking, FCC and hydrocracking. Out of 3.8 mb/d of medium-term additions, more than 52%, or 2 mb/d, is accounted for by hydrocracking. Hydrocracking is the favoured technology, due to its flexibility between middle and light distillates. At the same time, FCC capacity is expected to increase by 0.95 mb/d, or 25% of secondary capacity additions, while coking/visbreaking is projected to increase by 0.9 mb/d, or 23% of conversion capacity additions.

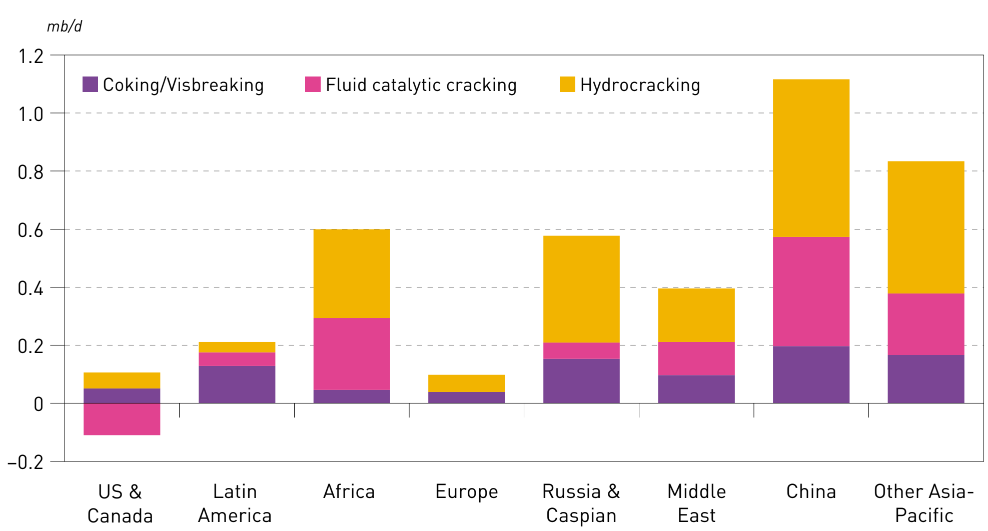
In line with distillation additions, the majority of incremental conversion capacity is located in the Middle East and the Asia-Pacific, with more than 61% of the total. The Middle East is expected to add around 0.4 mb/d of new conversion capacity, half of which is hydrocracking. The Asia-Pacific is expected to add almost 2 mb/d of conversion capacity. China alone is projected to expand secondary capacity by 1.1 mb/d. Again the

Table 5.6
Secondary capacity additions from existing projects, 2022–2027 *mb/d*

	By year		
	Conversion	Desulphurization*	Octane units
2022	1.3	2.2	0.7
2023	0.8	1.2	0.3
2024	0.5	0.7	0.2
2025	0.5	0.6	0.2
2026	0.4	0.6	0.2
2027	0.4	0.5	0.2
	By region		
	Conversion	**Desulphurization***	**Octane units**
US & Canada	0.0	0.2	0.0
Latin America	0.2	0.3	0.1
Africa	0.6	0.8	0.3
Europe	0.1	0.1	0.0
Russia & Caspian	0.6	0.4	0.1
Middle East	0.4	2.1	0.5
China	1.1	0.9	0.5
Other Asia	0.8	1.0	0.3
World	**3.8**	**5.8**	**1.8**

* *Desulphurization capacity in this table includes naphtha desulphurization.*
Source: OPEC.

Figure 5.20
Conversion projects by region, 2022–2027



Source: OPEC.

focus is on hydrocracking, which is more than half of secondary capacity additions. This is accompanied by around 0.6 mb/d of FCC capacity, while the rest is coking.

Russia & Caspian is projected to expand its secondary capacity by almost 0.6 mb/d, mostly hydrocracking. This reflects the efforts of the Russian downstream sector to increase its complexity and improve the structure of its product exports. Africa is also likely to add significant secondary medium-term capacities, mostly hydrocracking and FCC. Medium-term secondary capacity additions in other regions are rather modest and mostly relate to the enhancements of existing refineries.

Desulphurization units

Global medium-term desulphurization additions are estimated at around 5.8 mb/d, which is relatively high compared to distillation capacity additions. The rate of desulphurization relative to the distillation capacity is calculated at 80%, which is considerably higher than the current global level of below 70%. This reflects tightening product specifications in all major regions. This also includes IMO regulations related to sulphur content in marine bunkers, which has been in force since 2020.

Again, the largest share of additions are expected in the Middle East and the Asia-Pacific. The Middle East alone is expected to add around 2 mb/d of desulphurization capacity, which is due to the high sulphur content of crude in this region. This also explains why the ratio of secondary capacity to distillation additions is by far the highest in this region. A further 2 mb/d of desulphurization capacity between 2022 and 2027 is expected in the Asia-Pacific.

Africa is set to add around 0.8 mb/d of desulphurization units in the medium-term, while the rest is distributed across other regions.

Looking at desulphurization by product categories, the majority (almost 50%) is expected to come from middle distillates, around 2.8 mb/d, which reflects the trend towards low and ULS standards for diesel. Of the rest, 1.5 mb/d is for naphtha processing, 0.9 mb/d for heavy streams (vacuum gasoil/residue) and 0.6 mb/d for gasoline.

Octane units

Octane unit expansions are estimated at 1.8 mb/d for the period 2022–2027, mostly supported by rising gasoline demand in developing regions and increasing octane levels. Similar to other secondary units, the majority are expected to be installed in the Asia-Pacific and the Middle East. The Asia-Pacific is set to add around 0.8 mb/d of octane units in the medium-term, followed by the Middle East with 0.4 mb/d. Another sizeable addition is anticipated for Africa with around 0.3 mb/d between 2022 and 2027, supported by strong gasoline demand growth. In other regions where prospects for gasoline demand are relatively weak, there are only minor medium-term investments.

The majority are set for catalytic reforming (1.2 mb/d) and the remainder (0.5 mb/d) attributed to isomerization and alkylation. Some minor additions of methyl tertiary-butyl ether (MTBE)/ethyl tertiary-butyl ether (ETBE) are possible in Asia, notably China, where there continues to be interest in expanding MTBE use to meet rising gasoline pool octane requirements.

5.3.2 Long-term secondary capacity additions

Most medium- and long-term refinery additions comprise complex facilities with high levels of upgrading, desulphurization and related secondary processing. This is especially true for large projects in the Middle East and the Asia-Pacific where the production of high levels of petrochemical feedstocks is a key objective. This is increasingly driving secondary capacity additions.

There are also numerous smaller projects at existing refineries that are generally geared towards upgrading, reducing residual fuel output and achieving quality improvements for clean products. Once again, the driver is that most incremental fuel demand is for light, clean products, including petrochemical feedstocks. Another driver is the rising share of heavier crudes in the Reference Case outlook, which may require additional secondary capacities.

At the same time, condensate splitters that are currently primarily being built in the Middle East, are one exception to the overall trend towards increased complexity. Condensate splitter capacity tends to bring with it only limited secondary processing, often related to light products, such as naphtha and gasoline, and centred on catalytic reforming, isomerization and hydrotreating.

In setting out to capture the outlooks for global and regional refining, especially future processing needs by type of unit, the WOO 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 40% or more of petrochemical feedstocks. Additionally, it remains to be seen how the development of projects based on novel 'crude-to-chemicals' technologies will proceed.

With regard to petrochemicals, the modelling undertaken to project the refining outlook is designed to match demand for 'liquids'. This includes the more common roles that refineries play in producing petrochemical feedstocks. For example, the use of the FCC unit as a source of propylene, the use of catalytic reformers to feed aromatics extraction units to meet demand for aromatics, and the production of naphtha and LPG, which are then used as a feedstock to steam crackers and other units. In turn, petrochemical processes lead to by-products returning to the refinery as fuel blend stocks.

Projections for future required secondary processing through to 2045 (Table 5.7 and Figure 5.21), cover the conventional secondary refinery process technologies that comprise the vast majority of new units added. Similar to those for crude distillation units, these projections for secondary process units take into account the 2.6 mb/d of net refinery closures (including related secondary capacity closures) assumed for the period 2022–2027.

Table 5.7
Global capacity requirements by process, 2022–2045 *mb/d*

	Existing projects	Additional requirements		Total additions
	to 2027*	2027–2035	2035–2045	to 2045
Crude distillation	**7.3**	**5.6**	**2.6**	**15.5**
Conversion	**3.8**	**2.2**	**1.9**	**8.0**
Coking/visbreaking	0.9	0.7	0.6	2.1
Catalytic cracking	0.9	0.6	0.7	2.3
Hydrocracking	2.0	1.0	0.6	3.6
Desulphurization**	**4.4**	**7.3**	**4.1**	**15.8**
Gasoline	0.6	1.6	0.8	2.9
Distillate	2.8	5.1	2.4	10.4
VGO/residue	0.9	0.7	0.9	2.5
Octane units***	**1.8**	**2.1**	**1.7**	**5.7**
Catalytic reforming	1.2	0.8	1.2	3.2
Alkylation	0.2	1.2	0.3	1.7
Isomerization	0.4	0.0	0.0	0.4
MTBE	0.1	0.1	0.2	0.3

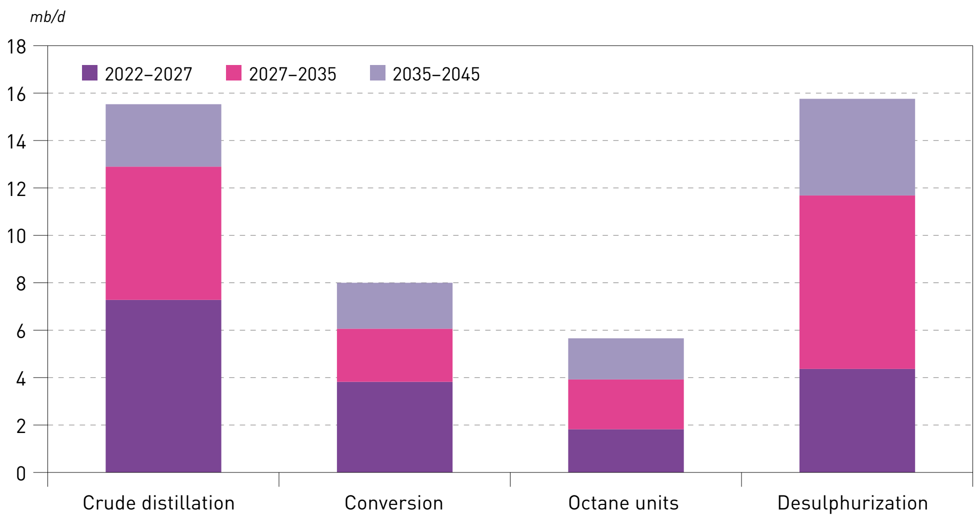
* *Existing projects exclude additions resulting from 'capacity creep'.*

** *Naphtha desulphurization not included.*

*** *New units only (excludes any revamping).*

Source: OPEC.

Figure 5.21
Secondary capacity requirements by process type, 2022–2045



Source: OPEC.

At the global level, projections indicate the need to add around 8 mb/d of conversion units, 15.8 mb/d of desulphurization capacity and 5.7 mb/d of octane units in the period 2022–2045, to go with the 15.5 mb/d of new distillation capacity. It is important to bear in mind that these projections will be influenced, up or down, by several factors. This includes the overall level of global liquids demand, biofuels and SAF supply; regional growth or decline in demand; the demand structure for major refinery products, such as gasoline, diesel and jet; and the evolution of the global crude slate between lighter, less sour and heavier, more sour grades.

The pace of change in product quality will also be critical, most notably the speed with which developing regions complete the move to Euro 4/5/6 standards for gasoline and diesel, and whether jet fuel sulphur levels are lowered. Moreover, the needed conversion and desulphurization additions will be sensitive to the extent to which the IMO 2020 Sulphur Rule is met by the use of on-board scrubbers, which would allow the continued use of high-sulphur fuel oil (HSFO) instead of 0.5% sulphur fuels.

To date, scrubber sales and installations have been buoyant, and HSFO bunker sales have been much higher at some bunkering ports than was anticipated. Another factor influencing scrubber penetration is the price differential between low-sulphur fuel oil (LSFO) and HSFO that has widened substantially over the past year. The call on the refining industry to add VGO/residue desulphurization and/or upgrading capacity will partly depend on long-term marine bunker sector developments.

Conversion units

As shown in Table 5.7, existing projects to 2027 have conversion additions at around 53% of new distillation capacity. Alongside Figure 5.21, it is indicated that this level is likely to drop to around 40% in the period 2027–2035, and then recover to around 74% from 2035–2045. This is as distillation additions slow in the long-term, but the world's crude slate becomes heavier.

The 0.9 mb/d of coking/visbreaking capacity – predominantly coking – added via existing projects to 2027 is followed by marginally lower projected additions of 0.7 mb/d from 2027–2035, then 0.6 mb/d from 2035–2045. The slowdown between 2027 and 2035 reflects the deceleration in overall capacity additions during this period as coking additions as a percentage of distillation additions remain steady at 12%. Moreover, this combines with a relatively stable global crude slate quality during the period.

From 2035–2045, the picture changes. Coking additions continue, as noted, reaching 21% of new distillation capacity and the utilization level is expected to increase. The key drivers are a projected 'heavying up' of the global crude slate between 2035 and 2045, together with a reduction in residual fuel demand.

More than 36% of total coking/visbreaking additions (again predominantly coking) are expected to take place in Latin America and the US & Canada. A recovery in heavy crude production in Latin America and a gradual, but sustained growth in the western Canadian oil sands are projected to be the primary drivers behind this (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.). The remaining additions are mostly in Africa and the Asia-Pacific, with some in the Middle East too.

This outlook includes the presumption that the Trans Mountain pipeline expansion will start up around the end of 2023, increasing western Canadian heavy crude exports to Asia and temporarily reducing them to the US. Over the longer-term, however, the ongoing growth in Canadian oil sands output leads to export growth to the US. Likewise, the projected recovery in Latin America's heavy crude production leads to a gradual rise in such crudes being exported to the US, which is their historical primary export market. As a result, coker utilizations are expected to be high in the US over the long-term – in the 88–92% range – while those in other regions are projected to be somewhat lower.

FCC additions are driven primarily by gasoline demand. Globally, this is projected to rise from just under 26 mb/d in 2021 to slightly above 28 mb/d in 2030, after which it declines gradually towards 27.5 mb/d in 2045. This rather static picture masks significant differences in the regional evolution of gasoline demand.

In developed regions (US & Canada, Europe, Japan and Australasia), gasoline demand is set to enter a sustained decline after 2025. In contrast, in developing regions (Latin America, Africa, the Middle East and developing Asia-Pacific) demand grows significantly. In fact, the loss in gasoline demand from industrialized regions is more than offset by demand gains in developing regions. This brings major implications for FCC and other gasoline unit utilizations, capacity additions and closures, and for gasoline trade.

The continued growth in developing regions helps sustain the need for new FCC and other octane units, despite the parallel demand decline in the industrialized regions. On top of 0.9 mb/d of medium-term projects, FCC additions of 0.7 mb/d are seen as needed for the period 2027–2035, then a further 0.6 mb/d for 2035–2045. This is in line with the decelerating gasoline demand growth in developing regions, especially after 2040.

Driven by the disparity in demand trajectories, around one third of the FCC additions between 2027 and 2045 are projected to be in industrialized countries and the Russia & Caspian region. The bulk of the additions are spread across Latin America, Africa, the Middle East, China and Other Asia-Pacific. Correspondingly, FCC utilizations are projected to decline steadily to 2045 in the US & Canada, Europe and other industrialized regions. This implies the need for FCC closures at refineries in industrialized regions that could total at least 0.6 mb/d over the long-term.

Conversely, the utilization of FCC units in developing regions is expected to rise gradually over the long-term. It also needs to be borne in mind that Asia, in particular, has a high proportion of residual FCC units and a growing tendency to utilize FCCs to produce petrochemical feedstock, such as propylene. These factors, plus the ability to at least partially swing FCC yields away from gasoline and toward distillates, are included in the modelling and tend to add a degree of long-term resiliency to FCC as a core upgrading 'engine'.

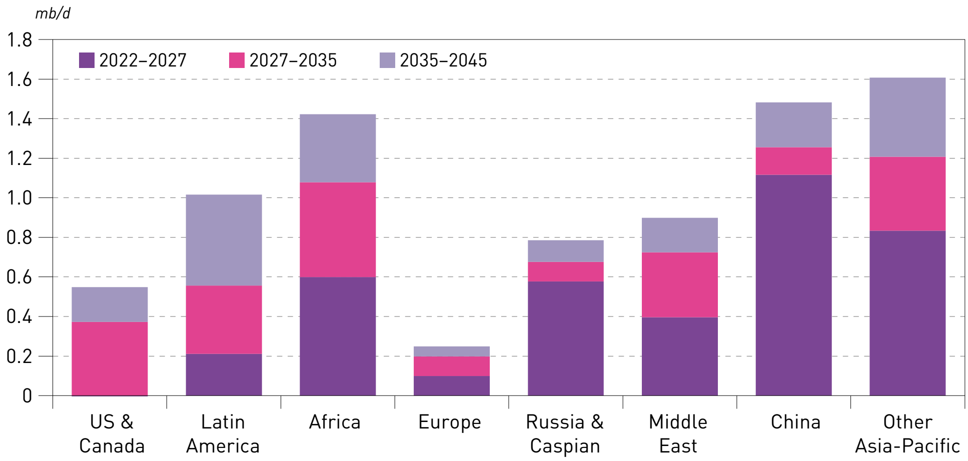
Hydrocracking units have inherent flexibility to alter yields to emphasize either naphtha/gasoline or distillates. Today, their use is mainly associated with increasing production of the latter (jet/kerosene and gasoil/diesel). Global project additions of 2 mb/d from 2022–2027 are projected to be followed by a further 1 mb/d from 2027–2035. This then reduces to 0.6 mb/d for the period 2035–2045. This slowing pace for additions is consistent with the projection for a deceleration in distillate demand growth over the longer-term.

Consistent with the regional differences in demand growth, hydrocracking additions, beyond projects, are forecast to be minor in the US & Canada and Europe. Combined, they are only around 2% of the global total. The Russia & Caspian region is expected to see around 5% of total additions, while the remaining 90%-plus are again spread across Latin America, Africa, and the Middle East, as well as Other Asia-Pacific. Unlike FCC units, hydrocrackers in industrialized region refineries are not expected to suffer the same risk of low utilization and closure. Globally, hydrocracker utilizations are expected to rise gradually over the long-term and generally be in the range of 75–80%.

The regional distribution of total future conversion capacity additions is presented in Figure 5.22. Requirements are expected to be led by the Asia-Pacific (including China), at around 39% of total additions to 2045, or 3.1 mb/d; Africa with almost 18%, or 1.4 mb/d; Latin America with almost 13%, or 1 mb/d; and the Middle East with 11%, or 0.9 mb/d. These are driven by sustained regional product demand growth, with the bulk of additions in the longer-term.

Additions in the Russia & Caspian region to 2045 are estimated at almost 0.8 mb/d, occurring predominantly in the period to 2030. Overall, it is the non-OECD regions that sustain conversion capacity growth over the period to 2045. Only 10% of total conversion capacity growth to 2045 is expected in the US & Canada and Europe.

Figure 5.22
Conversion capacity requirements by region, 2022–2045

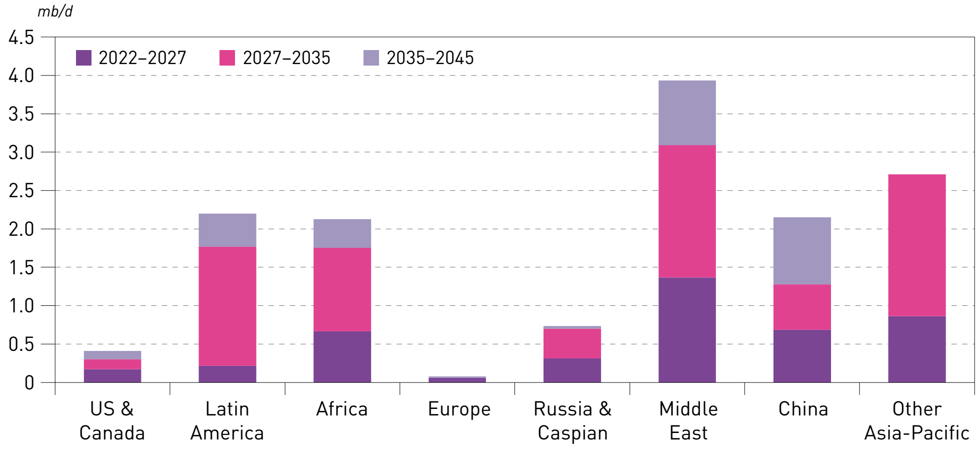


Source: OPEC.

Desulphurization units

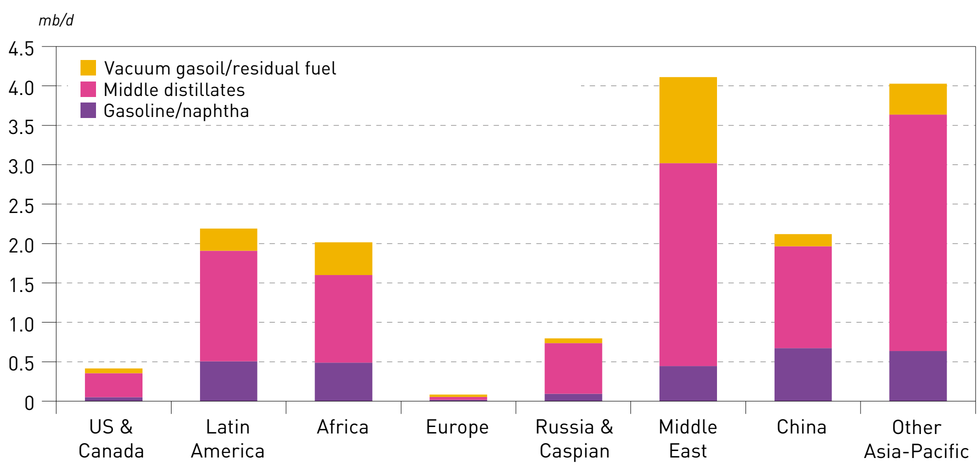
Desulphurization unit additions are projected to continue throughout the outlook period to 2045, but with the largest additions expected in the period 2027–2035. As illustrated in Table 5.7, and also shown in Figures 5.23 and 5.24, 4.4 mb/d of global projects for 2022–2027 are expected to be followed by some 7.3 mb/d of additions for 2027–2035, then 4.1 mb/d for 2035–2045.

Figure 5.23
Desulphurization capacity requirements by region*, 2022–2045



* *Projects and additions exclude naphtha desulphurization.*
Source: OPEC.

Figure 5.24
Desulphurization capacity requirements by product and region*, 2022–2045



* *Projects and additions exclude naphtha desulphurization.*
Source: OPEC.

A critical component of secondary capacity, desulphurization additions represent the largest capacity increases among all process units over the forecast period. The total of 15.8 mb/d of stated desulphurization additions by 2045, to which should be added over 2.5 mb/d for naphtha desulphurization, exceeds the 15.5 mb/d for added distillation capacity. It is evident that, while major new refinery projects are designed with significant built-in desulphurization capacity, the high-level of total desulphurization additions, relative to distillation, points to substantial desulphurization occurring at existing refineries as their processing complexity is raised in order to increase yields of predominantly light, clean products, and as product specifications and sulphur standards for those products are progressively tightened in most of the world's regions.

The continued move towards near-universal ULS gasoline and diesel standards is a key factor driving the high level of desulphurization additions. Further drivers are expected reductions in sulphur content for jet fuel and heating oils, as well as marine fuels given the impact of the IMO 2020 Sulphur Rule, and the possibility of additional Emission Control Areas (ECAs) in the future. The bulk of these changes are expected to be completed before 2035, hence, the pattern of extensive additions occurring in this period, followed by much lesser additions for 2035–2045.

In the period 2035–2045, desulphurization additions are driven largely by an expected steady increase in sulphur levels in the global crude slate, from approximately 1.23% in 2025, to roughly 1.35% in 2045.

The industrialized regions are already largely at strict ULS standards for gasoline and diesel. In the period to 2027, project additions are thus focused mainly on those regions that are undertaking, or completing, steps toward ULS gasoline and diesel standards, notably a series of countries across Africa, the Middle East, developing Asia, Latin America and the Russia & Caspian. The same applies in regions where there is heavy construction of new export refineries geared towards the production of Euro 5/6 fuels, for instance, the Middle East as shown in Figure 5.23.

Thereafter, to 2035, desulphurization additions are predominantly in developing regions where, as already noted, gasoline, jet fuel and diesel demand growth is expected to continue. The near expected universality of ULS fuels by 2035 calls for all such incremental demand to be desulphurized.

Driven by demand growth and goals to reach ULS standards, the developing regions of Latin America, Africa, the Middle East and developing Asia account for over 90% of total desulphurization additions (excluding naphtha desulphurization) to 2045, with the US & Canada plus Europe accounting for only 3%. The remaining 5% are projected to occur in the Russia & Caspian region.

Gasoline desulphurization additions, at a total of 2.9 mb/d by 2045, are focused on developing regions where, as noted, gasoline demand continues to grow and where the shift to ULS standards is still ongoing. Middle distillates comprise the bulk (66%) of total desulphurization additions, excluding naphtha, to 2045. They are anticipated across all regions but, again, with a primary concentration in developing countries led by the Middle East and the Asia-Pacific that have a combined 6.9 mb/d, out of a global total of 10.4 mb/d to 2045.

Vacuum gasoil (VGO)/residue desulphurization is the one category where additions are projected to increase rather than decline later in the outlook period. Projects to 2027 (Table 5.7) total 0.9 mb/d, in part associated with meeting increased demand for 0.5% VLSFO, as a result of the IMO 2020 Sulphur Rule. Further additions are projected at 0.7 mb/d for the 2027–2035 period, but are then expected to increase to 0.9 mb/d for the 2035–2045 timeframe. Total additions to 2045 are concentrated in the Middle East (44%) and Asia (22%), a result of these regions processing large quantities of sour crudes in the long-term. This is consistent with the anticipated rising share of heavy crudes in the global crude slate over the projection period.

Octane units

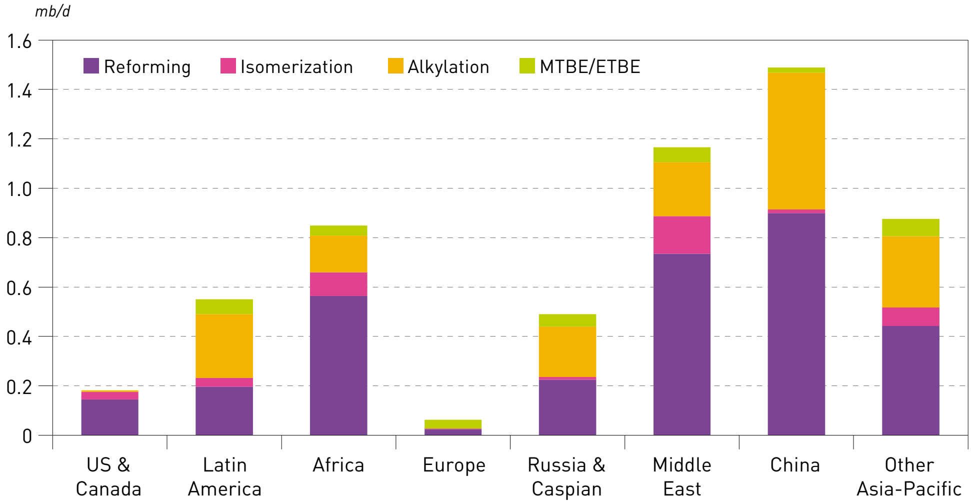
As shown in Table 5.7, additions for octane units are expected throughout the period to 2045, with a sustained pace through 2035, but slowing thereafter. By 2027, 1.8 mb/d of project additions are expected to be followed by another 2.1 mb/d for 2027–2035, before dropping to 1.7 mb/d for 2035–2045. As discussed in relation to FCC units, one primary driver of octane unit additions is the projected continued growth in gasoline demand in developing regions through 2045, albeit slowing towards the end of the period.

A second key driver is the presumed gradual increase in gasoline octane levels built into the modelling. Levels are projected to slowly increase in the developing world towards those currently seen in industrialized countries, as a series of countries seek to raise their minimum octane standards. Levels in industrialized countries also have the potential to rise in order to improve engine efficiencies. This progressive increase in octane requirements is projected to have largely played out by the longer-term, reinforcing the tendency for octane unit additions to eventually weaken, notably post-2035.

Maintaining the pattern visible in the projects, the majority of octane units are expected to be required in the form of catalytic reforming, with a total of 3.2 mb/d to 2045, alkylation at 1.7 mb/d, isomerization at 0.4 mb/d and MTBE/ETBE units at 0.3 mb/d. Reforming and isomerization raise naphtha's octane content and thus enable additional naphtha – including that from condensates – to be blended into gasoline.

In line with other secondary processes, the vast majority of these additions are projected for developing regions, led by the Asia-Pacific and the Middle East (at 62% combined). This is driven by large gasoline demand increases and expanding petrochemical industries. Latin America and Africa are also projected to have significant octane unit additions as their gasoline standards rise, accounting for 10% and 15% of the total additions, respectively. The US & Canada, Europe and the Russia & Caspian region together garner the remaining 13% of octane unit additions to 2045.

Figure 5.25
Octane capacity requirements by process and region, 2022–2045



Source: OPEC.

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 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 2022–2027. It also corresponds with the potential incremental output shown in Section 5.2.3.

Table 5.8
Global cumulative potential for incremental product output*, 2022–2027 *mb/d*

	Gasoline/ Naphtha	Middle distillates	Fuel oil	Other products	Total
2022	0.3	0.6	0.1	0.4	1.4
2023	0.7	1.3	0.2	0.8	3.0
2024	1.0	1.7	0.1	1.2	4.1
2025	1.3	2.2	0.2	1.4	5.0
2026	1.6	2.6	0.2	1.6	6.0
2027	1.9	2.9	0.2	1.8	6.8
Share	*27%*	*43%*	*3%*	*27%*	*100%*

* *Based on assumed 90% utilization rates for the new units.*
Source: OPEC.

5

Total potential refining capacity in the period 2022–2027 is around 6.8 mb/d, assuming maximum utilization of 90%. As already explained, the analysis shows a balance relative to 2021 and does not include refinery medium-term closures.

Similar to previous outlooks, the vast majority of incremental capacity is related to middle distillates, at almost 3 mb/d at the global level, or 43%. This is in line with strong middle distillate demand growth, including diesel and jet/kero, in developing regions. At the same time, gasoline/naphtha output is projected at 1.9 mb/d, while the potential output of other products is estimated at 1.8 mb/d. The potential output for fuel oil shows only minor levels in the medium-term, at around 0.2 mb/d.

Figure 5.26 shows regional and global balances for the main product classes. It is the result of the incremental refining potential by product (Table 5.8) and the regional incremental demand by major product. Before the assessment, any non-refinery streams are deducted in order to get only demand for refined products.

The estimated cumulative deficit of potential refining capacity relative to required capacity by 2027 is estimated at 1.4 mb/d (Section 5.2.3). Figure 5.26 shows the most significant deficit for gasoline and other products. A deficit of around 0.7 mb/d is estimated for gasoline and almost the same amount for other products. There is a minor deficit for fuel oil of around 0.15 mb/d. For middle distillates it is relatively balanced.

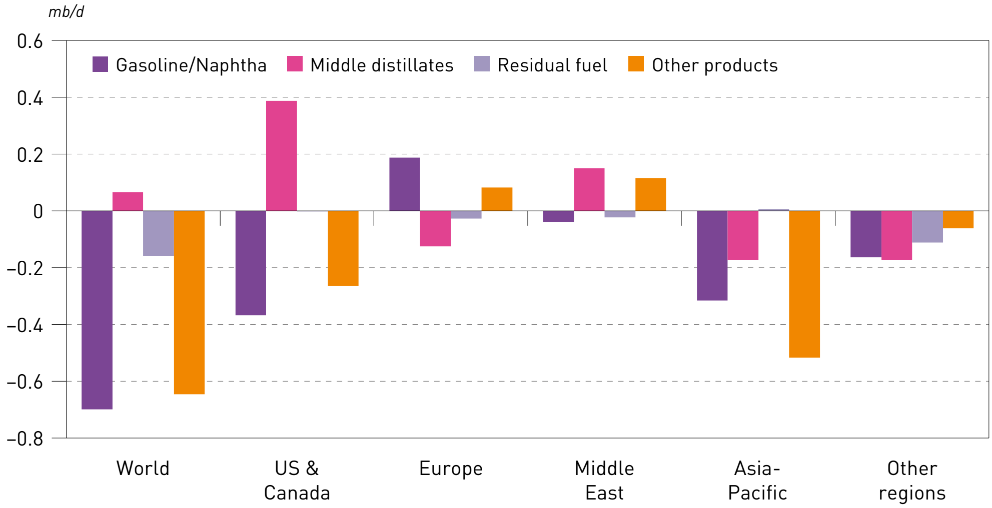
The largest deficit for most of the products is expected in the Asia-Pacific, totalling around 1 mb/d. This is mostly due to the Asia-Pacific (excl. China) having refinery capacity additions in the period to 2027 at a significant deficit to demand growth. The largest deficit is estimated for other products and gasoline.

Other regions, including Latin America and Africa, will also likely face a deficit of incremental refining capacity compared to demand. A total of 0.5 mb/d is dominated by gasoline and middle distillates. This is largely due to a lack of capacity additions in Latin America.

Other regions exhibit a mixed picture. Europe and the Middle East show a largely balanced picture in 2027, relative to 2021. However, the situation in Europe could see a short-term imbalance, due to rising demand and almost no capacity additions. The US is expected to see a deficit in gasoline capacity of almost 0.4 mb/d, and reach a similar surplus for middle distillates in the period 2022–2027.

Although this analysis does not consider trade between regions, it is important to note that missing Russian product flows, especially to Europe, could lead to stronger imbalances than assumed. Any missing product flows from Russia, would have to be replaced by additional throughputs elsewhere, creating extra pressure for an already tight market.

Figure 5.26
Expected surplus/deficit* of incremental product output from existing refining projects, 2022–2027



* *Declining product demand in some regions contributes to the surplus.*
Source: OPEC.

5.4 Investment requirements

Downstream sector investment requirements are shown in three separate categories, as illustrated in Figure 5.27. The first category relates to existing (identified) refinery projects (including expansions) that are expected to come onstream in the medium-term (2022–2027) as described in Section 5.2. To the extent possible, this category includes reported investment costs.

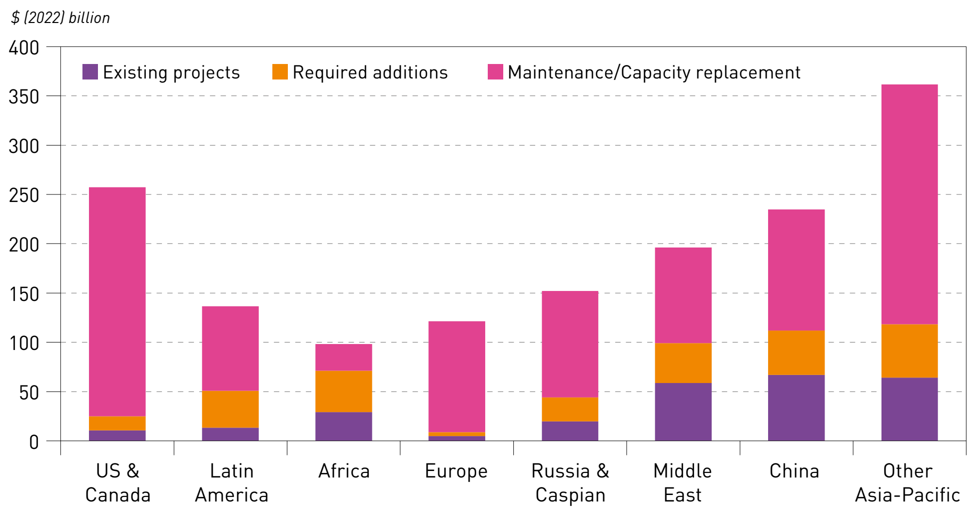
The second category is related to investment volumes in the long-term, those beyond 2027, and generally represents still generic projects. Long-term investments are calculated based on the assumed regional costs for a unit of refining capacity additions. The third category focuses on the continuous maintenance of the global refining system and covers necessary capital replacements throughout the whole projection period (2022–2045).

For the first category, the estimated investment volume is around $270 billion, slightly higher relative to the WOO 2021. More than $190 billion of investments, or 71% of the total, are expected in the Asia-Pacific and the Middle East, as the largest medium-term share of refinery additions are anticipated in these regions.

China accounts for $67 billion, while the investments in other Asia-Pacific countries are expected at $64 billion. Investment volumes in the Middle East are at around $59 billion in the period to 2027. Due to the relatively significant level of refinery additions in the medium-term, Africa is likely to see investments of close to $30 billion. In other regions, investments are lower. In the Russia & Caspian, investments of close to $20 billion are expected, mostly related to secondary capacity additions. In Latin America and the US & Canada, medium-term investments are calculated at $13.5 and $11 billion, respectively. Finally, in Europe, medium-term investments are expected at under $5 billion, attributed almost exclusively to secondary capacity enhancements.

In the period 2028–2045, total downstream investment volume is calculated at around $260 billion, slightly under the volume expected in the medium-term. Again, the majority of investments is anticipated in developing countries, led by the Asia-Pacific and the Middle East. In the Asia-Pacific, the total investment requirement is calculated at around $100 billion. In the Middle East, the investment requirement is around $41 billion. Although significant, these investments are still significantly lower compared to the medium-term period.

Figure 5.27
Refinery investments by region, 2022–2045



Source: OPEC.

In Africa, investment requirements are significant, reaching almost $42 billion beyond 2028, while downstream investment requirements in Latin America are calculated at $37 billion. Investments in other regions total around $42 billion, led by the Russia & Caspian.

Finally, maintenance requirements and the 'capital replacement' of installed refining capacity are calculated at above $1 trillion for the period 2022–2045, similar to the WOO 2021. The assessment of this investment category is based on the assumption that the annual capital needed for capacity maintenance and replacement is around 2% of the cost of the installed base. The leading region in terms of maintenance investments is Other Asia-Pacific, at around $240 billion, followed by the US & Canada at $230 billion.

In summary, the total of the three downstream investment categories is estimated at $1.55 trillion in the period 2022–2045.

5.5 Refining industry implications

The downstream market transited relatively fast from oversupply to tightness. While in recent years, refiners had been struggling with increasing competition and low margins, in 2022 they have enjoyed soaring margins. Some reasons for this are inherent to the energy sector, including long-term energy policies, others are external and related to geopolitics and the energy crisis in some regions.

In the medium-term, the tightness of refining capacity in developed countries and record refinery margins are probably not going to trigger major investments into new refining capacity. The general expectation is that energy policies in these regions will lead to an oil demand peak in the coming years, which does not support long-term investments into new refineries. This seems to mirror broader problems related to the energy industry and energy policy today. Even though energy policies discourage investments into fossil fuels, including oil, oil demand remains strong. This kind of dissonance creates potential market shocks, volatility and price spikes, which spread in the international market and also severely impact developing countries.

In the long-term, the downstream sector in developed countries is expected to go into a slow decline, with lower refinery throughputs and possible refinery closures. In order to continue operating, refineries in these regions will have to adapt – generally by petrochemical or biofuel integration. A reduction of the carbon footprint will also be important, with CCUS and renewable electricity potentially playing an important role. In some cases, refineries could be converted to produce alternative fuels such as biofuels, SAF and low carbon hydrogen.

The downstream sector in developing countries is expected to continue growing based on expanding demand. However, given that refinery throughput growth is expected to decline, the market can expect a significant slowdown in refining capacity additions beyond 2040, possibly with no new greenfield refineries. This is why securing a strong competitive position will be important for refiners. This includes petrochemical integration, which could provide a 'hedge' against a demand decline for traditional fuels.

Finally, the uncertainty over energy policies and related implications on oil demand in the long-term remain significant (see Chapter 8). Lower demand would necessarily lead to lower throughputs and possibly a higher rate of closures. Nonetheless, the refining sector will remain an important part of the global oil and gas picture and it has significant capabilities to help reduce emissions, thus, contributing to the common targets of security, efficiency and sustainability for the energy industry.

Oil movements

Key takeaways

- Following the outbreak of the Russia-Ukraine conflict, several countries and regions including the EU, UK, US and Canada imposed sanctions on oil and product imports from Russia. The full impact of these is expected in late 2022 and 2023, when most of the import bans become effective.

- Although it is unclear how long the embargo will last, this outlook assumes that Europe will continue importing some Russian crude in the medium- to long-term. However, this outlook also recognizes the potential permanent consequences of the oil embargo, with flows from Russia to the EU likely to be significantly lower compared to 2021. A high degree of uncertainty remains.

- Based on strong demand growth, total crude and condensate trade is expected to be almost 39 mb/d in 2025, an increase of nearly 5 mb/d relative to 2021. After 2025, total crude and condensate flows are forecast to stabilize and only increase gradually in the long-term. They are assumed to reach almost 40.5 mb/d by 2045, driven by oil demand deceleration and an increasing share of non-crude liquids, such as NGLs and biofuels.

- The Middle East remains by far the most important crude and condensate exporter throughout the forecast period. Total export volumes increase from 15.7 mb/d in 2021 to 22.7 mb/d in 2045, which is in line with rising demand for OPEC liquids. The main destination is the Asia-Pacific, which is set to account for more than 85% of total Middle East exports. Flows to Europe almost double in the medium-term, partly due to the European ban on Russian crude.

- Based on strong supply growth, Latin America increases its crude and condensate exports by around 2.3 mb/d in the outlook period to reach levels around 5.7 mb/d from 2035 onwards. The main destinations for Latin American crude are the US & Canada and the Asia-Pacific, with minor volumes to Europe.

- Crude and condensate exports from Russia & Caspian drop from 6 mb/d in 2021 to 5.3 mb/d in 2025 due to expected lower supply. Thereafter, levels recover towards 5.7 mb/d, mostly due to lower domestic crude use.

- Following the anticipated supply growth path, crude and condensate exports from the US & Canada peak in 2025 at around 4.7 mb/d and then decline gradually to 2.3 mb/d in 2045.

- The Asia-Pacific remains the main outlet for crude and condensate exports. Total imports rise from 22.5 mb/d in 2021 to above 30 mb/d in 2045. The Middle East increases its share in Asia-Pacific imports from 60% in 2021 to 65% in 2045.

- European crude and condensate imports drop from 8.2 mb/d in 2021 to 6.6 mb/d in 2045, as demand declines. Due to the oil embargo, the share of Russia & Caspian in the import mix is forecast to drop from 42% in 2021 to below 25% in 2025.

Oil trade movements are a crucial part of the global oil market and enable the integration of different regions into the overall global system. They help balance out the market, and alleviate supply shortages and surpluses on 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. 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 products for markets. For this reason, significant interregional 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 altered by the infrastructure that evolves. 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 interregional crude trade. This applies especially to China, the Middle East, the Russia & Caspian, along with the US & Canada.

6.1.1 The US & Canada

The interruption to US and Canada crude oil production growth because of the COVID-19 pandemic, coupled with the completion of several major projects, has transitioned the region from a period of barely adequate takeaway and export capacity to one of sufficient capacity that can accommodate future growth.

The biggest threat to takeaway capacity now lies with continued public resistance, political opposition and legal challenges to already operating capacity, more so than to new projects. It could be argued that with recent price increases and supply worries, the chances of shutting down existing infrastructure are lower than past 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), which reached 3 mb/d by mid-2019, broadly stayed at that level through 2020, 2021 and into the 1H22. While at first glance this may seem somewhat surprising, it stems from the fact that during the initial outbreak of COVID-19, both US production and US refinery runs dropped. As refinery runs recovered in 2021 and 2022, so did US crude production.

As of the 1H22, US refinery runs had fallen more *versus* pre-pandemic levels than US production, allowing US exports to grow slightly. Additionally, it must be recognized that exports are predominantly very light streams not readily suited to US refineries, hence, the continuation in the export of light grades, while heavier crudes continue to be imported. The vast majority of US exports, almost 3 mb/d in 2021, 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 projects, and given the setbacks to US production, the rapid build-out of pipeline capacity over the past few years has left the US with ample takeaway capacity, especially from the Permian/Eagle Ford Basins and from Cushing to the Gulf Coast. Even allowing for strong recovery in US tight oil production expected in this Outlook by 2027 (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.

The reversal of the Capline and expansion of the Dakota Access pipeline, both designed to bring crude from the US interior to the Gulf Coast, were completed in late 2021. Initial capacity on the reversed Capline is 300,000 b/d, although further expansion is possible (the northward capacity was 1.2 mb/d). The Dakota Access Expansion project adds 180,000 b/d to the line's previous 570,000 b/d capacity.

The US interior also has sufficient takeaway capacity with planned and existing pipelines, but there are regulatory uncertainties that could affect this, as discussed later. 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, notably if Dakota Access were to end up being shut down, which is still a possibility due to ongoing litigation.

Much of the crude oil moved on recently built pipelines to the Gulf Coast is destined for export markets. Like pipeline projects, what was once a bevy of port expansions has also faced delays or cancellations as a result of the impacts of COVID-19. Two leading offshore very large crude carrier (VLCC) loading projects – the Enterprise SPOT terminal, offshore Houston and the Phillips 66/Trafigura/Bluewater project, offshore Corpus Christi – remain active, but both continue to face delays and are unlikely to be completed before 2024, if at all. This leaves the Louisiana Offshore Oil Port (LOOP) as the only crude oil export terminal capable of fully loading VLCCs in the US. Originally designed to take imports, and to work with Capline to take mainly imported crudes into the US interior, the facility has also been exporting local GoM medium sour crudes and light sweet grades since 2019. Arguably, given that monthly US crude exports have exceeded 3.5 mb/d on several occasions, additional Gulf Coast export terminals are unnecessary.

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.

In July 2020, a federal court ordered the shutdown of the 750 tb/d Dakota Access pipeline out of the Bakken pending further environmental review. This marked the first time an existing pipeline had been ordered shut. Subsequent rulings have allowed the pipeline to remain operating until an environmental review is completed, but its future is uncertain. As discussed later, Enbridge's Line 5 renewal project also continues to meet resistance. The bottom line is that it is becoming increasingly difficult for US operators to build major new pipelines and a number of currently operating pipelines face 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. In total, some 1.5 mb/d of nameplate rail capacity exists to move crude oil from the US interior to the East and West, as well as Gulf Coasts.

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 limited increases in the medium- to long-term (Chapter 4). On this basis, few additions to takeaway capacity are required for 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.

A significant cross-border project completed in 2021 was the Enbridge Line 3 Replacement. This project restored the line's original capacity by replacing the ageing existing pipeline. In doing so, it added an effective 370 tb/d to cross-border capacity.

This leaves the Trans Mountain Pipeline Expansion as 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 and is unlikely to be completed until late 2023. In addition to the delays, the project has incurred dramatic cost escalations too. The current estimated price is $16.4 billion *versus* $5.7 billion when the project was purchased by the Canadian government in 2018.

Crucially, this project would enable Canada to open up export markets other than the US, 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. The extreme increase in the project's capital cost does, however, bring into question how economic the pipeline will be, given that tariffs are generally designed to recoup capital cost over time. It is conceivable that potential high tariffs could limit the expanded line's attractiveness and throughput, leading to Western Canadian crude volumes being moved preferentially on alternative pipelines and even by rail. Such a development would limit the change in Western Canadian crude destinations, as existing infrastructure and rail go predominantly to the US.

In principle, the 'mainline' and Trans Mountain upgrades should be more than enough to cover medium-term Western Canadian Sedimentary Basin (WCSB) production increases. The takeaway system also includes significant crude-by-rail capacity, a 'nameplate' of 850 tb/d. Although generally more costly than movement via pipeline, exports by rail ranged between 150 tb/d and 170 tb/d during 2020 and 2021 and have demonstrated an ability to reach over 400 tb/d.

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. This 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.

What does appear certain is that the high-paced build-out of pipelines and related infrastructure in the US (and Canada) in recent years is now over. The likelihood that any major new pipeline projects will be announced over the next few years appears low. Potentially, it will be some time, if ever, before logistics capacity once again becomes a constraint to supplying US and Canadian crudes to market.

That said, the difficulties and costs of getting projects built have also brought in a new element, namely uncertainty over the continuing operation of existing pipelines. Should the latter trend begin to have material impacts, such as forced pipeline closures, then a difficult and constrained situation could emerge.

Absent that, the Trans Mountain expansion is likely to have the largest impact on international oil trade since it is the one project that, subject to the caveats already mentioned, would move additional volumes WCSB crudes to the US West Coast and Asia, rather than to the US Gulf Coast.

6.1.2 Other regions

The start of the Russia-Ukraine conflict triggered discussions related to new oil pipeline projects in several regions. These are related to debottlenecking or capacity expansion on existing pipelines, as well as completely new projects.

One of the conditions for countries phasing out Russian supplies is securing crude supply through alternative routes. Currently, several European inland refineries do not have access to sufficient alternative supplies. These are refineries directly connected to the southern leg of the Druzhba pipeline system, including plants in Hungary, Slovakia and the Czech Republic. To this end, the EU is ready to finance the expansion of the Adria pipeline (Croatia to Hungary) and Transalpine pipeline (Italy to Central Europe).

Croatian pipeline operator Janaf could increase the capacity of the Adria pipeline, which flows from Omisalj on the Adriatic coast up to Hungary, and Slovakia, as a connection between Adria and Druzhba already exists. Currently, Janaf can supply around 230 tb/d of crude oil to Hungary and capacity could be increased by around 30% – with minor investments – before the end of 2022. Furthermore, the capacity on the Transalpine pipeline is expected to increase, especially the leg to Czech Republic (Ingolstadt–Kralupy–Litvínov pipeline).

From the Russian perspective, there were announcements for possible expansions of export infrastructure. This includes calls to build a new tanker fleet. Russia has already increased its shipments through the ESPO pipeline and these could reach maximum capacity soon. Further expansions on this route in the long-term are also possible.

In Kazakhstan, a study will be conducted to explore possible pipeline construction across the Caspian Sea, which would help to bypass Russia in the future. Currently, Kazakhstan exports the largest share of its crude through the CPC pipeline from the Russian port of Novorossiysk in the Black Sea.

6.2 Crude oil and product 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 in some cases also geopolitics. The downstream infrastructure (pipelines and shipping capacity) enable market participants to move large amounts of oil liquids (crude or products) between almost any two regions of the world, over short and long distances, via a variety of transport modes.

These interregional movements enable 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 a 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 include demand levels; the production and quality of crude and non-crude streams; product quality specifications and related changes; refining sector configurations; 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; 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 also play a role. Recent trends in the downstream sector clearly 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 medium and long-term outlook (Chapter 5) shows a continuation of this trend. 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 a 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 modelling approach that looks at the longer-term, with few restrictions on movement and that operates by minimizing 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. These projections are, of course, dependent on a number of assumptions used in this Outlook, which, if altered, could materially impact projected movements.

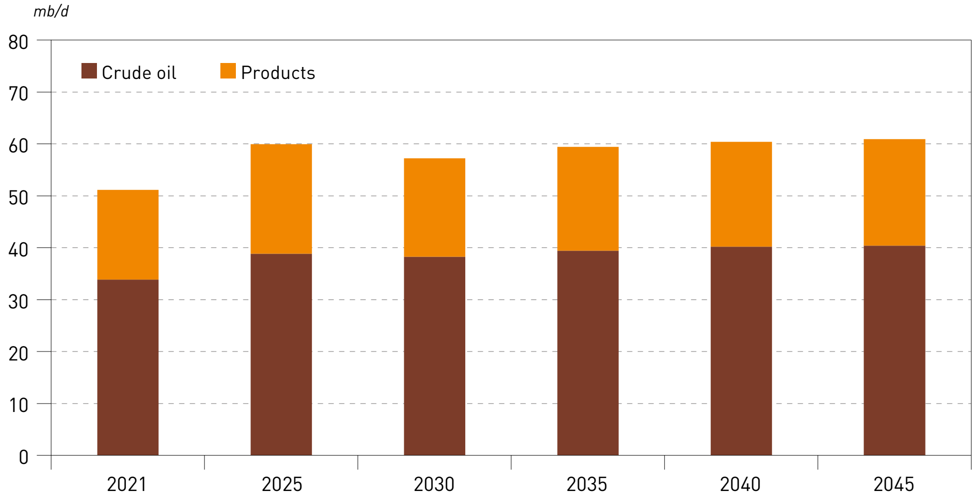
This approach alone, however, is not suitable for estimating the impact of geopolitics on oil trade. Therefore, the Reference Case mirrors not only the modelling results, but also the assessment of the oil embargo on Russian oil imports imposed by the EU, the UK and the US in 2022.

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 inter-regional 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.

Figure 6.1 shows global oil (crude oil, condensates and refined products) between seven major regions, excluding all intratrade between different countries within regions. Projections are made for anchor years (2025, 2030, 2035, 2040 and 2045), to illustrate the main long-term trends. As already noted, these projections are in line with demand projections (Chapter 3), supply projections (Chapter 4) and the outlook for the refining sector (Chapter 5).

As shown in Figure 6.1, global oil trade was estimated at around 51.2 mb/d in 2021, which is slightly higher relative to 2020, but still significantly lower relative to pre-COVID levels. Global trade is expected to increase strongly in the period to 2025, reaching nearly 60 mb/d, almost 4 mb/d higher relative to 2019. The increase is due to the strong expansion in demand, which leads to higher crude and condensate, as well as product trade. In 2030, global trade is set to drop to almost 57 mb/d due to rising refining capacity in developing regions, which reduces the need to import products and increases local crude use. After 2030, global oil trade starts rising again to reach almost 61 mb/d in 2045.

Figure 6.1
Interregional crude oil* and products exports, 2021–2045



* *Including condensates.*
Source: OPEC.

Crude and condensate flows represent a larger share of the total oil trade. In 2021, total interregional crude and condensate flows were calculated at around 33.8 mb/d. In line with the strong increase in demand by 2025, total crude and condensate flows are expected to increase by nearly 5 mb/d and reach 38.9 mb/d. By 2030, however, a minor drop is expected, largely due to higher local crude use in several regions. From 2030 onwards, global crude and condensate trade is set to increase gradually to almost 40.5 mb/d by 2045, following rising demand and declining supply in importing regions, such as the Asia-Pacific.

Trade in refined products is expected to reach 21 mb/d in 2025, supported by strong demand growth and insufficient refining capacity additions relative to demand growth. In 2030, capacity additions are expected to lead to lower interregional product trade, with volumes declining to 19 mb/d. After 2030, a gradual increase in total refined product trade is anticipated to reach 20.5 mb/d in 2045. This is mostly due to rising US & Canada exports, where, due to declining demand, idle refining capacity increasingly competes internationally.

6.3 Crude oil and condensate movements

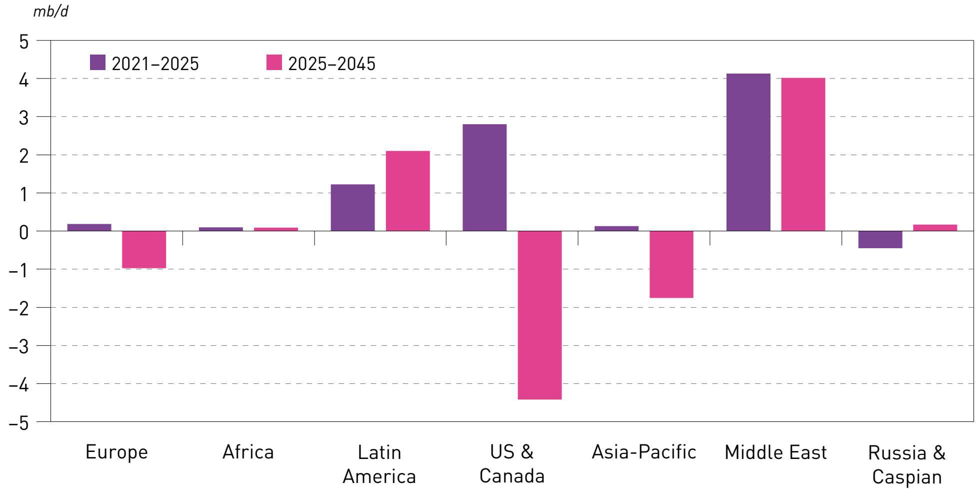
In order to provide background, this section first discusses changes in medium- and long-term crude and condensate supplies by major region. It then turns to the main trends in crude oil and condensate movements at the regional level, underscoring trade flows from the perspective of the main exporting and importing regions. More details are provided in Chapter 4.

Crude and condensate supply

Global crude and condensate supply is expected to increase by around 7.3 mb/d between 2021 and 2045. However, this growth is not even. In the period to 2025, global crude and condensate supply increases by more than 8 mb/d, in line with strong demand growth. In the years thereafter to 2045, total crude and condensate supply is forecast to decline by some 0.8 mb/d, which is due to the demand growth slowdown and strong expansion in non-crude supplies, such as NGLs and biofuels.

At the regional level (Figure 6.2), the highest increment is expected in the Middle East, a total of 8 mb/d between 2021 and 2045. Half of this increase is likely already by 2025, while the rest is added between 2025 and 2045. Crude and condensate supply in Latin America is also significant, with around 3.3 mb/d added between 2021 and 2045. This consists of 1.2 mb/d to 2025, and a further 2.1 mb/d in the period thereafter. The majority of the growth comes from Brazil and Guyana, with Venezuela and Argentina contributing too. This more than offsets declines in other countries, such as Mexico and Colombia.

Figure 6.2
Change in crude and condensate supply* between 2021 and 2045



* *Includes condensate and synthetic crudes.*

Source: OPEC.

The US & Canada is also likely to see strong supply growth between 2021 and 2025, estimated at around 2.8 mb/d. However, as US tight oil supply peaks somewhere between 2025 and 2030 and starts declining thereafter, US & Canada supply is forecast to decline by almost 4.5 mb/d between 2025 and 2045.

Other regions see more modest changes. In Africa, the increase in crude and condensate supply is estimated at a mere 0.2 mb/d over the full outlook period. European crude and condensate supply is seen increasing by 0.2 mb/d to 2025, but is then followed by a drop of 1 mb/d between 2025 and 2045 due to declining production in the North Sea. In the Asia-Pacific, crude and condensate supply is stable in the period 2021–2025. However, supply is expected to decline by 1.8 mb/d between 2025 and 2045 due to ageing production in several countries, including China, Malaysia and Indonesia.

Finally, production in Russia & Caspian is seen declining by almost 0.5 mb/d between 2021 and 2025, mostly as the result of the current geopolitical turmoil and its possible long-term consequences. After 2025, supply in Russia & Caspian is forecast to remain largely stable, only inching up by 0.2 mb/d. The current outlook for the Russia & Caspian region represents a significant downward revision relative to the WOO 2021. Consequently, total crude and condensate exports from Russia & Caspian are significantly lower compared to last year's Outlook, which is discussed in more detail later.

Crude and condensate oil movements

COVID-19 and the related oil demand shock in 2020 massively affected crude and condensate trade, which dropped from around 38.2 mb/d in 2019 to 33.8 mb/d in 2020. During 2021, the global interregional crude and condensate trade stabilized, with optimistic prospects for the short- and medium-term. It was in this environment that the Russia-Ukraine conflict started, with tremendous consequences for both oil and energy markets.

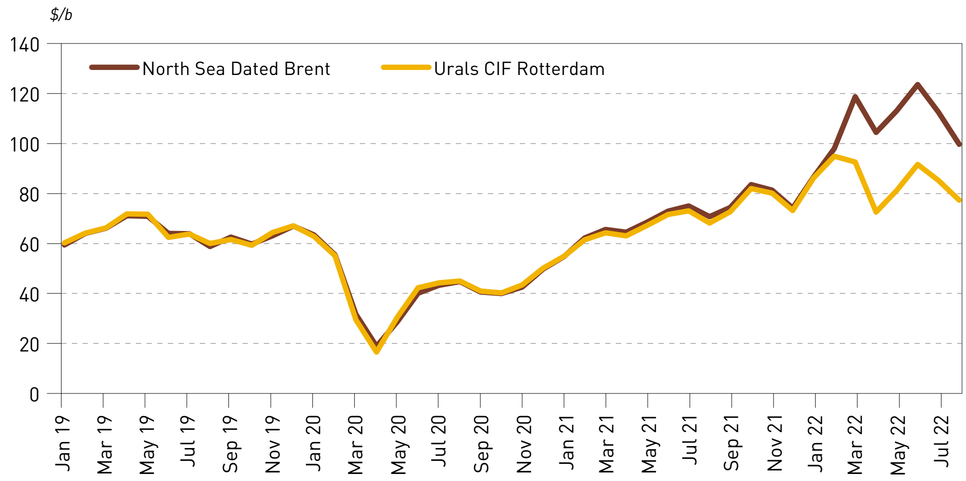
Several countries imposed embargos on Russian crude and product imports, including the EU, UK, US and Canada. Due to the size of trade volumes involved – around 3.5 mb/d of crude and products during 2021 – the EU embargo has the largest significance. The crude oil embargo will become effective in late 2022 and for refined products in early 2023. There are temporary exceptions, albeit relatively small volumes, for several countries due to particular dependencies, however, all Russian exports to the EU could be phased out by 2024.

Nevertheless, there remain some ambiguities as to how this will all play out, and the Reference Case view is that certain levels of Russian crude flows to the EU would likely be seen in the medium- and long-term.

The reshaping of trade patterns has already started with significant shifts in the global crude and condensate trade. Due to lower interest from Europe, Russia has already redirected significant crude volumes to Asian countries, especially India and China. Indian imports of Russian crude reached 1.1 mb/d in June 2022, up from below 50,000 b/d on a monthly average in 2021. This was possible due to hefty discounts of Urals *versus* Brent (Figure 6.3), which encouraged these flows. Due to the size of Russian crude and condensate exports to the EU, much higher volumes are likely to be redirected from late 2022 to other regions, predominantly the Asia-Pacific.

At the same time, Europe has shown interest in crude imports from the Middle East, which typically flow eastwards. Furthermore, Europe has increased purchases of additional barrels from West Africa (Nigeria and Angola), which are typically rich in middle distillates and represent a good fit for European refining configurations.

Figure 6.3
Dated Brent and Urals CIF Rotterdam*



* *Note that Urals trade information is relatively scarce, as many European buyers have stopped spot trades. Reports from late July 2022 mention much lower discounts of around $15/b, but no deals were confirmed.*

Source: Argus.

However, given the size of Russian crude and product exports, more diversification efforts will be required in the second half of the year and in 2023. It is likely that European refiners will amplify their efforts to increase supplies from the Middle East, mostly middle-distillate rich grades, including Arab Light, Basrah Medium, Murban and Oman. Furthermore, additional flows from Africa, the Caspian and possibly Latin America can be expected to provide required blends. Another probable development is that the EU increases imports of North Sea crudes. According to official statistics, Norway exported around 20% of its oil to non-EU destinations, largely the Far East, during 2021. Following the embargo, it is possible that more Norwegian crude will head to the EU instead.

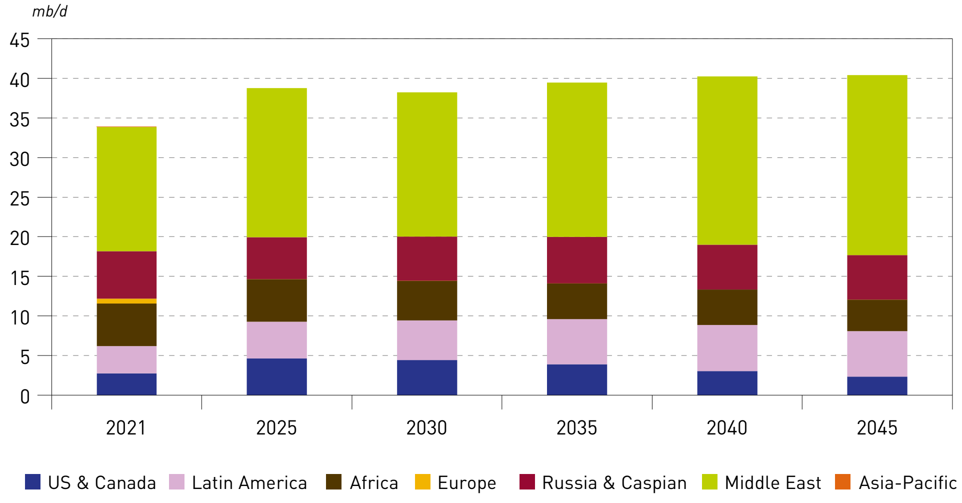
Some restructuring is possible within the Mediterranean market. The EU could attract Middle Eastern, African or Caspian cargoes, destined for Mediterranean consumers that have not been affected by sanctions, such as Turkey or Egypt. Turkish imports of Urals had already increased significantly in 2H22.

This Outlook maintains the view that the situation in the market will stabilize in the medium-term. However, it also recognizes possible lasting effects of the current geopolitical turmoil. This means that some flows of Russian crude to the EU could continue beyond the short-term. However, as some European refiners may permanently switch to alternative supplies, it is unlikely that flows will return to levels before the start of the Russia-Ukraine conflict.

Nevertheless, it is important to emphasize the uncertainty related to Russian crude and condensate flows to international market. More clarity can be expected only after the oil embargo comes into force in late 2022. The success or failure of European refiners to adopt to new suppliers and satisfy product demand will provide direction for further steps related to Russian crude and condensate flows.

Figure 6.4 shows total crude oil and condensate exports by major regions. These projections are in line with the outlook for oil demand and supply (Chapters 3 and 4), as well as refining capacity development (Chapter 5). Global trade is expected to increase strongly between 2021 and 2025, which is partly due to the post-COVID recovery and strong demand growth. Total crude and condensate trade is expected at almost 39 mb/d in 2025, an increase of nearly 5 mb/d relative to 2021. The 2025 level is also slightly higher compared to pre-pandemic levels in 2019.

Figure 6.4
Global crude and condensate exports by origin*, 2021–2045



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

Most of the regions will increase their exports markedly. The Middle East is projected to increase its exports by more than 3 mb/d to nearly 19 mb/d in 2025, which is in line with rising demand for OPEC liquids. Other regions are also expected to increase crude and condensate exports, such as the US & Canada, where outflows are expected to reach 4.7 mb/d in 2025, up from 2.8 mb/d in 2021.

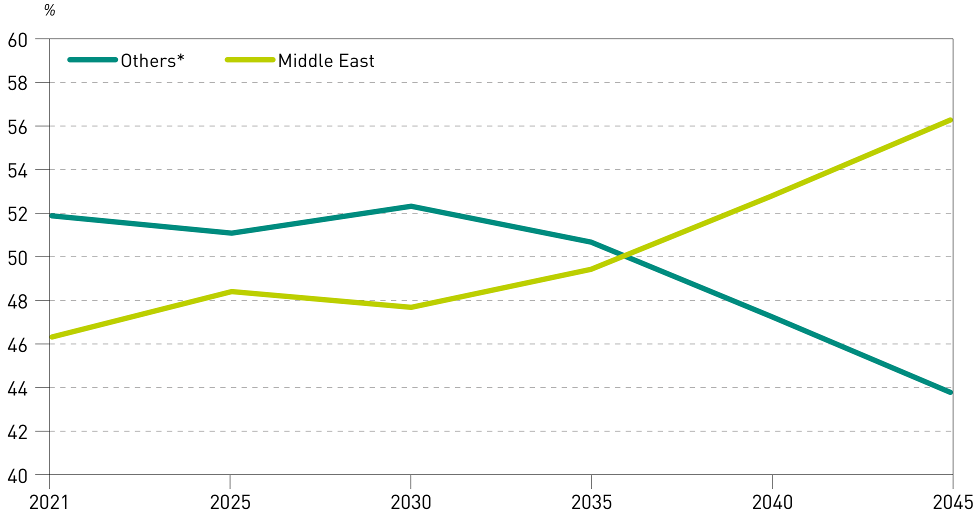
Crude and condensate flows from Latin America are projected to reach 4.6 mb/d in 2025, an increase of 1.2 mb/d relative to the base year. African exports remain stable in the period 2021–2025, which is due to the strong increase in domestic crude use. Russia & Caspian is the only region where crude and condensate exports are expected to decline by 2025, which is due to the expected decline in Russian production relative to 2021.

After 2025, total crude and condensate flows are expected to stabilize and only gradual increase in the long-term. Total crude and condensate trade reaches almost 40.5 mb/d by 2045, up from 38.8 mb/d in 2025. There are several parallel drivers behind the long-term dynamics.

First, global oil demand growth is expected to decelerate significantly in the long-term. Second, crude and condensate exports from Africa are expected to start declining after 2025, which is due to a significant increase in refinery throughputs and the local use of crude. This is also behind the strong deceleration in crude and condensate exports from Latin America after 2035. Furthermore, after a peak of 4.7 mb/d around 2025, crude and condensate exports from the US & Canada are expected to decline gradually to 2.3 mb/d in 2045, which is due to the anticipated significant drop in supply. These declines are more than offset, however, by the rise in exports from the Middle East, which reaches 22.7 mb/d in 2045, up by almost 4 mb/d relative to 2025 levels. A minor crude and condensate export increase in the period between 2025 and 2045 is expected from Russia & Caspian. This is due to the slight increase in supply and declining domestic refinery throughputs.

The Middle East remains by far the most important crude and condensate exporter throughout the period. In fact, it significantly increases its share in the global oil trade over the long-term. From around 46% in 2021, it increases its share to almost 49% in 2025 due to a large rise in exports. The share remains relatively stable to 2035. However, as Middle East exports continue expanding beyond 2035, the share of the Middle East in the global crude and condensate trade mix increases to above 56% in 2045 (Figure 6.5). This trend is also supported by declining exports from Africa and the US & Canada, as well as peaking Latin American exports around 2035.

Figure 6.5
Share of crude and condensate exports, 2021–2045

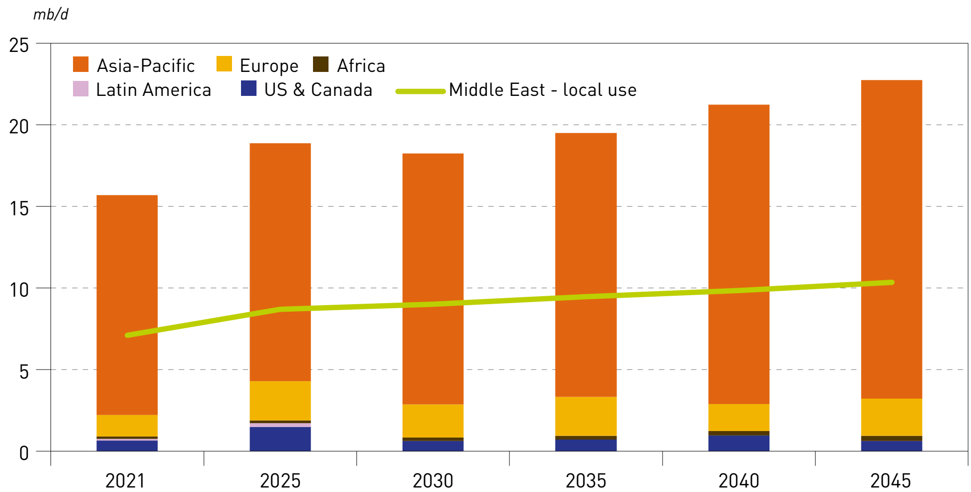


** Others include Latin America, Africa, Russia & Caspian and the US & Canada.*
Source: OPEC.

Figures 6.6 to 6.10 show the main trends related to crude and condensate exports from the main exporting regions – the Middle East, Russia & Caspian, Latin America, Africa and the US & Canada.

Figure 6.6 illustrates crude and condensate trade exports from the Middle East. Total export volumes increase from just below 15.7 mb/d in 2021 to 22.7 mb/d in 2045, an increase of 7 mb/d over the outlook period. The projected growth is front-loaded. More than 45%, or 3.2 mb/d, of this increase is expected to materialize in the period 2021–2025, in line with strong demand growth. This is followed by a small decline in the following period to 2030, which is due to rising local Middle East crude use and relatively stable demand for OPEC crude between 2025 and 2030. Nonetheless, exports then rise further and reach 22.75 mb/d by 2045, up by 3.9 mb/d relative to 2025.

Figure 6.6
Crude and condensate exports from the Middle East by major destination, 2021–2045



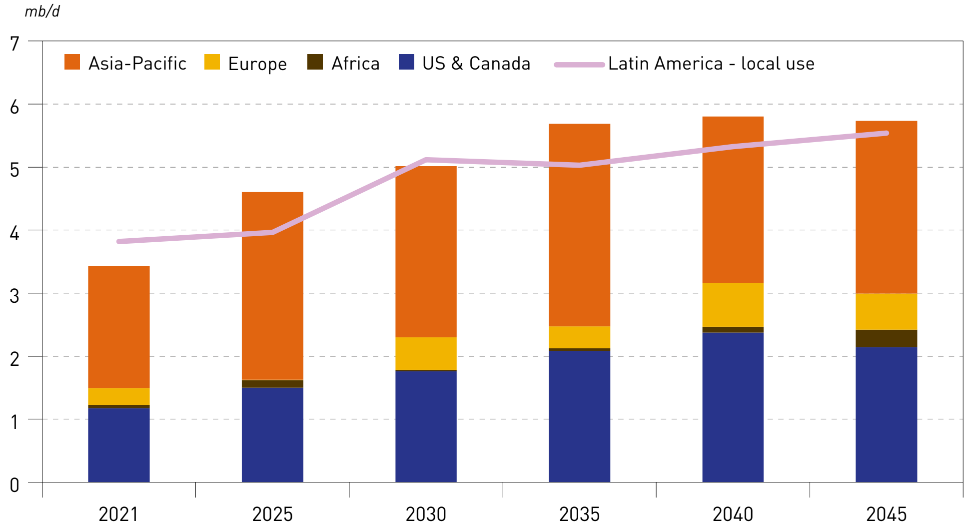
Source: OPEC.

The Asia-Pacific remains the main destination for Middle Eastern crude throughout the period. Export volumes are expected to increase from around 13.5 mb/d in 2021 to 19.5 mb/d in 2045. Flows to Europe are expected to almost double in the medium-term from around 1.3 mb/d in 2021 to almost 2.5 mb/d in 2025, after which they are expected to remain in a range around 2 mb/d.

Crude and condensate exports to the US & Canada are projected to increase strongly to 1.5 mb/d in 2025, up from 0.6 mb/d in 2021. In the long-term, however, Middle Eastern exports to the US & Canada decline to levels between 0.6 mb/d and 1 mb/d, which is in line with declining demand and rising domestic supply of heavier grades in this region (mostly from Canada).

Local crude use in the Middle East is set to increase throughout the outlook period, reaching 10.3 mb/d in 2045, up by more than 3 mb/d compared to 2021. This is in line with rising domestic demand, but also rising product exports to other regions. Figure 6.7 shows crude and condensate exports from Latin America. In line with strong supply growth,

Figure 6.7
Crude and condensate exports from Latin America by major destination, 2021–2045



Source: OPEC.

especially from Brazil and Guyana in the medium-term, exports from Latin America expand from 3.4 mb/d in 2021 to 5.7 mb/d in 2035. This is despite rising local crude use in this region, which increases by around 1.2 mb/d in the same period. However, crude and condensate exports are set to remain stable in the last ten years of the outlook, due to a slowdown in crude oil supply growth and a marginal increase in local crude use.

Any delays in refinery capacity additions in Latin America, or delays in assumed modernizations in the long-term, would necessarily lead to slower growth in refinery throughputs. This again could potentially push crude and condensate exports even higher.

The US & Canada and the Asia-Pacific are the main destinations for Latin American crude. Exports to the US & Canada increase continuously from around 1.2 mb/d in 2021 to 2.4 mb/d in 2040. This is followed by a dip to reach 2.1 mb/d in the final year of the outlook, which is in line with declining refinery throughputs. Latin American heavy-sour crude is in high demand in the US – mostly the US Gulf Coast – due to the high complexity of the refining system and relatively low transportation costs.

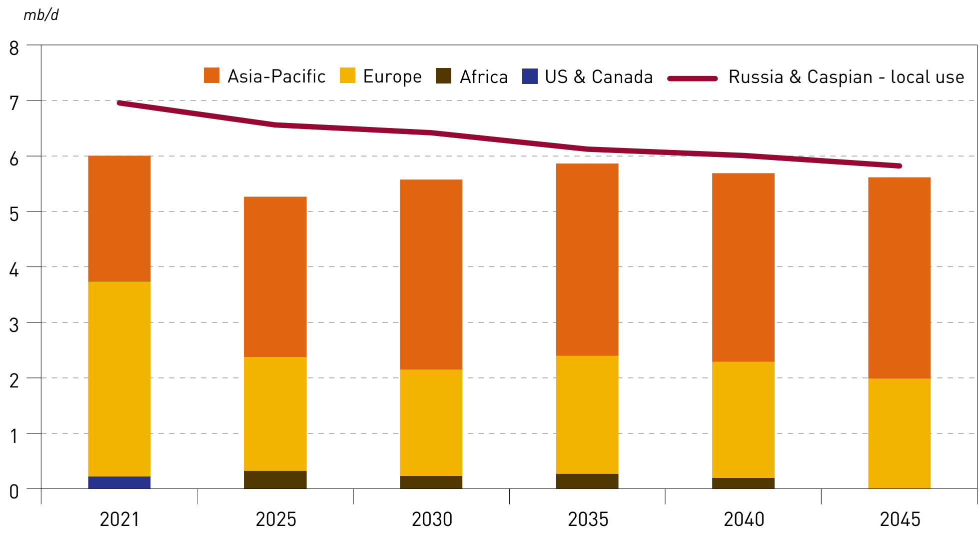
In the Asia-Pacific, crude exports from Latin America rise from just below 2 mb/d in 2021 to 3.2 mb/d in 2035. Similar to the US, Latin American heavier crudes are desired in the Asia-Pacific due to the refining complexity in some countries, particularly India and China. Beyond 2035, Latin American crude is set to decline to around 2.7 mb/d by 2045.

Although increasing, Latin American crude and condensate exports to Europe are not expected to go above 0.7 mb/d throughout the outlook period. Mostly sweet Latin American barrels are shipped to Europe, due to its lower refinery complexity.

Figure 6.8 shows crude and condensate exports from the Russia & Caspian region. The regional breakdown of crude and condensate exports from Russia & Caspian is expected to see a significant change from previous outlooks. As already mentioned, several countries/

regions have introduced embargoes on oil and refined products imports from Russia. Although the embargo could last for years, this outlook assumes that the EU continues importing some Russian crude in the medium- to long-term.

Figure 6.8
Crude and condensate exports from Russia & Caspian by major destination, 2021–2045



Source: OPEC.

However, this outlook recognizes the potential lasting consequences of the oil embargo on crude and condensate flows from Russia to the EU. This means that flows from Russia to the EU are likely to be significantly reduced compared to 2021 and relative to previous outlooks. This also means that Russia could redirect these volumes elsewhere – mostly to the Asia-Pacific, but also to non-EU European countries and some African countries.

It is important to note that this Outlook and Figure 6.8 shows flows from Russia & Caspian as one region. These include not only Russian barrels, but also volumes from Azerbaijan and Kazakhstan.

Due to the lower medium-term supply, total crude and condensate exports from Russia & Caspian are expected to decline to around 5.3 mb/d in 2025, down from 6 mb/d in 2021. In the long-term, exports are expected to initially increase gradually, reaching 5.9 mb/d in 2035, before dropping slightly to 5.6 mb/d in 2045. This is due to marginally higher supply, but also due to lower local crude use in this period.

Exports to Europe are projected to drop to below 2 mb/d in 2025, down from around 3.5 mb/d in 2021. As already mentioned, this Outlook assumes that Russian flows to Europe will resume beyond the short-term, albeit at lower level relative to 2021. In the longer-term, crude and condensate exports hover around 2 mb/d throughout the period. While the drop in 2025 can be largely attributed to the oil embargo, assumed long-term flows to Europe are the result of declining demand in this region.

Crude and condensate flows from Russia & Caspian to the Asia-Pacific are set to increase from 2.3 mb/d in 2021 to around 3.5 mb/d in 2030, after which they are expected to remain stable to 2045. The increase is not only due to Russian efforts to redirect their exports, but also due to rising oil demand and increasing refinery throughputs in Asia-Pacific. The Reference Case also expects minor flows from Russia & Caspian to Africa, which are set to be in the range of 0.2–0.3 mb/d between 2025 and 2040.

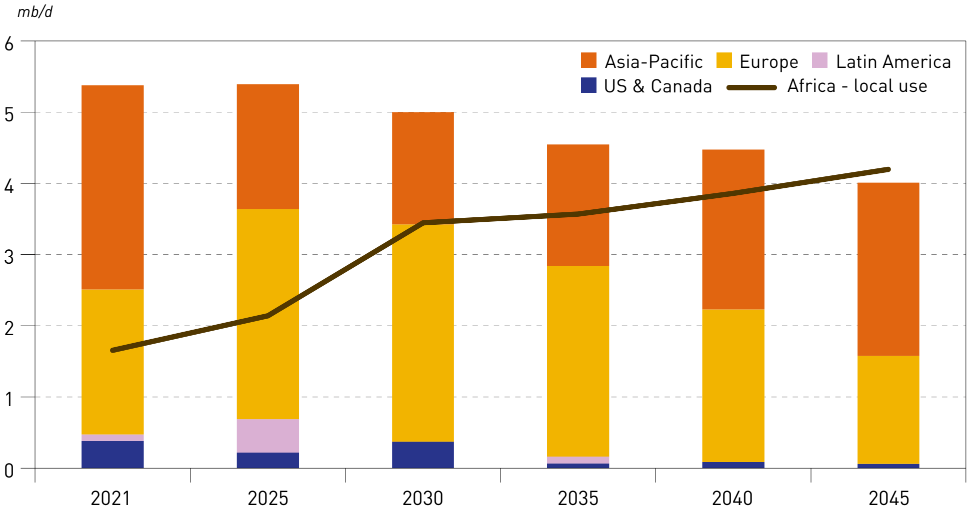
Local crude use in the Russia & Caspian region is expected to decline throughout the period, from around 7 mb/d in 2021 to 5.8 mb/d in 2045. This is only partly due to the announced EU embargo on oil product imports. More importantly, this is a continuing trend that was expected even before the Russia-Ukraine conflict, mostly due to demand decline in exports markets such as Europe. Given the uncertainty related to Russian product exports, refinery throughputs in this country could be even lower, especially in the medium-term, thus releasing additional crude for exports in the medium- to long-term.

African crude and condensate exports (Figure 6.9) are expected to remain relatively stable between 2021 and 2025 at around 5.4 mb/d. In the long-term, however, total crude exports are expected to decline gradually, from 5.4 mb/d in 2025 to around 4 mb/d in 2045. The major reason for this is the strong increase in local crude use, in line with expanding refining capacity and rising refinery throughputs.

The main destinations for African crude are the Asia-Pacific and Europe, with minor volumes flowing to the US & Canada and Latin America. Exports to Europe were estimated at around 2 mb/d in 2021. In the period 2025–2035, crude and condensate exports to this region are projected at a level between 2.7–3.1 mb/d, driven by declining domestic European supply and supported by relatively low transportation costs. Elevated imports in this period also mirror the replacement of Russian barrels in the EU. Beyond 2035, African crude and condensate exports to Europe are set to drop towards 1.5 mb/d in 2045, driven by declining oil demand.

African exports to the Asia-Pacific are expected to drop from almost 3 mb/d in 2021 to below 2 mb/d in 2025 and remain relatively stable to 2035. This is due to greater

Figure 6.9
Crude and condensate exports from Africa by major destination, 2021–2045



Source: OPEC.

competition from other regions, such as the US & Canada and the Middle East. Additional Russian flows to the Asia-Pacific are also set to replace some African supplies. Beyond 2035, African flows to the Asia-Pacific increase gradually to 2.4 mb/d, as there are set to be lower exports from the US & Canada, as well as rising demand.

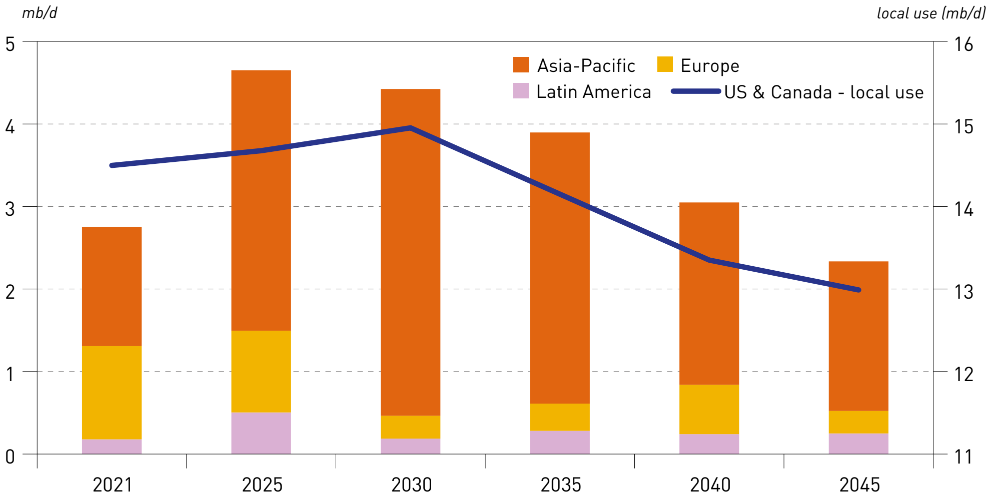
Africa is also expected to continue exporting crude and condensate to the US & Canada. However, these volumes remain negligible throughout the outlook period, mostly due to sufficient domestic supplies in the US and declining long-term demand in this region.

Local crude use in Africa is expected to increase strongly throughout the period, from around 1.7 mb/d in 2021 to 3.6 mb/d in 2030, and then further to 4.2 mb/d in 2045. Expected refinery expansion and rising refinery runs in Africa are the main driver behind this. However, if refining capacity expansion is delayed, it is likely that Africa would have lower refinery throughputs relative to the Reference Case. This would release additional crude and condensate volumes for exports to international markets.

Crude and condensate exports from the US & Canada averaged around 2.8 mb/d in 2021. In line with rising near-term supply, exports from this region are expected to increase to 4.7 mb/d in 2025 and then drop slightly towards 4.4 mb/d in 2030. Exports then decline further afterwards and reach 2.3 mb/d in 2045, in line with decreasing supply, predominantly from US tight oil.

The major export route for barrels from the US & Canada is the Asia-Pacific, which is forecast to increase from 1.4 mb/d in 2021 to 4 mb/d in 2030. Light-sweet US cargoes are expected to be in high demand in the Asia-Pacific due to their high light distillate yields, which is a good fit for numerous refineries geared towards petrochemical feedstocks. Nevertheless, exports from the US & Canada are set to start declining after 2030, reaching 1.8 mb/d in 2045. This is the result of lower total export volumes as explained previously.

Figure 6.10
Crude and condensate exports from US & Canada by major destination, 2021–2045



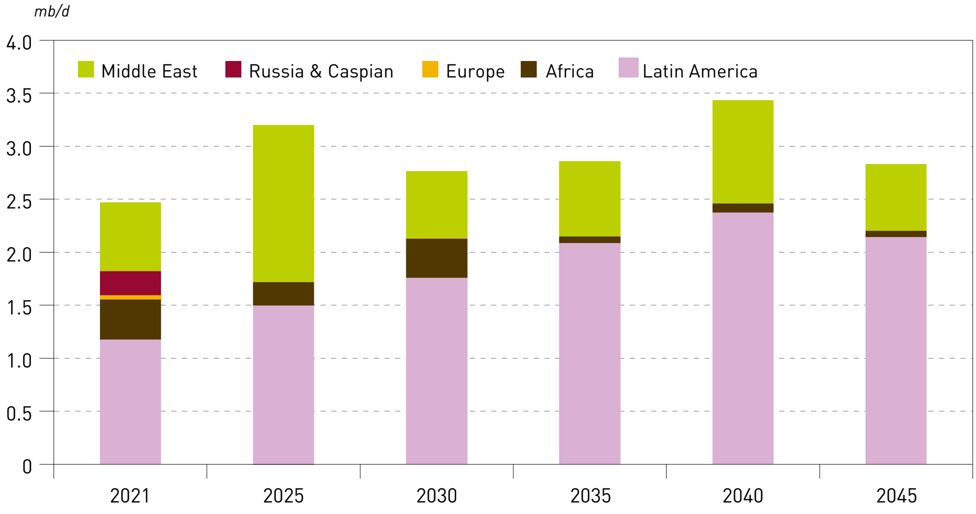
Source: OPEC.

Crude and condensate exports from the US & Canada to Europe remain relatively strong in the period to 2025 at around 1 mb/d. Nonetheless, volumes decline to more modest levels between 0.3 and 0.6 mb/d in the long-term as European refiners are expected to prefer more middle distillate rich crudes from the Middle East and Africa. Finally, the US & Canada continues exporting crude and condensates to Latin America. From around 0.5 mb/d in 2025, volumes decline to around 0.2 mb/d in the long-term.

Local crude use in the US & Canada increases from 14.5 mb/d in 2021 to 15 mb/d in 2030. Due to anticipated declining demand and refinery throughputs, local crude use then drops to 13 mb/d by 2045.

At the same time, the US & Canada (Figure 6.11) is projected to continue importing significant volumes of crude (mostly the US). These are mostly heavier grades from Latin America and the Middle East, which are well-suited to complex US refiners. Some minor volumes from Africa are also projected to head to the US & Canada throughout the outlook period.

Figure 6.11
Crude and condensate imports to the US & Canada by origin, 2021–2045



Source: OPEC.

Total crude and condensate imports are expected to increase from around 2.5 mb/d in 2021 to 3.2 mb/d in 2025, in line with rising refinery throughputs in the US & Canada. Beyond 2025, crude and condensate imports are seen oscillating between 2.8 mb/d and 3.4 mb/d, which is mostly the result of crude availability and resulting economics.

Imports from Latin America are set to double from 1.2 mb/d in 2021 to 2.4 mb/d in 2040. This is due to the increasing availability of crude and rising exports from Latin America. The proximity of the two markets also supports rising flows. In 2045, imports from Latin America are forecast to drop to around 2.1 mb/d, mainly due to declining refinery throughputs and rising heavy crude supplies from Canada.

Although lower relative to Latin America, crude imports from the Middle East remain significant. They are expected to increase to 1.5 mb/d in 2025, up from 0.6 mb/d in 2021, in line with rising demand and throughputs. From 2025 onwards, crude and condensate imports from the Middle East are estimated in a range between 0.6 mb/d to 1 mb/d.

Imports from Africa are set to decline in the long-term. From around 0.4 mb/d in 2021 to 0.1 mb/d from 2035 onwards. The major reason for this is declining demand in the US & Canada, as well as increasing competition with medium- and heavy-sweet imports from Latin America.

The US & Canada traditionally imported small crude volumes from Russia (around 0.2 mb/d in 2021). Due to the imposed sanctions and oil embargo by both the US and Canadian governments, no Russian crude and condensate flows to the US & Canada are expected.

European crude and condensate imports were estimated at around 8.2 mb/d in 2021. In line with the expected oil demand recovery, imports are set to increase slightly in 2025, reaching almost 8.5 mb/d. In the longer-term, crude and condensate imports to Europe are the function of declining demand and decreasing local supply. As demand is expected to drop significantly more, relative to local supply, crude and condensate imports are set to fall gradually, dropping to 6.6 mb/d in 2045.

Due to the Russia-Ukraine conflict, as well as the EU and UK embargoes on imports from Russia, the import mix is expected to change relative to previous outlooks. As mentioned already, the Reference Case assumes that the market will stabilize in the medium-term and that limited flows of Russian crude and products to the EU will continue. However, these volumes are not likely to reach pre-conflict levels, as some replacement of Russian crude are expected to be permanent. At the same time, the EU and the UK will have to replace missing Russian volumes with barrels from elsewhere, mostly likely from the Middle East and Africa, and possibly some minor volumes from Latin America and the US & Canada.

As already noted, it is important to stress that this outlook shows flows from Russia & Caspian as one region. These include not only Russian barrels, but also volumes from Azerbaijan and Kazakhstan. In addition, as shown in Annex C, the regional definition of Europe includes not only the EU and UK, but also numerous non-EU countries. This is why some exports of Russian crude could be redirected within Europe, from EU to non-EU countries, which are not affected by the embargo, such as Turkey.

Taking all this into account, the outlook sees a significant drop in crude flows from Russia & Caspian to Europe, but not a complete phase out of exports in the medium- and long-term. From around 3.5 mb/d in 2021 (and around 4 mb/d in 2019) imports of crude and condensate from Russia & Caspian are projected to decline to levels around 2 mb/d in 2025 and then remain stable to 2045.

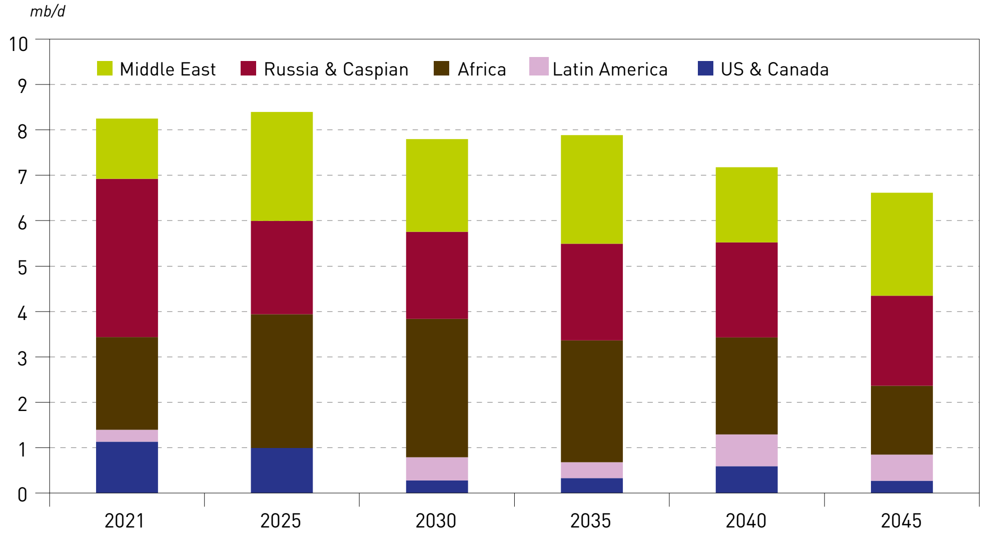
It is important to note that the Reference Case assumes that effect of the oil embargo is the strongest in the period to 2035. Beyond 2035, European imports of crude from Russia & Caspian would have been significantly lower relative to 2021, even without the oil embargo. This is due to lower demand in Europe and a rising focus of Russia & Caspian on the Asia-Pacific. This view is also noted in OPEC's previous WOOs. For instance, the WOO 2021 saw a drop from 4 mb/d in 2019 to 2.8 mb/d in 2045 for European crude and condensate imports from Russia & Caspian.

In order to replace missing Russian barrels, Europe is expected to import additional volumes from the Middle East and Africa, which are included in the Reference Case projections. Imports from the Middle East are projected to increase from 1.3 mb/d in 2021 to 2.4 mb/d in 2025. Beyond 2025, imports are set to oscillate between 1.7 mb/d and 2.4 mb/d until 2045. Furthermore, European imports of crude and condensate from Africa are expected to increase from 2 mb/d in 2021 to 2.9 mb/d in 2025 and then further to 3.1 mb/d in 2030. After 2030, these flows are set to decline gradually to 1.5 mb/d in 2045, mostly due to lower European oil demand.

Imports from the US & Canada are likely to remain relatively stable between 2021 and 2025 at around 1 mb/d. In the period 2025–2045, oil imports from the US & Canada are expected to decline to levels between 0.3 mb/d and 0.6 mb/d. The lower interest from European buyers can be explained by the relatively high light-distillate yields of US imports (mostly light-sweet tight oil). European buyers are more attracted by Middle Eastern and African grades, which are heavier and contain more middle distillates.

As Europe is not the primary outlet for Latin American crude, imports increase only slightly in the long-term. From around 0.3 mb/d in 2021, imports rise to around 0.6–0.7 mb/d in the period 2040–2045.

Figure 6.12
Crude and condensate imports to Europe by origin, 2021–2045



Source: OPEC.

Finally, the Asia-Pacific will remain the most important importing region throughout the outlook period. Total crude and condensate imports are projected to increase from 22.5 mb/d in 2021 to above 30 mb/d in 2045, due to rising demand, as well as declining local crude supply.

The Middle East remains the most significant supplier to Asia-Pacific, with volumes increasing stepwise from 13.5 mb/d in 2021 to 19.5 mb/d in 2045. The share of Middle East in total Asia-Pacific imports is expected to increase from around 60% in 2021 to almost 65% in 2045.

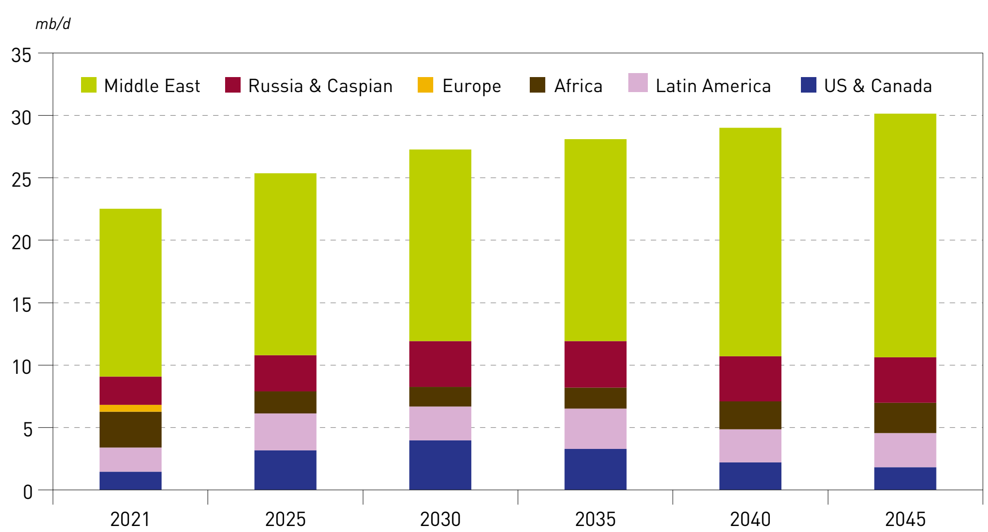
Imports from the US & Canada are projected to increase strongly, from 1.4 mb/d in 2021 to 3.2 mb/d in 2025 and then to almost 4 mb/d in 2030. This is driven by strong demand from Asian refiners for light-distillate rich crudes, which can provide sufficient petrochemical feedstocks. Post-2030, crude and condensate imports from the US & Canada are forecast to decline gradually to 1.8 mb/d in 2045, mainly due to declining US tight oil supply.

Crude and condensate imports from Russia & Caspian are expected to increase from 2.3 mb/d in 2021, to 2.9 mb/d in 2025 and 3.7 mb/d in 2030. They remain stable thereafter. As discussed, a part of these volumes are related to barrels originally destined for Europe, especially in the early years of the outlook. In the longer-term, Russia was expected to increase its exports to Asia-Pacific independently of the current geopolitical turmoil. In the WOO 2021, exports from Russia & Caspian to Asia-Pacific were expected at almost 3.8 mb/d in 2045, which is even higher compared to the current outlook for the same year.

Crude and condensate flows from Latin America to the Asia-Pacific are projected to increase from just below 2 mb/d in 2021 to 3.2 mb/d in 2035, in line with rising Latin American supply. Nevertheless, flows are expected to decline to around 2.7 mb/d after 2035, which is based on the lower availability of Latin American crude, predominantly due to higher local use.

Asia-Pacific's crude and condensate imports from Africa are expected to decline from almost 2.9 mb/d in 2021 to 1.5 mb/d in 2030, as Africa sees an increase in local crude, as well as rising exports to Europe. In the long-term, however, imports from Africa start rising again and reach 2.4 mb/d in 2045.

Figure 6.13
Crude and condensate imports to Asia-Pacific by origin, 2021–2045

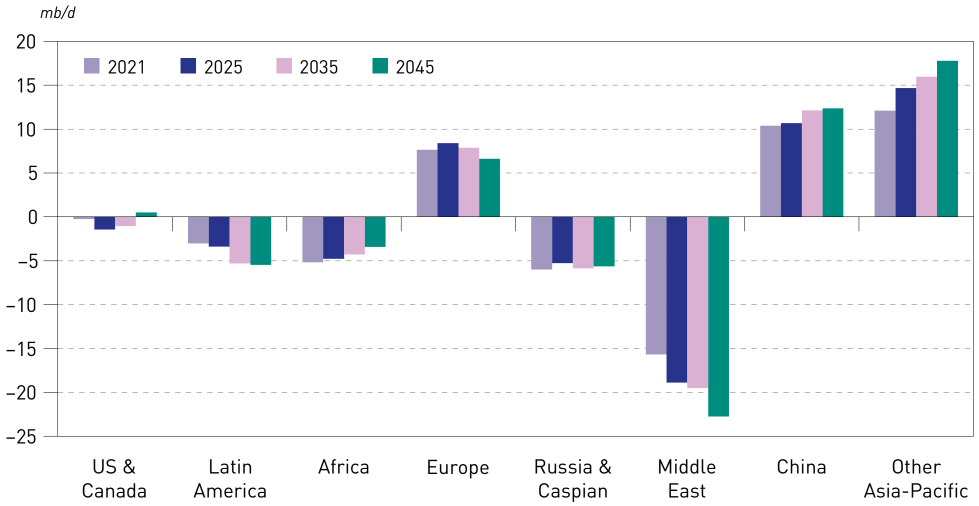


Source: OPEC.

Figure 6.14 shows net crude and condensate imports from all major regions with some clear trends.

On the net exporting side, the Middle East shows the highest growth in the outlook period, increasing from 15.7 mb/d to 22.7 mb/d in 2045. This is based on a strong

Figure 6.14
Regional net crude and condensate imports, 2021, 2025, 2035 and 2045



Source: OPEC.

demand increase for OPEC liquids and a corresponding rise in Middle Eastern supply. Latin America is also expected to increase its net exports, though less in magnitude. From around 3 mb/d in 2021, they increase to 5.5 mb/d in 2045.

Net crude exports from Russia & Caspian drop only slightly from 2021 levels, but recover again due to lower local use. In 2045, net exports from Russia & Caspian are expected at 5.6 mb/d, down from 6 mb/d in 2021. African net crude and condensate exports are seen declining throughout the period, from 5.2 mb/d in 2021 to 3.4 mb/d in 2045. This is due to the strong increase in Africa's local use, combined with only a minor increase in crude and condensate supply. The US & Canada is a net exporter between 2021 and 2035. Its highest net export level is reached in 2025 at 1.5 mb/d. However, due to declining supply, the US & Canada is set to become a net importer of around 0.5 mb/d by 2045.

On the net import side, China and Other Asia-Pacific combined are set to increase their crude and condensate net imports by around 8 mb/d, from 22.5 mb/d in 2021 to above 30 mb/d in 2045. This is a result of increasing demand and declining local supply, which drops almost 1.8 mb/d over the outlook period. After a minor increase to 8.4 mb/d in 2025, European crude and condensate net imports are expected to fall to 6.6 mb/d in 2045, mostly due to declining local demand.

6.4 Product movements

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 relative to refined products. The majority of refined products are produced and consumed within the respective regions.

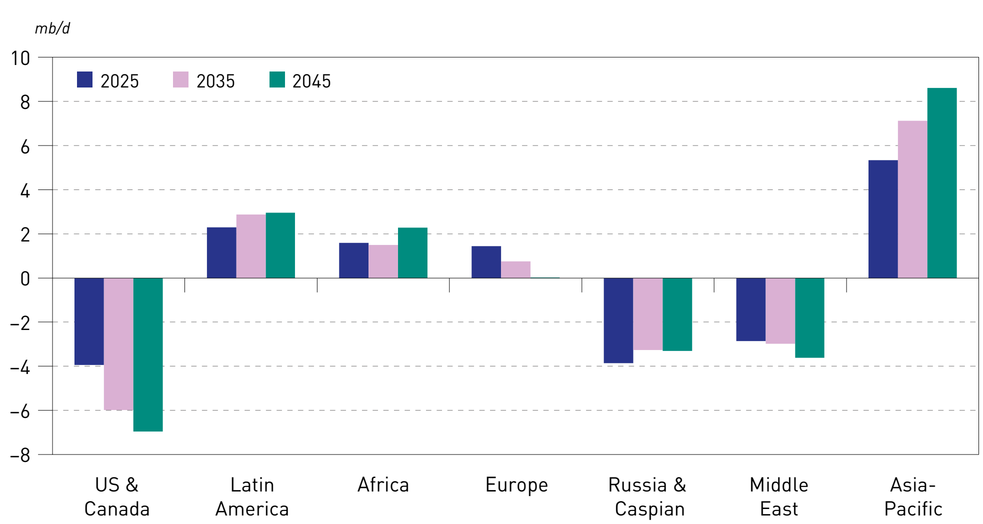
In other words, a large part of refined product trade remains an intratrade issue (trade within the region itself). However, there are still significant refined product flows from regions with sufficient refining capacity to others where local product demand is higher compared with local refinery production. Consequently, future trends depend on local demand growth, as well as available and new refining capacity (see Chapter 5).

On the net export side, the most important region is the US & Canada, where net product exports increase from 3.9 mb/d in 2025 to 7 mb/d in 2045. The main driver is declining demand in the US & Canada, which leads to rising product exports. The highly sophisticated US refining system is seen as competitive in the global downstream market. Net exports from the Middle East are set to increase from 2.9 mb/d in 2025 to 3.6 mb/d in 2045. These modest increases are the result of a strong demand increase that limits available capacity for exports.

Net exports from Russia & Caspian are expected to decline from almost 4 mb/d in 2021 to 3.3 mb/d from 2035 onwards. The drop is the result of declining demand in export outlets such as Europe, as well as increasing competition from other regions, such as the US and the Middle East. Furthermore, it is still unclear to what extent the oil embargo could hit Russian product exports and, consequently, the Russian refining sector. The impact could be significant with lower Russian product exports than projected, which could even lead to refinery closures in Russia.

On the net import side, the most important region is the Asia-Pacific, where volumes are expected to increase from 5.3 mb/d in 2025 to 8.6 mb/d in 2045, mostly due to rising demand. Net product imports to Africa are expected at around 1.5 mb/d between 2025 and 2035, followed by a modest increase to 2.3 mb/d in 2045. This is under the assumption that refining capacity is expanded as shown in Chapter 5. Any delays or cancellations would lead to higher net product imports.

Figure 6.15
Regional net product imports, 2025, 2035 and 2045



Source: OPEC.

In Latin America, net product imports are projected to increase from 2.3 mb/d in 2025 to 3 mb/d in 2045. The increase is due to rising demand and increasing competition from US refiners, as mentioned previously. Finally, net imports to Europe are set to decline from 1.4 mb/d in 2025 to nil in 2045, which is predominantly based on declining long-term demand.

Energy policy, climate change and sustainable development

Key takeaways

- At COP26 in Glasgow in October/November 2021, Parties to the Paris Agreement adopted a number of decisions that could allow the operationalization of the agreement. Parties have been called to consider how these decisions could be reflected into real climate action, noting with concern the mitigation gap in the pre-2020 period. Some Parties have submitted revised NDCs.

- Many OPEC Member Countries have submitted new or updated NDCs, and many have ambitious roadmaps to achieve climate change targets, for example, in blue and green hydrogen, the concept of circular carbon economy, the Saudi Green Initiative and the Middle East Green Initiative.

- In the current geopolitical context, coupled with the challenges and risks associated with climate change and the pandemic, it is evident that developing countries are more vulnerable, indebted and less resilient. Multilateralism and a holistic sustainable development approach could support the scaling-up of resources for mitigation, adaptation and resilience.

- Science provides evidence that climate action should go hand-in-hand with the provision of means of implementation, including climate finance. To scale-up mitigation ambition and implementation, policy action should adhere to the core principles and provisions of the Convention and the Paris Agreement. Developed countries should avoid imposing any undue burden on developing countries and should ensure addressing the consequences of response measures.

- Energy action is required more than ever amid present disruptions related to the impacts of the pandemic, geopolitics and the global economic situation, but the world is currently falling behind in the attainment of SDG 7 targets that are related to energy poverty eradication. International cooperation and finance are fundamental factors for achieving progress on the SDGs, including on universal energy access that leaves no one behind in ensuring a just and inclusive energy transition.

- In many countries there has been a noticeable increase in the rate of change of energy policy measures, with increased ambition in order to meet long-term climate goals.

- Hydrogen could play an important role in efforts to reduce future emissions. Hence, many countries increasingly focus on hydrogen as an integral part of their energy policies.

- CCUS represents another opportunity to increase the scale of clean hydrogen produced from fossil fuels by preventing direct emissions, as well as preventing emissions from fossil fuel facilities in the energy sector.

This chapter includes a brief assessment of the latest available NDCs communicated by Parties under the Paris Agreement, including matters related to enhanced mitigation action and implementation processes. It summarizes the information presented in regard to future emission reduction targets, with a focus on the energy sector, as well as actions required to address the concerns of Parties with economies most affected by the impacts of the implementation of climate mitigation response measures, particularly developing countries.

The key outcome of UNFCCC climate negotiations and the major decisions adopted by Parties for the full implementation of the Paris Agreement are critically discussed (e.g. the 'Glasgow Climate Pact'). This includes looking at various mandated activities and processes already launched in the run-up to and/or those planned to take place at COP27 in Egypt and beyond – such as the first global stocktake under the Paris Agreement and the progress achieved so far in negotiating a new collective quantified goal on climate finance.

This chapter also considers the latest available information in terms of the global efforts on the eradication of energy poverty, including progress made on achieving universal access to affordable, reliable, sustainable and modern energy by 2030, as per SDG 7. The critical elements of the 'global roadmap for accelerated SDG 7 action' and further guidance arising from the High-level Dialogue on Energy for a sustainable energy future for all are briefly highlighted too.

In addition, this chapter explores the key energy policies of major economies that are likely to have an impact on the energy sector and, therefore, the future energy mix. The use of hydrogen, which could play an important role in the long-term energy mix, is also discussed.

7.1 Climate change and sustainable development

It was in the summer of 1972, 50 years ago, that the First Earth Summit convened in Stockholm, Sweden, for global leaders to adopt a series of principles and resolutions on environmental matters within the overarching goal of sustainable development.

Recognizing the importance of multilateralism in tackling climate change, this landmark event brought environmental matters to the fore of international policymakers, introduced climate mitigation and adaptation action on the global agenda, called for collaboration between developed and developing countries in the context of sustainable development and efforts to eradicate poverty, and raised environmental awareness.

The need to limit global warming became more prominent in the ensuing years, with a continuously increasing number of environmental policies setting national targets that aim to address this challenge in the pursuit of sustainable development objectives. International climate policy and climate diplomacy has also evolved too.

Within this framework, over the years the inherent uncertainties, risks and complexities of developing sound national strategies that could reduce future emissions have been widely acknowledged amid social, economic, and political challenges, along with the need for global-scale efforts to tackle climate change. These laid the foundation of the UN climate processes and are reflected in the core principles and provisions of the Convention

(UNFCCC), the Kyoto Protocol and the Paris Agreement – such as those of equity, common-but-differentiated responsibilities and respective capabilities, and a just transition.

In 2020 and the 1H21, the COVID-19 pandemic led to a postponement of critical UNFCCC negotiation sessions that were focused on enabling the adoption of decisions for the Paris Agreement operationalization. Yet, there were still significant developments in the global response to climate change, with many countries announcing new targets and measures to contribute to the attainment of the Paris Agreement's long-term goals.

Against a backdrop of accelerating climate impacts and geopolitical tensions, developed and developing countries are currently being encouraged to enhance the implementation of the 'UN Decade of Action' and deliver the SDGs of the 2030 Agenda – such as on energy poverty eradication – while achieving the Paris Agreement goals, building back better resilient societies, and leaving no one behind.

The 'Stockholm+50' high-level meeting, organized from 2–3 June 2022, was both a commemoration of the first UN conference on the environment and a call to catalyze multilateral action on climate change, including through financial support and technology transfer. Among the key recommendations presented at this event were the need to rebuild relationships for strengthened cooperation and solidarity, and accelerate the transformations of high-impact sectors, such as energy and mobility.

This year also marks the 30th anniversary of the UNFCCC, and Parties are effectively looking ahead to COP27 that is scheduled to take place from 6–18 November 2022, in Sharm El-Sheikh, Egypt, and beyond, recognizing the importance of enhancing global collective efforts to address climate change and exhibit universal commitment to implement the 'Glasgow Climate Pact'.

As further elaborated later, the 'Glasgow Climate Pact' is a key outcome of COP26 – held from 31 October to 13 November 2021, in Glasgow, the UK, after a year's delay due to the pandemic. The pact aims to enhance action across the globe on climate change mitigation, adaptation, finance and collaboration.

Six years after the adoption of the Paris Agreement at COP21, Parties also agreed in Glasgow upon issues required for completing the Paris Agreement Work Programme, or the so-called rulebook of the agreement (e.g. on matters related to Article 6 of the agreement in terms of market and non-market approaches), therefore, paving the way for a new era of climate action.

In particular, Parties reconfirmed at COP26 the need to collectively reduce global emissions, adapt to the impacts of climate change, and mobilize climate finance at scale. Parties also reiterated their commitment to climate action and ambition, increasing efforts to implement initiatives related to climate mitigation and adaptation. Some signs of progress towards future emission reductions were seen prior and during the Glasgow meeting with the submission of new or updated NDCs.

Both developed and developing countries are, therefore, conscious of the urgent need to tackle the challenge of climate change. Yet, COP26 did not deliver sufficient results to meet the needs of developing countries for them to be able to contribute effectively to the Paris Agreement implementation.

The stakes are evidently high for this year's COP, with Parties acknowledging the need to provide adequate support to developing countries – including through climate finance, technology development and transfer, and capacity-building. This would help give them the possibility to adapt and mitigate to climate change, in line with the core principles and provisions of the Convention and the Paris Agreement, and in light of national circumstances and priorities.

Moreover, scientific evidence – as provided by the recently released IPCC sixth assessment reports (AR6) on adaptation and mitigation – indicates that global emissions are still increasing, leading to an observed global warming of approximately 1.1°C since the pre-industrial period. Over the period 2010–2019, average annual GHG emissions were higher than in any previous decade, but the rate of growth is lower.

As a result, it is estimated that without enhanced climate action, the world will significantly exceed the Paris Agreement temperature target by the end of the century. In addition, if global emissions remain at present levels of about 59 gigatonnes (Gt) per year, the remaining carbon budget is expected to be exhausted before 2030. Thus, climate action is needed, linking adaptation with mitigation and sustainable development for the world to be put on climate resilient development pathways.

However, future climate action needs to be implemented in a way that ensures a balanced treatment of adaptation and mitigation action, with developed countries fulfilling their commitments on the provision of accessible, adequate and timely support to developing countries. Increased climate action should be supported by *inter alia*, consistent and scaled-up financial flows to developing countries, which are the least responsible for climate change. Moreover, they are already being detrimentally affected by its impacts and have the least capacity to tackle this challenge.

Developed countries should, therefore, take the lead, including in closing the pre-2020 'mitigation gap', and avoiding the imposition of any undue burden on developing countries. Developed countries should also support developing countries by providing technology and capacity-building. Besides the provision of these enabling conditions, it is important to address the consequences and impacts of the implementation of climate response measures. This includes ensuring equitable access for developing countries to the estimated remaining carbon budget, and in pursuing sustainable development and poverty eradication.

Finally, the specific circumstances and capabilities of every country, including natural resource endowed countries, should be considered in future climate action and environmental policies. In this context, technological innovation offers an approach to address climate change. The wide deployment of technological innovation – such as CCUS technologies and hydrogen – is a viable option to achieve future emissions reduction. Such innovative approaches offer wider benefits not only for natural resource endowed countries, but also for the rest of the world, and to help ensure an inclusive, equitable, just and sustainable transition.

7.1.1 UN climate process and the Paris Agreement implementation

While the COVID-19 pandemic and energy security concerns put further pressure on governments of both developed and developing countries to ensure human well-being and a sustainable future for all, the importance of tackling climate change remains.

Intense negotiations at COP26 led to the adoption of a package of decisions that pave the way for the full implementation of the Paris Agreement. Reaching consensus on substantive negotiation issues, Parties identified work going forward in the key areas of enhancing ambitious climate mitigation actions to reduce GHG emissions and strengthening adaptation actions and support, including increasing the provision of finance to developing countries to promote their climate actions.

At the 'World Leaders Summit', held in the first days of COP26, the importance of international cooperation and partnership to enhance collective climate actions was highlighted. Particular attention was paid to launching a number of declarations and initiatives, including the following:

- The 'Global Methane Pledge', which relates to a 30% reduction of methane emissions from 2020 levels by 2030, and moving towards using the best available inventory methodologies to quantify methane emissions;
- The 'US-China Joint Glasgow Declaration on Enhancing Climate Action in the 2020s' to promote join efforts to address climate change, including by reducing methane emissions, phasing down coal, promoting decarbonization, protecting forests and conducting technical cooperation;
- The 'Glasgow Leaders' Declaration on Forests and Land Use', which aims to work collectively to halt and reverse forest loss and land degradation, including through reforestation and afforestation, by 2030.

A cover decision, the 'Glasgow Climate Pact', was adopted by Parties along with a set of decisions on the Paris Agreement rulebook and other main issues to address climate change. More specifically, it was decided to establish a work programme on NDCs to urgently scale up mitigation ambition and implementation by 2030, aiming to close the 'implementation gap' towards the Paris Agreement goals. The UN Secretary-General will convene a world leaders summit in 2023 to consider ambitions by 2030.

Parties also decided to convene an annual high-level ministerial roundtable on pre-2030 ambition, beginning this year in Egypt. Parties were also called to accelerate the development, deployment and dissemination of technologies, and the adoption of policies, to transition towards low-emission energy systems. This includes by rapidly scaling-up the deployment of clean power generation and energy efficiency measures, including accelerating efforts towards the 'phase down' of unabated coal power and 'phase-out' of inefficient fossil fuel subsidies, while recognizing the need for support towards a just transition.

Noting with concern the IPCC findings, Parties were further called to enhance adaptive capacity and strengthen resilience to climate change, highlighting that the current provision of climate finance for adaptation remains insufficient, and, therefore, underlining the urgency of scaling-up action and support, taking into account the priorities and needs of developing countries. To this effect, Parties welcomed the launch of a two-year Glasgow–Sharm El-Sheikh work programme on a global adaptation goal.

In addressing unresolved issues for the Paris Agreement operationalization, Parties agreed *inter alia* on the modalities, procedures and guidelines for the three components of Article 6 of the agreement on market and non-market approaches. A new set of common reporting and tools were adopted under the transparency of action and support to track the NDC-implementation and allow transparency on support provided and needed. Matters related to the impacts of the implementation of climate response measures were also addressed, and in the decision on the common timeframes for NDCs, Parties were encouraged to communicate in 2025 an NDC with an end date of 2035, then in 2030, an NDC with end date of 2040, and so forth every five years thereafter.

In regard to financial support to developing countries, Parties noted with deep concern that the commitment of developed countries to mobilize jointly $100 billion p.a. by 2020 has not been met. Developed countries were called to meet this target expeditiously and provide greater clarity on their pledges through their next biennial communications. An *ad hoc* work programme on the new collective quantified goal on climate finance from 2022–2024 was established and a high-level ministerial conference will be convened annually.

Following COP26, the intersessional climate negotiations took place in Bonn for the first time in three years. The 56th sessions of the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) and the Subsidiary Body for Implementation (SBI) lasted for two weeks (6–16 June 2022), with countries aiming to advance work and prepare draft decisions for potential adoption at COP27.

Negotiations were focused primarily on how to operationalize work programmes and processes for the Paris Agreement implementation, and at the end of these sessions some progress was made on a range of critical issues, such as for mitigation ambition and implementation, enhanced resilience to adapt to the impacts of climate change, and financial support for developing countries.

Matters such as collective progress on the Paris Agreement implementation were considered, with the first technical dialogue under the global stocktake convened in Bonn that aimed to build accountability and ambition into the agreement. The work programme on the global goal on adaptation was also launched in Bonn, and the critical issue of the new collective quantified goal on climate finance was considered in a technical expert dialogue.

The recently released IPCC reports on adaptation and mitigation influenced significantly the positions of Parties during negotiations in Bonn. Many developing countries highlighted that without sustainable development, poverty eradication, and a just energy transition, the global discussion on climate action would be lacking in its effective inclusion of equity, balance and ensuring that all Parties are truthfully coming together to advance solutions for all. It remains to be seen whether COP27 can address these concerns.

Looking ahead to COP27, it should be noted that by the end of 2021, a number of Parties refined, expanded and diversified their portfolios of climate mitigation and adaptation actions, with many focusing on the energy sector to achieve emission reductions and sustainable energy security. However, developing countries continue to face challenges in tackling climate change and attaining the SDGs, primarily due to a lack of financial resources.

At the time of writing, a total of 161 Parties have submitted to the UNFCCC Secretariat their new or updated NDCs, including most OPEC Member Countries. All OPEC Member Countries were signatories to the Paris Agreement. The overall total submitted NDCs represents more than 80% of global GHG emissions. Implementation of these NDCs – including their conditional elements on the provision of means of implementation – could imply that global emissions are likely to be higher in 2030, compared to 2010 levels.

Therefore, it should be highlighted that the implementation of conditional NDCs relates to the provision of financial support, technology development and transfer, and capacity-building. The need for support from developed countries has been stressed by many developing countries, with some including this in their NDC dedicated sections on means of implementation (see Box 7.1).

Finance and technology needs are presented by Parties, providing both qualitative and quantitative information, often for specific sectors – including the energy sector – and/or technology innovation, and research and development. Capacity-building is considered a prerequisite for NDC-implementation too. The critical role of international cooperation is highlighted, as well as the use of market-based mechanisms. For the implementation of NDCs, many Parties have provided information on institutional arrangements, stakeholder engagement, and policy instruments, including legislation, strategies and policies.

In particular, mitigation measures for achieving NDC-targets are outlined in Parties' submissions, with many focusing on specific sectors, such as energy supply, transport, buildings, industry and agriculture. The majority of Parties have presented policies that aim to increase the share of renewable energy sources in the energy mix and/or improve energy efficiency. Many Parties consider the use of cooperative approaches under Article 6 of the Paris Agreement to achieve their emission targets.

On energy-related priorities, renewable energy generation and the shift to low- or zero-emission fuels are indicated by many Parties, along with increased electrification in end-use sectors (e.g. transport and buildings) and energy efficiency improvements. Some provide information about the phasing out (or reforming) inefficient fossil fuel subsidies. The enhanced use of CCS technologies in the oil and gas industry is highlighted by a number of Parties, considering economic diversification approaches. A few countries have also circular economy strategies embedded in their NDCs.

Besides mitigation action, adaptation priorities are reflected in Parties' NDCs, with a focus on areas such as food security, human health, freshwater resources, terrestrial and wetland ecosystems, urban areas, as well as livelihoods and poverty eradication. In this context, some Parties refer to mitigation co-benefits that result from adaptation action and economic diversification plans, often elaborating on the positive and/or negative social and economic impacts of response measures.

A few Parties have included aspects related to a just and equitable transition through the implementation of climate policies, highlighting efforts related to sustainable development and poverty eradication. Almost all Parties present their NDCs as fair and ambitious in the light of national circumstances, being prepared in an inclusive and participatory manner.

In terms of emission reductions, many Parties included an absolute emission reduction target and some specified a year (or time period) for their emissions to peak. Other Parties preferred to present relative emission reduction targets below a business-as-usual level by a specific year. The target may be sectorial or related to the whole economy, and Parties aim to achieve carbon neutrality or intensity targets for specific GHGs per GDP unit relative to the base-year level.

In general, economy-wide NDCs include all sectors, relate to emission reductions of all gases (e.g. CO_2, methane and nitrous oxide emissions) over time, and refer to removals too. Most Parties present their targets by 2030, and many make reference to their long-term strategies up to and beyond 2050 – therefore, indicating climate neutrality, carbon neutrality, or net-zero emission targets.

It should be further noted that a total of 51 Parties have communicated their long-term strategies (LTSs), representing almost 60% of global GHG emissions. As previously stated, many of these Parties refer to their LTSs in the new or updated NDCs. Information presented in some NDCs is also based on national development plans and priorities, or sectorial approaches, including energy roadmaps. Moreover, some information included in the first NDCs has been updated, owing to various factors, such as changes in the methodological approaches used to develop NDCs (e.g. methods for estimating emissions and removals).

Overall, the latest NDCs contain additional information to increase clarity, transparency and understanding on emission reduction targets, means and approaches. Some state that they incorporate enhanced ambition and policies, and a few bring forward the expected date of emissions peak, while also providing information on adaptation action, linkages with national development plans and the SDGs.

The new or updated NDCs often include information on low-emission development strategies and energy plans. A few also refer to the impacts of the COVID-19 pandemic

Table 7.1
Mitigation targets of major economies

Country/region	Share of global GHG emissions *(%)*	NDC target by 2030	LTS (or NZT) target
Annex I Party			
US	11.84	50–52% below 2005 levels	NZT by 2050
EU27	6.81	55% below 1990 levels	Climate neutrality by 2050
Russia	4.07	30% below 1990 levels	NZT by 2060
Japan	2.36	46–50% below 2013 levels	Carbon neutrality by 2050
Non-Annex I Party			
China	23.92	65% below 2005 levels (GDP intensity)	Carbon neutrality by 2060
India	6.84	33–35% below 2005 levels (GDP intensity)	NZT by 2070
Brazil	2.90	50% below 2005 levels	NZT by 2050
South Africa	1.06	350–420 MtCO_2eq	NZT by 2050

Note: NZT stands for net-zero target.

Source: Climate Action Tracker, 2022.

on the Parties' economies, highlighting the importance of building resilient and sustainable economies while tackling climate change.

In addition to considering synergies between adaptation, mitigation and sustainable development, some Parties provided information about costs, and losses and damages related to climate change. Some paid particular attention to the need for reducing or eliminating the adverse impacts from the implementation of mitigation response measures on vulnerable groups and societies in terms of poverty eradication, job creation and equity. Approaches such as just transition mechanisms and just transition funds were identified by some Parties.

Table 7.1 includes the NDC and/or LTS emission reduction targets of major economies and regions, which collectively represent almost 60% of global GHG emissions.

In light of the above and in the run-up to COP27, Parties' NDCs have been assessed as not sufficient to achieve the long-term goals of the Paris Agreement. Thus, Parties have been called to deliver on the commitments they have made with strengthened and robust policy action. They are expected to build momentum and concerted action for the COP27 agenda and beyond. Breakthrough actions and innovative approaches are likely to be considered to also address the adverse impacts of the implementation of climate response measures.

Box 7.1

Climate finance

The effects of climate change are already directly impacting developing countries. Moreover, the deployment of resources from developed countries for them to mitigate and adapt to the impacts of climate change remains neglected. Considering the very limited fiscal leeway in developing countries and the lack of capacity to tackle climate change, support from developed countries is urgently required.

Indeed, in 2009, developed countries had a stated commitment to mobilize $100 billion a year to developing countries for climate action by 2020. However, this longstanding responsibility on climate finance has fallen short, and additionally the financing provided is mostly loans, which only increases the debt burden of developing countries.

At COP26 developed countries confirmed that this target will be met in 2022 or 2023, with the five-year climate finance average from 2020–2025 at about $100 billion. Developed countries have also announced greater flows from 2025, albeit details on this are still to be decided.

Concurrently, the implementation of developing countries' NDCs depends on the scale of access to financial support and other means of implementation. Some NDCs include information on the mobilization of national and international support, many often presenting detailed figures on financial needs and requirements. Thus, finance is considered a critical enabler for enhanced climate action.

In particular, there are NDCs that include qualitative information on how finance will be used and/or quantitative information on investment for supporting NDC-implementation. Some Parties clearly present their needs for financial support, differentiating the implementation of conditional and unconditional NDCs. Others also present separately mitigation and adaptation finance needs, including for specific sectors (e.g. the energy system) and for enhancing efforts on SDGs, such as SDG 7 on universal energy access.

Given the above, it is vital that developed countries mobilize finance and investment to developing countries for climate action, while reducing reliance on debt instruments. Developing countries' right to development should be protected, providing them with the adequate fiscal space and liquidity. Developed countries need to provide scaled-up climate finance, which is new and additional to existing overseas development aid budgets.

For the world to achieve the Paris Agreement goals, leadership, multilateralism and inclusive approaches are identified as a prerequisite for a just transition and enhanced ambition, in light of national circumstances. Amidst current geopolitical tensions, the provision of climate finance is a considerable contribution to the development of innovative approaches for developing countries in response to climate change concerns, as well as to address the impacts of climate response measures, without being detrimental to their sustainable development.

Climate finance is a priority area for the upcoming COP27 Presidency. In Sharm El-Sheikh, Parties are expected to make progress to eliminate the emissions and implementation gaps, holding countries accountable on their commitments. The COP is also anticipated to scale-up and deliver climate finance actions in developing countries to support their sustainable development and resilience.

The ultimate insight of recent scientific input provided by the IPCC is that sustainable development and equity – a core principle of the Convention – need to go hand-in-hand, and equity is fundamental to multilateralism.

Climate finance should, therefore, support a sustainable, resilient, equitable and just transition to a low-emissions future for all. Funding is required for technological breakthroughs and innovative solutions – such as CCUS technologies – that are viable options, without which the long-term goals of the Paris Agreement would be difficult to achieve, and offer wider benefits by reducing the adverse impacts of the implementation of mitigation response measures.

Overall, there is currently a pressing need to increase climate ambition, while also ensuring energy security and finding a resilient and sustainable way forward that leaves no one behind. Thus, it is vital to ensure that energy is accessible and affordable for all, being cognizant of the amount of investment required for all energy sources, and the potential implications of any shortfall.

7.1.2 Progress towards achieving eradication of energy poverty

During the 75th session of the UN General Assembly (UNGA 75) in September 2021, the UN Secretary-General presented his vision on the future of international cooperation and multilateralism. This was reflected in a report entitled 'Our Common Agenda', which focuses on actions designed to strengthen and accelerate multilateral agreements – particularly the 2030 Agenda for Sustainable Development.

Consultations and high-level events are currently being held on the proposals offered by the UN Secretary-General, aiming to *inter alia* advance implementation of the SDGs and reflect on climate ambitions. The 2022 session of the UN High-level Political Forum also provided a platform for assessing how much progress is needed within the next few years, and considered options on the best way forward. Its theme was 'Building back better from COVID-19 while advancing the full implementation of the 2030 Agenda for Sustainable Development'.

On this occasion, countries relaunched ambition and political commitment for the achievement of the 2030 Agenda at its mid-point implementation phase. Recognizing that the pandemic and economic crisis have exacerbated, among others, the vulnerability of the energy poor, the need to instil resilience and catalyze action for addressing present and future challenges, such as climate change, in the context of sustainable development, was highlighted.

In support of the 2030 Agenda and the Paris Agreement, a 'Global Roadmap for Accelerated SDG 7 Action' was also released in November 2021, as a forward-looking summary of the UN High-level Dialogue on Energy, organized in September 2021. The dialogue addressed five themes that focus on the energy transition. These were, energy access; energy transition; enabling the SDGs through inclusive, just energy transitions; finance and investment; and innovation, technology and data.

Besides the roadmap, the key outcomes of this event include a series of pledges – namely, the 'Energy Compacts' – and a report of the dialogue that gives more detail on the roadmap's recommendations along with announcements made by participants. A follow-up event was then held in May 2022, aiming to *inter alia* facilitate action for ensuring sustainable energy for all.

Acknowledging that energy is central to both achieving the 2030 Agenda and the Paris Agreement goals, countries were called to increase efforts in order to close the energy access gap, transition to low-emissions energy systems, mobilize adequate and predictable finance, and harness innovation and technology, leaving no one behind. The roadmap advocates the need for greater engagement from the international community to support developing countries in achieving the SDG 7 goals, paying particular attention to vulnerable African countries.

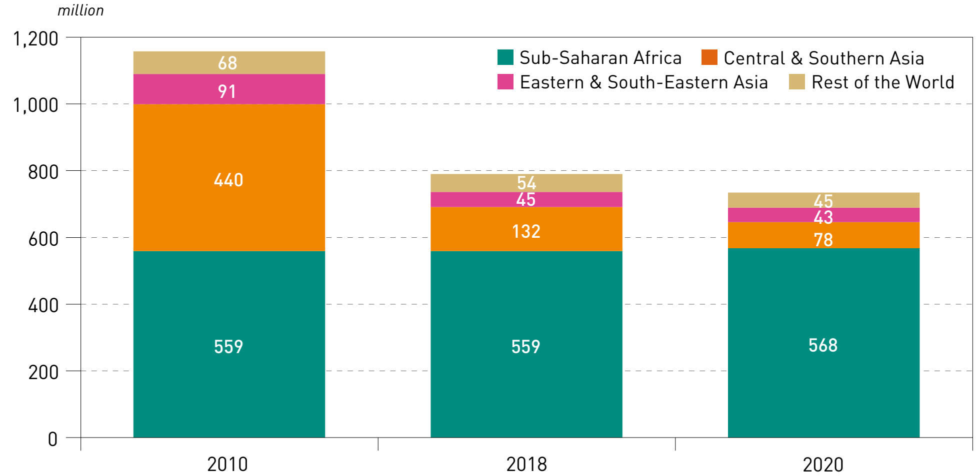
In light of the above, countries have taken stock of seven years of SDGs implementation and many have pointed to a significant implementation gap, underscoring the importance of strong action towards achieving particularly SDG 7, due to its interlinkages with all other SDGs.

These are supported by the latest available data, which indicates that some progress has been achieved in terms of access to electricity, but a slowing pace on energy access is evident along with a decline in international finance. The COVID-19 pandemic is viewed as the fundamental factor in the slowing progress towards universal energy access, as well as recent geopolitical tensions, that have affected global energy markets.

Advances in SDG 7 have been impeded in the most vulnerable countries and those already lagging in energy access. For instance, almost 90 million people in Asia and Africa who had access to electricity, are no longer in a position to pay for their basic energy needs. Although the share of access deficits has declined in specific regions (e.g. Central Asia and Southern Asia), the share of population without electricity in Sub-Saharan Africa has increased from 71% in 2018 to 77% in 2020, according to the World Bank.

At a global level, 91% of the population had access to electricity in 2020, and the increase in electrification outpaced population growth. However, about 733 million people remain without access to electricity, and approximately 80% of these people are located in Africa (Figure 7.1). This should be compared to 1.2 billion people who lacked access to electricity in 2010. It should also be noted that most of the countries with the highest access deficits are located in Sub-Saharan Africa. Nigeria reported the largest unserved population – namely 92 million people, with electrification access rates not keeping pace with population growth.

Figure 7.1
Global population without access to electricity

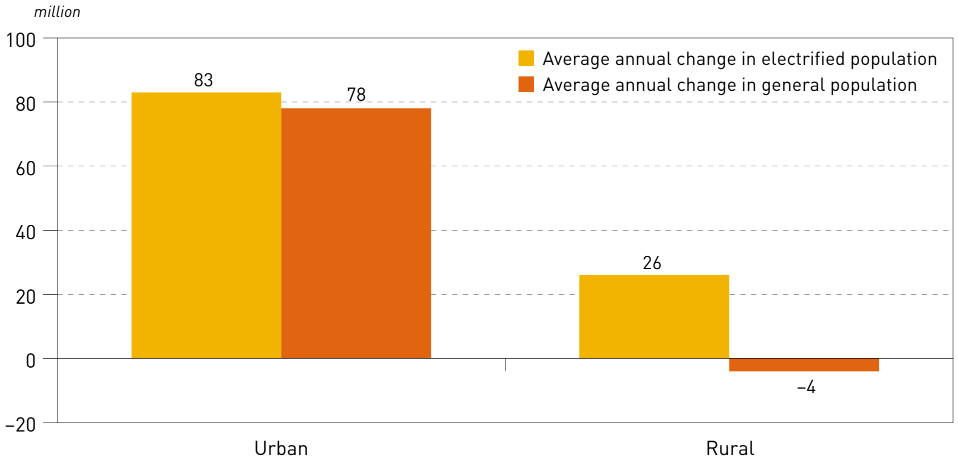


Source: World Bank, 2022.

Moreover, 119 million people in urban areas, or 3% of the global population, and 584 million in rural areas, or 17% of global population, were unelectrified in 2020. In Sub-Saharan Africa rural areas, access increased from 17% to 28% over the period 2010–2020. Global growth in electrification also surpassed population growth in both urban and rural areas (Figure 7.2).

However, it is worth noting that globally one in four children still attend schools without electricity. In Sub-Saharan Africa, only 31% of primary schools have access to electricity, and in Southern Asia it is 55%. Approximately 1 billion people are also served by unelectrified health facilities. Overall, the rate of increased electrification is not enough to close the energy access deficit, especially in the African continent.

Figure 7.2
Global electrified and general populations in urban *versus* rural areas, 2018–2020



Source: World Bank, 2022.

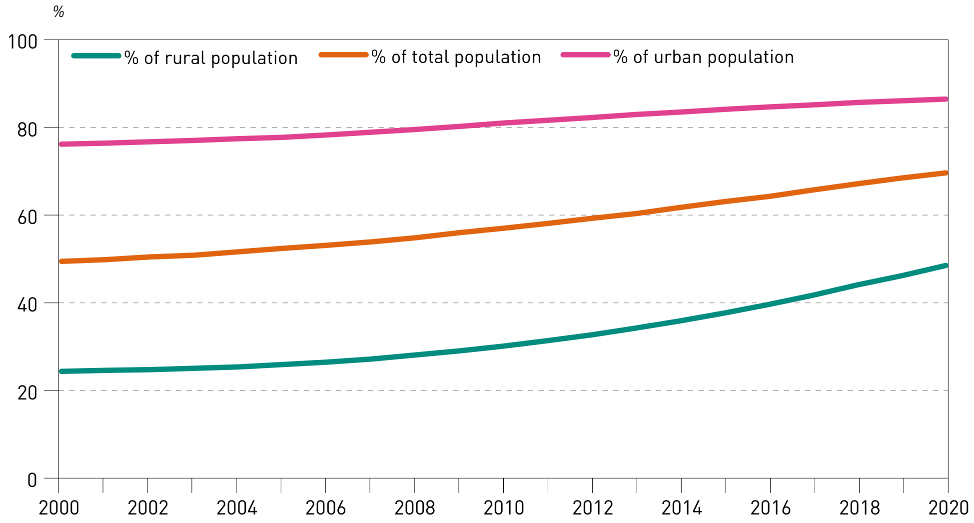
It should be further emphasized that 2.4 billion people still lack access to clean cooking solutions in 2020, accounting for one-third of the world's population. This is progress on the three billion number in 2010, with improvements in Asian economies, but this masks the deterioration in Sub-Saharan Africa where more than 920 million people do not have access to clean cooking (Figure 7.3).

Figure 7.3
Relative share of population without access to clean cooking

Source: World Health Organization, 2022.

Only 69% of the global population had access to clean cooking fuels and technologies, such as electricity LPG natural gas, biogas and solar in 2020 (Figure 7.4). In the Asia-Pacific countries, about 1.3 billion people do not have access to clean fuels and cooking stoves.

Figure 7.4
Access to clean cooking



Source: World Health Organization, 2022.

Considering the above trends and recent developments, it is estimated that 92% of the global population will be electrified in 2030. This implies that the number of people without electricity will be high by 2030 compared to the numbers projected in past years. About 670 million people are expected to still be energy poor in 2030. Moreover, the pandemic is also raising concerns related to affordability issues.

At the same time, about 2.1 billion people will likely not have access to clean cooking in 2030 (or about a quarter of the global population), if efforts to address this challenge do not improve.

International public financial flows to developing countries in support of clean energy have also dropped over the last few years, and are inadequate to support action needed to achieve universal energy access. This figure was at the level of about $10.9 billion in 2019, a more than 50% decline from the peak of $24.7 billion in 2017. Such a declining trend is, therefore, not aligned with the immense needs of developing countries due to emerging challenges and risks arising from the pandemic and the current economic situation.

Besides adequate finance and support to accelerate progress on sustainable energy for all, it is important to ensure access to reliable, sufficient and affordable energy. Considering the prevailing impacts of the pandemic, together with rising inflation, trade disruptions, policy uncertainties, and unsustainable debt in some developing countries, it is imperative to comprehensively respond to global crises, including through enhanced efforts for universal energy access – as an enabling factor for the global economy to rebound.

International support should be strengthened to achieve universal and sustainable energy access for all, considering also the strong interlinkages with other SDGs – such as on food, employment and sustained economic growth. Moreover, a just energy transition should mean inclusiveness for all energy sources, placing human well-being at the heart of resilient and sustainable societies. Therefore, the biggest challenge is to ensure that any transformation of the global energy market towards a low-emissions pathway is fair, equitable, non-disruptive, and leaves no one behind.

Against the backdrop of ever-increasing concerns over energy prices and the cost of living, matters related to energy security amplify the impacts of other challenges confronting countries, such as climate change and the pandemic. To this end, energy action should be designed to effectively deliver co-benefits and eliminate trade-offs, and in light of the special needs, national priorities and circumstances of developing countries. It is important to remain committed to continued action towards affordable, reliable, sustainable and modern energy for all, and to increase efforts to ensure that energy fulfils its key role in sustainable development, particularly in developing countries.

The above should be thoroughly considered at the 2023 session of the High-level Political Forum, on which occasion SDG 7 will be under in-depth review.

7.2 Energy policies and low-emission energy-related strategies of major economies

7.2.1 US

In the US, all three branches that make up the Government – the Legislative, Executive, and Judicial – have recently been important players in US energy and climate policy, although they have often been at odds with each other.

In the executive branch, the arrival of the Biden administration revived ambition around climate change. The re-joining of the Paris Agreement on the first day of the new President and new targets for at least a 50% reduction in GHG emissions by 2030 (from 2005 levels) and a carbon-free electricity sector by 2035 were among the headline changes. However, there have been several other targets and initiatives across various areas of government, as part of what was termed a 'whole-of-government' effort. For instance, as leader of the federal government, the President signed an executive order to require it to reach carbon neutrality by 2050, which due to the sheer size of the government would mean hundreds of thousands of buildings and vehicles being transformed.

The government also proposed an overarching legislative framework, originally called the 'Build Back Better Plan', which was enormous in scale and would include huge investments for climate programmes. There was even the intention of enacting legislation to mandate achieving net-zero emissions by 2050. However, getting proposals through a divided Congress proved to be an extremely onerous task.

In the legislature, the 'Build Back Better Plan' was ultimately broken up and in November 2021 the first component, the 'Infrastructure Investment and Jobs Act' was passed. While the legislation did include funding allocated to upgrade the electric grid, invest in new technologies, such as carbon capture and hydrogen, and to boost the EV charging network, it was not fundamentally the legislation the government wanted to support its climate targets.

Opposition to these remaining elements of the original plan appeared resolute until a surprise deal among Democratic Party senators allowed for progress of the IRA, which includes $369 billion for energy and climate programmes. Although smaller in size, the package would extend critical tax credits for clean energy projects and provide funding for technology that would be important for making progress towards 2030 and 2050 targets. As part of the deal, there are fees for companies that do not meet minimum methane emission regulations, but there are also several provisions that were welcomed by the oil and gas industry. This includes formalizing plans for leasing on federal lands and in the GoM, promises to improve permitting processes and support for the development of hydrogen and CCUS.

Decisions in the third branch of the government, the judicial branch, have also been vital in the evolution of energy policy and in the past few years a number of policies from different administrations have met court challenges. It was for instance, a 2007 Supreme Court decision that ruled that the EPA has the authority to regulate GHG emissions under the Clean Air Act and must do so in the case of motor vehicles, leading to emissions standards for vehicles, as well as additional regulations to reduce GHGs in other areas.

However, in the recent decision for the case West Virginia *versus* EPA, issued on 30 June 2022, the Supreme Court delivered an opinion on the statutory authority of the EPA for regulating GHG from stationary power plants. This ruling could result in the need for more direct authorization from Congress, which would be unlikely any time soon. Ultimately, and at least in the short-term, it could mean less room to manoeuvre for the Biden administration to achieve its climate goals.

Transportation

After the brief experiment with the Safer Affordable Fuel-Efficient Vehicles Rule (SAFE) during the previous presidency, the current administration transitioned in 2021 back to the familiar and more stringent CAFE standard. In March 2022, the next set of standards for vehicles made between 2024 and 2026 were released, with the principal target of a fleet-wide average fuel efficiency of 49 miles per gallon (mpg) for both passenger cars and light trucks in 2026. This marks a notable increase compared to the 40.4 mpg target for 2026 under the SAFE rule. For other more heavy-duty vehicles, the current standard applies from 2018 to 2027 with the aim to reduce CO_2 emissions, including a 16% reduction by 2027 for commercial pickups and vans.

The state of California has always been at the forefront of new vehicle standards and has been authorized by the federal government to reinstate its state-own Zero Emission Vehicle (ZEV) mandate rather than be subject to less ambitious federal standards. In August 2022, the State announced a ban on new ICE light-vehicle sales from 2035, with the first of the interim targets aiming for 35% of sales to be PHEV, BEV or FCEV by 2026. What is more, just as they have previously, other States could follow California's lead. Similar legislation has already been signed by the governor of New York, with new passenger and light commercial vehicles to be 100% emission free by 2035, as well as a 2045 deadline for medium- and heavy-duty trucks.

7.2.2 European Union

With its ambitious targets of reducing net-emissions of GHGs to zero by 2050 and decoupling economic growth from resource consumption, the EU continued to implement the European Green Deal in 2021 and 2022.

In July 2021, the regulation on the European Climate Law came into force, setting legally binding targets of a net GHG reduction of at least 55% by 2030 compared to 1990 levels, as well as climate neutrality by 2050, after which the EU commits to negative emissions. However, the EU's existing climate and energy policy framework was widely considered to be insufficient to reach the targets set in the European Climate Law. The EU Commission, therefore, prepared an interlinked series of legislative proposals, the so-called 'Fit for 55' package, covering a wide range of policy areas including climate, energy, transport and taxation, setting out ways to reach the updated 2030 target. In practice, the success of these policy proposals will ultimately determine if the 2050 net-zero emission target can be met. Box 3.1 provides additional discussion on the impact of the 'Fit for 55' package on oil demand.

On 14 July 2021, the European Commission presented the first elements of the 'Fit for 55' package which would revise key energy policies including the ETS, the Effort Sharing Regulation, the Renewable Energy Directive, as well as update the Energy Efficiency Directive and Land Use, Land Use Change and Forestry Regulation, amongst others. Moreover, the EU proposed to create a parallel ETS for buildings and the transportation sector, as well as introduce a CBAM in order to avoid what is known as 'carbon leakage' associated with businesses moving production to regions with lesser environmental restrictions. December 2021 saw the release of the second set of policy proposals that focused on reducing energy sector methane emissions, accelerating gas market decarbonization, and increasing the energy efficiency of buildings.

Such a significant economic transition requires major targeted investments towards sustainable activities. The introduction of the EU Taxonomy for Sustainable Activities supports investors, companies and national policymakers with information required for their climate and environmental shock mitigation efforts. With the first delegated act on sustainable activities for climate change adaptation and mitigation adopted in June 2021, the legal acts of the EU Taxonomy define technical screening criteria for a list of activities that have to be fulfilled to consider an activity as environmentally sustainable. In February 2022, the European Commission published the final Complementary Delegated Act on the EU Taxonomy of Sustainable Activities, introducing nuclear and gas to the EU Taxonomy, as well as specific disclosure requirements for businesses related to their activities in the gas and nuclear energy sectors.

However, the inclusion of nuclear and gas in this classification system has triggered heated discussions among EU Member States, several of which have expressed concerns that the addition would increase the chances for green-washing-related taxonomy abuse. This issue provides a small glimpse into the complexity of the 'Fit for 55' negotiation process, and any decisions made to amend the delegated acts of the EU Taxonomy could demonstrate the EU's ability to deal with such disagreements on a larger scale.

Energy policy

In May 2022, the RePowerEU plan was published – a proposal aimed first and foremost at saving energy, producing clean energy and diversifying the EU's energy supplies. As part of its ambitions to scale up renewable energy in power generation, industry, buildings and transport, the Commission proposed to increase the 2030 Renewables Energy

Directive renewables share target to 45%, from the respective 2018 and 2021 targets of 32% and 40%.

The plan also envisions an increase in the binding 'Fit for 55' Energy Efficiency Target from 9% to 13%, as well as the introduction of a hydrogen accelerator initiative, setting targets of 10 million tonnes for both domestic renewable hydrogen production and imports by 2030. Furthermore, the Commission also adopted a recommendation to speed up permit-granting procedures for renewable projects and to facilitate power purchase agreements.

Such measures are expected to lead to installed renewable energy generation capacity reaching 1,236 GW by 2030, compared to the 1,067 GW envisioned in the 2021 directive amendment.

On 14 September 2022, to help address rising energy prices the continent has seen in 2022, the EU Commission announced a proposal to intervene in the energy market to reduce demand and redistribute profits. The former involves a mandatory 5% reduction in electricity consumption at peak hours, as well as a target to reduce demand by 10% through to 31 March 2023. The later initiative proposes a 180 EUR/MWh revenue cap, at which point any further revenues will be pass on to the governments of Member States to be used to help consumers with their bills. This would have the effect of limiting the profit from the relatively low cost energy sources, such as renewables, hydro and nuclear.

Transportation policy

The EU has submitted an amendment that would increase the EU's emissions performance standards for passenger cars and light commercial vehicles, in addition to the road transportation sector being part of a new ETS. The fleet of newly registered cars has to reduce emissions by 55% by 2030 and by 100% by 2035, compared to 2021 levels. For new vans, the reduction targets are 50% and 100%, respectively. This could mean a *de facto* EU-wide ban on the sale of new gasoline and diesel cars from 2035.

The ReFuelEU Aviation initiative proposes EU-wide harmonized rules for SAF, regulating the minimum share of SAF in jet fuel supplied to operators at EU airports. This increases from 2% in 2025, to 5% in 2030 and then to as much as 63% by 2050.

The 'Fit-for-55' package also includes the FuelEU Maritime proposal aimed at decarbonizing the European maritime sector. This is through the introduction of increasingly stringent limits on carbon intensity of the energy used by vessels from 2025 onward, *de facto* obliging them to use alternative fuels. Starting January 2030, container and passenger ships at EU ports will also have to connect to onshore power supply (OPS) and use it for all energy needs while at berth.

7.2.3 China

In March 2022, China released its 14th FYP on Modern Energy System Planning, which focuses explicitly on the ongoing low-carbon transformation of the energy and industry sectors. The document is dated 29 January. This means that recent global energy market upheavals are likely to have only been taken into account to a limited extent. However, the energy shortage in 2021 has led the Chinese government to make national energy security one of its priorities.

China has managed to reduce its carbon emission intensity per unit of GDP by 18% over the last five years. In the future, the share of non-fossil energy consumption should increase to 20% by 2025 and 25% by 2030. The non-fossil share in the electricity mix is expected to reach about 39%, as the electrification of the economy continues.

The 14th FYP on Modern Energy System Planning aims to balance improvements in national energy security with achieving China's carbon emission targets. China aims for a carbon emissions peak by 2030 and to reach carbon neutrality by 2060. Energy security and independence should be improved by boosting national production of petroleum and natural gas. Crude oil output is to be kept at around 4 mb/d and annual gas production is set to increase to more than 230 bcm by 2025 (from 205 bcm in 2021).

In contrast to earlier FYPs, the new energy plan does not contain limits on total coal consumption or its share in primary energy consumption. Coal is considered to play a vital role in ensuring national energy security and to provide the required flexibility in an energy system with a significant share of variable renewable energy sources. In particular, the clean and efficient use of coal is highlighted. The new FYP also no longer imposes a cap on total energy consumption.

The FYP on Modern Energy Planning also calls to support developing countries with green energy, and not encourage new coal-fired power projects overseas.

China's National Economic and Social Development Plan for 2022, published at the 13th National People's Congress in March 2022, focuses explicitly on energy efficiency. It foresees measures to encourage industries with sub-benchmark performance to increase energy efficiency. Moreover, electricity and energy conservation will be promoted throughout society. The Chinese government targets a 13.5% reduction in energy intensity from 2021 to 2025, compared to 2020 levels.

China is planning to leverage the role of fiscal policies to achieve its carbon emission targets. According to the Notice on Financial Support for Carbon Neutralization of Carbon, which passed in March 2022, the country will update its financial policy framework by 2030 to support green and low-carbon investments. It is expected that a first update of the fiscal policy tools and the tax policy framework will be available by 2025. Before 2030, the finalization of the fiscal and taxation policy system is expected, which will enable the carbon-peaking threshold.

In October 2021, China updated its NDC and now aims for a 65% reduction in CO_2 emissions compared to 2005 levels.

Furthermore, in mid-2021, China launched the world's largest ETS market as one of the tools to reach its 2030 and 2060 emissions targets. It currently only covers the power and heat generation sector (around 40% of total CO_2 emissions), but could potentially include other sectors in the future.

Transportation policy

A number of key strategic documents – China's 14th FYP, the Action Plan for Carbon Dioxide Peaking Before 2030, the New Energy Vehicle (NEV) Industrial Development Plan 2021–2035 and the Technology Roadmap for Energy-Saving and New Energy Vehicles

2.0, form the basis for the country's transport sector decarbonization agenda. They outline specific targets for NEV market development, technological advancements, and the build-up of supporting services in a variety of planning horizons.

China has traditionally been the most ambitious nation in terms of electric mobility development. The phasing out of the national EV subsidy scheme launched in 2020 has demonstrated the government's efforts to decouple EV sector growth from subsidization by the end of 2022, in order to ensure its long-term self-sufficiency. The continued phase-out of subsidies and the emphasis on increased range have put serious pressure on manufacturers to improve. This has led to sustained development across the entire supply-value chain of the Chinese battery powered EV industry.

In the realm of commercial transportation, China's efforts are focused on the implementation of the China VI-b emission standard. This has been applied to gas-powered vehicles since January 2021 and will come into force for all new heavy-duty vehicles from July 2023 onward.

China is also promoting other zero-emission opportunities, mainly hydrogen. The 14th FYP defines an ambition for NEVs to account for 72% of national urban public transport (including light-duty vehicles and buses) and 20% of logistics distribution by 2025.

7.2.4 India

At COP26 in Glasgow in 2021, India's Prime Minister Narendra Modi announced several ambitious short- and long-term goals in the form of five climate pledges, which include:

- Updating the 2030 non-fossil – renewables and nuclear – generation capacity target from 450 to 500 GW (initially mentioned by Prime Minister Modi at the Climate Action Summit in September 2019);
- Meeting at least 50% of India's energy requirements (power generation capacity) through renewable energy by 2030 – also an update of its previous NDC commitment of 40%;
- Reducing the economy's carbon intensity by less than 45% by 2030, compared to the country's previous NDC of a 33–35% reduction from 2005 levels, announced in 2015;
- Reducing total projected carbon emissions by one billion tonnes by 2030;
- Reaching net-zero by 2070.

COP26 also saw the announcement of the Green Grids Initiative – One Sun, One World and One Grid. This is a joint India-UK project that envisions the building and scaling of a 'trans-national electricity grid' to supply solar power across the world.

Solar energy, equally desired for off-grid applications, such as rooftop solar or in communities without grid access, and larger solar power plants connected to the electricity grid, is set to make up the largest share of the envisaged installed renewable capacity – 60%, or around 280 GW by 2030, compared to 56.6 GW as of June 2022.

India also has a large and ambitious nuclear programme, currently in its second stage, with policies supportive of nuclear energy as a low-cost, low carbon energy source to meet the country's increasing energy demand. The government expects nuclear capacity to reach about 22.5 GW by 2031, compared to almost 6.8 GW as of the end of March 2022.

In August 2021, the Indian Ministry of Power circulated for discussion the Draft Electricity (Promoting Renewable Energy through Green Energy Open Access) Rules for the purchase and consumption of green energy. This includes energy from waste-to-energy plants, which, if enacted, could allow consumers to circumvent power distribution companies and purchase electricity directly from renewable power producers.

The measures envisioned by the document include temporary waivers on inter-state transmission charges, Renewable Purchase Obligation incentives for green hydrogen/ammonia manufacturers, as well as granting them and renewable energy plants prioritized grid connection. The National Hydrogen Energy Mission (NHM) also includes measures to facilitate demand creation in specific areas, including mandates for the use of green hydrogen in industry (production of fertilizers, steel, and petrochemicals) and the transport sector.

The Indian government's Union Budget 2022–2023 was published in February 2022, with several of its items aligned with newly announced policies. Funds would be allocated for renewable energy development and the promotion of clean technology and governance solutions, including:

- Issuance of sovereign green bonds to finance public sector projects;
- Allocation of 195 billion rupees for solar module production-linked incentives;
- Realization of four pilot coal gasification and coal-to-chemicals conversion projects;
- Introduction of special mobility zones with zero fossil-fuel policies;
- Scaling-up electric mobility through battery swapping and the introduction of interoperability standards for efficiency improvements;
- Facilitating credit availability for charging station construction projects;
- Additional funding for the NHM.

The government is also targeting a 'Net Zero' railway system by 2030 and expects the initiative to lead to an annual emissions reduction of 60 million tonnes. This is to be achieved through railway electrification, efficiency improvements and the acquisition of green certification for stations and installations.

7.2.5 Other regions

Africa

Africa's historical contribution to global GHG emissions is extremely low. It is a diverse continent with countries at various stages of economic development and with disparate and significant challenges. Looking ahead, if current demographic projections materialize, energy demand is expected to increase substantially.

While developed countries must take the lead on meeting climate change targets, most African countries have signed and ratified the Paris Agreement. Furthermore, 53 out of 54 states have submitted their NDCs and the majority of states have updated their NDCs in the context of COP26 and the need to further reduce GHG emissions.

Securing funding to support energy policies will be especially important to meet long-term ambitions and ensure sustainable development. This requires developed countries to fulfil commitments in terms of support, including finance to developing countries. For instance, Tunisia targets a 45% decrease in carbon intensity by 2030, from a 2010 baseline, with 28% unconditional and based on the country's own means. The remaining part is to be achieved with additional support. Likewise, Senegal's conditional aim is to reduce carbon intensity by 45% (27% is unconditional), and in Ethiopia's updated NDC, the country notes that 80% of its financing needs is assumed to come from international sources.

Throughout the continent, efforts are being made to eradicate energy poverty using all available energy sources. As part of this, many countries have ambitions to increase the share of renewable energy in their energy mixes, with the potential for both on-grid and off-grid solar power, in particular, driving new installed capacity. In Egypt, renewable energy capacity is targeted to reach a share of 42% in the electricity mix by 2035, as outlined in the Integrated Sustainable Energy Strategy 2035. Côte d'Ivoire has committed to reach the same target by 2030.

The continent's most developed country, South Africa, wants to move towards a net zero emissions target for 2050. It is also the largest user of coal, with coal use rather limited in other African countries. The EU, the US, the UK, Germany and France in their political declarations at COP26 offered an initial amount of $8.5 billion through a combination of financial instruments, including grants and concessional loans to support South Africa's just transition goal. The fund is to decommission, repower and repurpose old coal-fired power plants, in line with the 2019 Integrated Resource Plan, as well as develop new EVs and green hydrogen sectors, amongst other things.

Improving energy efficiency is also a key opportunity for African countries to lower needs for additional capacity in the system, both in energy supply and demand. For example, as economies develop, more efficient lighting, cooling, cooking and household appliances, will help people use electricity more economically and, in turn, save money. Zambia updated its NDC in 2021 targeting, if substantial international support is available, a reduction of up to 47% of emissions, below a 2010 business as usual baseline. The country's first NDC focused on improved cooking devices, an increase in the generation and use of renewable energy sources, and a fuel switch to biodiesel. The second edition added an improvement of the electricity supply network, improved fuel efficiency and transport infrastructure, and increased energy efficiency in processes.

Much effort is also being made with regional and international initiatives, such as the Regional Center for Renewable Energy and Energy Efficiency, which includes countries of North Africa. The ECOWAS Centre for Renewable Energy and Energy Efficiency support countries in this area too.

Russia

In October 2021, Russia adopted the 'Reduced GHG socio-economic development strategy until 2050' – a multi-sectoral document aimed at the realization of the Paris Agreement.

The strategy's target scenario considers technological, financial and fiscal policy measures aimed at reducing anthropogenic GHGs as an additional driver of the economy's technological renewal. Among such measures are carbon pricing mechanisms, GHG quota systems, the introduction of regulatory requirements for the mandatory use and promotion of technologies with low GHGs and high energy and resource efficiency and adjustments to the mineral extraction tax, among others.

Additional opportunities are associated with the implementation of 'green' projects, which, if they meet certain nationally set criteria, could be eligible for green energy financing, where such instruments as green bonds will be considered as a viable source of capital. The target scenario also provides for the introduction of standards for the system of climate project and carbon reporting verification, green project taxonomy, as well as so-called 'energy origin certificates' for carbon-free and low GHG generating facilities.

Under the target scenario, Russia expects a moderate annual drop in energy exports of around 2.1% starting from 2030, whereas the annual growth rate of non-energy exports is expected to reach 4.4%. There is a gradual introduction of technologies to reduce emissions and improve energy efficiency, which in the context of sustainable economic growth is accompanied by a slight increase in emissions until 2030. It is assumed that from 2031 onwards, technology scaling would allow this trend to reverse.

The measures envisaged by the target scenario provide for a reduction in gross emissions of 910 million tonnes of CO_2 equivalent by 2050, compared to the volume of emissions in the absence of such measures. The absorptive capacity of managed ecosystems is expected to increase from the current 535 million to 1,200 million tonnes of CO_2 equivalent, providing an additional emissions' reduction effect of up to 665 million tonnes of CO_2 equivalent.

According to the document, the implementation of the target scenario is expected to lead to a 60% reduction in net GHGs in 2050, compared to 2019 levels, and an 80% reduction compared to 1990. This would allow for the realization of Russia's NDC to the implementation of the Paris Agreement, as well as reaching net-zero by 2060.

The Federal Law on 'The limitation of GHG', which came into force in January 2022, defines the regulatory basis for economic activities accompanied by GHGs. It is aimed to create conditions for the country's sustainable and balanced economic development under the auspices of GHG reduction. The law stipulates the principles, measures, targets, rights and obligations of legal entities and individual entrepreneurs under national GHG reduction practices, as well as providing the regulatory basis for the use and tracking of carbon units.

Moreover, the Russian government has set out to achieve a share of low-carbon energy sources in the energy mix of at least 56.5% by 2050, with hydro, nuclear and renewables accounting for 19%, 25% and 12.5%, respectively. The share of natural gas in the energy balance is expected to reach 40% of aggregate generation, amounting to 600 billion kilowatt hours (kWh). The decommissioning of more than 22.2 GW of coal-fired thermal power plant equipment by 2050 is expected to lead to a drop in coal's share in electricity generation to 4.5%, or 67.7 billion kWh in absolute terms.

With the view of supplementing 'Russia's 2035 Energy Strategy', as well as the 'Concept of developing hydrogen energy in the Russian Federation', the Russian government is developing a 'Technological hydrogen sector development strategy until 2035'. This would underpin the foundation for the creation of competitive domestic hydrogen technologies, the optimization of production capacities, as well as improvements in the relevant regulatory framework.

Japan

Japan proclaimed its intentions at the 2021 Leaders' Summit on Climate Change to reduce GHG emissions by 46% by 2030, compared to 2013 levels. This was a significant increase from a previous target of only 26% and supports the ambition established in a prior announcement to target net-zero emissions by 2050. Both of these targets have been reflected in the country's updated NDC submitted in October 2021. While the 2030 target is not legally binding (a previous lesser target was), the 2050 target sets a level of ambition for the development of new policies and the amendment of existing policies.

Meeting these targets will require a large shift in the country's energy mix, which still relies more on coal than other OECD countries. Japan has also seen less renewable development compared to others. In the government's 6th Strategic Energy Plan, approved at the same time as its updated NDC, a 36–38% share of renewables is targeted in power generation by 2030. Solar and hydropower are envisaged to be the largest contributors to this target. The use of nuclear, which has never recovered to its previous levels seen before the Fukushima disaster in 2011, is expected to grow again and make up 20-22% of power generation by 2030. Ultimately, non-fossil fuel power sources will become the majority and continue to expand in the long-term.

In the transportation sector, the government had previously announced a ban on the sale of fossil fuel powered vehicles beyond 2035. However, HEVs, which currently dominate the market for what are known as clean energy vehicles in Japan, are not included. Other EV types are growing more rapidly, but represent only a small fraction of vehicle sales. The government has been supporting EV demand with increased subsidies that do not apply to HEVs in the 2021 National Budget, as well as improving the relatively small charging network.

Brazil

In November 2021, the Brazilian government announced its revised targets for net-zero emissions at COP26. The country announced that it would cut its GHG emissions by 50% by 2030, compared to 2005 levels. This was an update from the previous commitment to reduce emissions by 43% over the same period. Brazil also announced that it was committed to end illegal deforestation by 2028, two years earlier than previously announced. The updated trajectory includes reducing deforestation at a percentage of 15% p.a. between 2022 and 2024, 40% in 2025 and 2026 and 50% in 2027. Brazil´s commitments also include a long-term objective to achieve climate neutrality by 2050.

In terms of renewables, the Brazilian government has set a renewable energy target of around 45% of primary energy demand by 2030. It also plans to expand non-hydropower renewables to 28–33% by 2030. Brazil's NDC additionally includes increasing the share of sustainable biofuels in the energy mix to 18% by 2030, while raising the share of advanced biofuels and biodiesel too.

In January 2022, Brazil introduced the 'Just Energy transition' law with the main objective to help prepare the coal state Santa Catarina to phase out thermal coal-powered plants by 2040.

Brazil's national biofuel policy, 'RenovaBio', targets a 10% reduction in carbon emissions by 2028. The policy classifies biofuels according to their GHG emissions profiles, while introducing a tradable carbon credit system and creating a cost advantage for biofuels over fossil fuels. It establishes annual decarbonization targets for fossil fuel suppliers.

In 2021, the Brazilian Socioeconomic Development Bank created a loan programme under the RenovaBio Policy, with incentives to improve energy efficiency and production certification to support the development of carbon reduction projects. The budget allocated for the programme was R$1 billion, offering direct support through ESG credit for the biofuels sector.

As for nuclear power, the 'Angra 3 Nuclear Power Plant Critical Path Acceleration Plan' was established in 2021. The nuclear power plant, on which construction started in 1984, has been reinstated with an expected completion date of November 2026. The addition of 1,405 MW capacity from Angra 3 is expected to generate the equivalent of 50% of electricity consumption in the State of Rio de Janeiro.

South Korea

At COP26, South Korea announced that it will upgrade its NDC and pledged to curb its GHG emissions by 40% by 2030, from 2018 levels. This would raise South Korea's earlier NDC commitment, which had a target of 26% over the same period. South Korea also pledged to cut its methane emissions by joining the Global Methane Pledge, aiming for a reduction of at least 35% from 2018 levels, to reach 19.7 million tonnes of emissions by 2030.

The announced plan to reduce methane emissions cuts across different sectors, while setting specific targets for each. These targets aim to reduce methane emissions by 28.6% in energy, 20.9% in agriculture, and 46.5% in waste sectors by 2030, from 2018 levels. The government also passed the Carbon Neutrality Bill in August 2021, with a commitment to achieve carbon neutrality by 2050, which has now been officially set in law.

In terms of energy policy, South Korea hopes to achieve these targets by reducing coal power generation in its energy mix from 41.9% to 21.8% by 2030, along with increasing the share of renewables to 30.2%. Hydrogen is specified to play a significant role in achieving the long-term target.

South Korea announced at COP26 that it has actively begun taking accelerated steps to decommission existing coal power plants and has stopped approving new coal-fired power plants, with the goal to completely end coal-fired power generation by 2050. It had also previously announced that the country would end all financing for the construction of coal plants overseas.

The recent presidential election, held in March 2022, always looked likely to be a key source of change, with the two major parties diverging in their campaign promises on how best to decarbonize the country and particularly, the role of nuclear energy. The newly elected president has pledged an energy policy overhaul in his five-year term, and in particular, a revival of nuclear energy in a country that currently receives around one-third of its electricity from nuclear power plants. In doing so, this reverses the policy of slowing phasing out nuclear energy that was introduced by his predecessor in 2017.

Subsequently, the new government announced plans to resume the suspended construction of two reactors – Shin-Hanul 3 and 4 – which have been on hold since 2017. It also extended the operating life of the country's current nuclear fleet as long as possible, with the aim to broadly maintain the current share of nuclear in the energy mix.

United Kingdom

The UK's energy policy, since the establishment of the Climate Change Act in 2008, has focused on carbon emission reductions that are in-line with set carbon budgets for five-year periods. The country's climate targets are amongst the most ambitious of major economies and the sixth carbon budget set into law a target of a reduction in CO_2 emissions of 78% by 2035, compared to 1990 levels. In a noteworthy court case brought by three environmental groups, the UK High Court ruled that the government's net-zero strategy was in violation of the law and requires more quantifiable detail. The government has been ordered to update its net-zero strategy by March 2023.

A serious of policy papers, such as the Clean Growth Strategy (2017), Ten Point Plan for a Green Industrial Revolution (2020) and Net Zero Strategy: Build Back Greener (2021), have presented proposals and approaches for the government to decarbonize the economy. These various policy initiatives have steadily increased ambitions and reinforced efforts in different areas for the current decade. This includes expanding offshore wind power, developing low carbon hydrogen production capacity, and establishing four CCUS clusters across the country.

Due to the recent period of high-energy prices, which hit the UK particularly hard due to a high reliance on gas in electricity production, a low level of output from wind energy, as well as the crisis in Ukraine, the government has added a focus on energy security, alongside a reduction in carbon emissions. The 'British Energy Security Strategy' was published in April 2022, and included a policy to achieve zero Russian oil and coal imports by the end of 2022 and zero Russian LNG imports after this. To this end, and to increase energy independence, the strategy places attention on the evolution of the North Sea oil and gas industry. The focus is on the region continuing to supply the UK in the long-term, while also decarbonizing the industry, supporting offshore wind, and developing CCUS and hydrogen production.

The strategy also contains policies for a major revival of nuclear power in the UK. Most of the UK's ageing nuclear power plants are due to be decommissioned this decade – Sizewell B was the last power plant to be connected to the grid in 1995 and even it is expected to be decommissioned in 2035. Only one new nuclear plant is under construction, at Hinkley Point C, which will provide a sizeable 3.2 GW of capacity once operational in 2026. Another 3.2 GW of capacity should come from Sizewell C, with the project receiving planning consent in July 2022. The UK government now aims to progress several other reactor projects to reach a capacity of 24 GW by 2050, which it assumes would equate to 25% of the UK's electricity demand.

7.2.6 Hydrogen & CCUS/CCS

Increasingly, hydrogen looks set to play a major role in the energy system of the future and many countries are developing strategies and plans to take advantage of this promising energy carrier. The primary advantages of hydrogen are clear; it offers higher energy density than even gasoline and when hydrogen gas is burned, the only by-product is water, making it an obvious inclusion in a future low-carbon energy future. What is more, hydrogen can be produced from a wide range of sources, such as oil, natural gas, coal, biomass and electricity.

While hydrogen has a high energy density by weight, its volumetric energy density is low, requiring the gas to be pressurised or liquefied at extremely low temperatures. This adds difficulty to the distribution and storage of hydrogen and with existing pipeline networks typically limited to certain industrial areas, policies are needed to support the creation of a hydrogen infrastructure network that could enable its wider utilization. If the penetration of FCEVs is to be encouraged then infrastructure for fuelling stations needs to be developed in a similar way to that now being seen with the expansion of EV charging infrastructure.

To separate hydrogen from the compounds in which it is commonly found, there are several options available. Natural gas reforming and electrolysis (using electricity to split water into hydrogen and oxygen) are two of the most common processes today, but other processes are in use and more are in development.

If during electrolysis, the electricity used is provided from renewable energy sources there would be no GHG emissions throughout the production process – this is commonly referred to as 'green hydrogen'. Furthermore, hydrogen production from fossil fuels can be decarbonized if combined with CCUS technologies, known as 'blue hydrogen', and this represents another opportunity for upscaling clean hydrogen production.

In general, CCUS can be defined as the process to capture CO_2 emissions from industrial processes and store them in underground geological formations, in order to avoid their release into the atmosphere. In the IPCC's latest update to the Sixth Assessment Report on Climate Change, CCUS is highlighted as a key component to achieve a net zero energy system, as well as to aid carbon emission reductions in fossil fuel facilities. Many countries have begun adopting hydrogen and CCUS-related policies at an accelerated pace and with their own goals and roadmaps, including OPEC Member Countries, which reflect the unique needs and resources of each.

For instance, the deployment of CCUS technologies in the US could allow for notable progress in realizing the 2050 net zero ambitions of the country's leadership. The US is one of the top GHG emitters worldwide and is heavily reliant on fossil fuels to satisfy its energy demand, especially for its industrial sector.

In 2020, CCUS was integrated into energy and policy discussions and received bipartisan support. To facilitate its development, Title IV of the Energy Act 2020 incorporated provisions on carbon management technologies. Moreover, in order to encourage the adoption of CCUS technologies, section 45Q of the Internal Revenue Code introduced a tax credit mechanism.

The signing of the IRA into law in August 2022 provides support for both hydrogen and CCUS technologies. The Act extended the eligibility period for carbon capture projects to qualify for tax credits under Section 45Q for an additional seven years. It also increased the applicable credit rate, and substantially lowered the minimum capture thresholds for carbon capture projects to qualify for tax credits.

The first pieces of US legislation covering the development of hydrogen were enacted back in the early 1990s, which was followed by the Energy Policy Act of 2005 and more recently the 2020 Hydrogen Program Plan from the Department of Energy. The strategic framework for a hydrogen economy continues to be outlined, with ongoing efforts to reduce costs and address technological, regulatory, and market barriers.

In Canada, the government published its Hydrogen Strategy in December 2020. It articulates the vision of hydrogen's potential contributions to the economy by 2050 and looks to position the country as a worldwide supplier of clean hydrogen and hydrogen-related technologies. The strategy boasts of opportunities for 2050 of 20 mt/y of hydrogen demand covering 30% of Canada's energy needs, a $50 billion domestic hydrogen market and integrating advanced CCUS technologies.

In the EU, the European Green Deal, adopted in 2020, put forward a vision for the creation of a European hydrogen market, and to scale-up production and the required infrastructure. The 2021 'Fit for 55' package also promotes an uptake of renewable hydrogen in industry and transport. Furthermore, the amendment establishes new sub-targets for the use of renewable fuels of non-biological origin by 2030 – 50% in industry, and 2.6% in transport.

The European Commission's REPowerEU plan sets specific targets in three phases:

- Install at least 6 GW of renewable hydrogen electrolysers in the EU and achieve up to 1 million tonnes of renewable hydrogen production by 2024;
- Install at least 40 GW of renewable hydrogen electrolysers and reach up to 10 million tonnes of domestic renewable hydrogen production and imports each by 2030;
- Reach renewable hydrogen technology maturity and deploy it at large scale by 2050.

The 'Fit for 55' package also outlines the Commission's vision for carbon farming and industrial CCUS. By the end of 2022, the Commission will propose a regulatory framework for the certification of carbon removals based on accounting rules and requirements to monitor and verify the authenticity and environmental integrity of high-quality sustainable carbon removals. Such rules will provide the necessary legal framework to scale up carbon farming and industrial solutions removing carbon from the atmosphere.

The Commission aims to create an internal CCUS market in order to leverage CO_2 as a resource to fulfil energy and material needs. Major developments in recent years demonstrate an acceleration in terms of measures and projects in Northern Europe and the Netherlands, as well as Norway and the UK, which have the advantage of being able to rely on oil and gas-related infrastructure and expertize.

The EU also has the intension to partner with African countries especially those in close proximity in North Africa due to cost competitiveness in clean hydrogen production.

Norway's 'Long-term low-emission strategy for 2050' adopted by the Parliament in October 2019, identified hydrogen and CCUS as key technologies to meet zero emissions by 2050. Increased support for research and development is offered through new and existing funding schemes. Actors such as NEL, Statkraft and Equinor are involved in the planning and exploration of different options for both green and blue hydrogen production.

The government is setting up hydrogen value chains for land, sea and air transport, such as the first European maritime value chain project for liquid hydrogen – Aurora – which was shortlisted by Enova as one of the candidate projects for the Important Project of Common European Interest (IPCEI) initiative. Additionally, the Longship project constitutes an entire CCUS chain with the goal of demonstrating the potential of the technology in helping achieve climate goals in Norway and the EU.

Across the North Sea, in the UK, the government has allocated investment and committed to develop CCUS in four industrial clusters by 2030 as part of its 2020 Ten Point Plan. The ambition is to capture up to 30 mt of CO_2 per year by this time. The government expects two of these clusters to be ready by mid-decade. Furthermore, as part of an Energy Security Strategy published in 2022, the government doubled its hydrogen production target for 2030 to 10 GW, 5 GW of which is to come from hydrogen produced from electrolysis.

Australia's government hopes the country could be one of the top hydrogen exporters in the future, making use of its abundant fossil-fuel resources and its potential for renewable energy to produce hydrogen for demand centres in Asia. In 2019, Australia's National Hydrogen Strategy was presented that sets a path to accelerate the commercialization of hydrogen, reduce technical uncertainties, build up domestic supply chains and production capabilities and notes the potential for coupling production of hydrogen from fossil fuels with CCS. The intensification of dialogue with international partners culminated in the world's first shipment of liquefied hydrogen from Australia to Japan in January 2022.

In Japan, the government was quick to explore the possibilities that a future hydrogen economy would bring to a country that is heavily reliant on energy imports. Back in 2017, the country released its Basic Hydrogen Strategy, the goals of which were later supported through the publication of the Strategy Roadmap for Hydrogen and Fuel Cells. Amongst the country's ambitions are targets to reach 200,000 FCEV sales by 2025 and 800,000 by 2030, and to reduce the cost of hydrogen dramatically to 30 yen/m^3 by 2030 from around 100 yen/m^3 at that time.

The Japanese government's increasing targets for renewables will help support green hydrogen production, in addition to the adoption of CCUS technologies to increase blue hydrogen production. With an aim to begin storing CO_2 by 2030, the government presented a draft roadmap in April 2022, which is to be finished by the end of the year.

South Korea also has ambitious hydrogen plans, seeing this has an area not just for environmental benefits, but as a driver of economic growth and the creation of a new industrial ecosystems. While many other major countries are primarily focusing on EVs to electrify the transportation sector, South Korea has also included a significant focus on FCEVs with associated subsides. Following through with the targets set in its

Hydrogen Economy Roadmap announced in 2019, the production of FCEVs is set to grow exponentially from a target of 100,000 vehicles in 2025 to 6.2 million in 2040, alongside 1,200 fuelling stations. In November 2021, the Energy Ministry announced a goal to provide 27.9 million mt/y of 'clean hydrogen' and in doing so, replacing oil as the country's number one energy source by 2050.

To help meet policies relating to carbon neutrality, the Ministry of Science and ICT has supported the early stages of CCUS technology development with continued investment. The 2050 Carbon Neutral Strategy notes that "innovative renewable energy and fossil fuels with CCUS are the two essential elements" for the power sector.

In China, a medium- and long-term plan for the development of the hydrogen energy industry from 2021 to 2035 passed in 2022. The plan defines China's strategy to increase the supply of low-carbon hydrogen in energy-intensive and high-emission industries. The plan aims to ensure a comprehensive regulatory framework for the development of a hydrogen industry by 2025. The plan for hydrogen seeks to coordinate the development of a hydrogen energy infrastructure, including a storage and transportation system, by providing an improved policy framework and a system of industry standards.

In 2021, India announced the National Hydrogen Mission, containing the vision, intent and direction for harnessing hydrogen energy on a national scale with the aim of developing India as a global hub for hydrogen and fuel cell technology manufacturing across the entire value chain. More recently, in February 2022, the Indian Ministry of Power announced its Green Hydrogen and Green Ammonia policy. The aim is to facilitate the transition from fossil fuel/fossil fuel-based feedstock to green hydrogen/green ammonia. The measures include waivers on inter-state transmission charges, renewable purchase obligation benefits, prioritized grid connectivity and various storage benefits.

In terms of CCUS, the Accelerating CCS Technologies initiative was established with participating countries in Europe and North America to provide funding for projects that will help to develop CCUS technology. The first call for projects as part of the initiative was in 2016, and in 2022 applications were opened for the fourth time.

In the Middle East, Gulf Cooperation Council (GCC) countries have shown interest in developing the hydrogen economy, utilising low-cost gas and renewable energy resources. Many African countries have also showed interest in leveraging the potential of hydrogen as an energy carrier. Consequently, May 2022 saw the establishment of the African Hydrogen Partnership (AHP), aimed to facilitate cooperation in this area.

Energy scenarios

Key takeaways

- The global economy and energy system are at a crucial juncture, characterized by huge uncertainties and challenges. The input of all energy actors is required to alleviate the drivers of the current global crises, specifically taking into consideration the special needs, national circumstances and capabilities of vulnerable people and developing countries.
- Stakeholders are currently called on to collectively achieve ambitious emission reductions by accelerating action at an unprecedented scale in all key sectors, including energy systems, transport, buildings and industry.
- Oil and gas exporting countries are expected to respond to tightening international markets by increasing oil and gas production. At the same time, however, there are also calls to reduce oil and gas usage and actively discourage investments in the oil and gas industry.
- Two alternative scenarios to the Reference Case are presented in this Chapter. The first, the 'Advanced Technology Scenario', addresses the push to reduce emissions that follows an alternative trajectory to the mainstream focus on substituting fossil fuels with renewable energy sources.
- Emissions reductions achieved in the Advanced Technology Scenario over the forecast period are aligned with the long-term goals of the Paris Agreement. Moreover, they also correspond to an energy mix and future energy demand expectations that largely imply a significant offsetting of adverse socio-economic effects on energy exporting developing countries that typically arise from scenarios that focus on fossil fuel demand reduction as the main response measure to address climate change.
- In the second, the 'Laissez-Faire Scenario', faster economic growth and development needs in non-OECD countries highlight the potential for higher future energy requirements, with the continued use of oil and gas to facilitate this growth. At the same time there is no coordinated move to reduce global emissions.
- Needless to say, these two scenarios have starkly different outcomes, with oil demand by 2045 projected to reach 92 mb/d and 115 mb/d, respectively, compared to 110 mb/d in the Reference Case.
- It is vital that any adverse impacts for the economies and societies of energy exporting developing countries are addressed in the context of equity and sustainable development. Promoting partnerships and cooperative initiatives to invest in technology and innovation could help meet these goals.
- The critical role of oil and gas in meeting future energy demand and in helping eradicate energy poverty should be taken into consideration when developing future investment plans.

The world is currently living through multiple crises. These include a health crisis due to the COVID-19 pandemic; an economic and financial crisis with inflation on the rise and recessions in some parts of the world possibly looming; an energy crisis exacerbated by global under investment in past years and geopolitical tensions that have in turn led to both food and energy insecurity; as well as major global environmental challenges.

Due to the impact of many of these developments, progress achieved on sustainable development has slowed or even been reversed worldwide, poverty and inequalities have been exacerbated across countries and regions, and societies are shifting away from resilient development pathways. This is having significant impacts on human well-being and future economic growth, particularly for developing countries.

Considering the cumulative effects of these interlinked challenges and associated risks are global in nature, governments are aiming to ensure that the implementation of response and recovery measures are universal, integrated and transformative, and thus conducive to rebuilding a resilient and sustainable future for all. It is also recognized that at the heart of these stimulus plans lie energy systems that are integral to environmentally sound social and economic development. They play a central role in all three interdependent and mutually reinforcing pillars of sustainable development.

As evident from the review of energy policies in major economies and their mitigation actions, plans and strategies for the implementation of the Paris Agreement (Chapter 7), both developed and developing countries are in the process of enhancing their efforts to build back resilient and sustainable economies and increasing their capacity to act both domestically and globally, through national governance and international cooperation.

As a result, there is growing momentum from many countries to set net-zero emissions, carbon neutrality, or climate neutrality targets, to be achieved by 2050 or a few years later. The pledges and aspirations of major economies in order to tackle climate change, as reflected in their long-term development strategies, are often attached to bold policies and measures put in place as part of stimulus packages and recovery spending. Moreover, a prominent feature of countries' new or updated NDCs is their increasing emphasis on the energy-related component, with a primary focus on the power generation, transport and industry sectors.

At the same time, the world continues to experience growing challenges affecting the implementation of development plans and policies – especially those enacted or announced recently as policymakers in a number of countries shift their attention to pressing energy security issues that, potentially, could rework investment flows and defer the implementation of specific policies. Moreover, global emissions are still increasing, and together with rising inflation, unsustainable debt levels in some countries, trade disruptions and the uneven distribution of vaccinations, the world is likely to remain for the time being in a vicious cycle of energy insecurity, economic disparity and social inequality.

Importantly, 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. It is these countries – generally having little or no responsibility for climate change – that are, and will increasingly be disproportionately affected by climate change, as well as the measures taken to respond to it. Moreover, they remain without the expected support from developed countries to help them mitigate the impacts and adapt to the changing environment.

A contradiction has also been foisted on natural resource endowed countries, including OPEC Member Countries. On the one hand, oil and gas exporting countries are expected to respond to tightening international markets by increasing oil and gas production. At the same time, however, there are also calls to reduce oil and gas usage, and moves to actively discourage investments in the oil and gas industry.

This implies that there is an increasing likelihood of an oil and gas shortfall in the years ahead, which could exacerbate energy insecurity. For example, new exploration and production projects that require financing are expected to increasingly face substantial challenges. Efforts to discourage oil exploration and development are bound to sow the seeds of a more pronounced energy crisis, affecting the stability and sustainability of global energy markets, and undermining global energy security.

Moreover, they jeopardize efforts to achieve universal, reliable and affordable energy access for people across the globe. For natural resource endowed countries, particularly developing ones, it also adds to their risks and will likely hamper efforts to achieve sustainable development goals, including the eradication of energy poverty and sustained economic growth.

This is all ominous in light of the fact that in this report's Reference Case, total primary energy demand is projected to expand by 23% in the period to 2045. Additionally, oil is expected to retain the largest share in the energy mix throughout the projection period, as presented in Chapter 2. To place all this in an investment perspective, it is estimated that over $12 trillion of cumulative oil-related investment is needed between 2022 and 2045 to meet future demand (see section 4.7).

Against the backdrop of these multiple crises, it is important to consider future energy policies and enhanced climate mitigation ambitions. Despite the inherent uncertainties of energy systems, there is a need to consider all available options, means and approaches to address global challenges in light of national circumstances and capabilities, while supporting energy security in an inclusive, fair and just transition.

8.1 Alternative energy scenarios

This chapter aims to provide insights into alternative and plausible energy pathways, assessing the potential impacts of various fundamental factors such as economic growth, future energy policies, climate mitigation action and technological advancements, among others.

To this end, a different set of conditions for the future of energy systems is examined within a scenario analysis framework, taking into consideration energy policies and climate mitigation actions already presented in this Outlook. This includes an alternative mitigation pathway to the increasingly mainstream focus on maximizing the displacement of fossil fuels by renewable energy sources, which has potentially crippling socioeconomic implications for energy exporting developing economies. This is underscored in the '**Advanced Technology Scenario**', which is aligned with the long-term goals of the Paris Agreement.

This chapter also intends to raise awareness about the many challenges inherent in the energy transition by presenting a '**Laissez-Faire Scenario**', one of several possible paths that allows for economic growth and the transition to improved energy access and energy poverty eradication in least developed countries. At the same time, this leads to potentially higher energy demand, and where all energy sources, including oil and gas, play an important role.

Both scenarios are compared to the Reference Case projections presented in previous chapters of the Outlook, and, therefore, include the same basic socio-economic assumptions on global population and economic development until 2045. However, each scenario has a distinct narrative of energy policies, economic development and investment priorities and technology advances.

Advanced Technology Scenario

The Advanced Technology Scenario provides an alternative emissions reduction pathway consistent with the long-term goals of the Paris Agreement. It focuses on the greater deployment of CCUS technologies in industrial sectors, strong investment in hydrogen supply networks and the increasing adoption of the circular carbon economy (CCE) framework across the global economy, including energy efficiency measures.

A continued relatively high use of hydrocarbons in this scenario is assumed in the first half of this century. The exception to this is coal, which sees demand decline as regulatory policies are assumed to phase out/phase down its use in the industry and power sectors. Meanwhile, nuclear power plays a more significant role compared to the Reference Case. The advancement of CCUS and direct air capture (DAC) technologies is also assumed, with the large-scale deployment of bioenergy with CCUS in the second half of the century.

Laissez-Faire Scenario

The Laissez-Faire Scenario focuses on potential structural changes in the future energy mix in areas where efforts to reduce emissions are the primary driver reshaping future energy requirements. OPEC Member Countries are contributing to these efforts, both in their active participation at related UNFCCC negotiations and through large investments into their energy systems to reduce their own emissions, including providing cleaner fuels for consumers in other countries and regions.

It is a global aspiration that these efforts will lead to a sustainable long-term global energy system. At the same time, however, it is important to recognize that the interplay of various factors could potentially result in a scenario where higher economic growth in developing countries will allow for a faster change in the living conditions of millions of people in these countries, compared to the Reference Case.

To this end, the Laissez-Faire Scenario assumes improved energy access in least developed regions, the further eradication of energy poverty and a quicker transition to modern energy sources and technologies, including renewable energy, oil, gas and nuclear, especially in the second part of the forecast period. In this scenario, policies will be tightened in the future, contributing to improved efficiencies and support for the further expansion of renewables, however, in a more isolated manner given an absence of a coordinated move to reduce future emissions. Recent geopolitical tensions in several regions indicate that protectionism and unilateralism could play a more prominent role in the future.

8.2 Energy demand and the energy mix

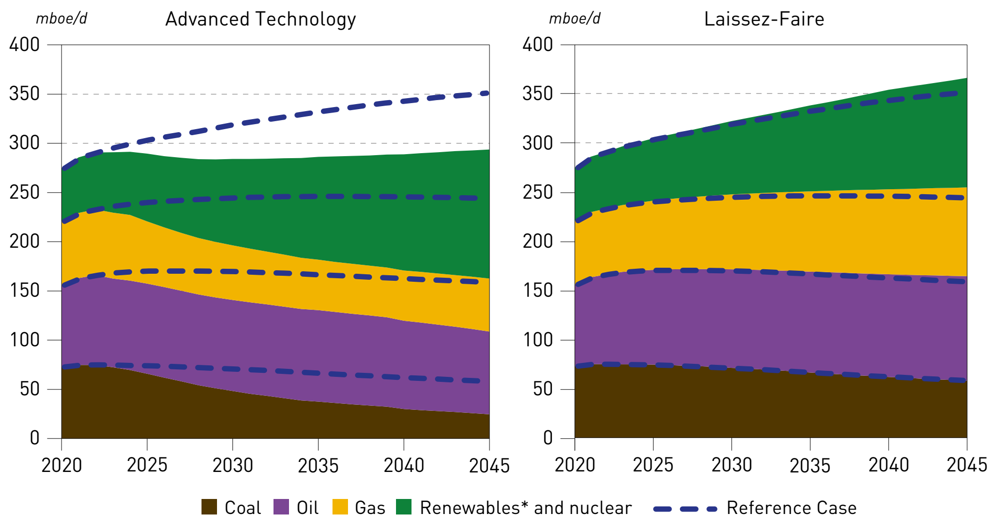
Four fundamental factors determine the dynamics of the energy system in the alternative scenarios:

- Socio-economic developments;
- Different levels of climate mitigation ambition across countries and regions;
- Difference in timing of climate mitigation action across sectors; and
- Mixture of preferred technologies that enable the implementation of climate ambitions.

It is a combination of these factors that determines the specific path for any future energy system. This includes implications for varying demand levels, the energy mix, the level of emissions and socio-economic impacts. The diverging impact of these factors is clearly demonstrated in the two alternative scenarios presented in this Chapter.

Starting with future primary energy demand levels and the corresponding mix of fuels, the summary of results for the alternative scenarios is presented in Figure 8.1 (for the period of 2020–2045) and Figures 8.2/8.3 (for selected years).

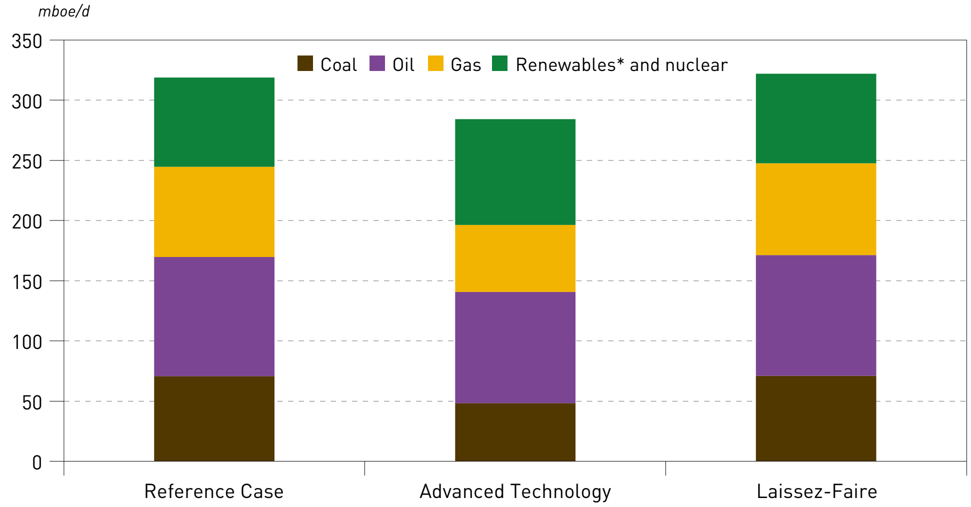
Figure 8.1
Global primary energy demand in the Reference Case and in alternative scenarios, 2020–2045



** Note: Renewables include hydro, biomass and other renewables (e.g. wind, solar, geothermal).*
Source: OPEC.

8

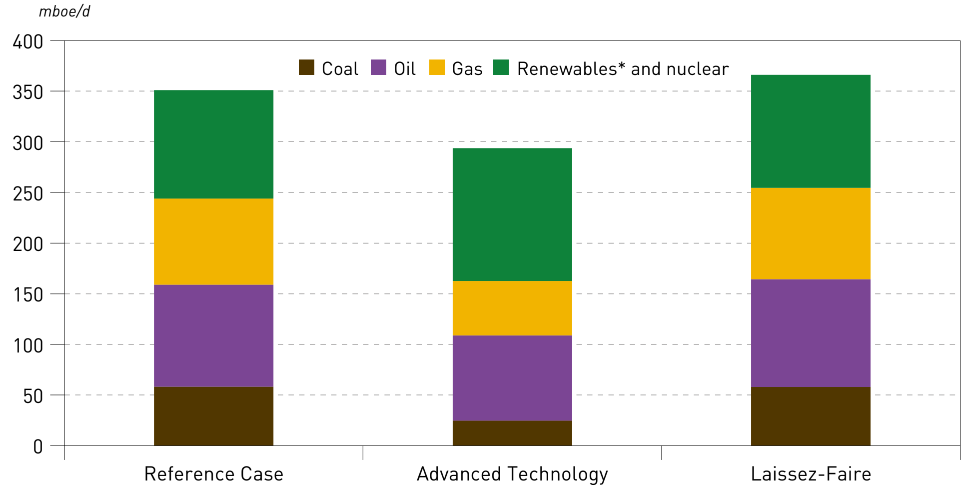
Figure 8.2
Global primary energy demand in the Reference Case and in alternative scenarios, 2030



** Note: Renewables include hydro, biomass and other renewables (e.g. wind, solar, geothermal).*
Source: OPEC.

While in the Reference Case, global primary energy demand by 2030 rises to nearly 320 mboe/d, and to comparable levels in the Laissez-Faire Scenario, assumptions considered in the Advanced Technology Scenario lead to lower total primary energy demand. At the global level, after fully recovering from the COVID-19 induced crises, primary energy demand in this scenario declines by around 7 mboe/d during the remaining part of the

Figure 8.3
Global primary energy demand in the Reference Case and in alternative scenarios, 2045



** Note: Renewables include hydro, biomass and other renewables (e.g. wind, solar, geothermal).*
Source: OPEC.

current decade (Figure 8.1). Moreover, the energy mix in this scenario will be different. By 2030, demand for coal is reduced by almost 32% compared to the Reference Case. This is due to an accelerated phase-out of unabated power generation from coal in countries such as China, India and South Africa.

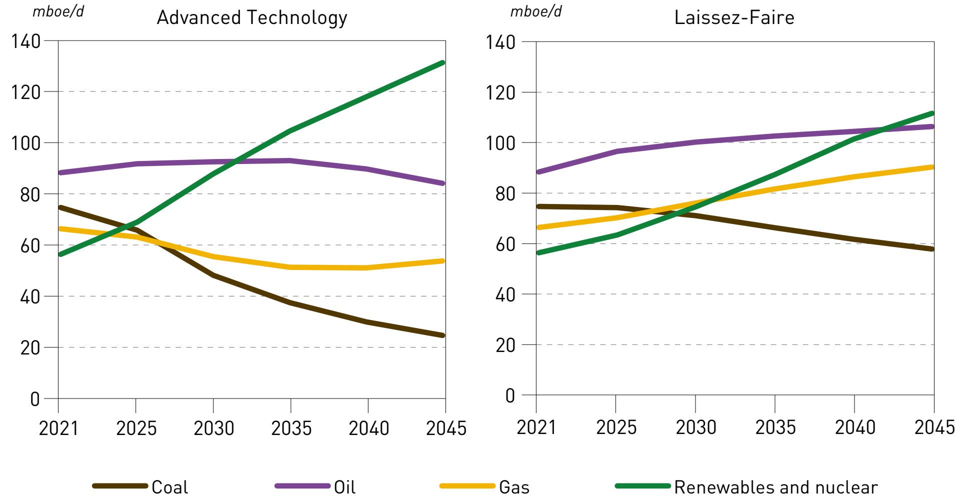
In contrast, demand for non-fossil fuels (renewables and nuclear) is 18% higher compared to the Reference Case in 2030 and 41% higher by 2045. This corresponds to an almost 45% share for renewable energy and nuclear in total primary energy demand in 2045. This is significantly higher than the corresponding 30% share projected in the Reference Case.

Gas substitution with renewable sources, further electrification of residential and industry sectors and energy efficiency improvements in major developed and developing countries – mainly the US and China – lead to a 26% drop in global gas demand by 2030, compared to the Reference Case. The corresponding change for oil demand is lower, estimated at a 6% reduction, considering technological transformation in the road transport sector, as well as reductions in energy demand from aviation and maritime freight. Contrary to these fuels, renewable energy grows much faster than in the Reference Case for the rest of this decade, compensating for declining fossil fuel demand.

However, this trend diverges sometime after 2030 as CCUS and DAC increasingly play a more significant role. As presented in Figure 8.4, the most visible impact relates to natural gas demand, which will start to moderately expand again, supported by the use of CCUS. Coal and oil demand continue declining in the Advanced Technology Scenario during this period. Coal demand is projected to fall to around 25 mboe/d by the end of the forecast period, while oil is projected to be at around 85 mboe/d.

This represents a demand reduction of around 58% for coal, compared to the Reference Case by 2045. Demand for gas is reduced by 37%, and oil demand is 16% lower. Yet there

Figure 8.4
Global primary energy demand by fuel in alternative scenarios, 2021–2045



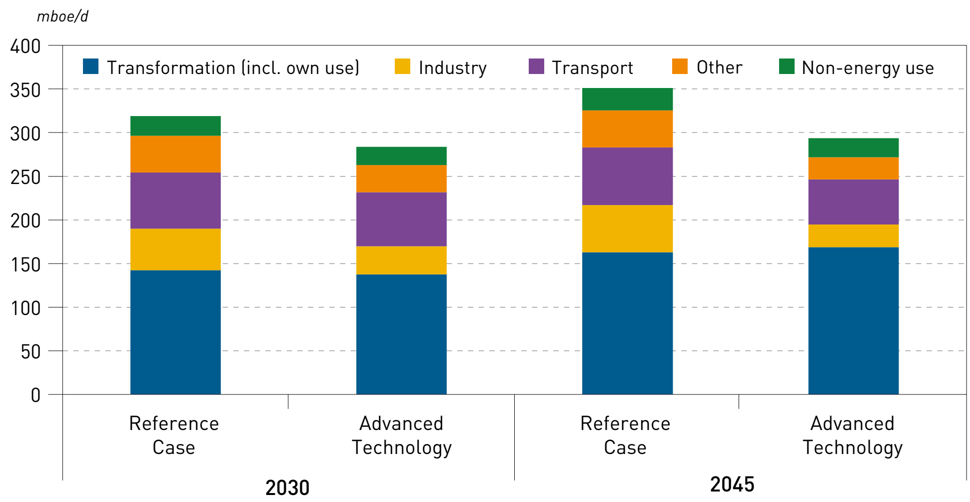
Source: OPEC.

remains substantial demand for fossil fuels, accounting for about 55% of total primary energy demand in 2045.

At the same time, demand for renewable and nuclear energy will extend its strong growth and is projected to be above 130 mboe/d by 2045.

On a sectoral level, the Advanced Technology Scenario, in particular, also has significant implications for the global energy demand breakdown, as presented in Figure 8.5. In the period to 2030, energy demand in all major sectors (at the global level) is projected to decline. The largest demand decline of almost 16 mboe/d is projected in the industry sector, followed by the 'other' sector (–11 mboe/d) and the transformation sector (–5 mboe/d). In the sectors of final energy consumption, there are two primary reasons for these reduced levels: energy efficiency measures and progressing level of electrification across all sectors.

Figure 8.5
Global primary energy demand by sector in the Reference Case and Advanced Technology Scenario, 2030 and 2045



Source: OPEC.

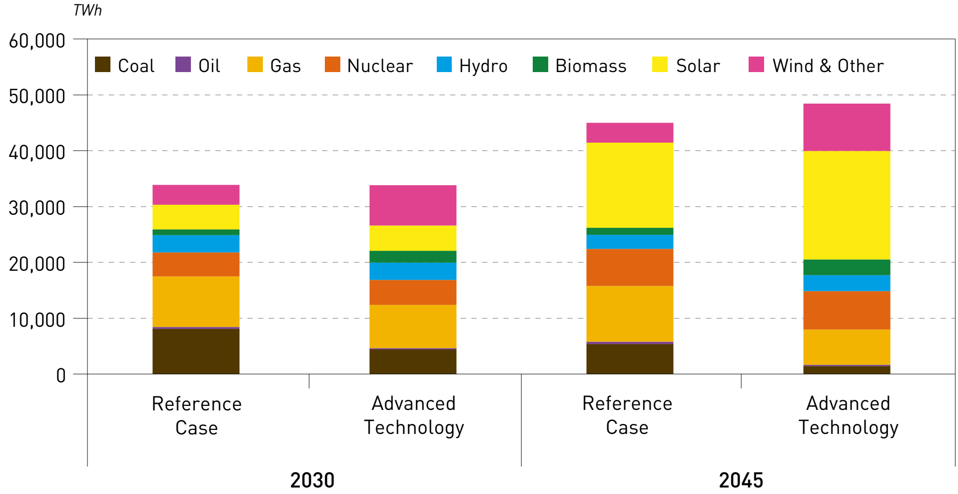
In the transformation sector, however, the overall decline is more related to the changing pattern of electricity generation, particularly replacing the inefficient use of coal with renewable electricity that allows for a comparable amount of electricity with a lower input of primary fuels.

These trends are exacerbated further when moving towards 2045. By then, global energy demand in the industry sector will be almost 29 mboe/d lower compared to the Reference Case, supported by the further penetration of energy efficient technologies, hydrogen use and increased recycling rates. Similar measures, combined with strict building codes and widespread building insulation, could lead to global energy savings in the range of 17 mboe/d in the 'other' sector. During the second part of the forecast period, the advancement of electrification in the transportation sector, combined with more efficient vehicles, is projected to lower energy demand in this sector by around 14 mboe/d, compared to the Reference Case.

It is worth noting that despite a significant reduction in global primary energy demand in the Advanced Technology Scenario; energy demand in the transformation sector by 2045 will be around 6 mboe/d higher than in the Reference Case. This will likely happen on the back of expanding demand for electricity in this scenario, while the effect of displacing coal with renewables is anticipated to be broadly exploited towards the end of the forecast period. Moreover, as mentioned earlier, and presented in Figures 8.4 and 8.6, the availability of CCUS technology will enable a revival in gas demand to meet electricity demand without increasing CO_2 emissions.

Figure 8.6 also shows how the power sector will progressively shift towards non-fossil fuels based electricity under the Advanced Technology Scenario. Indeed, more than 60% of global electricity was produced from fossil fuels in 2021, with coal alone accounting for around 35%. However, coal's share would need to decline to 24% by 2030 and to below 10% by 2045 if advanced technologies are implemented, as suggested in this scenario. Moreover, the share of electricity from fossil fuels would be almost halved in this scenario by 2045, compared to 2021.

Figure 8.6
Electricity generation by fuel in the Reference Case and Advanced Technology Scenario, 2030 and 2045



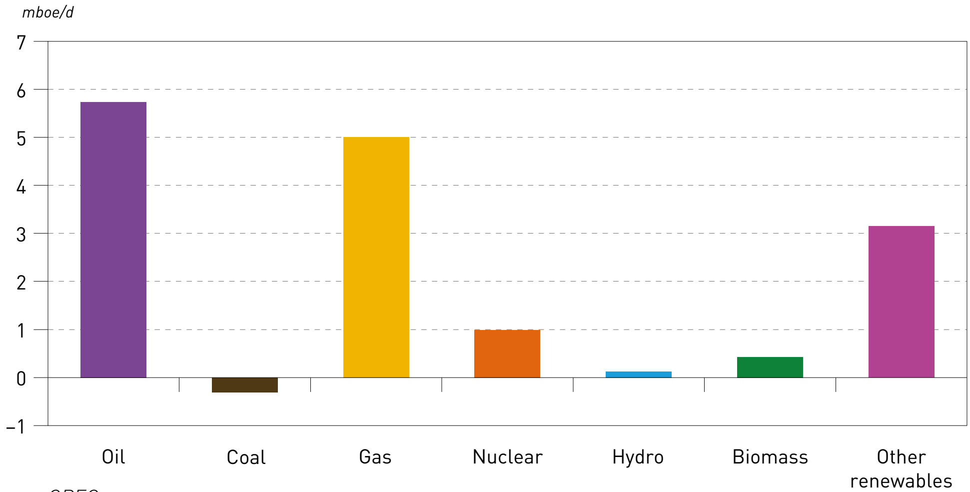
Source: OPEC.

In contrast, electricity generation from renewable sources would almost quadruple between 2021 and 2045, rising from around 7,400 TWh in 2021 to almost 27,000 TWh in 2045. Out of this, close to 20,000 TWh would come from solar photovoltaics, making it the single largest source of electricity by 2045.

Turning to the Laissez-Faire Scenario, global primary energy demand is projected to continue expanding over the forecast period, exceeding the growth projected in the Reference Case on the back of faster economic development. The underlying global GDP growth rate assumption is not dramatically different to the Reference Case. On average, it is assumed to be in the range of 0.2% to 0.3% p.a. higher. Nevertheless, the cumulative effect is that global GDP in the Laissez-Faire Scenario would be almost $17 trillion higher in 2045, with a large part of it materializing in developing countries.

Accordingly, as presented in Figure 8.7, global primary energy demand in the Laissez-Faire Scenario would be around 15 mboe/d higher than in the Reference Case by 2045. This gradual emerging gap, compared to the Reference Case, will mainly be met by oil and gas, with each contributing an additional 5–6 mboe/d to expanding energy needs. Other renewables are projected to have by far the fastest growth in this scenario, almost sextupling their contribution to the future energy mix, rising from around 7 mboe/d in 2021 to almost 42 mboe/d in 2045. Some additional demand is also projected for nuclear energy, while other energy sources are expected to oscillate around their Reference Case levels.

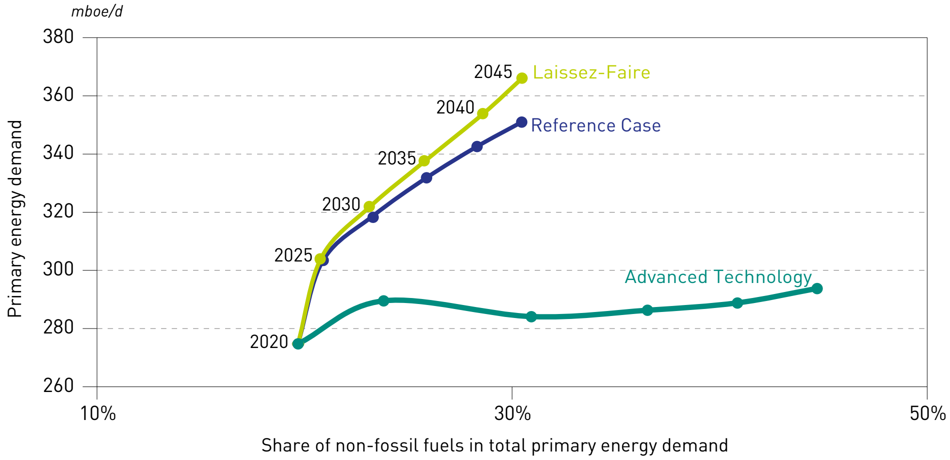
Figure 8.7
Change in primary energy demand between Laissez-Faire Scenario and the Reference Case in 2045



Source: OPEC.

Figure 8.8 captures the above trends and compares the dynamics of the links between primary energy demand and the share of non-fossil fuels for the scenarios considered in this Outlook. It demonstrates how the energy mix in both the Reference Case and Laissez-Faire

Figure 8.8
Global energy system in the Reference Case and alternative scenarios, 2020–2045



Source: OPEC.

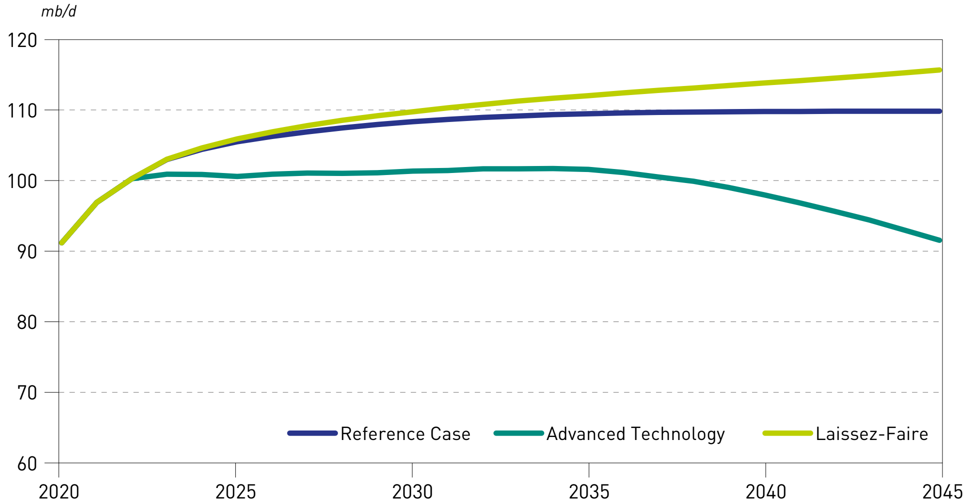
Scenario gradually incorporates a higher share of renewables and nuclear energy. Combined, this grows from around 20% in 2020, to 23% in 2030 and then to more than 30% in 2045.

However, the Advanced Technology Scenario incorporates much faster dynamics as by 2030 the share of non-fossil fuels in global primary energy demand has already advanced to almost 31%, before reaching almost 45% by 2045.

8.3 Oil demand

Looking specifically at the implications of these scenarios on future oil demand, Figure 8.9 provides a high-level summary of global oil demand projections in the two alternative scenarios, as well as in the Reference Case. It should be noted that these demand projections are expressed in volumetric terms (mb/d) and include corresponding volumes of non-oil based liquid products, such as biofuels, GTLs and CTLs. Therefore, these figures are not directly comparable with those mentioned in the previous part of this Chapter that are presented on an energy content basis.

Figure 8.9
Global oil demand in the Reference Case and alternative scenarios, 2020–2045

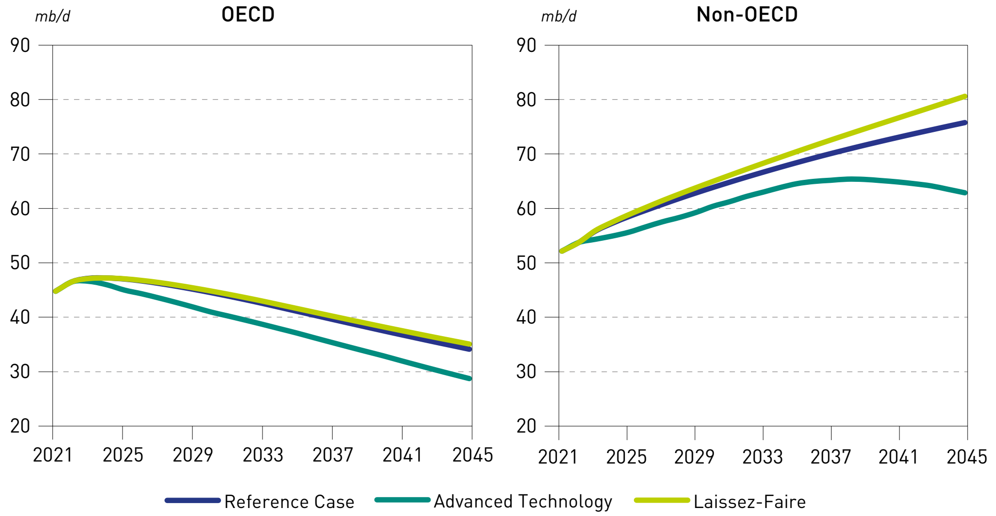


Source: OPEC.

In the Advanced Technology Scenario, oil consumption remains lower than in the Reference Case. However, as already articulated, it is less adversely affected than in the mainstream mitigation scenarios, on the back of an accelerated use of hydrogen, CCUS and a CCE framework. This 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. Oil demand in the Advanced Technology Scenario is projected to grow during the initial years of the forecast period (recovering from the COVID-19 crisis). It stabilizes at levels above 100 mb/d over the next 15 years, before dropping back to around 92 mb/d by 2045.

Finally, oil demand in the Laissez-Faire Scenario is projected to be 5.8 mb/d higher by 2045, compared to the Reference Case. As shown in Figure 8.10, this

Figure 8.10
OECD and non-OECD oil demand by scenario, 2021–2045



Source: OPEC.

incremental demand will be disproportionally distributed between OECD and non-OECD countries. In the case of the OECD, part of the potentially higher oil demand will be offset by additional policy measures and the faster penetration of more efficient technologies. Moreover, better economic conditions in the OECD will allow for even faster renewable energy growth that will further displace coal and limit demand growth in oil and gas. Therefore, the overall change in OECD oil demand is less than 1 mb/d by 2045, compared to the Reference Case.

In contrast, non-OECD oil demand in the Laissez-Faire Scenario is projected to reach more than 80 mb/d in 2045, which is almost 5 mb/d higher compared to the Reference Case. Moreover, as oil and gas investments are assumed to be largely restricted in OECD countries in this scenario, additional (compared to the Reference Case) oil supply growth in non-OPEC countries will be limited to less than 2 mb/d by 2045, which corresponds with overall non-OPEC oil supply approaching 70 mb/d in 2045. As a result, demand for OPEC liquids would be pushed higher by more than 4 mb/d, compared to the Reference Case. It reaches almost 47 b/d in 2045. In turn, this will require substantial investments to provide the required supply in the future.

8.4 Socio-economic implications and emissions

As noted in Chapter 2, annual energy-related CO_2 emissions in the Reference Case are estimated at 33.7 bt in 2021 and are projected to be in a range around 35 bt by the end of the current decade. Afterwards, they are expected to start declining slowly for the rest of the forecast period, returning broadly to 2021 levels by 2045.

In the Advanced Technology Scenario, the respective emissions reductions compared to the Reference Case is estimated at around 34% by 2030 and more than 62% by 2045. It has the potential to be consistent with the long-term Paris Agreement goals, provided there is an ambitious deployment of CCUS and DAC in the second half of the century. In contrast, developments along the pathway described in the Laissez-Faire Scenario would result in marginally higher future emission trends compared to the Reference Case.

It is important to note that emissions reduction achieved in the Advanced Technology Scenario during the forecast period, are not only aligned with the long-term goals of the Paris Agreement. They also correspond to an energy mix and future energy demand expectations that largely implies a significant offsetting of the expected adverse socio-economic effects on energy exporting developing countries that typically arise from scenarios that focus on fossil fuels demand reduction, as the main response measure to address climate change issue.

Moreover, under the Reference Case, the total CO_2 emissions of developed countries are on a declining trend, primarily due to structural changes in their economies, while the emissions increase in developing countries may be attributed to rapid economic and population growth. However, developed countries still have higher per-capita emissions than developing countries (Chapter 2, Figure 2.16), and developed countries have higher cumulative emissions over the period 1900–2045 (Chapter 2, Figure 2.17). Moreover, this disparity in per capita emissions between OECD and developing countries is set to continue over the forecast period in the alternative scenarios considered in this Chapter.

Another important aspect of the scenario development relates to the potential socio-economic implications. In particular, recent estimates indicate that the GDP of OPEC Member Countries in typical mainstream emissions-mitigation scenarios (with a strong focus on renewables displacing oil and gas) could be as much as 16% lower than in the Reference Case by 2045. The impact on Russia's GDP would be moderately lower, but still reduced by around 10%, compared to the Reference Case. The overall impact on non-OPEC countries participating in the DoC could be in the range of a 5% decline, which is comparable to the estimated GDP reduction for Canada.

These adverse impacts are driven by a loss of value in traditional hydrocarbon sectors, lower export revenues and weakened terms of trade. In addition, the GDP reduction of energy-exporting developing countries is expected to be larger than the overall effect on the global economy.

Besides losses in the wider economy and declining consumption, employment levels are also likely to be adversely affected in energy-exporting developing countries. This is not only the result of job losses across the hydrocarbon industry, but also losses in the public sector that relies on fiscal flows from the industry.

However, these adverse impacts on energy-exporting developing countries could be significantly mitigated if advanced technology options were implemented at scale, as suggested in the Advanced Technology Scenario. While this scenario is in alignment with the long-term targets of the Paris Agreement, owing to technological advancement in the oil and gas industry, its economic impacts are lower in magnitude when compared to typical mainstream emissions-mitigation scenarios that primarily target a reduction in fossil fuels demand.

8.5 Conclusions

Analysis included in this chapter indicates that a plausible alternative pathway to mainstream emissions mitigation trajectories exist. In the latter, while any potential adverse impacts from the implementation of mitigation action are only modest at a global level (due to the offsetting effects among major country groups, such as net energy exporters/importers, developed/developing countries etc.), the implications for energy exporting-developing countries means a higher likelihood of facing substantially larger mitigation costs than major economies.

Therefore, it is necessary to promote partnerships and cooperative initiatives to invest in technology and innovation that could enable inclusive and just solutions. The wide deployment of technological innovation – such as CCUS technologies and hydrogen – is a viable option, without which the long-term goals of the Paris Agreement would be difficult to achieve. Besides combating climate change, technological innovation offers wider benefits. Innovative solutions could lead to the creation of new jobs and new value-added potential, reducing the adverse impacts of climate mitigation response measures.

In summary, Parties to the Paris Agreement have outlined their national visions, pathways and mitigation policies as reflected in their NDCs and long-term low-emission development strategies. However, it is worth emphasizing that developing countries are not only affected by climate change, but also by the impacts of the measures taken in response to it.

The enduring search for appropriate policies and solutions to reconcile socio-economic development and environmental protection is more urgent than ever. Nobody should be left behind, and all viable mitigation measures, technological innovations, as well as improved energy efficiency and enhanced investment for universal reliable and affordable energy access must be part of the solution.

The SDGs of the 2030 Agenda for Sustainable Development also set out a desired state for inclusive and sustainable societies. 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.

Parties' contributions to reducing global emissions should be subject to differentiated responsibilities, based on capabilities and national circumstances. The different starting point between developed and developing counties needs serious consideration for the implementation of the Paris Agreement. Developing countries should have the policy space to address climate change in the context of sustainable development.

Determined leadership, adequate finance, the utilization of all relevant technologies and collaboration among countries will be needed to reduce emissions, while also eliminating any adverse impacts of mitigation measures on livelihoods and societies.

Annex A
Abbreviations

AFVs	Alternative fuel vehicles
AHP	African Hydrogen Partnership
AI	Artifical Intelligence
AR6	(Sixth) assessment report
bcm	Billion cubic metres
BEV	Battery electric vehicle
boe	Barrels of oil equivalent
bt	Billion tonnes
CAFE	Corporate Average Fuel Economy
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon capture and storage
CCUS	Carbon capture, utilization and storage
CDB	China Development Bank
CNG	Compressed natural gas
CO_2	Carbon dioxide
COP	Conference of Parties
COTL	Crude oil-to-chemicals
COVID-19	Coronavirus disease 2019
CTLs	Coal-to-liquids
DAC	Direct air capture
DoC	Declaration of Cooperation
ECAs	Emission Control Areas
ECB	European Central Bank
EEDI	Energy Efficiency Design Index
EIA	Energy Information Administration (US)
EPA	Environmental Protection Agency (US)
ESG	Environmental, Social and Governance
ETBE	Ethyl tertiary butyl ether
ETS	Emissions Trading System
EU	European Union
EVs	Electric vehicles
FCC	Fluid catalytic cracking
FCEV	Fuel cell electric vehicle
FEED	Front end engineering design
FED	US Federal Reserve
FID	Final investment decision
FPSO	Floating production storage and offloading vessel
FYP	Five-Year-Plan
GCC	Gulf Coopration Council
GDP	Gross domestic product
GGO	Global Gas Outlook
GHG	Greenhouse gas
GoM	Gulf of Mexico
Gt	Gigatonnes

GTLs	Gas-to-liquids
GW	Gigawatt
HEE	Hygienic earth energy
HEV	Hybrid electric vehicle
HSFO	High sulphur fuel oil
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICEs	Internal combustion engines
IEA	International Energy Agency
IMO	International Maritime Organization
IMF	International Monetary Fund
IOCs	International Oil Companies
IPCEI	Important project of common European interest
IPPC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
kg	Kilogram
km	Kilometre
kW	Kilowatt
kWh	Kilowatt hour
LNG	Liquefied natural gas
LOOP	Louisiana Offoshore Oil Port
LPG	Liquefied petroleum gas
LSFO	Low-sulphur fuel oil
LTSs	Long-term strategies
MaaS	Mobility as a service
mb/d	Million barrels per day
mboe/d	Million barrels of oil equivalent per day
Mbtu	Million British thermal units
mpg	Miles per gallon
mt/y	Million tonnes per year
MTBE	Methyl tertiary butyl ether
MW	Megawatt
NDCs	Nationally determined contributions
NEV	New energy vehicle
NGLs	Natural gas liquids
NHM	National Hydrogen Energy Mission
NPR	National Petroleum Reserve Alaska
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
p.a.	Per annum
PHEV	Plug-in hybrid electric vehicle

POX	Partial oxidation
pp	Percentage point
PPP	Purchasing power parity
PV	Photovoltaic
RED-II	Renewable energy directive
RFNBO	Renewable fuels of non-biological origin
RFS	Renewable Fuel Standard
SAF	Sustainable aviation fuel
SAFE	Safer Affordable Fuel Efficient
SBI	Subsidiary Body for Implementation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SDG	Sustainable Development Goal
SMR	small modular reactor
SNR	Steam naphtha reforming
SUV	Sport utility vehicle
tb/d	Thousand barrels per day
tcm	Trillion cubic metres
TTF	Title transfer facility
TWh	Terawatt hour
UAE	United Arab Emirates
UK	United Kingdom
ULS	Ultra-low sulphur
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNFCCC	UN Framework Convention on Climate Change
UNGA	UN General Assembly
US	United States
VGO	Vacuum gasoil
VLCC	Very large crude carrier
VMT	Vehicle miles travelled
WCSB	Western Canadian Sedimentary Basin
WOO	World Oil Outlook (OPEC)
y-o-y	Year-on-year
ZEV	Zero emission vehicle

Annex B
OPEC World Energy: definitions of regions

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-Pacific, 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 the Congo
Equatorial Guinea
Gabon
IR Iran
Iraq
Kuwait
Libya
Nigeria
Saudi Arabia
United Arab Emirates
Venezuela, Bolivarian Republic of

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
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: definitions of regions

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 the 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

AG Energiebilanzen
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
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
Equinor
Ernst & Young
EUREL
European Automotive Manufacturers Association (ACEA)
European Commission
European Council
European Environment Agency
Eurostat
Evaluate Energy
Financial Times
FrauenHofer Institue
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
Haver Analytics
HSBC
Hydrocarbon Processing
International Commodities Exchange
IEA Monthly Oil Data Service (MODS)

IEA Oil Market Report
IEA World Energy Outlook
IHS Markit
IMF, Direction of Trade Statistics
IMF, International Financial Statistics
IMF, Primary Commodity Prices
IMF, World Economic Outlook
India, Ministry of Petroleum & Natural Gas
India Times
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
Petrobras
Petroleum Economist
Petroleum Intelligence Weekly
Platts
PricewaterhouseCoopers
pv Europe
Reserve Bank of Australia
Reuters
Rystad Energy
Seatrade
Siemens AG
Smart Energy International
Society of Petroleum Engineers (SPE)
Solomon Associates
Stratas Advisors
Sustainable Energy for All
The Economic Times
Turner Mason and Company
UN Department of Economic and Social Affairs
UN Energy Statistics
UN Food and Agriculture Organization (FAO)
UN International Trade Statistics Yearbook
UN National Account Statistics
UN Conference on Trade and Development (UNCTAD)
UN Development Programme (UNDP)
UN Economic and Social Commission for Asia and the Pacific (UNESCAP)
UN Educational, Scientific and Cultural Organization (UNESCO)
UN Environment Programme (UNEP)
UN Framework Convention on Climate Change (UNFCCC)
UN International Labour Organisation (ILO)
UN Statistical Yearbook
UN World Tourism Organization (UNWTO)
US Bureau of Labor Statistics
US Department of Energy (DoE)
US Department of the Interior (DoI)
US Energy Information Administration (EIA)
US Environmental Protection Agency (EPA)
US Geological Survey (USGS)
Wall Street Journal
World Bank
World Coal Association
World Coal Institute
World Energy Council
Wood Mackenzie
World Economic Forum
World Nuclear Association
World Resources Institute
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