



GECF

Gas Exporting Countries Forum

**GLOBAL GAS
OUTLOOK
2050
SYNOPSIS**





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ABOUT THE GECF

The Gas Exporting Countries Forum (GECF or Forum) is an intergovernmental organisation established in May 2001 in Tehran, Islamic Republic of Iran. The GECF Statute was signed in 2008 in Moscow, Russia. The GECF became a fully-fledged organisation in 2008 with its permanent Secretariat based in Doha, Qatar.

As of February 2022, the GECF comprises eleven Members and seven Observer Members (hereafter referred to as the GECF Countries). The Member Countries of the Forum are Algeria, Bolivia, Egypt, Equatorial Guinea, Iran, Libya, Nigeria, Qatar, Russia, Trinidad and Tobago, and Venezuela (hereafter referred to as Members). Angola, Azerbaijan, Iraq, Malaysia, Norway, Peru and the United Arab Emirates have the status of Observer Members (hereafter referred to as Observers).

The GECF is a gathering of the world's leading gas producers, whose objective is to increase the level of coordination and to strengthen the collaboration among Member Countries. The Forum provides a framework for the exchange of views, experiences, information and data, and cooperation and collaboration amongst its Members in gas-related matters.

In accordance with the GECF Statute, the organisation aims to support the sovereign rights of its Member Countries over their natural gas resources and their abilities to develop, preserve and use such resources for the benefit of their peoples, through the exchange of experience, views, information and coordination in gas-related matters.

In accordance with the GECF Long-Term Strategy, adopted during the 18th GECF Ministerial Meeting, the priority objectives of the GECF are as follows:

- To maximize gas value, namely, to pursue opportunities that support the sustainable maximisation of the added value of gas for Member Countries.
- To develop the GECF view on gas market developments through short-, medium- and long-term market analysis and forecasting.
- To promote cooperation, namely, to develop effective ways and means of cooperation amongst GECF Member Countries in various areas of common interests.
- To promote natural gas, namely, to contribute to meeting future world energy needs, to ensure sustainable global development, and to respond to environmental concerns, particularly regarding climate change.
- To reinforce the international positioning of the GECF as a globally recognized intergovernmental organization, which is a reference institution for gas market expertise and a benchmark for the positions of gas exporting countries.

The GECF Global Gas Outlook Synopsis is among the main key initiatives and instruments identified in the GECF's Long-Term Strategy.

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The publication of this Edition of the GECF Global Gas Outlook Synopsis 2050 could not have been possible without valuable assistance from many experts. We would like to thank all those who contributed to the development of this report, especially the GECF Executive Board Members and GECF Technical and Economic Council Members. The GECF Secretariat is grateful for the kind contribution from the Organization of the Petroleum Exporting Countries (OPEC) Secretariat, featured in Chapter 3.

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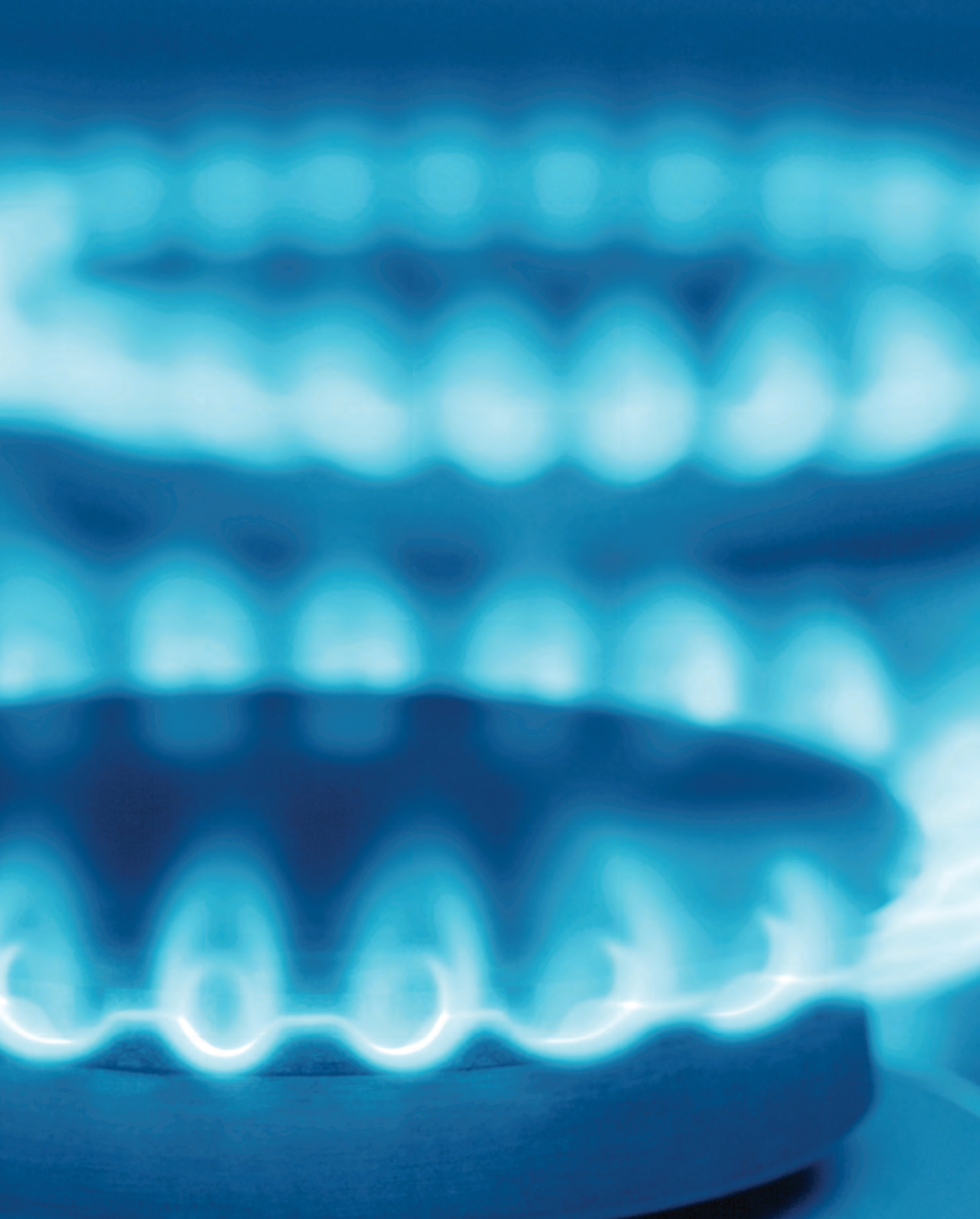
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FOREWORD

The Gas Exporting Countries Forum (GECF) generally publishes its Global Gas Outlook 2050 (GGO) at year-end. The unveiling of this edition has been timed to coincide with the 6th GECF Summit of Heads of State and Government, to be held on 22 February 2022, in Doha, the State of Qatar.

This alignment is to a large extent welcome, and symbolic of 2021, which was a year of contrasts. When the work on this edition started, the world was still reeling from the adverse impacts of the COVID-19 pandemic. However, the global economy was showing signs of strong recovery; vaccine deployment, albeit unequal among nations, provided hope that the end of the tunnel was in sight; a colder-than-usual winter stimulated the needed impetus for energy prices - and gas prices in particular - to extract themselves from the deep trough into which they fell in 2020. And then, as the post-pandemic recovery accelerated, commodity prices began their upward trajectory to reach unprecedented levels. For natural gas, extreme price volatility was exacerbated by the vagaries of weather conditions and the intermittency of wind- and solar-based power generation. Then came COP26, a milestone in global efforts to mitigate and adapt to climate change, and which was preceded by a flurry of net-zero pledges and greenhouse gas emissions reduction initiatives. Towards the end of the year, a new coronavirus variant, Omicron, appeared. More transmissible but less severe, it nevertheless led to another round of restrictions and caused further havoc to supply chains. In the meantime, inflation reached levels not seen for decades, prompting the question of whether this is just a temporary phenomenon, or rather more structural in nature.

The GGO assesses the global and regional prospects of economic growth, energy demand and supply, natural gas trade and investment, and the effect of policies, technologies and other drivers. It also explores several scenarios, such as an accelerated energy transition, or a rapid hydrogen deployment.

The key take-away of this new edition of the GGO is quite straightforward: natural gas will play a pivotal role in alleviating energy poverty, fuelling economic growth, improving living standards and expanding prosperity, whilst contributing to the protection of the environment. In short, natural gas is the energy for sustainable development.

According to the United Nations, the global population is expected to increase by 1.9 billion people by 2050, with the large majority of this demographic change taking place in Asia and Africa. The level of urbanisation will rise to 68%, meaning that 2.5 billion additional people will live in cities. Global GDP will more than double in real terms, with China and India contributing to over a third of global output in 2050.

Consequently, and despite energy efficiency improvements, global energy needs will grow. All energy sources will contribute to satisfying these needs. There is no one-size-fits-all model. Future energy pathways will vary from one country to another. Understandably, the energy transition in India cannot be the same as in Europe. Natural gas is energy that fits most pathways. It helps to transition away from the use of wood and dung for cooking; thus alleviating the adverse impacts of indoor pollution and reducing deforestation. It contributes to improving air quality, notably in densely populated megacities and urban sprawls. It is a partner of renewables; providing much-needed backup and stability to power grids. Available, reliable, flexible and with a diversity of producers, natural gas is a true pillar of energy security.

Recent energy markets developments have underlined the critical role of natural gas in ensuring a continuous and affordable supply to end-consumers, in particular when the wind is not blowing and the sun not shining. They have also epitomised the globalisation and increased financialisation of natural gas markets. Additionally, they have emphasised the positive role that natural gas plays in many important sectors and for the daily life of people. This even includes food security, as natural gas is a key input in the production of fertilisers.

Furthermore, and perhaps most importantly, these developments have demonstrated that investment in natural gas is critical for the stability of global energy systems. The GGO projects that by 2050, total upstream and midstream investments will reach a hefty USD 8.7 trillion. A lack of investment will lead to higher gas prices, which, coupled with higher carbon prices, may result in inflationary pressures so high that they may trigger people's resistance to energy transition policies in developed countries. The ripple effect of these undercurrents will be even more dramatic in developing countries.

Environmental policies are a key driver of the projections contained in this Outlook. In this context, whilst upholding that natural gas is the cleanest of fossil fuels, the GGO explores the state of technologies that will make it even cleaner. Carbon capture, utilisation, and storage (CCUS) is a promising pathway, as it involves proven technologies and attracts increased interest. The number of new CCUS projects launched in 2021 has sharply increased. Methane emissions are expected to be reduced, especially considering that in most cases, this is a commercially-sound undertaking. Blue hydrogen derived from natural gas is the least costly option to decarbonise high-temperature process industries, such as steel and cement industries. Direct air capture, though still very expensive, is also attracting more attention and research funds.

In closing, I would like to express appreciation to my predecessor, HE Dr Yury P. Sentyurin. It is under his tenure that most of this edition has been prepared. I would also like to thank the team of the GECF behind this report. It has worked with



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Eng. Mohamed HAMEL

Secretary General

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EXECUTIVE SUMMARY

The GECF Global Gas Outlook Synopsis 2050 (GGO) represents the GECF's long-term projections on the global energy system. The GGO focuses on the long-term role of natural gas in meeting global energy needs in different settings and under various energy pathways.

Population growth and urbanisation will be the main drivers of future energy trends

The global population is set to rise from 7.8 billion in 2020 to 9.7 billion by 2050, which will create upward pressure on energy demand. Almost all of these additional two billion people will live in urban areas. Just the two regions of Africa and Asia Pacific alone will add 90% of total population in the coming 30 years. Of this, 60% of the growth will come from Africa.

Global real GDP will more than double over the coming 30 years with pre-COVID and current projections narrowing down to only USD10 trillion in 2050

The global economy is gradually walking away from the shadow of the COVID-19 pandemic – an improved view on recovery but divergent across developing and advanced economies. Key factors of recovery: pace of vaccination rollout and continuity of policy support.

Global GDP growth will average 2.7% per annum in real terms to 2050. The majority - over three fourth - of the global real economic growth will be attributed to labour productivity up to 2050, while the rest will be on account of population growth.

Long-term growth will largely come from the expansion of developing economies, especially in Asia. The Asia Pacific region will be at the frontier of economic growth, contributing 60% of global real GDP growth over 2021–2050, with developing South and Southeast Asia leading the way.

Natural gas is a fundamental pillar of the energy mix and continues to receive policy support in major consuming countries

Since the publication of the previous GGO in 2021, pledges and commitments to achieve carbon neutrality have expanded substantially, driven by governments and companies as well as by other stakeholders, including financial institutions and non-governmental organisations.

Gas continues to receive policy backing across many parts of the world, especially as a substitute for coal and a complement to renewables. However, its role is increasingly being challenged by developed economies and blocs, such as the EU, U.S. and Japan.

Despite aggressive decarbonisation actions under the EU's proposed 'Fit for 55' package, natural gas is still seen as having a future in the Union, especially for lending balance to the power system and displacing coal in several central and eastern European countries.

Coal is under increasing pressure while renewables are growing under technical constraints

Many regions have revised their renewables and energy efficiency targets upwards, but a combination of technical and economic challenges, for instance, integration issues and the impact of COVID-19 could hinder the achievement of these goals.

Natural gas will increase its share in the global energy mix from over 23% today to 27% in 2050, becoming an important pillar of decarbonisation and sustainable development

Global energy demand will rise by 29% over the next three decades, with the majority of that increase emanating from growing economies in Asia Pacific and Africa.

There exists a real need to promote energy options that achieve the right balance between post-COVID-19 economic and social requirements and environment-related constraints. In this context, natural gas and renewables will lead the way towards a balanced energy transition and will grow substantially up to 2050, together accounting for more than 90% of the incremental rise in global energy demand.

Natural gas will come out on top in the global energy mix, raising its share to 27% by 2050, and will be one of the global enablers for reducing emissions uninterruptedly and steadfastly by replacing carbon-intensive fuels and backing up intermittent renewables.

Global natural gas demand will rise by 46% from 3,840 bcm in 2020 to 5,625 bcm in 2050. Asia Pacific region will represent the largest growth share

The reference case scenario (RCS) in the GGO doesn't foresee any peak in natural gas demand, which is tipped to grow to 5,625 bcm by 2050 – 46% higher than in 2020. Key determinants to ensuring a resilient outlook for natural gas will be policies on air quality improvements, coal- and oil-to-gas switching and the development of carbon capture, utilisation, and storage (CCUS).

This abundant, flexible and clean source of energy will expand particularly across the Asia Pacific, Middle Eastern and African markets, areas that will be responsible for the bulk of future demand growth. Asia Pacific region, almost doubling its current gas consumption, will make the largest contribution to this growth: more than 45% of additional global gas volumes through to 2050.

The power generation sector will take a frontline place, accounting for 42% of the total increase in gas demand. The transport sector and blue hydrogen generation will emerge as significant new areas of gas demand expansion

Power generation will be the key driver of growth, thanks to the greater electrification of end-use sectors as well as policies supporting the phase-out of coal-fired capacity. Meanwhile, gas-fired generation will become more central to system flexibility amidst the emphatic development of variable renewables.

The transition to low-carbon transport systems creates a promising source of natural gas demand. Gas in the road and marine transport is slated to take off, mostly driven by increasing usage of LNG as bunker fuel and in heavy goods vehicles on the back of policy initiatives and environmental regulations.

Blue hydrogen generation will be another major avenue for gas demand expansion, on the assumption of mounting efforts to scale up the deployment of low-carbon hydrogen in energy systems.

The Middle East will deliver 32% of the global gas supply increase. This Outlook expects a growing role for deepwater and unconventional resources

The GGO forecasts that global natural gas production will continue to rise by an average annual growth rate of 1.2%, from around 3,840 billion cubic metres (bcm) in 2020 to 5,625 bcm in 2050. The Middle East will contribute the largest growth share, accounting for almost 32% of the total change, followed by Eurasia, North America, and Africa.

Globally, deepwater offshore production is expected to grow strongly, contributing more than 1,000 bcm of annual output by 2050 – a nearly fivefold increase compared to current levels. In contrast, conventional associated gas is expected to decline from a 12% share of global gas production in 2020 to around 7% in 2050, as oil production peaks before falling off. The share of unconventional gas is expected to rise from 25% in 2020 to 30% in 2030 before levelling off and remaining at that level.

GECF Countries will maintain around 50% of the global gas supply

Most GECF Countries will maintain or expand their gas production capacity over the outlook period. The GGO predicts that total gas production from current GECF Members will increase by more than half, reaching approximately 2,600 bcm by 2050. This translates to a 1.4% annual growth rate over the forecast period, positioning the GECF to retain its share of global gas production at around 47%.

Global gas trade will increase by 45% by 2050 and become more integrated and interrelated through the expansion of LNG trade

The global gas trade is expected to grow by 45% by 2050, at 1.5% per annum between 2020 and 2050 to reach 1,815 bcm, and account for a third of global gas demand. Regional natural gas markets are expected to become more integrated, interconnected, and globalised during this period.

Global LNG trade will be the key driver underpinning natural gas exports, in fact accelerating even faster than the previous

forecasts, and overtaking pipeline trade around 2030 to reach 845 million tonnes (1,150 bcm). The trade of carbon-neutral LNG could be crucial in determining the role of natural gas in the energy transition.

Asia Pacific, the main destination of the world's LNG at present and also in 2050, will represent the largest transformational challenge for the currently fragmented natural gas market. Asia Pacific enjoyed a 70% share of LNG trade in 2020, which will increase to an even more remarkable 80%+ by 2050. New countries will join the existing LNG importers predominantly from developing Asia – China, India, South and Southeast Asia. Over the forecast period, three out of the five leading LNG exporters globally – Australia, Mozambique, Qatar, Russia, and the U.S. – will be from the GECF Countries.

Upstream and midstream natural gas investment will decelerate to USD 8.7 trillion between 2020 and 2050

Between 2020 and 2050, total estimated upstream and midstream natural gas investment will decelerate slightly to USD8.7 trillion due to lower global natural gas demand growth, resulting in 300 bcma less consumption by 2050 compared to the previous GGO forecasts.

Natural gas is versatile and fits various energy pathways, with almost half of hydrogen expected to be sourced from natural gas

In the Energy Transition Scenario (ETS) of the GGO, CO₂ emissions will shrink significantly by 60% compared to the Reference Case Scenario (RCS), reaching around 11.7 gigatonnes (Gt) CO₂. Although the ETS trajectory remains incompatible with the 1.5°C target, it is consistent with the Paris Agreement's objective to achieve a 2°C limit by the end of the century.

The ETS envisages a drop of fossil fuel's share to 38% by 2050. Natural gas will remain the most resilient fossil fuel, with 21% share in 2050. Demand will be peaked in 2027 at 4,250 bcm. However, gas usage will plateau in the later years and will decrease slowly by 2050.

In the Hydrogen Scenario (HS) of the GGO, the implementation of aggressive hydrogen development contributes to narrowing the gap between the RCS and the Paris-aligned trajectory. The level of emissions is expected to be 2.6 Gt CO₂ lower than that for the RCS by 2050.

The HS foresees that the demand for hydrogen will rise to more than 620 Mt of H₂. Almost 46% of total hydrogen production will be sourced from blue hydrogen. However, the share of the entire natural gas-based hydrogen generation, including other clean pathways such as turquoise hydrogen, is almost half of the total output.

The HS suggests that around 145 Mt of H₂, accounting for more than 23% of the total hydrogen supply, will be traded annually by 2050. The GECF Members boast a compelling potential to export almost half of the future global hydrogen trade, mainly from Eurasia, North Africa and the Middle East.





INTRODUCTION AND SCOPE

The GECF Global Gas Outlook 2050 is the only energy outlook worldwide to focus solely on natural gas and aims to be a global reference for insights on the future developments of natural gas markets. The document also represents an impartial view on gas market evolution by highlighting the most likely developments in the medium and long term.

The GECF Reference Case Scenario (RCS) highlights the current situation and the evolution of the gas market and energy trends to 2050, in terms of global energy demand (by region/sector/fuel) and global gas supply (conventional and unconventional), for GECF and non-GECF countries. It also reflects current energy policies and the potential introduction of new policies that are likely to materialise throughout the forecast period, according to our assessment.

Additionally, this document explores the subject of competition from alternative sources of energy as well as technological developments and their eventual impact on the energy mix and gas market shares, with a focus on power generation as a strategic sector for gas demand growth. Energy efficiency, environmental policies and other regulations have been considered in the RCS, to study their impact on gas penetration in key markets/sectors.

The GECF Secretariat believes that it is impossible to cover all future uncertainties with a single scenario; multiple scenarios are needed to have a broader mapping of the uncertainties shaping the development of gas markets. In this regard, the Secretariat is addressing future uncertainties and their possible impact with alternative scenarios through the annual publication of the GECF Global Gas Outlook.

This document is divided into six main chapters. Chapters I and II introduce key global gas demand assumptions, including economic, energy price and policy assumptions, as well as environmental policy development. Chapter III highlights energy and gas demand trends, followed by supply assumptions in Chapter IV, which include global gas resources and upstream production. Chapter V is dedicated to natural gas trade and investment outcomes resulting from the equilibrium between supply and demand, as well as pipeline, LNG liquefaction and regasification capacity assumptions, natural gas contracts, and the corresponding investment figures. It takes into consideration gas market constraints in terms of supply infrastructure, international supply contracts and gas supply policies (e.g., the satisfaction of domestic gas demand as a priority for some countries).

The final chapter casts a critical eye over significant developments in the energy transition, analysing them from an oil and gas perspective and weighing up the opportunities they could present in the Energy Transition Scenario (ETS) and Hydrogen Scenario (HS). The GECF's ETS has a view of the energy transition and fundamental transformation of the global energy sector, induced by a pressing climate change mitigation agenda and a call to decarbonise the global economy by mid-century. The GECF's HS accounts for all the announced hydrogen strategies and adds to a higher uptake of natural gas decarbonisation with the use of pre-combustion CCS/CCUS.

All three scenarios are quantified through the use of the GECF Global Gas Model (GGM), a unique energy model developed in-house at the GECF Secretariat, which includes different sub-models with each one focused on one segment of the gas value chain.

The GECF GGM model is characterised by its uniquely high granularity, encompassing:

136 country-level forecasts (115 detailed breakdowns, 21 simplified), with over 85 regional and economic aggregations,

Complete energy balance estimates, covering 37 sectors and 35 fuels p.a., from 1990 to 2050,

Around 4,000 gas supply entities representing gas supply potential at a global scale, including but not limited to:

- 510 existing production facilities that are in operation, including aggregates
- 119 sanctioned projects that are under development

- 1,112 new projects based on existing reserves
- 1,709 yet-to-find entities based on the USGS resource base
- 360 unconventional (existing, new and yet-to-find) – global shale gas, tight gas and coal bed methane

The infrastructure database contains:

- 637 liquefaction plants
- 813 regasification plants
- more than 4,500 gas pipeline and shipping routes

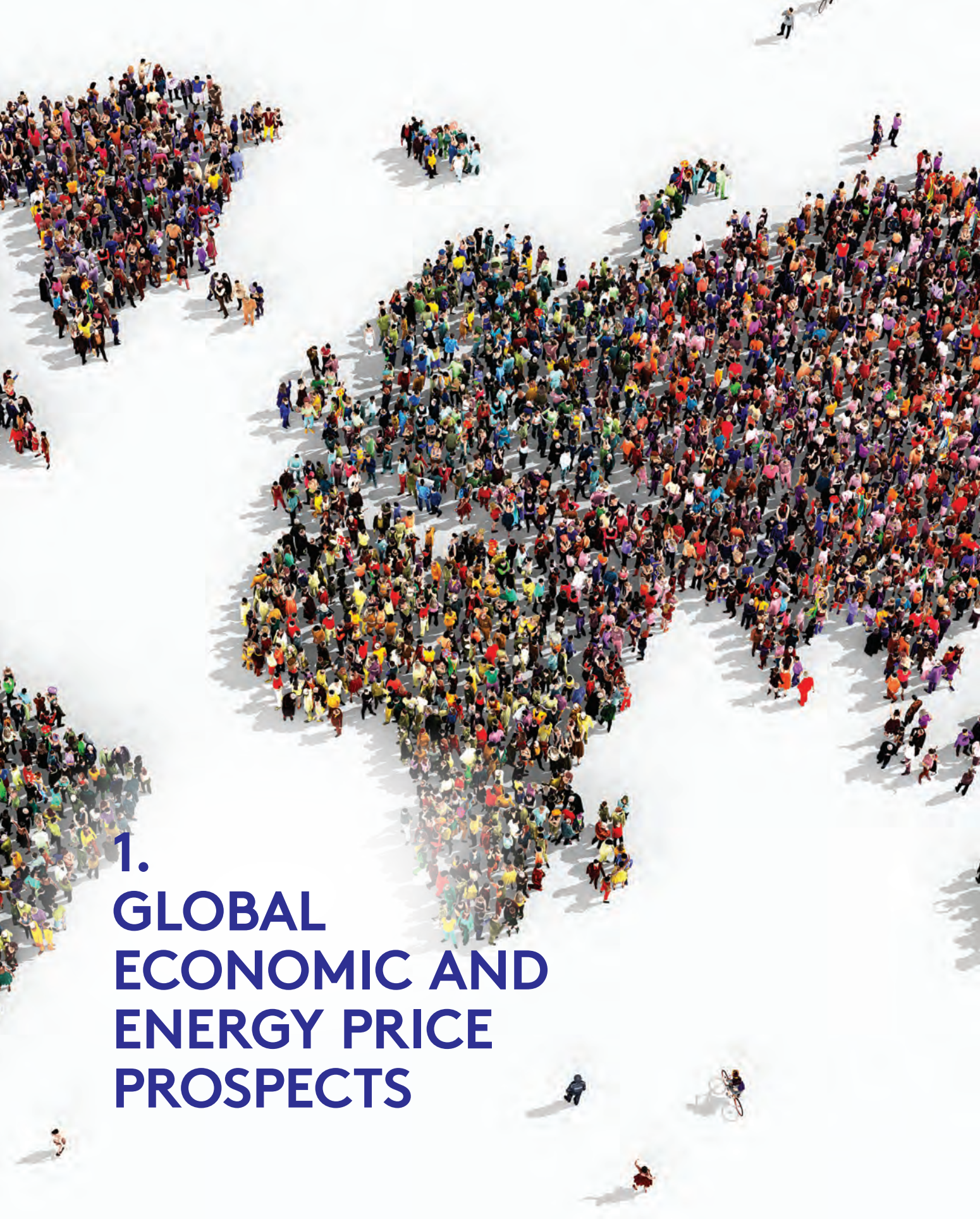
The gas contracts database contains:

- Annual contracted and delivered volumes, including nearly 700 contracts (country-to-country and non-dedicated), based on more than 1000 company-to-company contracts

All of the sub-models have been calibrated and based on 2020 as the last available year of historical data. Energy and natural gas demand forecasts are derived based on a set of primary and secondary assumptions fed with macro and energy price data, utilising econometric modelling techniques using time-series back to 1990.

In terms of data sources and historical data, we mainly reference the United Nations (UN) for demographic data, the International Monetary Fund (IMF) for economic data, and the IHS Markit and the International Energy Agency (IEA) for energy and gas demand data. These are cross-checked with other international and regional statistical sources, especially for the GECF Countries. For data on gas supply, we use an in-house database updated by the GECF Countries and secondary sources, which also plays an important role in the GECF GGM calculations.

All data from 2021 to 2050 in the following analysis is considered to be a part of either the GECF assumptions or forecasts unless otherwise stated.



1. GLOBAL ECONOMIC AND ENERGY PRICE PROSPECTS

KEY FINDINGS:

- The global population is set to rise from 7.8 billion in 2020 to 9.7 billion by 2050 which will create upward pressure on energy demand. The fastest growth will be seen in Africa, where the population is expected to almost double by 2050 to 2.5 billion.
- Almost 70% of the total population in 2050 will live in urban environments, pointing to greater use of electricity in final demand as well as demand for fuel inputs to power stations. This could have a beneficial impact on gas demand as a complement to increased renewable electricity.
- Global long-term economic growth is based on two core factors: rising productivity - GDP per capita - as well as accelerated demographics, namely population increase combined with surging urbanisation.
- Global GDP growth will average 2.7% p.a. in real terms to 2050, with growth returning to pre-pandemic levels once the short-term effects of COVID 19 have dissipated during 2021-2022. Long-term growth will largely come from the expanding developing economies, especially in Asia. Asia Pacific region will be the economic growth 'champion', contributing 60% of global real GDP growth over 2020 - 2050, with developing South and South-East Asia leading the way.
- Overall, GECF countries are expected to grow at an average of 2.5% p.a. to 2050.
- China will lead economic growth in Asia as the developed economies in the region expand, albeit following a slower trajectory. India will also show rapid economic growth, thanks to the impacts of urbanisation and improvements in infrastructure and human capital. Overall, GDP growth in Asia Pacific region is expected to be 3.6% p.a. in the 2020-2050 period, although China will grow at 4.5% p.a. and India at 5.2%.
- India and China combined currently account for 36% of the global population and 21% of global GDP. In 2050, the respective totals will be 31% and an impressive 33%.
- The global gas model assumes a real oil price of USD60/bbl (Brent) based on long-run marginal costs of supply and the belief that efficiency improvements will dampen demand in the transport sector over time.
- Gas prices will remain high until supply and demand are rebalanced but will then move back towards historical norms of around USD9/mmbtu in Asia, USD7-8/mmbtu in Europe and USD4/mmbtu in the US.
- Coal prices are expected to fall back from current high levels and remain depressed throughout the period to 2050 as demand declines. The only saviour could be the broad development of CCUS, but this is not assumed in this Outlook. As a result, it is expected that the global coal price will fall back below USD 80/t for the period to 2050.
- Carbon pricing and taxation is expected to become a major force behind the energy transition, with many countries expected to set up carbon markets. The Outlook assumes that the real carbon price will reach USD74/t in the EU and USD42/t in the US by 2050.

1. GLOBAL ECONOMIC AND ENERGY PRICE PROSPECTS

2021 GGO REFERENCE CASE KEY ASSUMPTIONS

| | |
|---|------------------------------|
| Base year | 2020 |
| End year | 2050 |
| Population, billion people | 2020: 7.8 2050: 9.7 |
| Population growth rate | 0.75% p.a. (2020 – 2050) |
| % urban in total population | 69% in 2050 |
| Number of households | 3.0 bn in 2050 |
| Global economic growth rate, % real GDP | 2.7% p.a. (2020-2050) |
| Oil Brent Price | USD 60/bbl |
| Carbon prices (per ton in 2020 USD) | 2050: USD74 - EU, USD42 - US |

Chapter 1 describes the key macroeconomic assumptions behind the 2021 Global Gas Outlook (GGO). Key assumptions include quantitative assumptions such as population and urbanisation trends, economic prospects, projections for natural gas, oil and coal as well as carbon prices. Energy and environmental policy assumptions are covered in Chapter 2.

In 2021 after a downward revision in 2020 as a consequence of COVID-19, which poses a more promising view for global sustainable economic development compared to the last edition of the GGO in 2020. Meanwhile, we assume an evolutionary shift in the institutional setting and structure of the global economy, with relatively stronger economic growth for the emerging market economies, with an average annual growth rate for global GDP of 2.7% from 2020 through to 2050. The pace of the COVID-19-induced economic recovery and change in global economic behavioural patterns will remain the major factors posing limitations and risks for the underlying forecasting exercise.

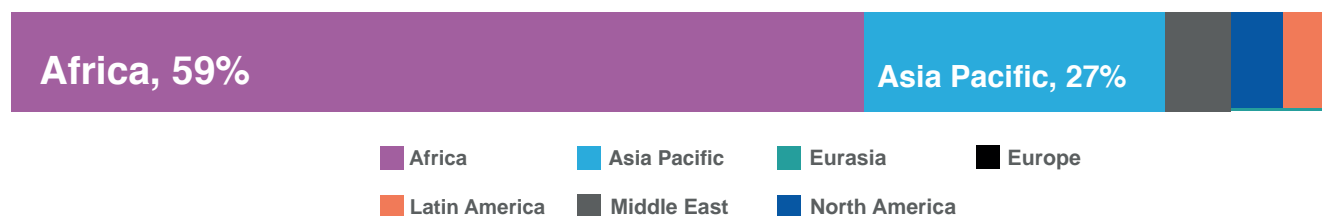
LONG-TERM OUTLOOK 2020 – 2050



1.1 Population and demographics

Population growth is the main driver of future energy trends. For the GGO 2021, we use the medium variant of the UN projections as the basis for our analysis, more specifically the UN medium fertility outlook in the 2019 Revision of World Population Prospects, developed by the UN Department of Economic and Social Affairs. Population growth will slow in all regions, moving from 1.2% p.a. growth between 2000 and 2020 to 0.8% p.a. from 2021 to 2050. The main reason behind the decrease in global population growth rates is the decline in fertility rates in developing regions as they progress towards the completion of their fertility transition. Between 2021-2050, the global population increase of almost a quarter from the current 7.8 billion in 2020 to 9.7 billion in 2050.

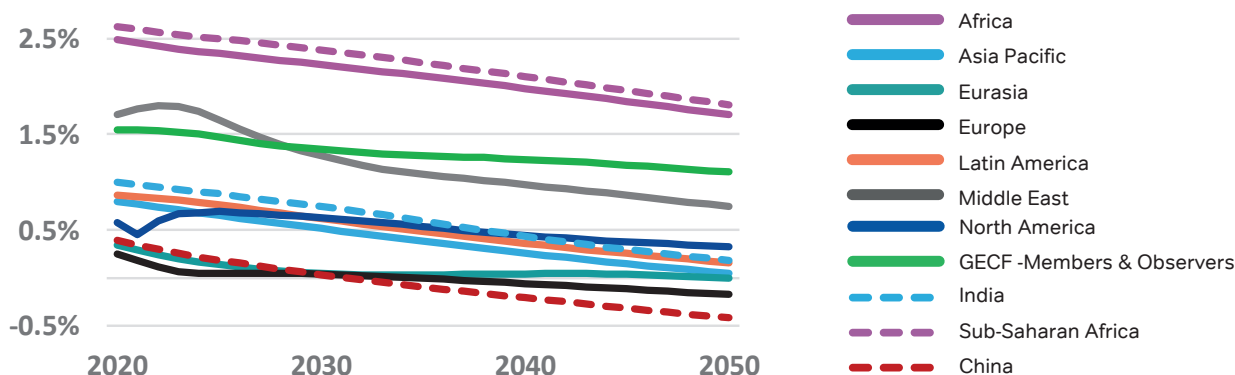
Figure 1.1. Global population growth in 2020-2050 by region (% of total)



Source: GECF Secretariat based on data from the GECF GGM

The African continent will almost double in population, its growth accounting for around 1.2 billion by 2050. Nigeria's population is set to reach 400 million people by 2050, overtaking the U.S. as the world's third-most-populous nation. Asia Pacific will account for an additional 0.5 billion people by 2050. India will become the world's most populous country by 2027 surpassing China. Just two regions combined - Africa and Asia Pacific - will account for the majority of incremental growth - 86% - in the forecast period.

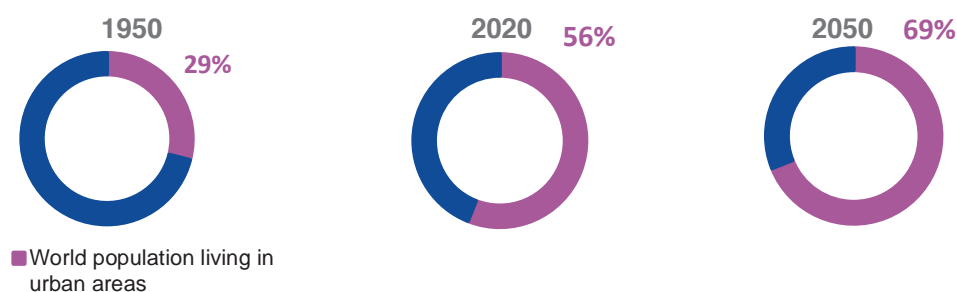
Figure 1.2. World population growth rates (% p.a.)



Source: 2019 Revision of United Nations World Population Prospects

Today 56% of the world's population lives in urban areas. Urbanisation levels globally will rise to almost 70% in 2050. Rapid urbanisation is underway which will support almost all additional population growth, and focused on the regions with the most upside potential, namely Africa and developing Asia, but primarily India. The urbanisation prospects which underlie the Outlook are based on the 2018 Revision of the UN's World Urbanisation Prospects. Global sustainable development and wealth creation are driven by persistently high levels of urbanisation: the world is now 56% urbanised, versus 29% in 1950 and 39% in 1980. Global urbanisation is increasing, and the share of the urban population in the total population will grow to 69% in 2050.

Figure 1.3. Share of urban population (%) in total population



Source: 2018 Revision of United Nations World Urbanization Prospects

1.2 Economic projections

For around 2 years the COVID-19 pandemic adversely affected all world economies. As of 1st February 2022, there had been 5.7 million deaths and over 377 million COVID-19 cases, alongside a long-lasting adverse health, social, economic and humanitarian impact on people, livelihoods and communities resulting in exacerbated global poverty and growing inequality. But there is definitely a light at the end of the tunnel as national economies are improving, coming back on track towards a strong rebound. Accelerated vaccination rollouts are taking place but at very different speeds across the globe, consequently adding to the diversions of the recovery. A total of 9.9 billion vaccine doses have been administered as of 30th January 2022. Also, there is an evident advancement in the provision of relevant monetary and fiscal policies and measures

to help support the recovery. Disruptive supply chains and rising inflation are the two greatest challenges to be highlighted in the short run. The resurgence of new variants for some countries is restricting activities again and leading to additional supply shortages and bottlenecks.

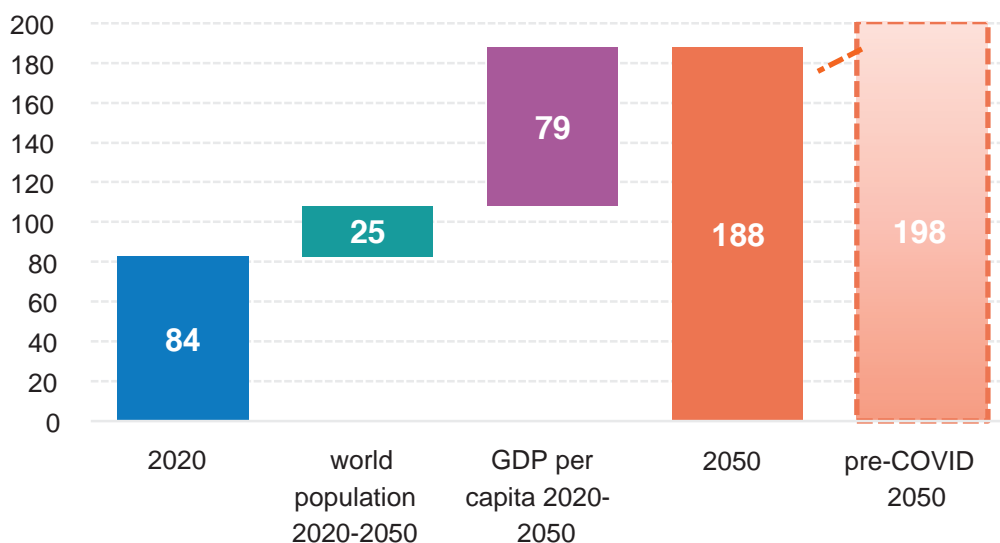
The US and China are key driving forces behind the post-COVID recovery, with the U.S. economy showing outstanding resilience. Global trade will remain one of the most important drivers of global sustainable growth in the years to come and will continue to be impacted in the short- to medium-term by the US-China trade tensions which have emerged since 2018.

1.2.1 Medium-term and long-term economic outlook

The medium-term as well as, to some extent, the long-term economic outlook is significantly impacted by pace of the post-COVID recovery, by the persisting trade frictions, primarily between the US and China, with growth in world trade slowing and de-globalisation also challenging overall economic growth.

Incremental population growth, mainly driven by Africa and developing Asia, coupled with strong urbanisation and labour productivity trends, will continue to remain the key engines behind sustainable economic development as well as behind primary energy demand. Over three-quarters of global real economic growth will be attributed to labour productivity over the long run until 2050, while the rest will come from population growth.

Figure 1.4. Global real GDP, 2020 - 2050 (trillion USD)



Source: GECF Secretariat based on data from the GECF GGM

Growth of the global economy, anchored by strong labour productivity growth, is expected to average 2.7% p.a. in real GDP between 2020 - 2050. This growth rate will largely be provided by the expanding developing economies, especially in Asia, with a growing role taken by a burgeoning middle class, with China growing by 4.1% p.a. on average and India at an average of 5.2% p.a. over the Outlook horizon (2020 - 2050).

Globally, the projected decrease in labour input is considered to be detrimental to growth. To some extent, this will be remedied by extensive use of the labour force well above the present pension age in most European labour markets. In developing economies, the labour force will be significantly extended (by up to 50%) by the fast-growing inclusion of women and minorities. However, even these labour market changes pose a tremendous challenge for labour productivity to maintain growth. Of the expected GDP growth of 2.7% between 2020-2050, over three quarters comes from the developing economies. Additionally, out of the 3.8% p.a. of expected growth in these developing economies (2020 - 2050), over three-quarters of this is expected to be from productivity improvements as the employment contribution decelerates.

Developing economies are already almost 50% larger than developed economies in terms of their GDP and will be around 2.5 times larger by 2050. They will take over the role in the global economy that advanced economies have been playing over the past thirty years. The centre of economic gravity will shift towards Asia Pacific, more specifically to developing Asia.

REGIONAL PROSPECTS FOR ECONOMIC GROWTH

Asia Pacific

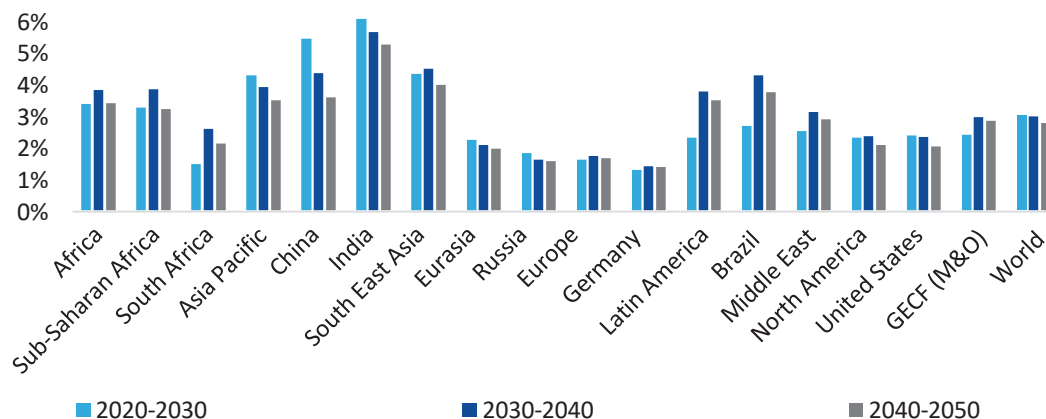
Despite the fact that Asia Pacific will be the fastest-growing region globally, the divergence between advanced economies and developing economies in Asia is emerging more strongly on the back of the COVID-19 recovery, reflecting the speed and scale of the vaccine rollout as well as differing levels of policy support. The factors which will drive Indian growth, in the long run, are structural.

Figure 1.5. Global GDP growth in 2020 - 2050 by region (%)



Source: GECF Secretariat based on data from the GECF GGM

Figure 1.6. Projected GDP growth rates by region 2020 - 2050 (%)



Source: GECF Secretariat based on data from the GECF GGM

India is set on a strong growth pathway with a 'toolkit' which includes: the urbanisation of the world's largest rural population, demographics skewed towards young people, a step-by-step transformation of the informal sector into the formal, significant and continuous investment in infrastructure and, most importantly, investment into the nation's human capital. Long-term prospects in Asia Pacific region have seen average GDP growth rates reduced to 3.6% over the 2020 - 2050 period, with Chinese growth expected to gradually slow to 5% p. a. during 2020-2030, and then again to an average of 4% p.a. between 2030 - 2040, finally reaching 3.3% p.a. in 2040 - 2050.

Africa

Demographic trends will continue to provide a foundation for longer-term growth, combined with technological advances that have been catalysed by the pandemic, with digitalisation having a critical role. Overall, though, urbanisation in many regions and increasing levels of individual wealth will be the main drivers of energy consumption.

Though Africa is likely to experience medium-term negative consequences from the pandemic, in particular, due to capital outflows and reduced investor confidence, long-term economic growth rates will be the second-fastest (after Asia Pacific), averaging 3.3% p.a. during 2020 - 2050.



North America

Economic growth in the U.S. is set to continue being driven forwards by ongoing innovation and research and development, as well as a capital investment. The long-term forecast in North America has been reduced, with average GDP growth rates of 2.1% expected over the 2020 – 2050 period. The U.S. is expected to experience exactly the same growth of 2.1% over the same period. Average GDP growth in the region is set to decrease (compared to 2010-2019) to 2.1% p. a. during 2020-2030, due to the short-term and mid-term implications of COVID-19, then reach an average of 2.2% p.a. between 2030 – 2040 and 1.9% p.a. in 2040 – 2050.

Eurasia

The Eurasian economy is anticipated to increase at a modest average rate of 1.9% p.a. over 2020-2050 showing only a small variation between 1.8 - 2.1% in each of the three upcoming decades. The lower levels of Eurasia's long-term growth are explained by negative population growth rates with an accelerated trend in the aging population similar to an observed European trend, together with very limited upside potential for productivity growth. Eurasia is one of the most natural resource-rich regions in the world, but its economies lack diversification and require a decisive shift towards more technology-intensive and higher value-added sectors.

Europe

The uneven impact of the crisis will lead to a sizable reallocation of labour in Europe over the medium term. Public policies will have to increasingly support structural transformations. To that effect, temporary investment incentives and hiring subsidies will dovetail structural policies. Other challenges facing policymakers include boosting productivity growth, tackling the problems posed by aging populations, and filling gaps in the green and digital infrastructure. Europe's economy in the long run is set to grow at a modest average rate of 1.5% p.a. over 2020-2050 with a small variation of 1.5 - 1.6% in each of the three upcoming decades. European long-term growth at these lower levels is underpinned by negative population growth rates with an accelerated trend in the aging population together with very limited upside potential of productivity growth due to its high initial levels.

Latin America

Broadly favourable external conditions, primarily positive spillovers of the US economic rebound, high commodity prices and pent-up demand support short-term growth, while monetary and fiscal policy reversals work in the other direction. The average annual real growth of the region's GDP combined is expected to be 2.9% for 2020-2050. The pandemic-induced lower average GDP growth rate of 2.1% over the 2020-2030 period will be replaced by a considerably higher 3.5% and 3.2% average for 2030-2040 and 2040-2050, respectively, due to population additions and considerable growth of productivity from a lower base. In the long-term, Brazil will dominate growth in the Latin American region with an average of 4.0% and 3.5% for 2030-2040 and 2040-2050, respectively.

Middle East

Factors such as the extreme volatility of the oil and natural gas markets on the back of limited economic diversification, in addition to the fact that these economies rely heavily on exports, plus are suffering from high agricultural prices, food insecurity, exacerbating regional conflicts and social unrest all play a role in defining the Middle East's future. Another longer-term risk, especially for the oil and gas-exporting countries of the region, will be posed by the energy transition challenges as the afore-mentioned countries will have to recalibrate their economic structures and undergo fundamental transformations to adapt to the new global 'greener' economic realities. The average annual real growth of GDP in the Middle East region is expected to be 2.6% for 2020-2050. The pandemic-induced lower average GDP growth rate of 2.3% over the 2020-2030 period will be replaced by average rates of 2.9% and 2.7% for 2030-2040 and 2040-2050 respectively.

1.3 ENERGY AND CARBON PRICE PROJECTIONS

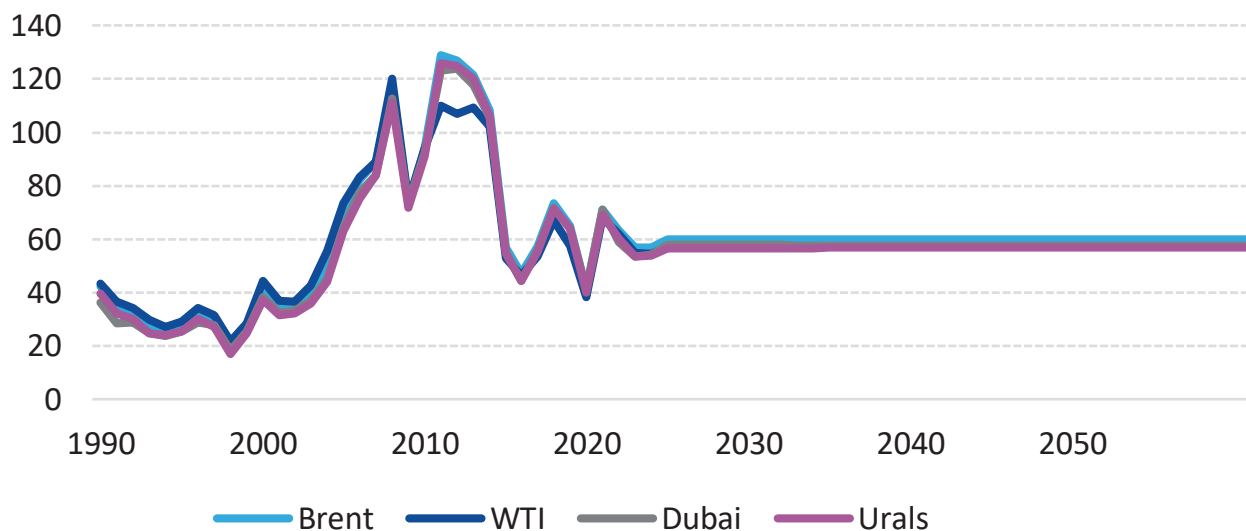
1.3.1 Crude oil projections

The Brent oil price has been hit hard by COVID-19 and averaged USD41/bbl in 2020. After a strong recovery, it was USD71/bbl on average in 2021. Over the longer term, the expectation is of an average level of USD60/bbl. This forecast is in line with the views of many of the key energy companies, based on comparable data, and with the assumption that OPEC retains its role as the global swing producer.

Oil markets in the future will remain largely subject to COVID-19 uncertainty and the pace of economic recovery together with the rebound in energy demand. Additionally, the precipitous decline in oil and gas investments, the challenges of an accelerated energy transition to combat climate change, geopolitical events in the Middle East becoming more numerous as well as stronger oil production in several non-OPEC+ countries, the normalization of Libya's and Iran's oil production, plus a breakdown in the OPEC+ agreement should all be factored into any future price forecasting exercise.

In the medium-term, we anticipate the crude oil market will stabilize, and assume beyond 2026 it will follow the long-term trend price of USD60/bbl, reflecting the COVID-19 effect and also taking into account efficiency savings. The Brent crude oil price assumption for the long-term is in line with its historical average price over the thirty years from 1990 to 2019, which was USD60/bbl.

Figure 1.7. Brent crude oil price (USD per bbl)



Source: GECF Secretariat based on data from the GECF GGM

The OPEC+ alliance has reclaimed the status of swing producer, which has contributed to market stability over the last five years. After a severe supply disruption in the spring of 2020 and a well-orchestrated rebound of the oil market in late 2020 - throughout 2021, it is obvious that spare capacity held by OPEC+ can, to a significant level, guarantee oil market stability in the medium-term.

1.3.2 Natural gas

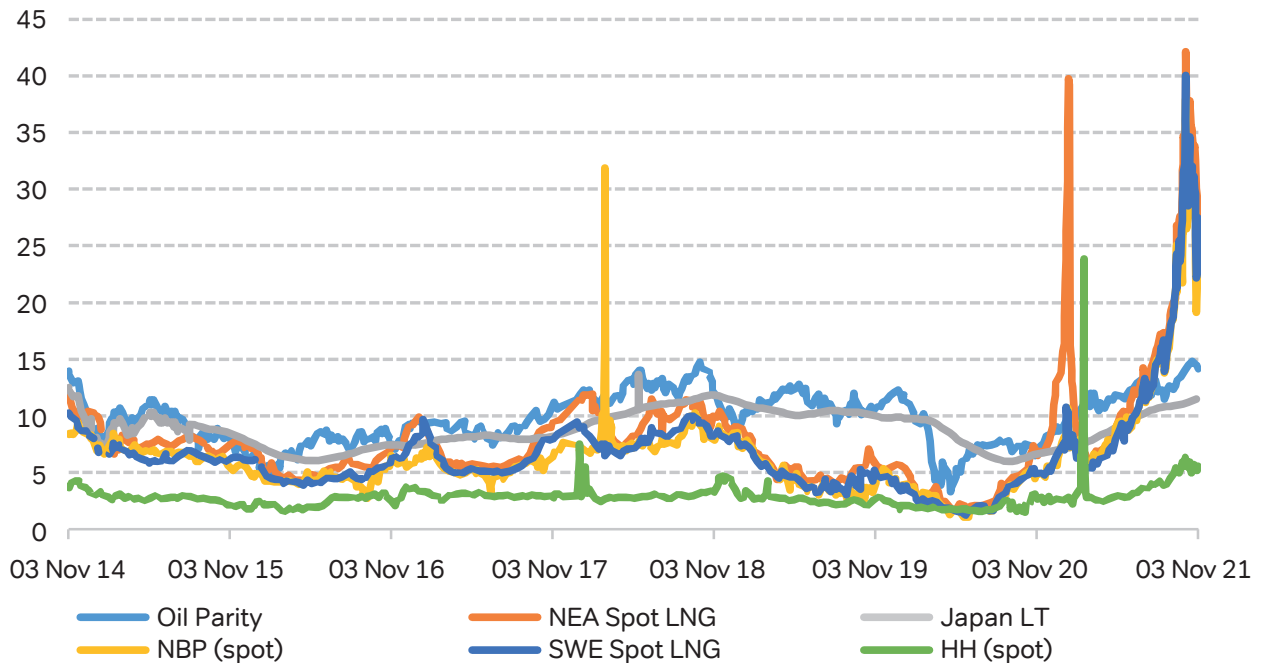
In the gas market, the combination of a post-COVID rebound in LNG demand, low storage utilisation in Europe, a tight LNG shipping market and the cold winter of 2020-2021 caused a strong recovery in demand and, as a consequence, in prices across the globe in 2021.

Gas prices will continue to be structurally higher. Volatility will continue due to the investment cycles for LNG, but increasing globalisation of trade will help to keep inter-regional prices competitive. The challenge of energy transition and decarbonisation will have an important impact in Europe, which will remain the balancing market for LNG, while in Asia, demand growth will likely see the continuance of the "Asian premium" through the 2020s despite the developments we witnessed in the 2H2021 when European LNG was traded at the premium to the Asian contracts.

According to 2021 estimates, the Henry Hub (HH) price in real terms will reach USD3.5/mmbtu in 2030, USD3.9/mmbtu in 2040 and USD4.7/mmbtu in 2050.

We project that the structure of the natural gas market over the outlook period will remain largely geographically segmented. As storage capacities grow and gas grids expand, LNG shipments will be increasingly used to eliminate intra-regional, intra-year price arbitrage. Regional gas markets, which currently have weaker connectivity, are expected to become strongly integrated post-2035, as the rapid development of LNG capacity, as well as transportation and trading networks, including large-scale export pipeline projects, stimulate market integration. Thus, we expect that until at least 2035, American and European markets, as well as the Asian and Latin American markets will remain integrated market regions with the most natural gas liquidity, whereas after that date it is projected that a global gas market will start emerging, with regional differences being less significant.

Figure 1.8. Natural gas short-term prices 2020 - 2021 (USD/mmbtu)



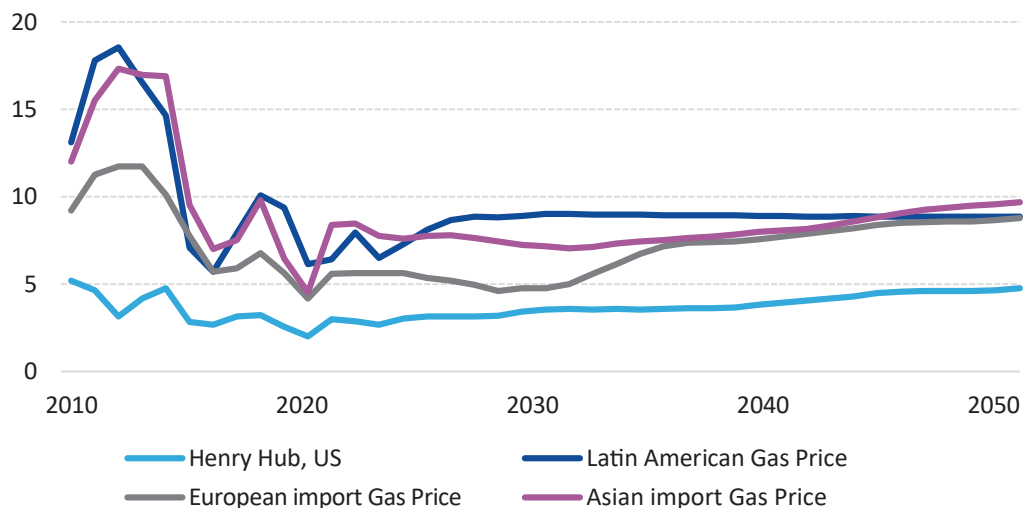
Source: GECF Secretariat based on data from the GECF GGM

The long-term trend in natural gas prices will be driven higher by the following:

- despite the technological advancement, gas production is expected to become increasingly capital intensive, with an increasing demand facing higher LRMC.
- increasing carbon tax and methane abatement policies will put additional pressure on the cost of using natural gas after coal-switching benefits have been exhausted.

The market structure in the long-term will likely gravitate towards many instruments traditionally present in the other commodity markets, such as an increased role for trading hubs, growth in the financialization of the natural gas trade and the greater role that settlement trades typically play. However, most commodities trade in hubs with proper infrastructure,

Figure 1.9. Natural gas long-term prices 2020 - 2050 (USD/mmbtu)



Source: GECF Secretariat based on data from the GECF GGM

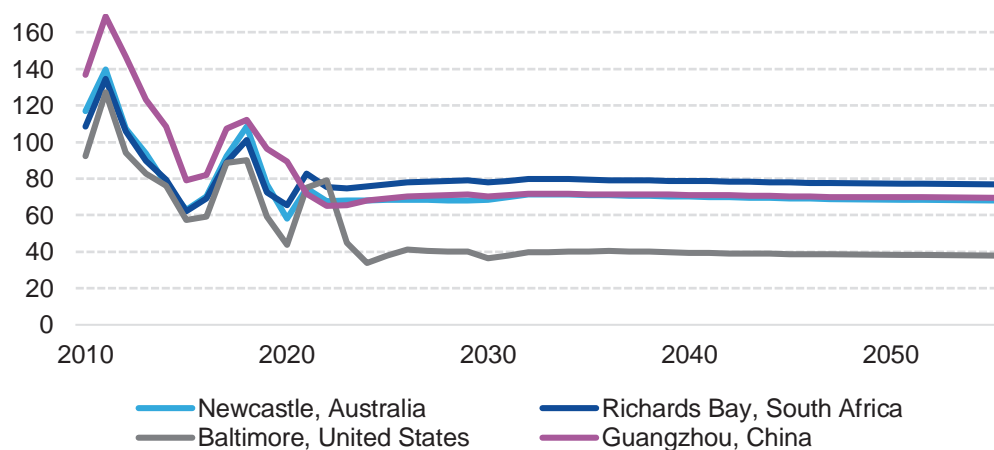
which is why futures markets such as the JKM will need infrastructure support. In the longer-term, LNG indices based on growing markets will be more suitable to use as a benchmark, as these markets are striving to develop a gas trading infrastructure that can provide backing for settlement trades.

1.3.3 Thermal coal

The coal market is relatively strong in the short term but will be under increasing pressure due to competition from gas and also thanks to the increasing focus on net-zero emissions targets globally. Without the commercial deployment of CCUS, which is not assumed, the prospects for demand are weak and the price is expected to remain depressed. There is an important challenge for technological advancements in coal production in this respect.

Coal prices have been decreasing due to competition with natural gas for electricity generation, although supply problems in South Africa and strong demand from Indian industrial buyers have sustained South African coal prices. In Australia, coal prices have been pressured by China's more stringent import restrictions. We expect that in the long-term, prices will be driven by these factors and global prices for coal will fall below USD80/t on average.

Figure 1.10. Thermal coal price (USD per tonne)



Source: GECF Secretariat based on data from the GECF GGM

The long-term Outlook for thermal coal prices is to a lesser extent shaped by the supply-demand balance, as capacity is expected to adjust to the accelerating decline in global demand. So far, coal remains the cheapest power sector energy source on a non-adjusted basis. The coal market will be significantly impacted by: (i) the global increase in carbon prices and proactive air quality policies in developing countries; and (ii) strong electricity demand growth in capital-strapped developing Asia and Africa, and the strategies for the energy sector which those countries will adopt. While modern coal power has higher emissions than any other modern source of energy, it is still widely seen in these countries as a valid competitor to reduce emissions against traditional biomass and older technology.

1.3.4 Carbon

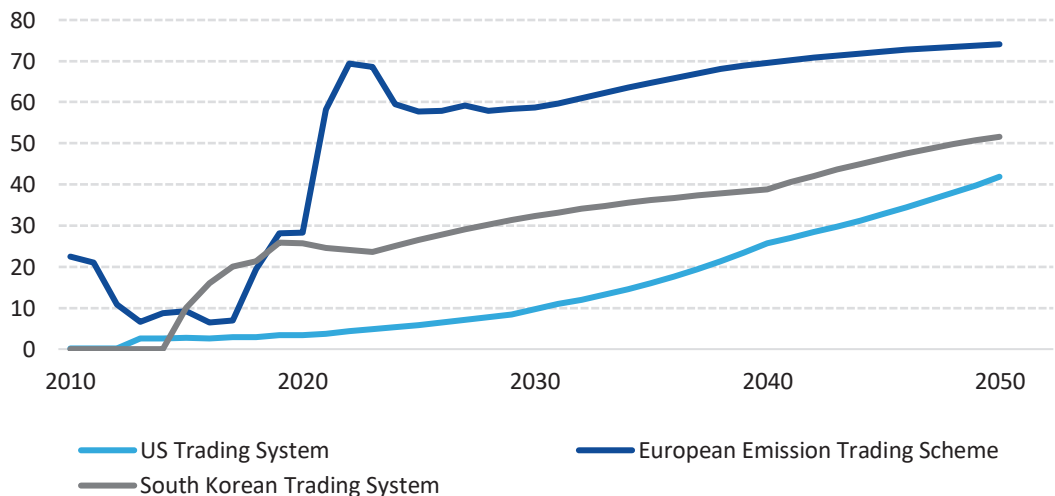
Carbon pricing is a key instrument in managing the climate agenda and accelerating the energy transition. Putting a price on carbon, either in the form of carbon taxation or through the application of carbon price references from the ETS, is considered by many countries as an important lever in the mitigation of CO₂ emissions.

A significant rise in EU ETS prices over the past will have long-lived upwards pressure repercussions on the EU ETS market in the range of USD58-74/t CO₂ (and might drive even more upward) as well impacting other regional and country-level emissions trading marketplaces. At a supranational level, the EU ETS, which was introduced 16 years ago, so far remains the only initiative of regional integration within a unified framework.

There are 65 carbon pricing initiatives in place or scheduled for implementation globally. According to World Bank estimates, there are about 45 national and 34 sub-national carbon pricing mechanisms that have been currently implemented or which are planned to be implemented shortly, which afford coverage of 12 GtCO₂, equivalent to approximately 22% of global GHG emissions.

An increasing number of global carbon trading systems are expected to be set up and will function on a regular basis, and towards 2050 they will be integrated into a global carbon trading system. A balance between competitiveness and climate goals will strongly impact carbon regulation.

Figure 1.11. Carbon prices (USD per tonne CO₂)

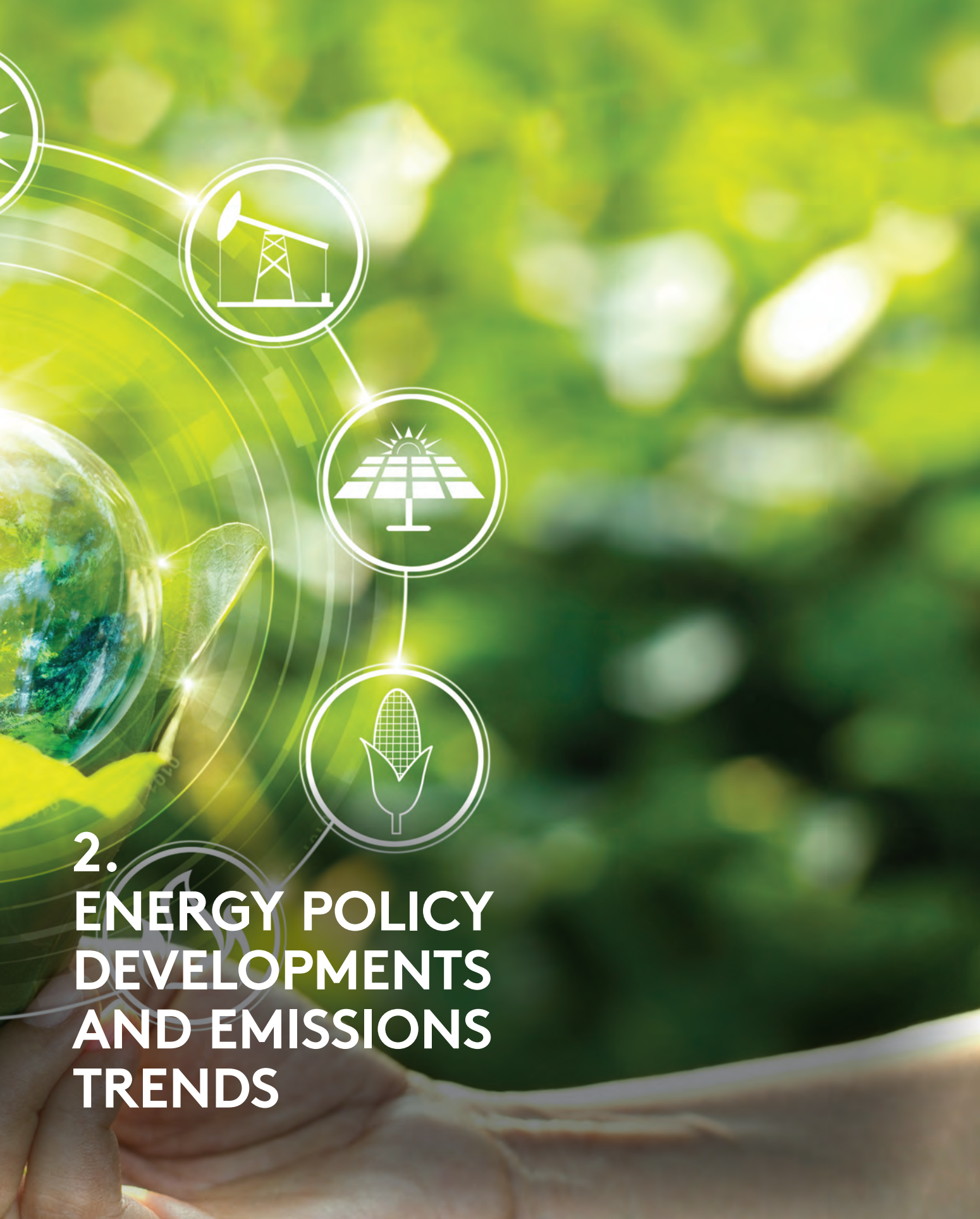


Source: GECF Secretariat based on data from the GECF GGM

Carbon price assumptions affect inter-fuel competition, especially the process of coal-to-gas switching.







2. ENERGY POLICY DEVELOPMENTS AND EMISSIONS TRENDS

KEY FINDINGS

- Commitments to net-zero have been substantially accelerated, with countries adopting or considering net-zero targets covering almost 90% of current global emissions.
- Gas still receives policy support, especially as a substitute to coal and a complement to renewables, but is increasingly challenged in recent plans released by developed countries (e.g. the EU, US and Japan). Gas suppliers are under pressure to reduce the GHG footprint along the gas value chain.
- Many regions have revised their renewables and energy efficiency targets upwards, but a combination of technical and economic challenges (e.g. integration issues) and the impact of COVID-19 could inhibit the achievement of these goals.
- China, India and Southeast Asian countries are advancing plans and market reforms to encourage development of the gas sector. However, gas progress faces competition from renewables and other sources. Coal is still supported to secure affordable energy despite its environmental impact.
- In Latin America, recent problems with hydro have encouraged support for gas as a reliable source for power generation. A number of countries are also introducing new measures to encourage gas market development and the expansion of demand.
- Despite aggressive decarbonisation actions under the proposed 'Fit for 55' package, natural gas is still seen as having a future in the EU region, especially in its role as balancing the power system and displacing coal in many central and eastern European countries.
- The new US administration has radically shifted policy back towards meeting emissions goals and leading the climate debate. Policy measures to inhibit the role of gas have been taken (e.g. an exploration moratorium on federal lands), but the fuel will still have a significant role to play both for domestic consumption and for LNG exports.
- Policy momentum is spreading around the world to support hydrogen as a key driver of future deep decarbonisation. There is a push to promote green hydrogen, but other more competitive sources (e.g. gas-based hydrogen) will play a critical role in establishing and scaling up the hydrogen market.
- Energy-related CO₂ emissions are expected to peak by 2024, and then show a significant decline to reach nearly 29.5 GtCO₂ by 2050. Despite this decrease, huge additional carbon mitigation efforts are needed, much more than the last NDC pledges submitted for COP 26, to close the gap with the Paris Agreement-aligned trajectory.

This chapter highlights the main energy and climate policy developments and assumptions affecting the long-term prospects for gas. The first section covers policy trends at a global scale, while the second part outlines the key policy drivers and assumptions in the main energy markets which are factored in the GGO. The third part analyses the prospects for energy-related CO₂ emissions and provides some key insights about these emissions in the big emitting countries.

2.1 POLICY DEVELOPMENTS AND TRENDS AT A GLOBAL LEVEL

Accelerated momentum towards net-zero pledges, driven by governments and companies

Since the publication of the last GGO, pledges and commitments to achieve carbon neutrality over the long-term have substantially accelerated, driven by governments and companies as well as by other players including financial institutions and NGO organizations.

At a governmental level, the number of countries adopting or considering net-zero emissions targets increased to around 140 (including the EU 27) as of November 2021. Between the end of 2019 and November 2021, the GHG emissions covered by countries having net-zero pledges on their agendas expanded from 23% to almost 90% (1). These pledges have been significantly reinforced by the arrival of China and the US which together accounted for 36% of global GHGs emissions in 2020. Other countries with a large reliance on coal, like Indonesia, India, Colombia and South Africa, have also recently announced a vision to reach net-zero emissions around mid-century (or by 2070 in the case of India). These are in addition to major oil producers in the Middle East such as Saudi Arabia and the UAE

All these recent developments raise the pressure to decarbonise energy systems and exacerbate the challenges for the hydrocarbon industry. Although the extent and speed of decarbonisation are different for each country, depending on their national circumstances, there is a real need for the industry to adapt and increase its effort to mitigate its carbon footprint.

Revised NDCs: despite enhanced ambitions, more effort is needed to close the gap with a Paris Agreement-aligned trajectory

The COP 26 conference is a milestone event for the global climate agenda since it aimed at advancing some critical aspects for the operationalization and implementation of the Paris Agreement. A key aspect relates to the updating process of countries' NDCs, according to the 'ratchet mechanism' stated in the Paris Agreement. This mechanism requires countries to ensure an improvement of their NDCs ambition every five years.

Ahead of November 2021, the date of the COP 26 conference, countries submitted their new or updated NDCs to the UNFCCC. Despite that the larger proportion of NDCs considers enhanced climate targets and commitments, preliminary assessments show that these targets are far from closing the gap with the 1.5°C Paris Agreement trajectory. The difference between GHGs emissions resulting from the updated NDCs and the 1.5°C target is estimated, as of November 2019, at more than 19 GtCO₂eq by 2030 (1). It highlights the huge additional effort that needs to be deployed, in a context where countries are still suffering from the severe economic and social consequences of the COVID-19 outbreak.

Access to competitive and reliable energy sources is of paramount importance for a sustained economic recovery. Therefore, hydrocarbon sources, including the cleanest amongst them, natural gas, still have a role to play in the post COVID-19 era, given their large availability and reliability. However, we should not ignore the fact that pressure on the gas industry is rising, especially with the recent release of the first part of the 6th IPCC Assessment Report (AR6) (2). This pointed out the worsening consequences of climate change, with accelerated temperature rises and greater occurrences of extreme events. The gas industry is at a crossroads, and it needs to improve its resilience to a changing environment, including through technological innovation.

Gas still receives policy support but is increasingly challenged in the developed world. Decarbonisation of natural gas emerges as a key requirement

Natural gas continues to receive policy support and incentives, specifically in emerging and developing countries in Asia Pacific, Latin America and Africa. The recently released plans and measures adopted in these countries give more emphasis to natural gas as a key substitute for coal and oil, and a flexible complement to intermittent renewables. The record level of drought in many developing countries and larger requirements for balancing reinforce the importance of gas-fired power plants to comply with the variability in electricity output and to secure power supply.

Several gas-supportive policies and measures have occurred since the publication of the last GGO. Countries such as China and Brazil have progressed with their gas market reforms, which aim to improve competition, support investment in gas supply capacities and enhance the functioning of gas markets. India is pursuing the implementation of an aggressive gas infrastructure plan to increase gas penetration and support its ambitious target, despite the significant impact of COVID-19 on its economy. In Southeast Asia, Indonesia and Malaysia have launched new incentives and fiscal reforms to promote upstream development. Thailand has granted more facilitations for gas infrastructure buildings in line with its vision to become an LNG hub in the region.

The implementation of clean air policies, including strengthened emissions standards, is also a driver for higher gas penetration against coal in power generation and industry, and against oil in the transport sector. These policies are in addition to the launch or reinforcement of carbon pricing schemes in various countries such as China, South Korea or even in European countries which might drive more coal to gas substitutions over the mid- to long term.

Despite the implementation of the above-mentioned gas-supportive policies, the recent period has also seen increasing pressure to achieve deep decarbonisation and to reduce emissions from natural gas, especially in Europe, the US and Japan. These countries have unveiled policies (e.g. Fit for 55 package in the EU; carbon-free power in the US) and released plans (e.g. draft 6th Strategic Energy Plan in Japan) which revise downwards the contribution of natural gas amid the strong expected expansion of renewables, electrification and green hydrogen. Furthermore, the EU policy proposal to limit carbon and methane content for gas imports will increase the burdens on the gas producers and trigger incentives to undertake actions that decarbonise gas supply chains (3).

Gas producers are very conscious of the decarbonisation challenges. They have already started implementing solutions and policies that promote options to reduce the GHGs footprint of gas supply chains. Among these solutions are carbon capture, utilisation and storage (CCUS), the conversion of gas to hydrogen and ammonia, digitalization and efficiency improvements, the electrification of processes and the deployment of methane abatement technologies.

In addition to decarbonisation, it is worth mentioning that the recent upsurge in gas prices adds another layer to the pressure on future gas demand and raises the fear of increased gas price volatility. Nevertheless, several consuming countries are deploying policies and measures that aim to manage this volatility through expanding gas storage capacities, reinforcing diversification of supply sources and building reliable partnerships with different gas suppliers. Oil-indexed gas contracts have some key advantages in smoothing volatility (the pricing formulae often include smoothing mechanisms) and in providing stability and security of supply in an increasingly uncertain environment (4).

Renewables and energy efficiency: revised ambitions, but technical and economic headwinds might create a mismatch with the stated targets

Since the publication of the last GGO edition, several countries have revised their renewables penetration and efficiency targets upwards. The EU has announced new renewable and efficiency directives with updated targets. China's 14th Five-Year Plan unveiled an ambitious commitment for renewables and strengthened its energy intensity target. In Southeast Asia, the ASEAN cooperation framework updated its collective energy intensity target and added more commitments for renewables. South Korea and Japan have also emphasized a strengthened role for renewables and efficiency.

Despite reinforced renewables ambitions and support schemes, several barriers still exist in various countries that might prevent them from meeting their stated targets, particularly over the next decade. Among the main observed barriers, there is: the increased risk carried by renewables project developers due to fewer direct subsidies and higher exposure to market prices and competition; the severe impact of COVID-19 which has delayed renewables projects and auctions; organizational constraints of the power sector and difficulties in accessing networks; the lack of transmission capacities that hinders the development of large-scale projects and contributes to significant renewables curtailments and competition from conventional hydrocarbon sources to meet development requirements.

The integration of intermittent renewables remains a key challenge for renewables expansion, even though a significant effort is being deployed to improve flexibility and balancing options in different countries. The integration challenge is set to increase as the development of renewables grows. It will require huge investments and deep transformation of power systems to maintain networks' stability and reliability. The recent power outages in the US and Japan are an important indicator of the difficulties in maintaining reliable power systems with increasing electrification, extreme and uncertain climate events and larger intermittency as a result of renewables expansion. Gas-fired power plants will continue to play a central role in supporting flexibility and renewable integration. This has been exemplified in the recent decision by California to support gas-fired capacities to ensure the required back-up for intermittent renewables.

Although policy orientations and adopted measures indicate more support for energy efficiency, its progress faces several headwinds. These include the severe impact of COVID-19 that has slowed economic activities and impacted investments

for modernization and efficiency improvements. Companies have instead directed their investments and actions towards recovering their core activities, while some governments have temporarily relaxed their efficiency standards (e.g. India, Indonesia). Moreover, the growth of energy-intensive industries is also another constraint to global efficiency improvements.

The GGO factors in that these constraints might slow efficiency improvements over the short term but considers that the implementation of strengthened policies will drive a significant improvement over the long term, specifically in buildings and industrial sectors.

Strengthened climate and clean air policies raise the pressure on the coal, but concerns around energy affordability and reliability slow its decline

Coal is under increasing policy pressure as it is the most carbon-intensive fuel and responsible for a severe degradation in air quality. This pressure on coal comes from various measures including the adoption of reinforced emissions standards and carbon prices, restrictions on financing coal projects, mandated switching from coal, imposed closure of old coal-consuming plants, and even the more radical acceleration of the phasing out of coal, particularly in power generation.

Nevertheless, it is worth noting that several countries continue to build coal power plants, although more slowly than in previous years. In Asia Pacific, coal continues to be seen as an important contributor to ensure affordability and security of supply. Coal demand has significantly increased in the region during the last few months, driven by high gas prices and tensions over the electricity supply. China has allowed the reopening of coal-fired power plants, which had been forced to close amid environmental restrictions. In Southeast Asia, Indonesia, in particular, has more than 30 GW of new coal-fired capacities in the pipeline. The ASEAN energy ministers emphasized in their last declaration the importance of coal to secure an affordable source of energy amid growing demand (5). Overall, the implementation of strengthened climate and clean air policies will drive the structural decline of coal over the long term. However, the competitiveness of coal, especially given the high gas prices experienced in 2021, together with its ability to secure energy supply and support recovery from the deep post-COVID-19 recession, might slow this structural decline over the next decade.

Policy momentum spreading around the world to support hydrogen as a key driver of future deep decarbonisation

The release of national strategies and roadmaps promoting hydrogen development has seen unprecedented momentum during the last two years. These policy dynamics have expanded across all the continents of the world, following the early publication of hydrogen strategies in Japan in 2017 and South Korea and Australia in 2019.

In Europe, there is a strong engagement to put hydrogen at the heart of an aggressive decarbonisation agenda, boosted by the adoption of the new Green Deal and the publication, in July 2020, of the EU's hydrogen roadmap. Several EU Member States have now communicated their hydrogen strategies (e.g. Germany, France, Spain, Portugal and the Netherlands), while Norway and the UK have also developed their own roadmaps, leveraging on the large potential to use synergies between hydrogen and their existing gas resources and assets. Other countries have either published their strategies (e.g. Canada, Russia, Colombia and Chile), or are in the process of developing a comprehensive roadmap (e.g. China, the US, Italy, Argentina). In the Middle East and North Africa, Saudi Arabia and the UAE are positioning themselves as key exporters of hydrogen. Qatar, Egypt, Morocco and Algeria are considering scaling up hydrogen production, building on their huge solar and natural gas resources.

The published hydrogen roadmaps show some common trends including i) the positioning of hydrogen as a key driver to support carbon neutrality; ii) a significant focus on the 'hard-to-abate' carbon-intensive sectors like heavy industries (e.g. petrochemicals, steel) and transport (e.g. heavy trucks, buses); iii) an orientation to promote green hydrogen as a major long-term solution for achieving deep decarbonisation and supporting renewables integration; iv) the consideration of other competitive sources of hydrogen production (e.g. blue hydrogen) to establish and scale up the hydrogen market; v) the consideration of repurposing existing gas infrastructures (through blending or complete adaptation) to support hydrogen supply chains.

Companies have also embraced this hydrogen momentum, incentivized by policy developments (e.g. funding resources) and business commitments towards deep carbon mitigation. Projects for hydrogen pipelines have seen an unprecedented expansion, with the involvement of major oil and gas companies, including those in the gas exporting countries. The GGO factors in these dynamics in support of hydrogen, which will drive a substantial upward revision in demand compared to last year's edition.



2.2 POLICY DRIVERS AND DEVELOPMENTS IN THE KEY MARKETS

European Union

Natural gas: still part of the energy transition equation, but increasing policy pressure to decarbonise this fuel and repurpose gas infrastructures

The recent gas policy developments indicate that the EU continues to consider natural gas as a key contributor to the energy transition, despite clear opposition expressed by various stakeholders. The EU ministers agreed to extend support (e.g. fast-track authorisation procedure) for some cross-border gas infrastructures within the framework of the TEN-E policy, which defines projects of common interests. Furthermore, the EU has kept the door open for gas-consuming activities (e.g. gas-fired power plants and gas-based heat) to be included in the Sustainable Finance Taxonomy (6). The latter classifies the sustainable economic activities that might benefit from public funding and policy incentives.

Pragmatically, natural gas, as the cleanest fossil fuel, has a role to play in Europe, since it can compensate for the accelerated phasing-out of coal and the potential decline of the old nuclear fleet. Gas-fired power plants also offer an undeniable advantage in maintaining the reliability of the electricity supply and stability of the power grid, given the increasing penetration of renewables. Although several options exist for improving flexibility (e.g. battery and hydropower storages, demand-side response, hydrogen), these options are still experiencing significant technical and economic challenges and might not be available at the required scale to meet the huge flexibility requirements. Gas-fired power plants can provide the appropriate flexible response.

There is a clear split between the various EU MS around the future role of natural gas in a climate-neutral Europe. Several east European countries have explicitly expressed the importance of this fuel in their move away from coal. They have argued that natural gas can support them in reducing emissions immediately and cost-effectively with existing and well-known technologies, and in balancing renewables intermittency (7). For these countries, discontinuing support to the development of gas infrastructures will make their efforts to combat climate change very expensive. Nevertheless, there is increasing policy pressure within the EU to decarbonise gas and repurpose gas infrastructures to accommodate the new low-carbon gases, including hydrogen, biomethane and synthetic gas.

The GGO considers that the implementation of strengthened decarbonisation policies will add new economic burdens for gas supply and negatively affect gas demand, especially after 2030. Nevertheless, it assumes that gas will continue to play a critical long-term role, particularly in east European countries. Moreover, the GGO assumes the implementation of policy support to low-carbon gases will drive a considerable increase in demand for new decarbonised gases, particularly hydrogen. Gas-based hydrogen will play a role over the next decade but will be substantially challenged by renewables-based gas beyond 2030.

China

Natural gas continues to benefit from policy support, with a significant focus on promoting a stable and reliable gas supply

Recent policy measures indicate that promoting a reliable gas supply has gained more significance. The government has advanced its gas market and pricing reforms, notably through the installation of new market-based mechanisms for pipeline tariffs under the supervision of the recently established pipeline company (Pipechina). It has also reinforced incentives for building infrastructures (e.g. accelerated permitting), and extended VAT rebates for the supply of gas and the procurement of gas-related equipment. Furthermore, other measures have been announced which aim at boosting upstream developments, in addition to the recent opening up of the sector to foreign companies.

On the demand side, reinforced emissions standards for pollutants (e.g. clean air policy) and the establishment of the national ETS system are set to give a push to gas demand in different sectors. The implementation of these policies will encourage further coal-to-gas and oil-to-gas switching in different sectors. Moreover, gas for power generation is being encouraged to support increasing intermittent renewables development.

The GGO factors in gas supportive policies, and assumes that these policies will contribute to driving an increase in both demand and production of natural gas. However, the GGO considers that the competition of alternative sources (e.g. renewables, clean coal and nuclear), and the technical and economic challenges of ramping up domestic production will weigh on this progress over the long term. China is assumed not to be on track to achieve the already announced 15% gas penetration target by 2030.

India

Gas market reforms and support to infrastructure will drive gas progress, but it remains far from the gas-based economy ambition.

India is pursuing its gas-supportive policy, driven by its ambition to shift towards a gas-based economy and meet 15% of its primary energy demand by natural gas. The government is implementing a plan to expand gas networks by two-thirds over the next decade and has released a draft LNG policy envisioning more than doubling regasification capacity by 2040 (8). It has advanced some key reforms and measures aimed at encouraging competition for gas procurement and improving market functioning. Among these measures are: allowing companies to freely market gas to their clients using an online platform; introducing more market-based pricing schemes for gas sales including from domestic supply sources; unveiling new tariff rules for pipeline transport aiming for better transparency and uniformity; reducing the monopoly of distribution companies for city gas and launching the 11th city gas licensing round.

On the demand side, clean air policies are a key driver for the larger penetration of natural gas, particularly in the residential and transport sectors. For the transport sector, India is substantially promoting the conversion of vehicles to CNG and supporting the extension of gas refuelling stations. More than 200 stations were inaugurated in June 2021. In the power generation sector, although there is a lot of uncertainty around government supports to stranded gas power plants (or those operating at low utilisation rates), their role in balancing renewables is increasingly being recognised. The most recently released draft National Electricity Policy (NEP) outlined the importance of gas-fired plants in creating flexibility and reliability of power grids given the substantial anticipated expansion of intermittent renewables (9).

The GGO assumes the implementation of gas supportive policies in the country that will drive an increase in gas demand. Nevertheless, India is assumed to not be on track to reach its 15% target by 2050, due mainly to competition from alternative sources including coal and renewables. On the supply side, although the Indian policy effort will contribute to increasing the level of domestic production, the pace of progress is expected to be much lower than demand. The country could leverage accessing a large base of international supply through pipeline and LNG imports. Cooperation and reliable partnerships with gas producers will be a key instrument in supporting India in its quest to raise the contribution of gas in its energy configuration

Southeast Asian Countries

Natural gas benefits from key policy support, as a viable substitute to coal and a complement to renewables

Countries in Southeast Asia continue to support natural gas, specifically for power generation and industrial use, as an option which can ensure clean and secure energy in order to meet the anticipated large expansion in demand. Natural gas is also seen as a viable option to substitute for coal and provide the required flexibility to balance the increasing penetration of renewables.

During the last year, countries in the region have undertaken various steps to advance gas market reforms and attract investors. Indonesia, for instance, announced a new package last June which incentivises deep-water gas developments. Thailand is pursuing its efforts to become an LNG hub by encouraging infrastructure development and facilitating permits for LNG imports and reloads. Vietnam, the Philippines and Malaysia have also shown ambition to support more gas penetration, are considering a downward revision of coal in their energy mix and leveraging on cooperation and ASEAN gas market integration.

There is an increasing policy orientation to impose limitations on coal, through strengthening emissions standards, establishing carbon pricing schemes (e.g. the pilot ETS scheme launched by Indonesia in March 2021), and cancelling the construction of new projects. These policy developments will offer room for more coal-to-gas switching, although coal is still expected to maintain a role in the future energy mix, amid competitiveness and security of supply concerns in the region.

At a regional level, the ASEAN action plan (Stage II) envisages a continuation of the reinforcement of gas infrastructure integration, promoting open access to LNG terminals and encouraging small scale LNG as well as LNG as bunkering fuel (10). The GGO factors in supportive gas policies both at the ASEAN and national levels, which will drive increasing gas demand. The GGO assumes progress of gas market reforms and cooperation in the region that will mitigate the decline of domestic gas production and enable more integration between gas infrastructures and markets



United States

Natural gas has less policy support but is expected to keep a role due to its economic and environmental advantages

The Biden administration has already started rolling out various supportive policies for natural gas. After imposing a moratorium on federal oil and gas developments, strengthening methane emissions and control rules, the administration has proposed to review tax advantages and remove subsidies that benefit gas companies, repeal permitting facilitation and environmental rules for gas pipelines and limit funding for international gas projects. Furthermore, it has announced significant support to renewables for power generation that might affect gas consumption in this sector.

Despite these restrictive policies for gas, this fuel still has a role to play in the US, given its numerous economic and environmental advantages. For the economic aspects, gas is a source of substantial revenues for the American economy and the oil and gas producing states in particular. In this context, several voices and opposing forces have been raised at state and business levels to lift the drilling moratorium on federal lands and avoid an aggressive shrinkage of production and tax revenues. The US court in the western district of Louisiana has ordered to end the moratorium which will cause significant financial difficulties to several states (11). In the meantime, the US administration approved more than 3000 oil and gas drilling permits and offered new leases for oil and gas companies, specifically in the Gulf of Mexico. This exemplifies the importance of hydrocarbons in the US economy, both at federal and state levels.

The GGO takes into account the implementation of gas policy restrictions, which will contribute to a downward revision of gas demand and domestic supply compared to the last GGO edition. Nevertheless, natural gas is assumed to keep a considerable role in power generation, including through CCS abatement, and heating services. Gas utilisation in the transport sector, especially LNG for heavy vehicles, will benefit from strengthened emissions standards.

Latin American Countries

Recent policies confirm significant support to natural gas amid growing power generation requirements and lack of hydropower availability

Several Latin American countries experienced record droughts in 2020, putting large pressure on hydropower availability. This situation has reinforced policy momentum to support gas-fired power plants as a way to compensate for hydropower fluctuations and meet the growing power generation needs. The use of natural gas is also being incentivized as a clean source in the industry and transport sectors and an appropriate enabler for intermittent renewables development.

Gas-supportive policies involve both the supply and demand sides of the equation. On the supply side, countries in Latin America are striving to diversify their sources, including both domestic production and imports. They have also deployed significant efforts to overcome the challenges and difficulties brought about by COVID-19 on the gas industry. Mexico has taken some steps, notably through accelerated permitting, to facilitate LNG imports and the building of storage capacity amid the recent concerns about pipeline availability from the US (due to the freeze on imports from Texas). Brazil achieved a milestone step with the adoption of its gas liberalization law. This aims to increase competition for the development of gas supply chains and lower gas prices for domestic customers (12). The country is striving to reinforce its relationships with neighboring pipeline exporters, namely Bolivia and Argentina. The latter has resumed gas exports to Brazil after a six-year hiatus.

Argentina is pursuing the implementation of its gas incentive plan (GAS PLAN 4), a key element of which is to set a floor price for domestic producers which is higher than local market prices. Trinidad & Tobago has launched a reform process to relax drilling terms, attract investors and accelerate licensing for gas exploration and development, including in deep off-shore areas. Moreover, Suriname and Guyana have recently announced developing a joint gas strategy aimed at leveraging partnership to develop infrastructures and boost gas developments.

The GGO assumes the implementation of gas supportive policies in most Latin American countries, targeting particularly the power generation sector, and to a lesser extent, industry and transport. Nevertheless, the GGO considers an increasing contribution of gas-fired power plants for meeting peak-load regimes and complementing hydro and renewables. This will limit the utilisation rates of gas-fired capacities and weigh on the growth potential of gas demand for power over the long term.)

African and the Middle Eastern Countries

Natural gas: policy push to develop domestic capacities and increase gas penetration

Africa and the Middle East have almost 50% of the proved gas reserves in the world with a significant resource potential that can still be tapped, specifically in the under-explored African areas. Recent developments show an increasing policy effort to encourage investment in developing upstream capacities and gas infrastructures, particularly in countries endowed with gas resources. Algeria and Nigeria have recently adopted new hydrocarbon laws that aim to incentivize investments in this sector. Algeria has announced a substantial increase in the investment effort to renew its reserve basis (13), while Qatar is pursuing an aggressive plan to reinforce its production and export capacities, with a target to reach 126 mt LNG exports per year by 2027. Egypt is implementing reforms aimed at encouraging competition and the opening of its gas sector, and it has also accelerated the bidding rounds for gas exploration and development, specifically in deep waters and western areas.

On the demand side, countries in the Middle East and Africa continue to promote gas as a key fuel for meeting growing baseload power generation (e.g. Nigeria), substituting oil products (e.g. Saudi Arabia), encouraging industrial developments (e.g. Algeria, Egypt, Qatar), monetizing associated and flared gas (e.g. Nigeria; Iraq) or substituting for coal (e.g. South Africa). Other countries, like Mozambique, Tanzania and Senegal, are actively promoting natural gas in order to leverage recent gas discoveries..

Despite these gas-supportive policies, several challenges might affect the progress of natural gas in Africa and the Middle East. These include the restrictions on funding gas infrastructures from some banks and financial institutions, the lack of capabilities and access to technologies, political and regulatory issues affecting attractiveness in various countries and the volatility of international gas prices that constrain investments. To overcome these challenges, some regional initiatives have been launched, notably in Africa, such as the regional gas master plan for southern African countries backed by the Development Bank of Southern Africa (DBSA), the African Energy Chamber initiative for gas trade and investment and the LNG to Africa initiative aiming at strengthening LNG exchanges and encouraging small-scale LNG options (14)(15).

The GGO supposes that natural gas will benefit from a policy push in the Middle East and Africa, specifically through measures that encourage investment and infrastructure development. The two regions will substantially increase the domestic production that will enable them to satisfy national demand and exports. Penetration of natural gas will grow but will be increasingly challenged by the anticipated expansion of renewables, solar in particular.

2.3 ENERGY-RELATED CO₂ EMISSIONS PROSPECTS

After a strong post-COVID-19 rebound in 2021 (almost 4% growth compared to 2020), the future energy-related CO₂ emissions are expected to grow in 2022 by 1.6%, before plateauing and peaking by 2024 at around 34.6 GtCO₂. After this date, emissions will observe a significant decline to reach nearly 29.5 GtCO₂ by 2050.

The emissions increase in 2021 is not only being driven by the recovery of economic activity in several regions, but also by the increased use of energy-intensive hydrocarbons, particularly coal. Indeed, the substantial growth of energy prices and tensions on power generation outputs give some push to coal, specifically in Asia (16). It is estimated that coal-related emissions represent around 40% of the anticipated additional emissions between 2020 and 2021. Over the longer term, the implementation of strengthened policy actions contributes to driving the decline in emissions by 2050 by more than 3.2 GtCO₂ compared to the 2020 level.

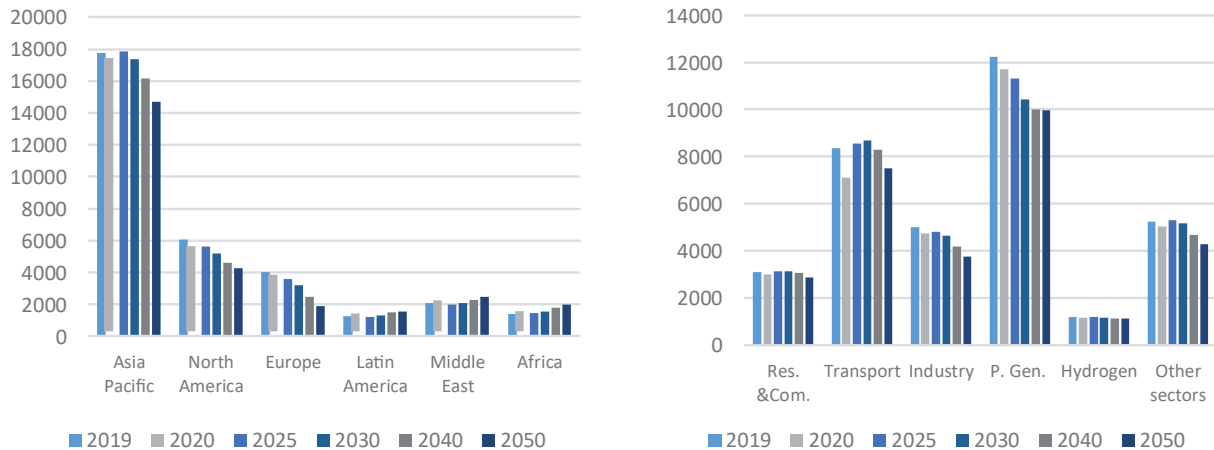
Emissions by regions and sectors

Despite the anticipated decline of energy-related CO₂ emissions at the global level, the future prospects of emissions at a regional level exhibit differentiated trajectories. Africa, the Middle East and Latin America are set to increase their emissions substantially, even when compared to the pre-COVID level in 2019. Together, they are forecast to add around 1.3 GtCO₂ in 2050 compared to 2019 (a 27% increase).

Africa will observe the highest emissions progression, followed by Latin America, with annual growth rates estimated respectively at around 1.2% and 0.8% over the 2019-2050 period. Growth in the two regions will be driven by the progress of economies and populations as well as by an increased access to natural gas and oil to replace traditional usage of biomass and to deal with hydropower fluctuations. Emissions are also expected to grow in the Middle East. Nevertheless, the pace of progress in this region will be slower than in Africa and Latin America, since the expansion of solar power, efficiency improvements and nuclear (e.g. the UAE) will contribute to reducing emissions growth.



Figure 2.1. CO2 emissions forecasts by regions (left) and by sectors (right) (MtCO2)



Source: GECF Secretariat based on data from GECF GGM
 Note: 'Other sectors' include energy-related and transformation industries

Conversely, Europe and North America will pursue their steep emissions reductions, with an annual downward trajectory estimated at 2.5% and 1.1% respectively between 2019 and 2050. Europe will more than halve its 2050 emissions compared to pre-COVID levels. These forecasts are underpinned by the efforts of the EU and also the UK to support their deep decarbonisation pledges. North America will also accelerate its emissions decline after the dramatic reversal in US policy under the new Biden administration.

Asia Pacific is expected to cap its emissions by 2024 before observing a decrease through 2050. OECD Asia (including Japan and Korea) together with China will be the key driver of this reduction. Together, these three countries will decrease their total energy-related CO2 emissions by more than 45% compared to 2019 levels, amid strengthened efforts to support their carbon neutrality pledges. China, in particular, is set to peak its emissions by 2024 before starting a gradual decline, mainly underpinned by the huge progress in renewables and a shift away from coal.

Conversely, Southeast Asia and India will increase their collective emissions by almost 60% between 2019 and 2050. Growing energy needs and the still-important role of coal will support growing emissions in the region, albeit at a slower pace than in previous GGO forecasts because of the larger deployment of renewables, efficiency options and coal-to-gas switching.

Regarding the emissions prospects by sector, power generation is expected to decrease from 12.3 GtCO2 in 2019 to 10 GtCO2 in 2050 (a decrease of around 19%), as shown in Figure 2.2. The decline of emissions in this sector is mainly underpinned by the large penetration of renewables, particularly solar and wind, the steep reduction of coal following the implementation of phasing-out decisions and reinforced environmental restrictions, the penetration of natural gas at the expense of coal and oil as well as improvements in power plants' thermal efficiency. These options will largely compensate for the upside effect on emissions due to the global increase in electricity demand. However, despite this decline, power generation will remain the major contributor, accounting for more than one-third of global energy-related emissions.

The industrial and transport sectors are expected to cap their emissions, by 2025 and 2030 respectively, before observing a significant decrease after that date. Compared to pre-COVID levels in 2019, 2050 emissions will shrink by 1.2 GtCO2 for industries and 0.8 GtCO2 for transport. Electrification and efficiency improvements with the implementation of strengthened emissions and energy performance standards will be the key drivers of the decarbonisation of these two sectors. These drivers are in addition to fuel substitutions, notably through the penetration of gas at the expense of coal and oil products in the industry, and to a lesser extent the deployment of hydrogen-based technologies. Hydrogen demand is set to represent 5% and 4.5% of final demand in industry and transport by 2050. It could also play a larger decarbonisation role in mitigating emissions from the hard to abate sectors, such as heavy trucks for transport and steel and cement for industries.

The carbon mitigation potential in residential and commercial sectors is less than other end-use, energy-consuming sectors due to the dominance of electricity in these sectors. Nevertheless, further electrification of heating and efficiency improvements are the main contributors in decreasing the emissions by around 7% in 2050 compared to 2019. The emissions from hydrogen conversion will observe a stable profile over the forecast period, despite a substantial increase in conversion capacities. The deployment of green hydrogen, CCS/CCUS and the improvement of conversion efficiency will contribute to this stability.



**3.
ENERGY AND
GAS DEMAND
OUTLOOK**

KEY FINDINGS

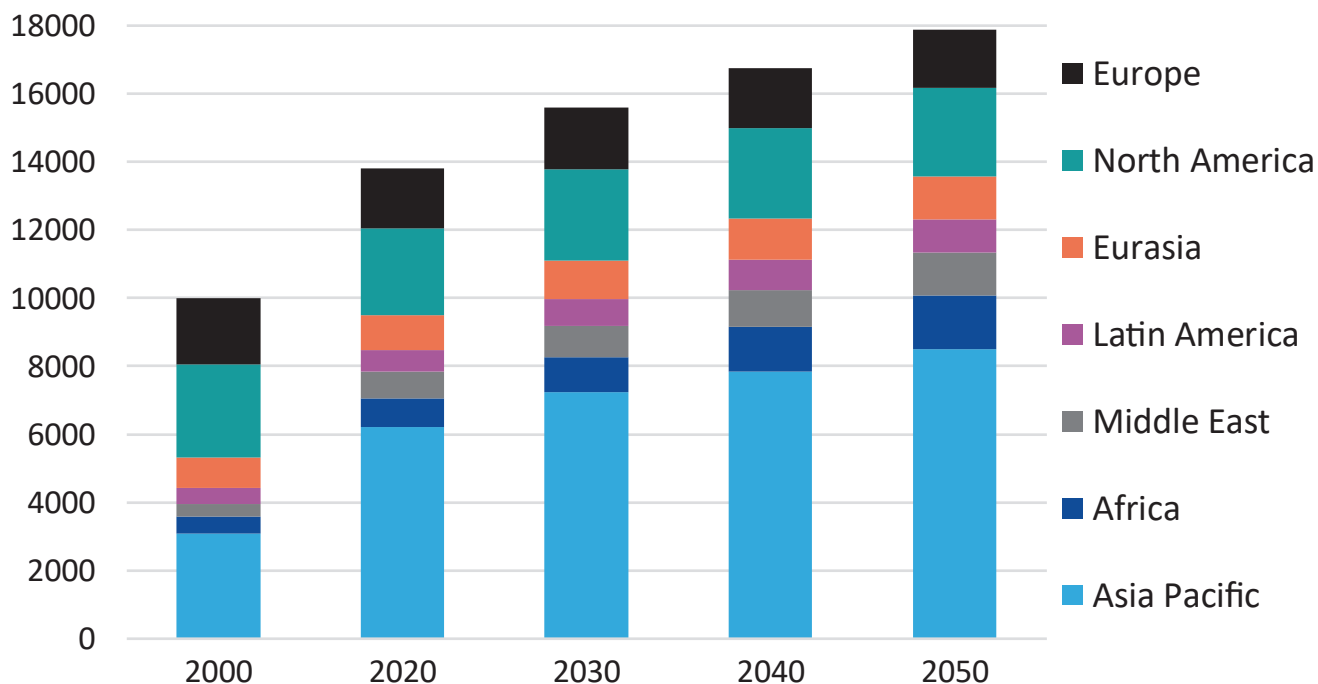
- Global energy demand will rise by 29% over the next three decades, with 56% of that increase coming from Asia Pacific region, driven by the fast-growing economies of China, India and South East Asia, with high potential in Africa.
- Natural gas and renewables grow substantially to 2050, together accounting for more than 90% of the incremental rise in global energy demand.
- Fossil fuels will continue to dominate the global energy mix and will account for 65% in 2050. In the context of energy transition, natural gas is becoming an important pillar of decarbonisation and will increase its share from over 23% today to almost 27% in 2050.
- There is no peak in gas demand, which rises by 46% from 3,840 bcm in 2020 to 5,625 bcm in 2050. This resilient outlook is underpinned by policy efforts aimed at air quality improvements, coal- and oil-to-gas switching and the development of CCUS.
- Asia Pacific region will represent the largest growth engine, almost doubling its consumption to 1,680 bcm by 2050 and contributing more than 45% to additional global gas demand. Africa and the Middle Eastern markets will be responsible for around 30% of incremental volumes.
- The power generation sector will be the key area of gas demand expansion, accounting for 42% of the total growth, thanks to greater electrification of end-use sectors as well as policies supporting the phase-out of coal-fired capacity. Meanwhile, gas-fired power plants will become more central to system flexibility amidst the emphatic development of variable renewables.
- Natural gas will retain its place as the key fuel suited for medium and high temperature processes as well as a feedstock for manufacturing petrochemicals and chemicals. In addition, hard-to-decarbonise industries will start to use natural gas in combination with CCUS as the optimal way to reduce emissions and to adapt to environmental initiatives.
- Gas in the transport sector will take off, predominantly in the form of LNG as bunker fuel and in heavy goods vehicles. In road transport, mature CNG and LNG technologies may represent a bridge to more sustainable and decarbonised mobility in the future.
- Blue hydrogen generation will be another major avenue for gas demand expansion, on the assumption of mounting efforts to scale up the deployment of low-carbon hydrogen in energy systems. Growth opportunities will come from the development of an internationally traded hydrogen market, while substitution of grey hydrogen with blue hydrogen in existing industrial applications will also take place.

3.1 GLOBAL PRIMARY ENERGY DEMAND OUTLOOK

Trends in energy demand and the corresponding evolution of the energy mix, presented in this chapter, encompass cumulative economic and population drivers as well as current policy settings and measures governments have actually put in place. With the arrival of the COVID-19 pandemic, enhanced decarbonisation initiatives and zero-carbon pledges have come to the fore, and clean energy investment promoting energy transition has received an additional impetus as a way to the recovery and long-term growth of devastated economies. In this context, considerations for the rapid development of low-carbon sources are taken into account. Simultaneously, the reference case scenario (RCS), which implies a more pragmatic and realistic approach, highlights the leading role of fossil fuels due to the scale of their contribution to the current global energy mix and also their ability to achieve long-term goals to eliminate energy poverty and provide consumers with reliable and affordable energy sources.

According to the RCS, global primary energy demand will rise by 29% over the next three decades, reaching 17,880 Mtoe by 2050 amid higher living standards, growing prosperity and better access to energy in some regions. It remains 2% lower than we estimated in last year's GGO as the post-COVID recovery is offset by efficiency gains. A look at the regional breakdown of primary energy demand demonstrates that 2,275 Mtoe or around 56% of the global increase between 2020 and 2050 will stem from Asia Pacific region, while the fast-growing economies of China, India and South East Asia will remain major contributors. High growth potential will be also observed in Africa, the next largest source of incremental energy demand, responsible for 18% of the total increase and adding 750 Mtoe over the outlook period.

Figure 3.1. Global primary energy demand trends by region (Mtoe)

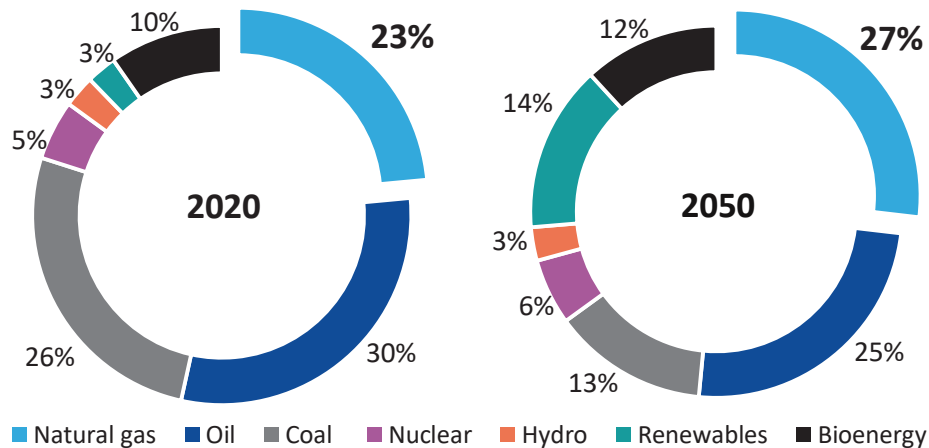


Source: GECF Secretariat based on data from the GECF GGM

In terms of inter-fuel competition, fossil fuels will continue to dominate the global primary energy demand and will account for 65% in 2050. The discussion on promoting decarbonisation initiatives rests in finding a balance between the achievement of GHG emission reduction targets, energy security and economic growth. In our view, a multi-dimensional approach should be the way forward to deal with the climate challenge in which the oil and gas industry forms the bedrock of the solution.

Specifically, natural gas is one of the global enablers for reducing emissions uninterruptedly and steadfastly by replacing carbon-intensive fuels and backing up intermittent renewables. At the same time, the emission mitigation potential of natural gas will increase with a larger deployment of decarbonisation options, including gas paired with CCS/CCUS and the production of blue hydrogen and blue ammonia, which will help establish a leading role for this fuel in the long-term.

Figure 3.2. Global primary energy demand in 2020 and in 2050 (%)



Source: GECF Secretariat based on data from the GECF GGM

Note: Numbers are rounded. Bioenergy includes traditional and modern biomass. Renewables include solar, wind, tidal and geothermal energy

According to estimates, natural gas will increase its share in the global energy mix from over 23% today to almost 27% in 2050 and will be an indispensable fuel in the transition to a lower-carbon energy system. Oil will continue to be an important source of energy, but its share is expected to decline to 25%. In response to environmental concerns, coal will drop sharply to 13% with countries adopting policies to reduce its role amid carbon neutral commitments.

The rapid growth of renewables will contribute to a more diversified structure of the global energy mix, with their share rising to 14% by 2050. Nuclear and hydro will capture 9%, slightly higher than in 2020. Global bioenergy demand will rise, driven by the expansion of modern biomass, however traditional forms of biomass will continue to stay high predominately in the residential segment of developing Asia and sub-Saharan Africa countries. This represents an additional potential for clean energy sources to substitute and meet energy needs, while supporting the attainment of the UN’s Sustainable Development Goals, in particular, Goal 7.

Thus, the energy transition is underway and natural gas together with renewables will gain in importance and will be the major contributors to incremental growth in global energy demand, together accounting for more than 90% of the additional growth through to 2050. Natural gas, as the second-largest contributor to the increase in global energy demand, will overtake coal in 2025 and become the most utilised fuel by about 2045.

Global oil demand will increase by 7% to 4,410 Mtoe in 2050, although the overall growth masks noticeable changes in the consumption trajectory. Recovering after the significant drop in 2020, oil demand continues to grow in the coming decade before reaching a long plateau in 2030–2035 and decreasing in later years. Despite the expansion of oil usage in petrochemical manufacturing, efficiency improvements in the transport sector together with greater penetration of alternative fuels, such as electricity, natural gas and hydrogen, will outweigh these gains. Lower oil usage will be also observed in the power generation sector. Declining oil demand is centred in developed countries, while all the growth will stem from developing markets.

Coal demand is expected to decline by 35% to 2,400 Mtoe in 2050. Coal consumption will decrease across many sectors and the strongest contraction will be in power generation and in the industry due to policy-driven fuel switching, environmental concerns and increasing competition from natural gas and renewables. The fall in coal use will be dominated by China, reflecting a strong policy focus on air quality issues, and will be compounded by substantial drops in the US, Japan, South Korea and European countries.

Nuclear energy demand is forecast to rise by 47% to 1,030 Mtoe. Although nuclear power offers carbon-free baseload capacities, a number of factors will affect its long-term prospects. These include tighter safety regulations, the issues of treatment and storage of nuclear waste, uncertainties about decommissioning costs and low public acceptance. The centre of gravity for nuclear power shifts towards Asia Pacific, while significant declines in consumption are forecast in Europe and North America amid decommissioning of ageing plants.

Hydropower will capture the smallest portion in the global energy mix and its demand is forecast to rise by 40% to 525 Mtoe by 2050. The increase in demand is expected to be less promising than its global potential as high construction and installation costs as well as environmental concerns, associated with the protection of biodiversity and climate change, will pose barriers to broadly based deployment.

Global renewable energy consumption will experience a dramatic increase, surging by 632% to 2,590 Mtoe in 2050. Solar PV as well as onshore and offshore wind installations will drive demand, supported by aggressive policy targets, regulations encouraging a shift to lower-carbon energy sources and continued cost reduction. However, scaling up of renewables will require more backup generation to deal with their intermittency and this challenge will mount over the outlook period.

Bioenergy demand, including traditional and modern biomass (such as modern solid bioenergy, biofuels and biogases), is forecast to grow by 58% to 2,115 Mtoe by 2050. The majority of the increase (more than 90% of additional volumes) will occur in modern biomass, which will double to reach 1,400 Mtoe by 2050. The main contributors will be the power generation sector and residential segment, while demand for biodiesel, ethanol and bio-jet fuel within the transport sector will also rise.

Box 3.1. The long-term outlook for liquids demand and supply¹

Prepared by the Organization of the Petroleum Exporting Countries (OPEC) Secretariat based on the OPEC World Oil Outlook 2021

Following an unprecedented decline of 9.3 mb/d in 2020, global liquids demand started its recovery path in 2021, although this was far from a full revival, especially in the road transportation and aviation sectors. The recovery process is set to continue in 2022, despite the number of challenges and uncertainties primarily related to the omnipresent COVID-19 pandemic.

At the global level, liquids demand is projected to reach 103.6 mb/d by 2025, which is 13 mb/d higher than in 2020. However, more than 80% of this incremental demand will materialize in the period to 2023, primarily as part of the recovery process from the COVID-19 crisis. OECD liquids demand is projected to grow by more than 4 mb/d in the period to 2025 (compared to 2020). However, this increase will not be sufficient to return to pre-COVID-19 demand levels in this region. In contrast, non-OECD demand is expected to increase by almost 9 mb/d by 2025 from 48.6 mb/d observed in 2020, of which less than 4 mb/d will be needed to offset the demand decline in 2020.

In the long-term, global liquids demand is forecast to rise by 17.6 mb/d between 2020 and 2045, growing from 90.6 mb/d in 2020 to 108.2 mb/d in 2045. Similar to the medium-term prospects, long-term projections even accentuate a contrasting demand picture between continued growing demand in the non-OECD and declining demand in the OECD. Indeed, OECD liquids demand is projected to peak at levels around 46.6 mb/d in 2023, before it starts a longer-term decline towards a level of 34 mb/d by 2045. This demand decline, however, will be more than offset by continued growth in non-OECD countries, which is expected to increase by 25.5 mb/d between 2020 and 2045, reaching a level of 74.1 mb/d in 2045. Primary drivers for this strong non-OECD demand growth include higher population growth rates, expanding middle class, and stronger economic growth potential.

Figure 3.3. Global liquids demand, 2019–2045 (mb/d)

| | 2019 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | Growth 2020-2045 |
|--------------|--------------|-------------|--------------|--------------|--------------|--------------|--------------|---------------------|
| OECD | 47.7 | 42.1 | 46.3 | 44.0 | 40.8 | 37.3 | 34.2 | -7.9 |
| Non-OECD | 52.3 | 48.6 | 57.3 | 62.6 | 67.1 | 70.8 | 74.1 | 25.5 |
| World | 100.0 | 90.6 | 103.6 | 106.6 | 107.9 | 108.1 | 108.2 | 17.6 |

Source: OPEC

¹ This box focuses on the liquids demand outlook, which includes not only oil-based liquids but also other liquids (i.e. biofuels, coal-to-liquids and gas-to-liquids). Furthermore, liquids demand is expressed in volumetric units (mb/d), thus accounting for the oil product mix and its evolution over time. This is why the figures shown in this box are not directly comparable to those in which primary energy demand for oil is shown in energy equivalent units (e.g. Mtoe).

Turning to the sectoral perspective, the transportation sector (combined road, aviation, rail, waterways and marine transport) is forecast to be the major contributor to future incremental demand, adding around 13 mb/d to global oil demand between 2020 and 2045. More than 90% of this demand increase is projected to come from the road transportation and aviation sectors, with each contributing around 6 mb/d, although a large part of these increases will be due to the recovery from the sharp demand declines experienced in these two sectors in 2020.

Prospects for the road transportation sector will be impacted by rising penetration of electric vehicles (EVs). Recent projections indicate that the total vehicle fleet will reach 2.6 billion by 2045, increasing by around 1.1 billion from the 2020 level. EVs are set to approach 500 million by 2045, representing almost 20% of the global fleet by then. Some growth is also projected for natural gas vehicles (NGVs), with an expected increase of 80 million vehicles projected between 2020 and 2045. As a result, also considering efficiency improvements in future oil-based internal combustion vehicles and expected average mileage driven, 2045 liquids demand in the road transportation sector will be more than 6 mb/d higher compared to 2020. However, this will be just 1.6 mb/d higher compared to pre-pandemic levels in 2019, despite the substantial increase in the number of vehicles. Moreover, these developments are expected to keep road transportation demand in a narrow range of 46 mb/d to 46.5 mb/d after 2025.

In the aviation sector, the outbreak of the COVID-19 pandemic had a devastating effect on this industry. However, demand for aviation fuels is recovering gradually and is projected to reach pre-pandemic levels of 6.7 mb/d sometime in 2024. In the long-term, robust GDP growth in developing countries, a growing population and expanding middle class, an expected increase in the frequency of air travel per citizen, and increasing cargo movements between regions, will work towards supporting a rising number of flights and related oil demand. A counterbalancing effect to this potential growth will come in the form of a quest for improved efficiency and emissions reductions. The net effect of these trends will likely be a demand expansion by almost 6 mb/d during the forecast period, from 3.5 mb/d in 2020 to 9.3 mb/d in 2045. Similar to other sectors, the larger part of this incremental demand is projected for non-OECD countries (+3.5 mb/d), while total OECD is set to grow by 2.3 mb/d.

Figure 3.4. Sectoral oil demand, 2019–2045 (mb/d)

| | 2019 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | Growth 2020-2045 |
|------------------------|--------------|-------------|--------------|--------------|--------------|--------------|--------------|---------------------|
| Road | 44.6 | 40.0 | 46.3 | 46.5 | 46.4 | 46.2 | 46.2 | 6.3 |
| Aviation | 6.7 | 3.5 | 7.1 | 7.6 | 8.3 | 8.8 | 9.3 | 5.8 |
| Rail/waterways | 1.9 | 1.8 | 2.0 | 2.0 | 2.1 | 2.1 | 2.0 | 0.2 |
| Marine bunkers | 4.2 | 3.9 | 4.3 | 4.5 | 4.6 | 4.6 | 4.6 | 0.7 |
| Transportation | 57.3 | 49.2 | 59.6 | 60.7 | 61.4 | 61.8 | 62.2 | 13.0 |
| Petrochemicals | 13.7 | 13.0 | 14.8 | 15.9 | 16.5 | 16.9 | 17.3 | 4.3 |
| Other industry | 12.9 | 12.7 | 13.1 | 13.5 | 13.7 | 13.4 | 13.3 | 0.6 |
| Industry | 26.6 | 25.7 | 27.8 | 29.4 | 30.2 | 30.3 | 30.5 | 4.9 |
| Resid./Comm./Agr. | 11.1 | 10.9 | 11.4 | 12.0 | 12.0 | 12.0 | 11.6 | 0.7 |
| Electricity generation | 4.9 | 4.9 | 4.7 | 4.5 | 4.3 | 4.0 | 3.9 | -1.0 |
| Other uses | 16.1 | 15.8 | 16.2 | 16.5 | 16.3 | 16.0 | 15.5 | -0.3 |
| World | 100.0 | 90.6 | 103.6 | 106.6 | 107.9 | 108.1 | 108.2 | 17.6 |

Source: OPEC

Compared to road transportation and aviation, the overall change between 2020 and 2045 in the marine transport sector is 0.7 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 on the back of robust economic growth in developing countries. However, 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 higher efficiency of oil-based vessels, will counterbalance the still-growing trade.

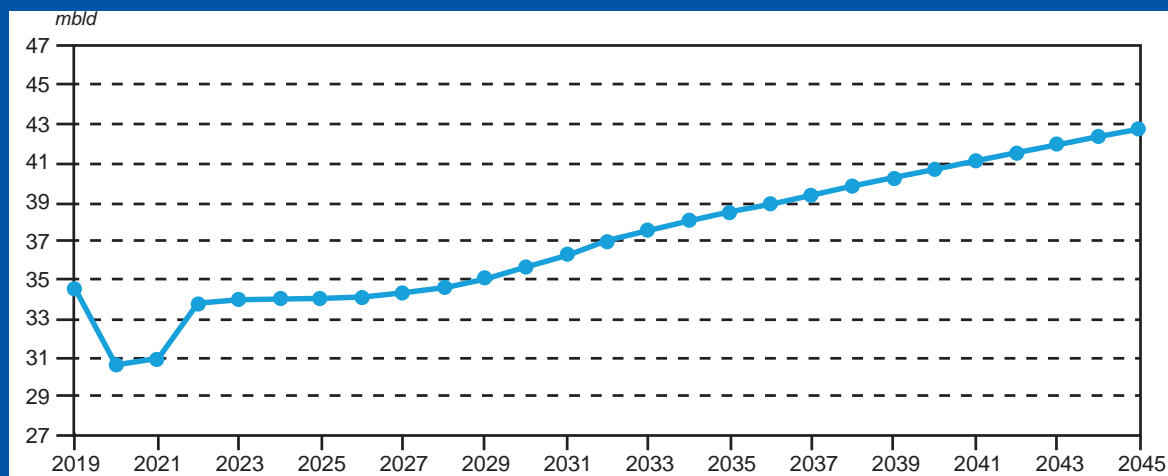
Some demand growth is also projected in the industrial sector, driven by strong demand for petrochemical products. The overall demand growth in the industrial sector is forecast to be 4.9 mb/d, of which 4.3 mb/d relates to petrochemical feedstock.

Combined, the residential, commercial and agricultural sectors account for around 12% of total oil demand. At the global level, demand in this sector is projected to grow by around 1 mb/d during the next 10–15 years and then decline by around 0.5 mb/d by the end of the forecast period. This overall pattern results from varying trends between the major regions. Strict policy measures, especially for building codes and heating systems, combined with electrification and fuel substitution, is expected to cause OECD demand in this sector to slowly, albeit steadily, decline during the current decade. However, strong growth in the non-OECD region, especially India, China and Africa, is anticipated to offset demand losses in the OECD and result in net growth of 1.3 mb/d in the period to 2035. Demand growth in the non-OECD region will decelerate during the remaining part of the forecast period, which, combined with declining demand in the OECD, is set to lead to an overall demand increase of around 0.7 mb/d by 2045.

Finally, electricity generation is the only sector in which liquids demand is forecast to decline, a result of increasing competition from natural gas and renewables. The overall loss is projected at 1 mb/d between 2020 and 2045.

As the world gradually moves beyond COVID, stable and supportive oil market fundamentals will also see recovery on the supply side. In particular, 2022 will see a return to growth for US tight oil production, which is expected to rise from 11.5 mb/d in 2020 to 14.5 mb/d in 2025. Tight oil output is expected to peak at 15.2 mb/d in the late 2020s, with US total liquids hitting a maximum of around 20.5 mb/d around the same time. Other significant contributors to non-OPEC supply growth in the medium-term are Brazil, Russia, Guyana and Canada.

Figure 3.5. OPEC total liquids supply (mb/d)



Source: OPEC

In the longer-term, as a result of US liquids supply peaking, and few other sources of meaningful growth, total non-OPEC liquids output is set to decline from a high of 71 mb/d around 2030 to 65.5 mb/d in 2045, basically level with pre-pandemic 2019. This has a significant bearing on OPEC liquids, which after recovering to pre-pandemic levels around the mid-2020s, rise further, increasing from 35.7 mb/d in 2030 to 42.7 mb/d in 2045. OPEC’s global market share rises from 33% in 2020, to 39% in 2045.

Significant and sustained investments in the oil sector will be needed to meet projected demand. Cumulative investment requirements in the oil sector amount to \$11.8 trillion in 2021–2045 (in 2021 US dollars). Of this, 80% or \$9.2 trillion, is directed towards the upstream, the bulk of which is in North America, as US tight oil, in particular, drives medium-term non-OPEC supply growth. Downstream and midstream investment needs, in order to expand and maintain the associated refinery, storage and pipeline systems required to bring oil to market, necessitate another \$1.5 and \$1.1 trillion, respectively.



3.2 NATURAL GAS DEMAND OUTLOOK: GLOBAL OVERVIEW AND SECTORAL TRENDS

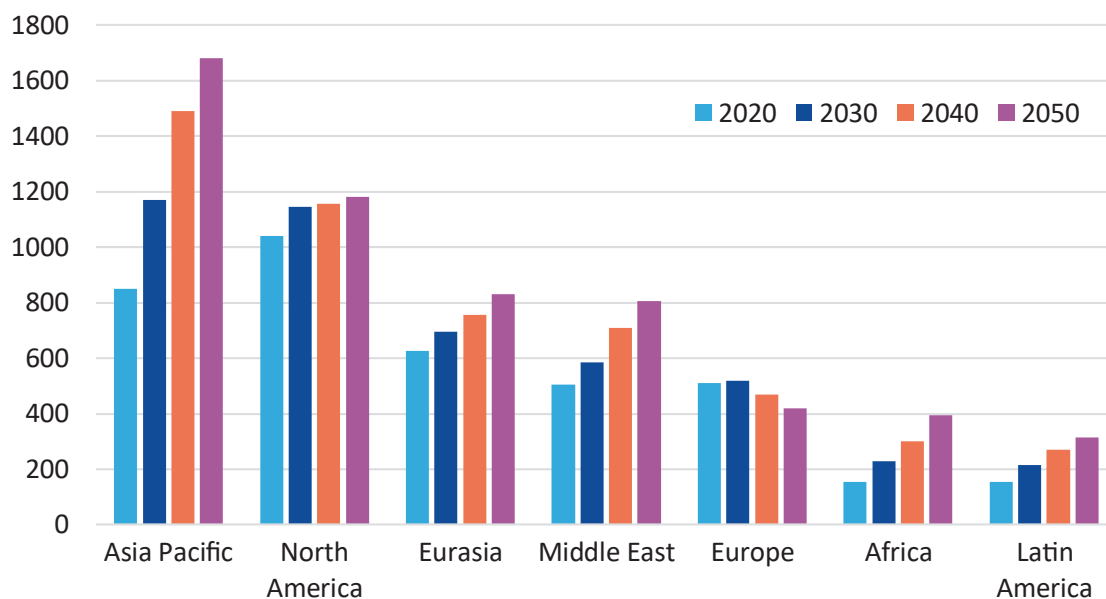
Global overview

In the context of energy transition and countries' intentions to mitigate the negative impact on the climate, natural gas, which today provides almost one quarter of the world's energy supply, will play a critical and unique role in meeting the growing demand for clean and affordable energy. With its important role in the decarbonisation process, natural gas has the potential to achieve progress within the environmental and sustainable development agendas.

In the RCS, there is no peak in natural gas demand, which grows to 5,625 bcm by 2050 – 46% higher than in 2020. However, compared to last year's GGO, the forecast for 2050 has been revised downwards by around 300 bcm (a reduction of 5%). The revision has come on the back of countries' commitments towards net-zero, which are expected to affect gas demand especially in Europe and in the US, as well as increased policy support for renewables and alternative decarbonisation options, such as pervasive electrification, energy efficiency, deployment of biomethane and low-carbon hydrogen. Concerning the latter, a transition to green hydrogen will have a small impact on global gas demand. This is partially due to the deployment of blue hydrogen, a new gas growth sector, which will offset the displacement, but this effect will take varying shapes across different markets. Simultaneously, key determinants which will ensure a resilient outlook for gas will be policy efforts aimed at air quality improvements, coal and oil-to-gas switching, and the development of CCS/CCUS (including direct use of this technology at power plants and large industrial sites).

As for regional trends, Asia Pacific region will see sustained gas demand growth and will make the largest contribution – more than 45% of the additional global 1,785 bcm through to 2050. Africa and the Middle Eastern markets will together be responsible for around 30% of incremental volumes. In Europe, gas demand is forecast to go into gradual decline amid adherence to environmental policies, energy efficiency gains and advancement in renewables.

Figure 3.6. Global natural gas demand trends by region (bcm)



Source: GECF Secretariat based on data from the GECF GGM

The potential for an increase in gas demand in **Asia Pacific** is enormous. At present, coal accounts for more than 46% of the regional energy mix, but the main trait that unites countries is a policy shift to improve air quality, reduce pollution and emissions. Accordingly, significant investments in gas infrastructure and policy-related measures to promote the use of gas at the expense of coal and liquid fuels will support environmental goals, while simultaneously meeting surging energy demand. Gas consumption will rise by 98% to 1,680 bcm by 2050 and will expand strongly across all sectors. Power generation will take a frontline role, accounting for 45% of the total gas demand increase, although consumption in industry, residential and commercial, and transport sectors will also rise considerably. China, India and Indonesia will be the main contributors to additional gas demand growth in the region.

In **North America**, increasing policy pressure, mainly driven by the US commitment to achieve carbon neutrality by mid-century plus a growing focus on cleaner energy, contributed to a downwards revision of gas demand in the region compared to our previous GGO. As a result, consumption will rise by 13% to 1,180 bcm by 2050 with Mexico in the lead due to an ongoing strategy to add numerous CCGTs to its power grid. Demand in the US will peak in the early 2030s, however gas will continue to play a remarkable role in the energy mix of this country. Overall, the push for gas demand in the region will mostly originate in the transport sector and for blue hydrogen generation. Concerning the latter, the region is well-positioned to scale-up blue hydrogen as a tool to decarbonise the non-power sectors, given the low-cost nature of gas production and availability of infrastructure to support capacity developments.

In **Eurasia**, natural gas maintains the largest share (52%) in the regional energy mix and will remain the dominant energy source over the outlook period. Demand will increase by 33% to 830 bcm by 2050 and more than 30% of this growth will be attributed to blue hydrogen generation, driven by Russia's strategic initiatives to produce and export low-carbon hydrogen. Incremental gas usage will also come from the development of NGV markets and from the industrial sector with the expansion of gas-to-chemicals, petrochemicals and non-metallic minerals production. Stronger gas demand growth in the region will be constrained due to high potential for energy savings, especially in the power and heat generation sectors.

In the **Middle East**, gas demand will grow by 59% to 805 bcm by 2050. The increase in gas consumption will be driven by sustained economic growth, strong demographic trends and the scope for displacing oil products in a range of sectors, mainly in power generation. Given rising gas production, countries will also place more emphasis on value-added industries as a route towards economic diversification. New gas demand area will be blue hydrogen generation and countries have strong intentions to scale-up its production to supply Asian and European markets, simultaneously ensuring the long-term viability of the oil and gas industry.

Natural gas demand in **Europe** will drop by 18% to 420 bcm by 2050. Nevertheless, natural gas will remain resilient at least up until 2030 as emission-reduction measures are expected to initially have more impact on coal and oil within the power generation and transport sectors. Over the long term, increased decarbonisation efforts through energy efficiency, elec-

trification, renewables and low-carbon hydrogen, particularly green hydrogen that will be introduced for a wide range of sectors, will create pressure for natural gas demand. The transport sector and blue hydrogen generation will present the best growth potential, partially offsetting declines in other sectors.

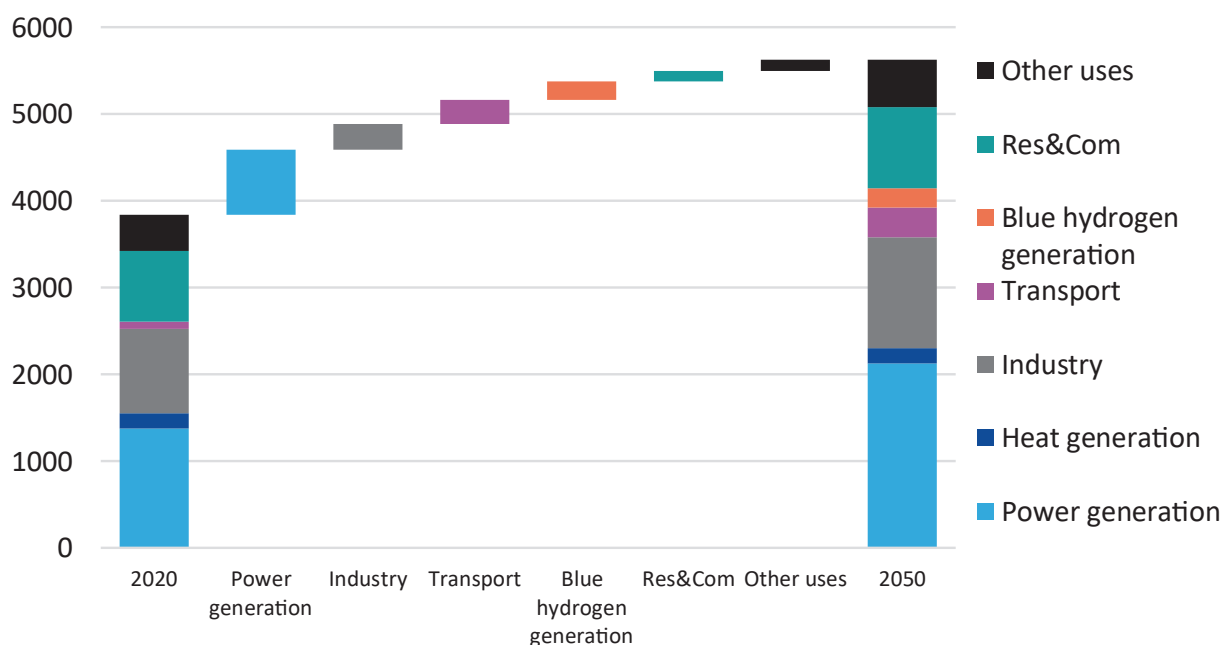
Africa will witness the highest growth rate in natural gas demand among all regions, rising by 155% to 395 bcm by 2050. The availability of rich gas reserves and the upbeat outlook for indigenous production offer significant prospects for its increased domestic usage. Infrastructure expansion could be a potential obstacle in the region, but a number of countries have plans for pipeline construction and network development to stimulate local consumption. Accelerated economic activity and a rising urban population, accompanied by an unprecedented increase in electricity demand, will be the key drivers.

In **Latin America**, gas demand will rise by 103% to 315 bcm by 2050. Over the next three decades natural gas will make the most significant in-roads, compared to other forms of energy, being a major component in building a more sustainable energy system. This growth will be supported by domestic gas resources and government policies to promote gas in power generation, for industrial applications and in road transport. The development of gas-fired generation, including the bulk of LNG-to-power projects, will be a driving force thanks to the transition from fuel oil and an overdependence on hydro to more diversified power supplies. However, gas demand will continue to be weather-dependent, given the critical role that hydro plays.

Sectoral trends

Looking at the various sectors, power generation will be the key driver of growth, accounting for 42% of incremental gas demand volumes through to 2050. This is in contrast to the residential and commercial sector, which is projected to provide just 7% of the total gas demand growth between 2020 and 2050.

Figure 3.7. Global natural gas demand trends by sector (bcm)



Source: GECF Secretariat based on data from the GECF GGM

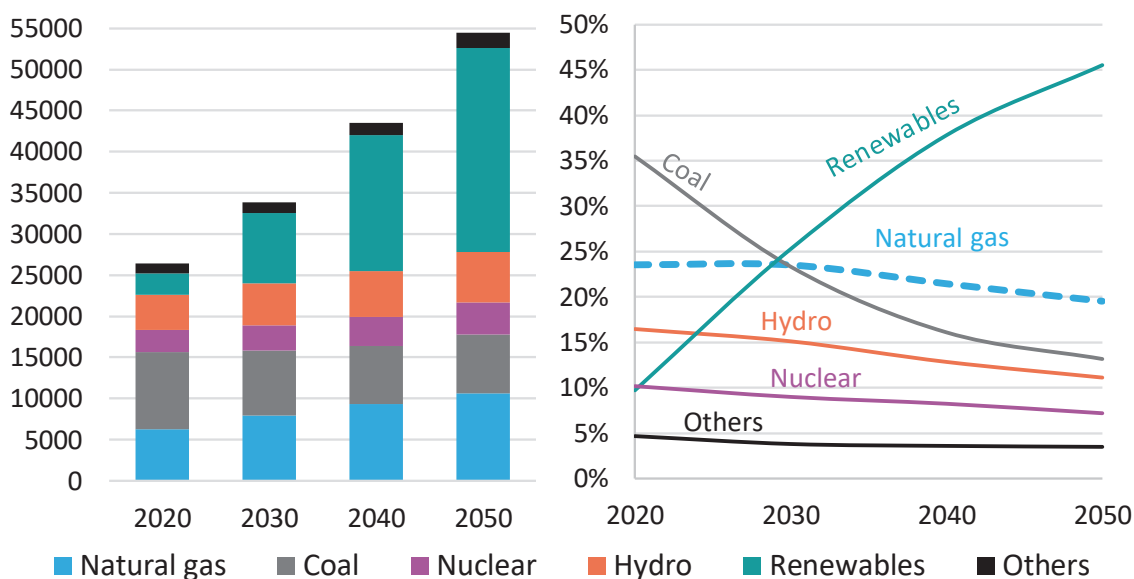
Note: 1) Gas demand in the heat generation is expected to remain flat; 2) Industry includes gas used as energy fuel and feedstock as well as for grey hydrogen generation and the production of liquid fuels; 3) Transport includes road transport and marine bunkers; 4) Other uses include gas demand for energy industry own use, for rail and pipeline transport.

The **power generation** sector will represent the largest growth engine thanks to the substantial rise in electricity demand as well as government policies and regulatory initiatives to phase out coal-fired capacity and nuclear power plants in some regions. In addition, with progressive solar and wind capacity additions, the need for flexibility as a pillar of electricity security will mount, and gas-fired power generation is expected to play a growing role in helping to balance variable renewables and providing stability of power systems. Batteries and demand-side response will cover part of that role, but they are unlikely to be able to offer long-duration and seasonal storage. In this context, dispatchable, low-emission generating capacities will become more central to the provision of system flexibility and gas-fired generation will remain the primary choice.

Overall, between 2020 and 2050, gas demand in the power generation sector will increase by 755 bcm (or by 55%) to 2,130 bcm by 2050. At a regional level, Asia Pacific and Africa will contribute the most to this growth, together accounting for more than 70% of the increase, although Latin America and the Middle East will also demonstrate a considerable rise. Europe will be the only region to experience an evident declining trend, however, gas in this sector will remain resilient in the coming decade, filling part of the gap left by retiring nuclear and coal capacities, but gradually falling thereafter as renewables growth strengthens.

Global electricity generation will more than double from 26,460 TWh in 2020 to almost 54,500 TWh. Simultaneously, the power generation mix continues to shift towards low-carbon sources. Assertive development of renewables will push their share from 10% in 2020 up to 46% by 2050, while the share of coal – the main fuel to lose ground – will fall from 35% to 13%. The shares of hydro and nuclear, despite output rising in absolute terms, will also decrease, although much less sharply, and will provide nearly 11% and 7% of the power generation mix respectively in 2050. In its turn, gas-fired generation, which will meet around 16% of rising electricity needs over the forecast horizon, will maintain its current share in the generation mix at 24% until the early 2030s, decreasing thereafter to 20% by 2050. In terms of gas-fired capacity additions, an expansion from 1,892 GW in 2020 to 3,170 GW by 2050 is forecast, given all the commissioning and retirements within the outlook period.

Figure 3.8. Global electricity generation growth (TWh) and fuel shares (%)



Source: GECF Secretariat based on data from the GECF GGM

Note: Others include oil, bioenergy and hydrogen. In the RCS, hydrogen-based generation is not deployed on a significant scale

In **industry**, gas demand is forecast to rise by 295 bcm (or by 30%) to 1,275 bcm by 2050, contributing 17% to global gas demand growth over the outlook period. Besides traditional drivers, such as continued industrialisation in developing countries and population growth, coal-to-gas switching will be the biggest opportunity for growth and policies to curb emissions will also be a strong catalyst, mainly in China and India. Natural gas is expected to retain its place as the key fuel suited for medium and high-temperature processes as well as a feedstock for manufacturing petrochemicals and chemicals. The growing availability of global LNG supplies will also support this trend. Among all the regions, Asia Pacific will represent more than 50% of growth in natural gas consumption in the industrial sector, followed by the Middle East and Eurasia markets, together responsible for around 40% of sectoral incremental volumes between 2020 and 2050.

Moreover, CCUS has a potentially powerful role to play as the optimal way to reduce emissions and to adapt to new environmental initiatives, such as the Carbon Border Adjustment Mechanism. Many core industries that use natural gas are assumed to start equipping themselves with CCUS, thereby enhancing the resilience of this fuel. The primary applications for CCUS will be in hard-to-decarbonise industries, such as steel, cement, glass and fertilizer, while the deployment of this technology at a much greater scale is expected in industrial clusters. It is worth adding that CCUS is already at the centre of decarbonisation strategies of a number of countries, especially in Northwest Europe, which are aiming to capitalise on their offshore geology to decarbonise key industries.



The **transport** sector will become the third-largest source of growth, accounting for 15% of incremental gas demand. The rise in demand in road and marine transport is projected to be particularly robust, growing by 270 bcm (or by 360%) to 345 bcm by 2050 on the back of policy initiatives aimed at abating emissions. The majority of gas demand growth will stem from the development of the global NGV market. Tougher rules imposed by the IMO on shipping will further increase gas consumption in this area, with shipowners already beginning to switch to LNG to reduce the carbon intensity of their fleets.

The bunkering infrastructure is responding dynamically to the expansion of the world's LNG-powered fleet and many more ports are projected to ensure refuelling capacity. Thanks to the combination of environmental advantages and increasing availability, the share of LNG in the global bunker fuel market will rise from 3% in 2020 to 32% by 2050. Accordingly, LNG demand in marine transport is forecast to reach 90 bcm by 2050. Hydrogen-based fuels are seen as the next generation fuel for shipping and will potentially start to penetrate the shipping sector after 2030. As it could take several decades for the fleet to move to zero-carbon fuels, LNG will continue to provide an efficient alternative to conventional fuels in the long-term.

Natural gas demand in road transport will rise by 190 bcm between 2020 and 2050. Favourable government policies, regulatory frameworks and the expansion of refuelling infrastructure will be driving forces. Implementation of forward-looking national or regional sales bans on new diesel or petrol vehicles for 2025-2050 will implicitly support gas mobility, despite the rapid penetration of EVs. However, there is a higher potential for uptake of NGVs expected in the heavy goods vehicle segment, where electric technologies cannot fit the specifics in the best way. In this context, anticipated restrictions on diesel truck movements in a range of countries and large cities open up prospects for CNG and specifically for LNG powertrains, capable of delivering lengthy driving ranges.

Blue hydrogen generation represents another major avenue for natural gas to expand. Currently, around 100 Mt of hydrogen (pure and in mixed form) is produced worldwide, with low-carbon hydrogen accounting for less than 2% of the total. Natural gas is the primary source of its generation, making up 60% of annual global hydrogen production. Apart from hydrogen's role in chemicals, refining and steel making, the hydrogen industry is in its infancy. However, more than twenty

countries have already declared corresponding strategies and roadmaps, enhancing efforts to scale up the deployment of low-carbon hydrogen to supply power generation, industrial, residential and transport consumption. Blue hydrogen is expected to play an important role, given its competitiveness, scalability and synergies with existing gas infrastructure.

Global hydrogen production will increase 2.7-fold to reach 270 Mt by 2050, mostly driven by rising consumption in industry (including as a feedstock) and the transport sector. In 2050, almost 60% of projected volumes will be provided by sustainable, low-carbon technologies with blue hydrogen achieving a 21% share. Growth potential will come from the development of an internationally traded hydrogen market (somewhat similar to that seen for LNG today), which will have implications on natural gas demand for blue hydrogen exporting countries. Substitution of grey hydrogen with blue hydrogen in existing industrial applications will also take place. Overall, gas demand for blue hydrogen generation is forecast to grow by 220 bcm between 2020 and 2050 and will develop in tandem with CCUS infrastructure development. Eurasia and Europe will be responsible for almost 70% of the total increase in sectoral gas demand, followed by North America and the Middle East.

In the **residential and commercial** sector, gas demand will rise by 120 bcm (or by 15%) to 935 bcm by 2050. The increase will be much less dynamic than in other sectors, as electrification, energy efficiency improvements, building retrofits and alternative heating options (such as biomethane, hydrogen or renewables) will limit the scope for gas to develop. A structural decline in consumption will be observed in Europe but will be largely offset by potential growth in other regions, primarily in Asia Pacific amid switching from coal and LPG, the development of city gas distribution and growing household connections.







4. NATURAL GAS SUPPLY OUTLOOK

KEY FINDINGS

- Natural gas is expected to become the dominant fossil fuel by 2050, given its position as the cleanest fossil fuel, when combined with CCUS and methane abatement technologies. Increased demand for hydrogen in the energy sector is also expected to enhance the role of natural gas.
- This report forecasts that global natural gas production will continue to rise by an average annual growth rate of 1.2%, from around 3840 bcm in 2020 to 5625 bcm in 2050. The Middle East will contribute the largest share of growth, accounting for almost 32% of the total change, followed by Eurasia, North America and Africa.
- Gas production in Africa is expected to increase by an annual average growth rate of 2.8%, from about 230 bcm in 2020 to about 520 bcm in 2050.
- Gas production in Asia Pacific will expand by 22% to reach around 815 bcm by 2050. However, the region's share of the global natural gas supply will reduce from 16% in 2020 to 15% in 2050. This is primarily due to a more significant expansion in other regions and a slower increase in Asia Pacific production in the period between 2040 and 2050 due to gas reserves constraint. The bulk of growth will be seen in China.
- Eurasia produced more than 850 bcm of natural gas in 2020, accounting for almost 22% of global production, of which 79% was sourced from Russia. The region is expected to add more than 480 bcm to its current production by 2050, mainly driven by Russia. Eurasian gas production is expected to increase at an annual average growth rate of 1.5% for the period between 2020 and 2050.
- Europe is the only region in which natural gas production will fall over the next three decades. The most significant fall will be seen in Norway, where production will decline by around 65 bcm, followed by the UK (-33 bcm) and the Netherlands (-23 bcm). Regional production will fall from 200 bcm in 2020 to 155 bcm in 2030, 115 bcm in 2040 and then to 85 bcm in 2050.
- With almost 17% of global gas production, the Middle East is the third-largest gas producing region worldwide after North America and Eurasia. Rapid growth in Iran, Qatar and Saudi Arabia will lead to an average growth rate in the region of 2.0% per annum between 2020 and 2050, with supply reaching 795 bcm in 2030, 955 bcm in 2040 and 1180 bcm in 2050.
- North America produced more than 1100 bcm in 2020, accounting for almost 30% of global production. The region is expected to display the largest overall level of natural gas production compared to other regions
- Globally, deepwater offshore production is expected to grow particularly strongly, contributing more than 1,000 bcm of annual output by 2050 – an almost fivefold increase compared to current levels, with significant contributions from Australia, Mozambique and Egypt. In contrast, conventional associated gas is expected to decline from a 12% share of global gas production in 2020 to around 7% in 2050 as oil production peaks and then declines. The share of unconventional gas is expected to rise from 25% to 30% in 2030 before levelling off and remaining at that level.
- Most GECF countries will maintain or expand their gas production capacity over the outlook period. We expect that total gas production from current GECF members will increase by more than half, reaching approximately 2,600 bcm by 2050. This translates to a 1.4% annual growth rate over the outlook period, which will enable the GECF to keep its share of global gas production at around 47%.

4.1 GLOBAL NATURAL GAS PRODUCTION OUTLOOK

Maintaining and expanding demand is the main driver for the supply of any fuel, and natural gas is no exception. The economic utilisation of natural gas in many sectors such as industry, power and construction will sustain its role in becoming the dominant fossil fuel in the entire energy system through to 2050. Other significant drivers will pave the way for natural gas to maintain its position. Its position as the cleanest natural fossil fuel coupled with other measures to reduce its carbon footprints, such as CCUS and methane leakage abatement technologies, are creating the policy support which will enhance the role of natural gas. Hydrogen, a promising fuel for the future energy mix, is another expected development in the energy sector in which natural gas is assumed to play a role. Blue hydrogen is a very economical fuel and a solution for decarbonising hard-to-abate sectors while simultaneously being a pathway to decarbonising natural gas's abundant resources.

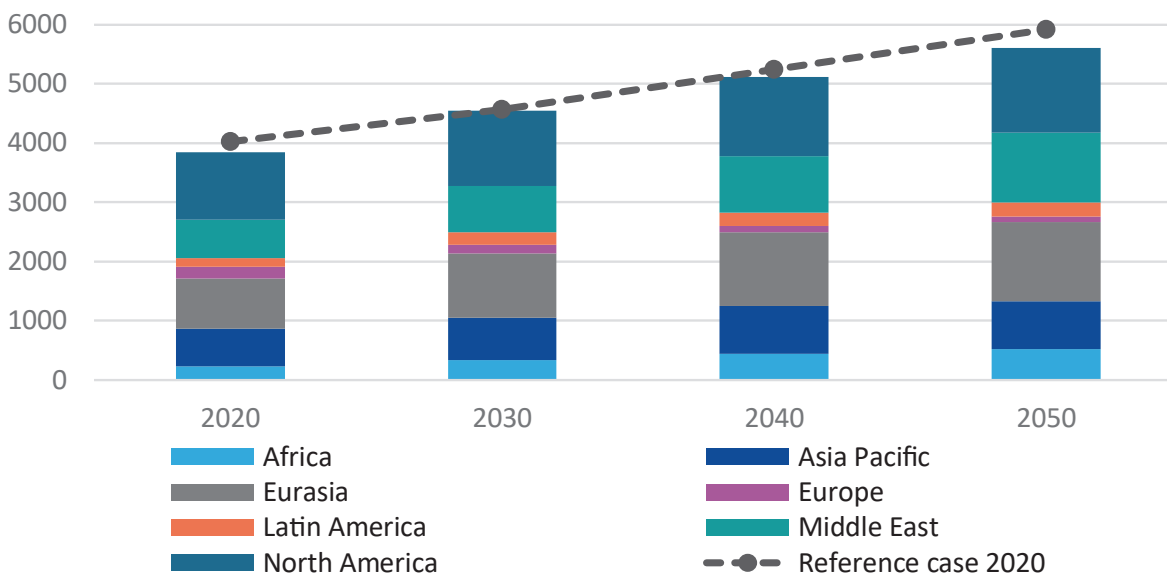
Apart from the expansion in natural gas demand which is the main stimulus for natural gas production, the economic benefits of natural gas, technological enhancements and resource readiness are also among the main drivers in global natural gas production. Advances in deep-water offshore output, unconventional production with a lower carbon footprint and economical extraction of remote reserves will maintain the level of extractable resources and consequently increase the level of available gas.

In terms of offshore production, it is forecast that around 43% of total natural gas production will be sourced from offshore reserves by 2050, compared to the current share of almost 29%. This edition of the GECF GGO forecasts that production from deep-water fields will contribute almost one tcm of annual output by 2050, an almost fivefold increase from current levels. Accordingly, the share of deep-water production will reach almost 17% by the Outlook horizon compared with the current share of 6%. In particular, India and Indonesia are expected to source the bulk of their expansion in natural gas production from deep-water fields. Deep-water production is also responsible for the upbeat forecast in natural gas production in Mozambique.

Production from the arctic area is also forecast to continue with the bulk of production coming from Russian arctic regions. According to the modelling analysis results for this Outlook, in the 2040s, more than 600 bcm of natural gas will be extracted annually by Russia from its arctic area. Unconventional natural gas production in the Reference Case Scenario is also forecast to be strong, mainly as a result of shale gas production that will be discussed further in the document.

Advancement in technologies to abate methane emissions, the most critical drawback of natural gas, as well as improvements in CCUS through growth in economies of scale and the introduction of cleaner pathways for natural gas use (such as blue hydrogen), will maintain the role of natural gas by 2050. However, with emerging zero-carbon policies and pledges for carbon neutrality, the demand for natural gas and, consequently, its production is forecast to some extent lower in this edition of the Outlook compared with the previous one.

Figure 4.1. Outlook for global natural gas production (bcm)

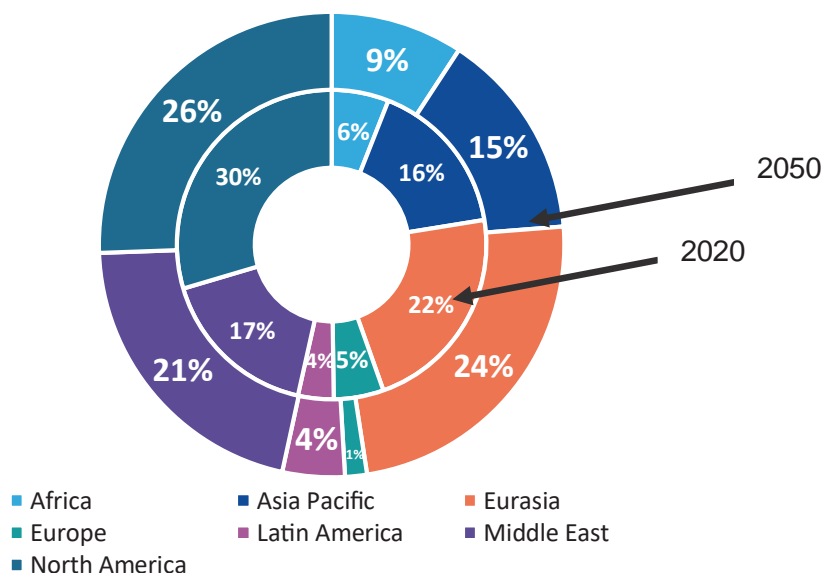


Source: GECF Secretariat based on data from the GECF GGM



This report forecasts that global natural gas production will continue to rise by an average annual growth rate of 1.2% from around 3840 bcm in 2020 to 5625 bcm in 2050. The Middle East will contribute the largest share of the growth, accounting for almost 32% of the total change, followed by Eurasia, North America and Africa. Similar to the previous edition of the Outlook, Europe is the only region to record a negative contribution to the global gas growth amounting to 7%.

Figure 4.2. Regional share in global natural gas production (bcm)



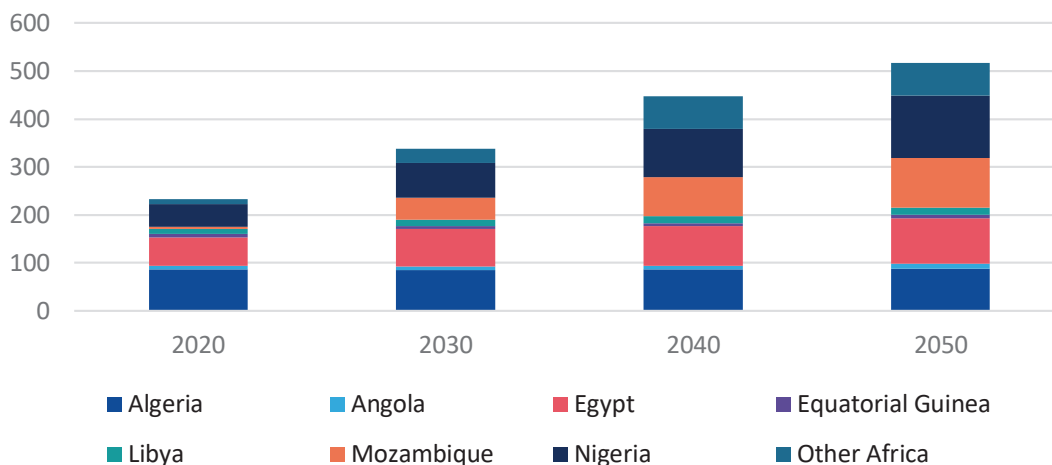
Source: GECF Secretariat based on data from the GECF GGM

4.2 REGIONAL NATURAL GAS PRODUCTION OUTLOOK

Africa

Natural gas is Africa’s greatest opportunity, not just as a transition fuel to a green economy but also as a long-term solution for energy supply. The continent is the fastest-growing region for natural gas production. Much of this expansion originates from production developments for LNG exports in three projects in Mozambique and Nigeria’s LNG (NLNG) Train 7 project, as well as the joint offshore development in Mauritania and Senegal, in addition to production from North African countries

Figure 4.3. Outlook for Africa natural gas production (bcm)



Source: GECF Secretariat based on data from the GECF GGM

such as Algeria and Egypt to support their domestic market growth. Africa has stepped up exploration activities despite a global downturn in oil and gas production and investment.

This report estimates gas production in Africa will increase by an annual average growth rate of 2.8% from about 230 bcm in 2020 to about 520 bcm in 2050.

Asia Pacific

Asia Pacific has enhanced its position in global gas production and in 2020 produced almost 16% of the total global gas supply, of which half was sourced from China and Australia. Other countries such as Indonesia, Malaysia, Pakistan, Thailand and India are also significant contributors to the current production picture in the region.

Asia Pacific gas resources, specifically in its established gas producers such as Indonesia and Malaysia, are comparatively mature. Subsequently, the expansion potential for gas production within the region is not particularly significant except for China and India. In terms of these countries, we forecast an aggregated expansion of around 240 bcm, which will contribute to more than 87% of the incremental gas supply volume in the region by 2050. Other incremental expected volumes come from Indonesia, Vietnam and Australia, while other countries such as Malaysia, Thailand, Pakistan and Bangladesh are expected to show lower gas production by 2050, primarily due to an inadequate level of economic reserves or field maturity.

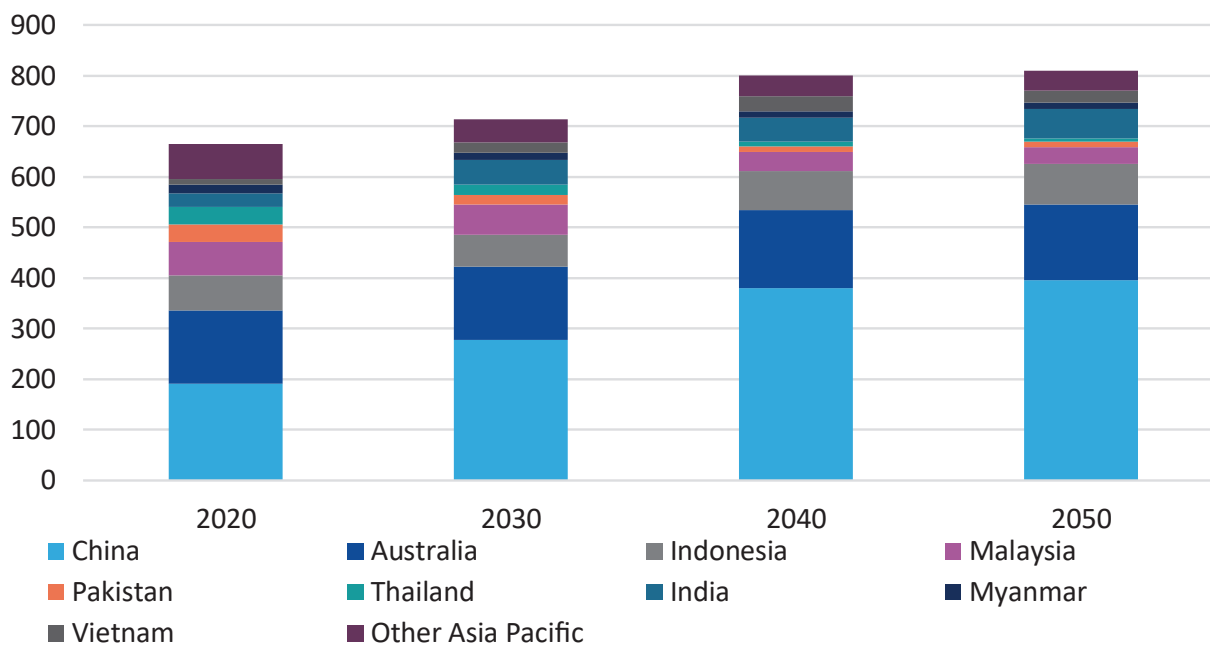
Unconventional production is one of the backbones of production growth in Asia Pacific region. It is expected that more than 310 bcm of annual natural gas production will be extracted from almost all known forms of unconventional resources such as shale gas, tight sands and coalbed methane (CBM) by 2050.

Australia and China are the main suppliers of CBM, referred to in Australia as coal seam gas. However, CBM production in Australia's Queensland is forecast to see a downward trend, but China will offset this reduction, and together with a slight addition from Indonesia, this type of production is forecast to increase by around 15 bcm in total.

Besides CBM, China will also emerge as a significant supplier of the other types of unconventional gas. Around 130 bcm of shale gas and 100 bcm from tight gas are expected to come to the market in China. Overall, China will be the source of more than 85% of total unconventional production and be responsible for almost half of the entire output in Asia Pacific by 2050.

According to modelling results based on the quantity of reserves and their signature profiles, most of this expansion will take place up until 2040, after which a slight reduction or stable production level is seen in most countries in the region.

Figure 4.4. Outlook for Asia Pacific natural gas production (bcm)



Source: GECF Secretariat based on data from the GECF GGM

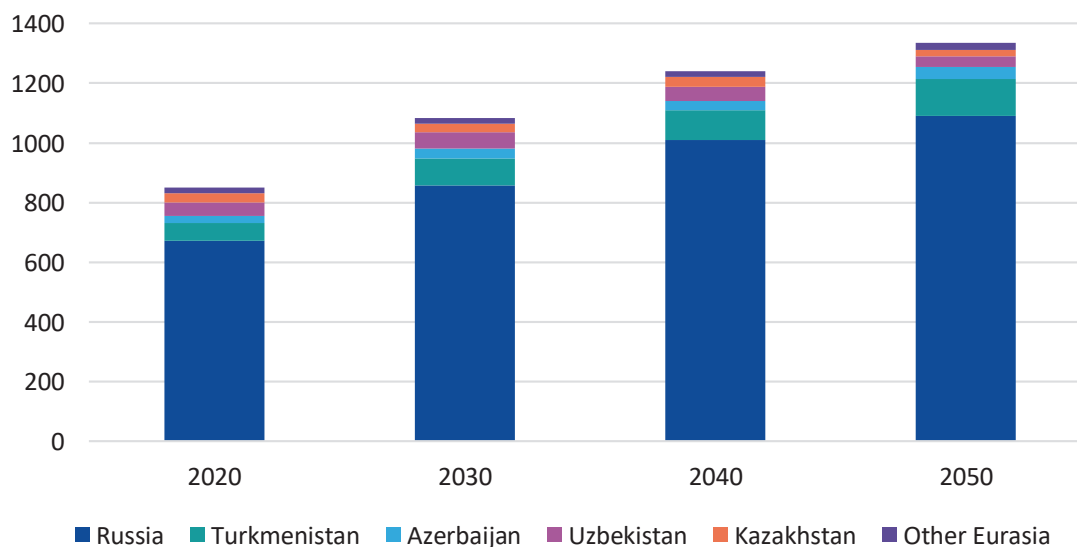
This report expects that gas production in Asia Pacific will expand by 22% to reach around 815 bcm by 2050. However, the region's share of the global natural gas supply will reduce from 16% in 2020 to 15% in 2050. This result is primarily due to a more significant expansion in other regions and only a mild increase in Asia Pacific production in the period from 2040 to 2050 due to the reserves constraint.

Eurasia

Eurasia produced more than 850 bcm of natural gas in 2020, which accounted for almost 22% of global production. Russia sourced more than 79% of the region's gas production in 2020, while other countries, including Turkmenistan, Uzbekistan, Kazakhstan and Azerbaijan, contributed 7%, 5%, 4%, and 3%, respectively. Russia, Turkmenistan and Azerbaijan are forecast to increase their level of gas production over the outlook period, while the level of gas production in Kazakhstan and Uzbekistan is expected to reduce slightly after 2040. The region is expected to add more than 480 bcm to its current production, driven by Russia which will contribute more than 85% of this expansion, expected to total around 410 bcm by 2050. Eurasian gas production is expected to increase at an annual average growth rate of 1.5% for the period between 2020 and 2050.

The main drivers behind the growth are the development of demand markets such as China and niche markets in Asia that will stimulate production, along with pipeline exports from countries in the region. LNG development in Russia will also bring export opportunities that will unlock some fields, for example in the Arctic, and will support the expansion in Russia's gas production.

Figure 4.5. Outlook for Eurasia natural gas production (bcm)



Source: GECF Secretariat based on data from the GECF GGM

Europe

Natural gas production in Europe peaked in 2004 at around 322 bcm and since then has exhibited a declining trend. In 2020 the continent produced about 200 bcm of gas, of which 85% was supplied by Norway, the UK and the Netherlands.

In the Netherlands, production from the Groningen gas field, which provided the main supplies of gas for Europe for decades, has declined from over 50 bcm in 2013 to about 9 bcm in 2020. The full closure of the field, which is expected to happen between 2025 and 2028, is estimated to leave more than 450 bcm of gas in the ground.

The UK's natural gas production is also in long-term decline. Ageing infrastructure in the North Sea, a government policy that is encouraging green energy, climate change and net-zero targets are the main drivers of the decline in the UK.

Additionally, last July, the European Commission (EC) released its 'Fit for 55' package legislative proposal, aimed at reducing GHG emissions by 55% by 2030 versus 1990 levels, and it is expected that the 'Fit for 55' proposals will have an impact on gas production in Europe. As an illustration, since natural gas extraction is not included in the carbon leakage list for the

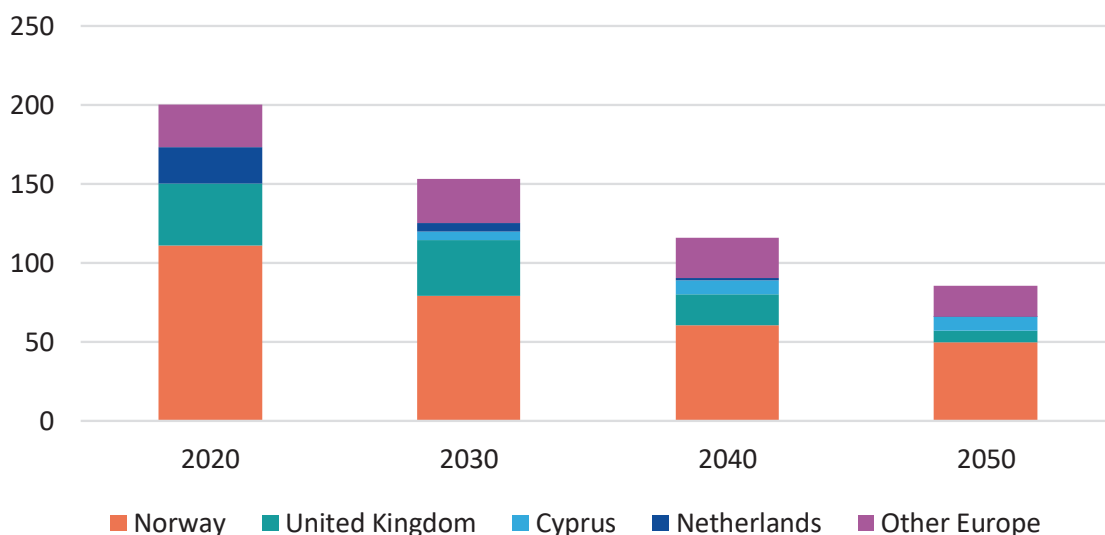
2021-2030 period in Phase 4 of the proposal, free carbon allowances will be phased out for gas, which could add additional costs for operators making gas more costly for producers and final consumers. The phasing-out of free allowances for gas producers comes at a time when carbon prices under the EU Emissions Trading System (ETS) reached more than EUR 64/tonne in October 2021.

A similar principle of free carbon allowances will be amended in the UK ETS system as well. Therefore, gas producers in the North Sea and the Black Sea will have to purchase more permits to offset their CO₂ emissions, taking into account that prices on the UK ETS reached more than £75 (around EUR 88) per tonne in September 2021.

Consequently, Europe is the only region in which natural gas production will fall over the next three decades. The most significant fall in natural gas production by 2050 will be seen in Norway, where production will fall by around 65 bcm, followed by the UK (-33 bcm) and the Netherlands (-23 bcm).

Over the medium- to long-term, the EU will continue to invest in infrastructure that enables clean gas, such as blue hydrogen and biomethane for its energy sector. However, as mentioned above, it is forecast that natural gas production in Europe will fall between 2020 and 2050 by an annual rate of 2.8% on average, to 155 bcm in 2030, 115 bcm in 2040, and then to 85 bcm in 2050.

Figure 4.6. Outlook for Europe natural gas production (bcm)



Source: GECF Secretariat based on data from the GECF GGM

Latin America

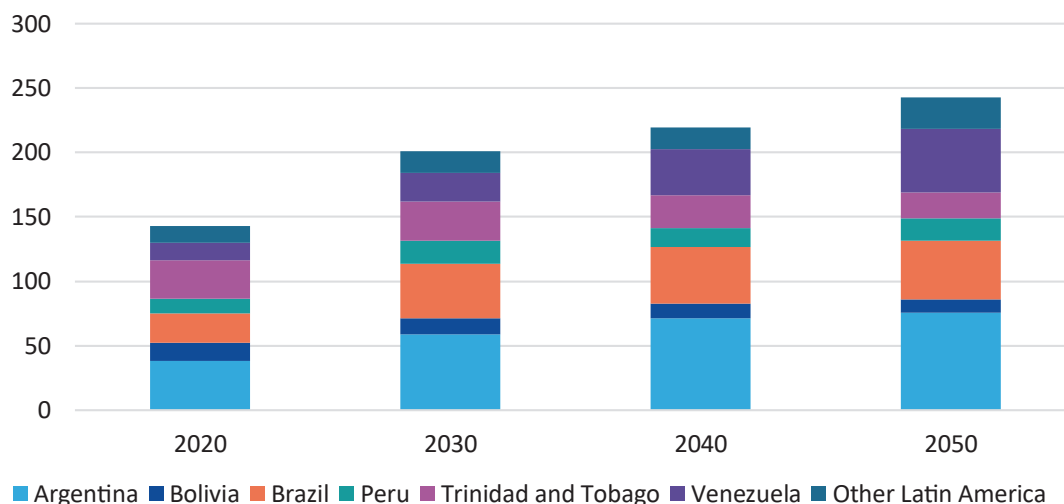
Natural gas production in Latin American countries amounted to about 150 bcm in 2020, down from 175 bcm reported a year earlier due to the COVID-19 pandemic. However, between 2000 and 2020, gas production has increased by 50% overall. Due to the enormous volume of unexplored gas resources, the region has a promising future for natural gas supply. Almost all types of gas, including shale gas, tight gas, CBM and conventional resources, are contained within the region.

In Argentina, after the decline in gas production in 2020, it is expected that its series of Gas Scheme Rounds will support the supply recovery over the mid-term. In the longer term, a stable system of legislation, the ability to enter into long-term sales agreements and defined pricing policies will drive production growth.

Venezuela's natural gas reserves are the biggest in the region, and among the world's largest proven reserves as well. However, the lack of investment and the economic situation are reflected in Venezuela's low domestic gas production.

Over the long term, the start-up of major gas fields will drive the gas market in the region. The key to effectively developing assets is to expand the transmission pipeline infrastructure and improve policy and market conditions. This report forecasts that between 2020 and 2050 natural gas production in the region will increase by an annual growth rate of 1.6% on average to 200 bcm and 245 bcm in 2030 and 2050, respectively.

Figure 4.7. Outlook for Latin America natural gas production (bcm)



Source: GECF Secretariat based on data from the GECF GGM

Middle East

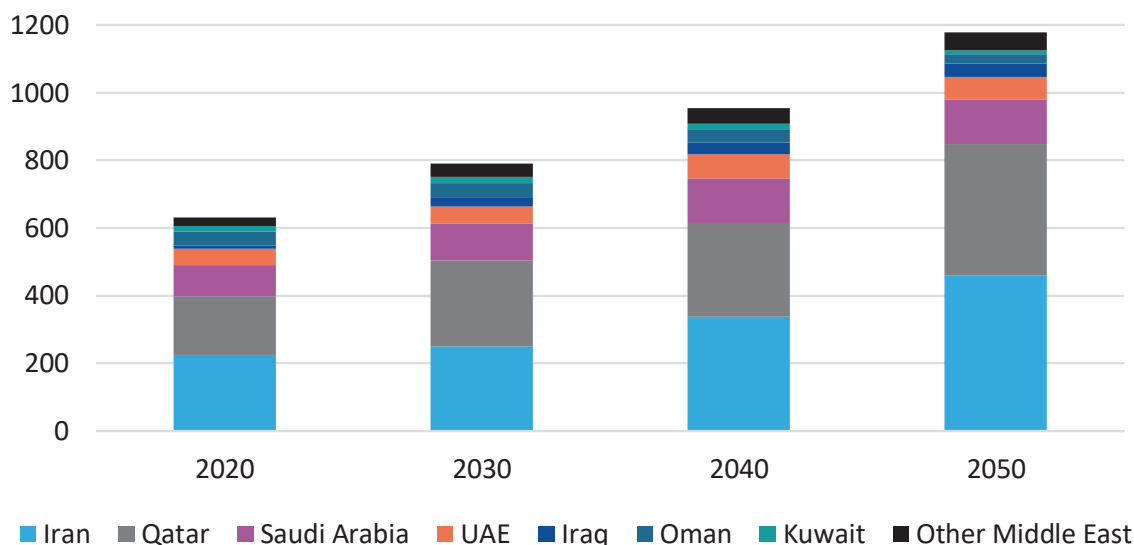
With almost 17% of global gas production, the Middle East is the third-largest gas-producing region worldwide after North America and Eurasia. The region is a net exporter of gas, and supply has been growing rapidly by an annual average growth rate of 6.3%, from about 190 bcm in 2000 to around 650 bcm in 2020.

Iran, Qatar and Saudi Arabia are the bright spots for Middle Eastern gas output over the next three decades. Between 2020 and 2050, the natural gas supply is set to climb by an annual average growth rate of 2.4% in Iran, 2.2% in Qatar and 1.2% in Saudi Arabia.

National oil companies in the Middle East are focusing on developing their gas fields. As most of the countries in the Middle East are also crude oil producers, the majority of natural gas production in the region is associated gas.

Qatar aims to maintain its status as the top LNG producer and exporter in the world. The planned expansion of production from the North Field and other fields will increase Qatar's total gas production by an overall of 91%, from about 175 bcm last year to 330 bcm in 2050.

Figure 4.8. Outlook for the Middle East natural gas production (bcm)



Source: GECF Secretariat based on data from the GECF GGM

In Saudi Arabia, crude oil and natural gas together will account for 85% of the country’s energy mix in 2050. Saudi Arabia is looking to attract more foreign investment to develop its non-associated and shale gas resources, including the 2.2 Bcf/d Jafurah Basin gas megaproject.

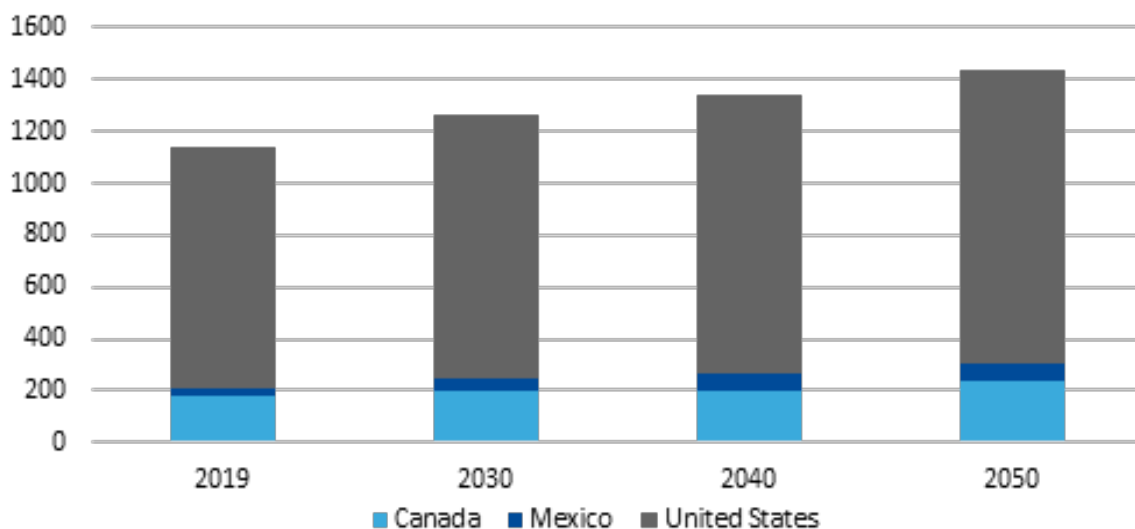
The UAE aims at ensuring gas self-sufficiency and the Abu Dhabi National Oil Company (ADNOC) is tapping its unconventional new reservoirs and sour gas fields, such as Abu Dhabi’s off-shore Hail and Ghasha resources to meet its target. Additionally, by leveraging the existing gas infrastructure and its CCUS capabilities, ADNOC plans to produce blue hydrogen from its industrial hub in Ruwais by 2025.

Iraq is seeking to spend USD 15 bn to increase its gas output. As part of the Gas Master Plan, the country will develop its associated gas resources from the Basrah Gas Gathering project, the gas from which is currently mostly being flared. The project is looking to produce 2 bscfd from gas flared by 2025, primarily from three oil fields, namely Rumaila, Zubair and West Qurna Phase 1.

Backed with a huge level of gas resources and the potential for gas exports along with ongoing increasing demand, the outlook for this region has always been promising, and the latest results from the GECF GGM were no exception.

This report forecasts that natural gas production in the Middle East will grow by an average growth rate of 2.0% per annum between 2020 and 2050, to 795 bcm in 2030, 955 bcm in 2040 and 1180 bcm in 2050.

Figure 4.9. Outlook for North America natural gas production (bcm)



Source: GECF Secretariat based on data from the GECF GGM

North America

The region tops the list of gas-producing regions, and North America produced more than 1100 bcm in 2020, accounting for almost 30% of global production. During 2019, North America added nearly 80 bcm to its gas output due to the commissioning of new export facilities and pipeline expansion from several production points to consumption centres, but in 2020, the region’s production dropped by about 20 bcm. This fall was primarily due to the COVID-19 pandemic and lockdown and was seen in all three producing countries in the region, namely, the US, Canada and Mexico. In the US, for example, the fall in the oil price during 2020 coupled with COVID-19 negatively impacted the country’s main producers. Tight oil producers slowed down their upstream activity by reducing the number of drilling rigs, with a resultant decline in associated gas production.

Since the collapse in fuel prices, most gas producers in Canada have significantly reduced their drilling activity levels, with only a few examples, such as the Montney formation, of producers maintaining their drilling activities. However, this impact has not lasted long, and the market turned bullish in 2021, resolving the issues.

Figure 4.9 illustrates the production outlook for North America. Canada, the US and Mexico are all expected to contribute positively to the expansion of gas production in the region. In the US and Canada, the main driver of expansion is the development of LNG export facilities as well as pipeline infrastructures that enable the countries to transport natural gas from producing areas to the consumption centres or export trains.

The region is expected to display the largest value of natural gas production compared to other regions over the outlook period, with more than 560 bcm of natural gas expected to be added to the region’s annual production. This means production will reach more than 1,670 bcm by 2050.

4.3 OUTLOOK FOR THE CHANGING PROFILE OF GAS PRODUCTION RESOURCES

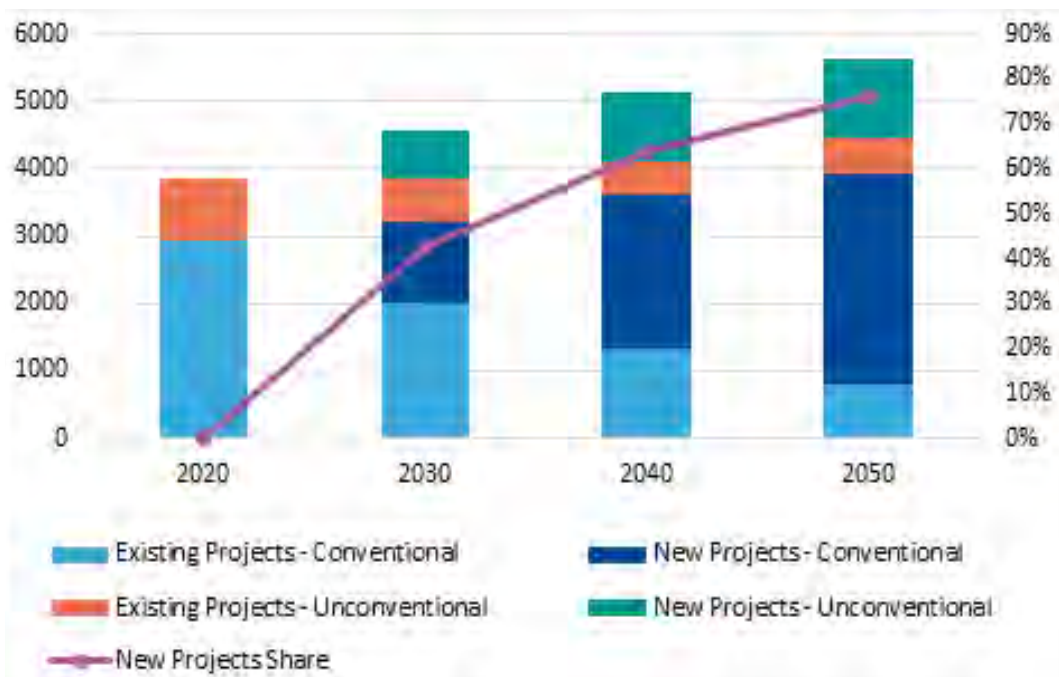
Production from YTF resources and new projects

The role of YTF resources in the natural gas production outlook is very significant. It is forecast that more than 31% of total production by 2050 will be sourced from gas resources that have not yet been categorized as proven reserves (YTF). This indicates that the gas industry needs to lead exploration projects to discover reserves to avoid facing a volume of reserves insufficient to meet the global gas demand and implies that the current level of proven reserves is not adequate to furnish rising demand.

Leading discovery projects is needed, but the discovered and YTF resources need to be explored and come into production over the medium-term; otherwise, there will be a lack of supply and feed gas for LNG infrastructure.

This Outlook expects that around 76% of global gas output in 2050 will be sourced from new projects, and this considerable share highlights the importance of investment in upstream and all aspects of the supply chain for natural gas.

Figure 4.10. Outlook for global natural gas production by project status and type of resource (bcm, %)



Source: GECF Secretariat based on data from the GECF GGM

Offshore and onshore production

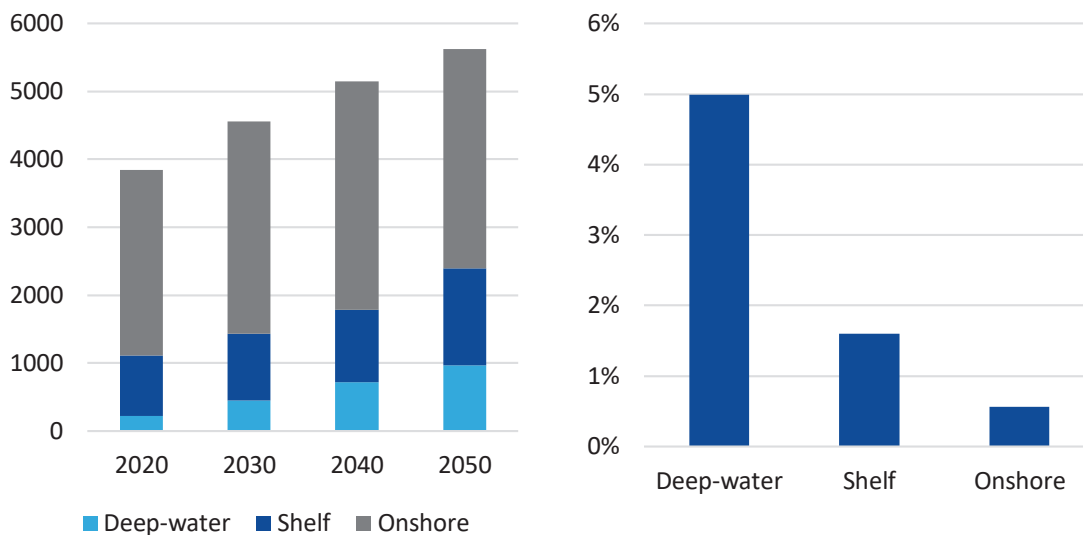
With the enhancement of upstream technologies as well as technologies for monitoring, communication, process and operation control and logistic support, the level of offshore gas production is presumed to increase over the outlook horizon. It is estimated that more than 26 tcm of proven reserves are located offshore in deep-water areas, of which approximately 4 tcm have already been under exploration. There are additional sanctioned projects which will target another 2 tcm of natural gas out of the total proven reserves. The remaining 20 tcm gas reserves in deep water are forecast to be developed by the sanctioning of new projects over the outlook period.

There are also significant levels of YTF reserves estimated to be lying in deep-water locations in remote areas that remain

untouched and even undiscovered. YTF gas resources in deep water areas are estimated at around 80 tcm. The huge potential of this reserve will be unlocked by advancement in various technologies such as discovery methods, advanced floating platforms, IT, etc.

It is forecast that the level of deep-water production will increase from almost 220 bcm in 2020 to almost 1 tcm by 2050, which amounts to 17% of total production. Total annual offshore natural gas production will more than double from 1.1 tcm in 2020 to around 2.4 tcm. The share of offshore natural gas production as a total of overall production is expected to reach 43% compared with the current 29%.

Figure 4.11. Off-shore and on-shore production outlook (bcm) and their CAAGR (%)



Source: GECF Secretariat based on data from the GECF GGM

The annual growth rate of production from deep-water fields is forecast to be 5% per annum in the period between 2021-2050 compared with 1.6% for shallow-water offshore production and only 0.6% in the case of extraction from onshore reserves.

The most significant contributors to deep-water natural gas production include Australia, Mozambique and Egypt, with each of these countries expected to produce around 100 bcm of natural gas annually from this type of terrain by 2050. Other countries also have the potential to develop their deep-water sources, such as Nigeria, Indonesia, Brazil, etc. Currently, Norway is the largest deep-water natural gas producer with a level of around 65 bcm. However, Iran and Qatar have seen the most significant level of annual off-shore production (shallow-water).

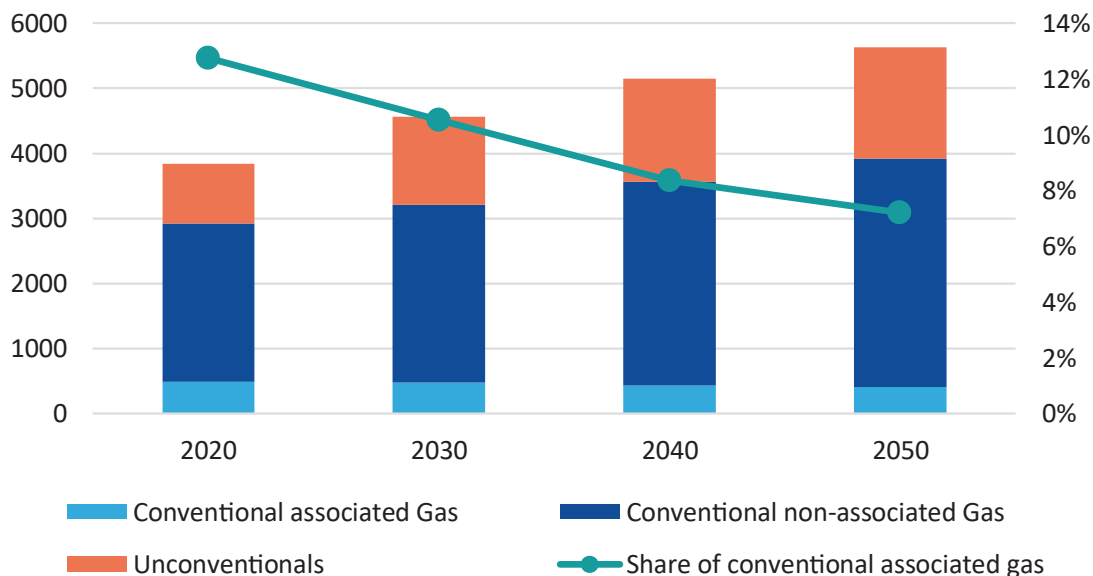
Outlook for associated gas production

Associated-dissolved natural gas (gas obtained from crude oil reservoirs) has always been accounted for as a share of total gas production. This gas can be found as free gas (associated) or in solution with crude oil, referred to as dissolved gas. Like the impact that COVID-19 had on non-associated gas production, the demand for oil also declined in 2020, resulting in a lower level of associated gas production in that year. According to the EIA, associated gas production in the US fell in 2020 by 1.5% reaching a level of around 140 bcm, following three years of growth. For the first time since 2016, the share of associated gas production in the US was reduced to almost 37.7%.

As mentioned in the previous chapter, this report forecasts that the demand for oil will stabilise through to 2050 and the level of global oil production will peak at slightly more than 100 mboe/d in around 2035 and will steady at around 90 mboe/d by 2050. This lower level of crude oil production will consequently affect the level of associated gas production. Furthermore, the need for EOR measures by the injection of associated gas into oil wells will be magnified by the ageing oil reservoirs. So a lower level of associated gas will reach the market, and the total volume of production from this category in the future is forecast to be lower than current levels.

Currently, it is estimated that slightly less than 500 bcm of marketed natural gas is sourced from oil wells, and this level excludes the volume of the gas obtained from unconventional crude oil production. The total level of associated gas production is even higher than this, as injection and recirculation do not count in marketed production.

Figure 4.12. Outlook for associated and non-associated gas production (bcm, %)



Source: GECF Secretariat based on data from the GECF GGM

This Outlook projects that the level of associated gas will decline to around 400 bcm, which will contribute to about 7% of total gas production by 2050 compared with the current approximate 12%.

Russia, Saudi Arabia, the US, Brazil, Nigeria, UAE, Venezuela, Mexico, Indonesia and Kazakhstan are among the main contributors to associated gas production.

Unconventional gas production outlook

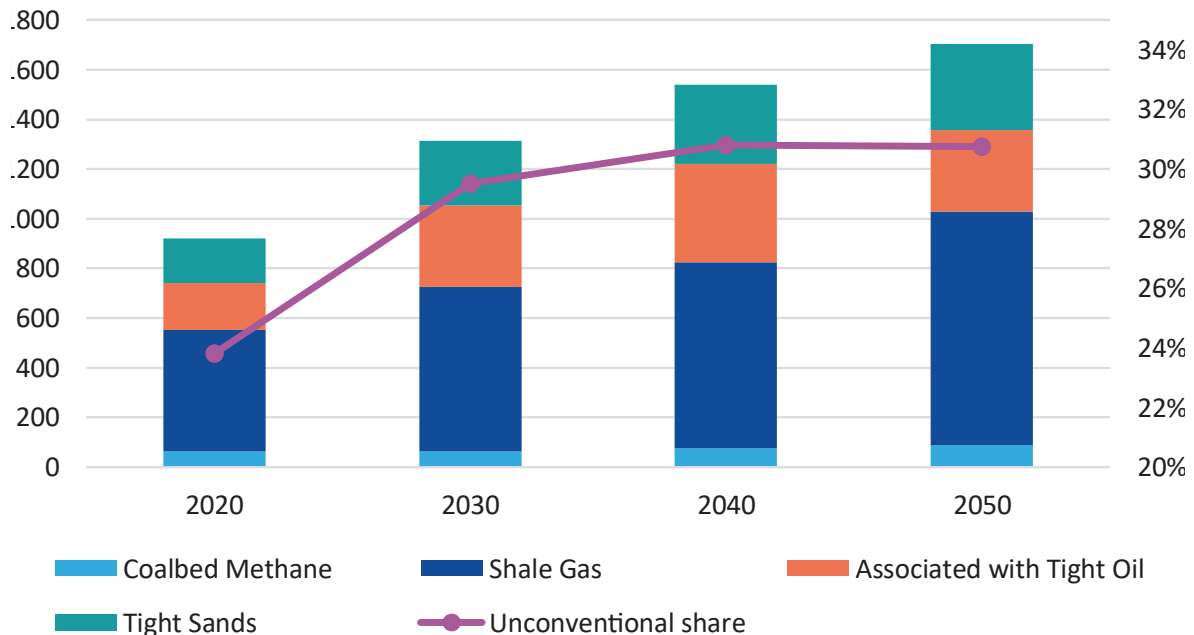
In recent decades, the advancement in upstream technologies such as horizontal and directional drilling, logging while drilling (LWD) and hydraulic fracturing have positively impacted the production level of almost all types of unconventional resources.

Progress in shale gas extraction, as well as other types of unconventional gas resources, has resulted in a considerable reduction in production costs across the entire production chain. Currently, almost one-quarter of total gas production is sourced from unconventional resources, and this share is forecast to level out at 30%, a number which is 4% lower than our previous forecast. In terms of the absolute volume of unconventional production, it is predicted that around 1700 bcm of natural gas from all known types of unconventional resources will be produced annually by 2050. This forecast is almost 300 bcm lower than our previous forecast published in 2020.

The drivers behind this lower forecast include an overall lower projection for gas production compared with last year report's due to the efforts and policies for decarbonisation and, to a lesser extent, due to the delay in exploration and development of projects as a result of the COVID-19 pandemic.

There are other concerns, such as water contamination and air pollution in shale gas production due to the injection of chemicals into the underground reservoirs during the drilling process. Natural gas or methane emissions and other gasses that are released into the atmosphere are also barriers to unconventional development that are currently being widely debated. Considering the announced strategies and policies which are growing around decarbonisation and achieving carbon neutrality which are expected to reduce fossil fuel production, the future for unconventional resources with regards to their higher level of imposed contamination is uncertain. Nevertheless, this Outlook is based on the current technological situation and markets as well as assumptions for the future which still predict a strong role to play for unconventional production; however, it is more pessimistic than our previous forecast.

Figure 4.13. Global conventional and unconventional gas production (bcm, %)



Source: GECF Secretariat based on data from the GECF GGM

Shale gas development is the main factor behind unconventional expansion over the outlook period. Production from shale plays has been developing in the last decade, especially in North America. China is expected to join the US as a significant producer of shale gas, and we forecast that China will pass the level of 125 bcm per year of production from its shale plays by 2050, followed by Argentina and Mexico. The US will remain the largest shale gas producer with a significant level of around 650 bcm per year by 2050.

Production from tight sands (or tight gas) is also forecast to more than double by 2050 reaching 360 bcm per year, with meaningful contributions from Canada and China. Over the forecast period, Canada is assumed to contribute well over half of total tight gas production; in 2050, the country is forecast to produce 205 bcm per year.

Natural gas output from unconventional oil production, referred to as tight oil in this report, will also be enhanced, predominantly by the US. However, this expansion peaks around the year 2040 at a level of 400 bcm per year due to the stabilisation of oil production in the last decade of the forecast period (the 2040s). Natural gas production from unconventional oil plays will be reduced and level out at around 330 bcm per year by 2050.

Production from coalbed methane (CBM) is also forecast to grow slightly and maintain a level of around 85 bcm per year, with production dominated by China and Australia. Currently, Australia is the largest producer of CBM, but over the forecast period, China will enhance its position to become the largest CBM producer, while Australia is forecast to halve production of this unconventional type of gas by 2050.

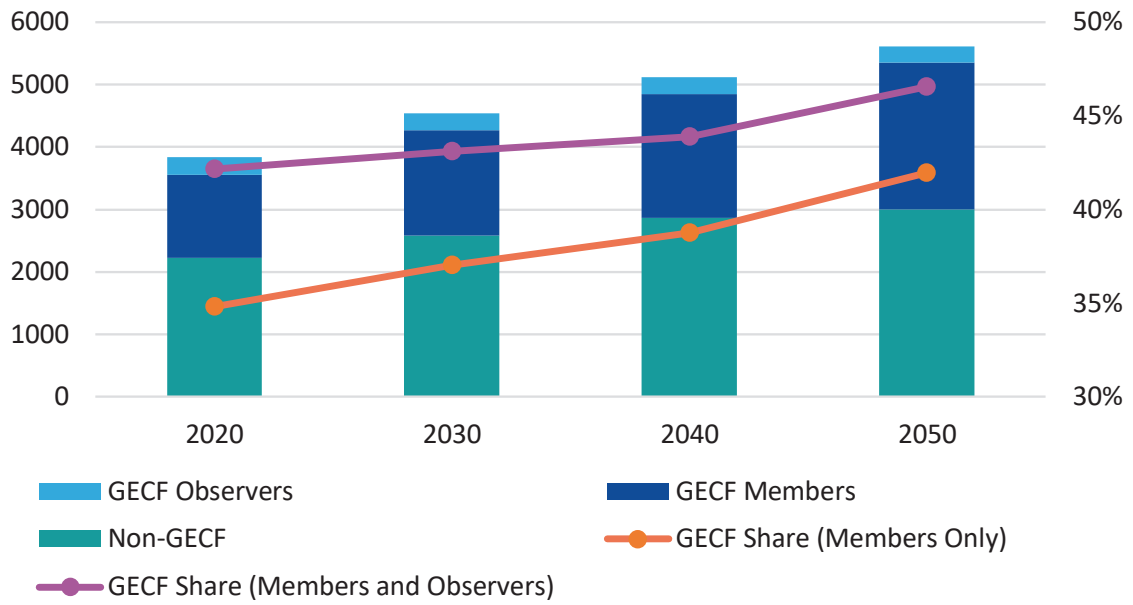
4.4 GECF COUNTRIES' GAS PRODUCTION OUTLOOK

Most GECF Countries will maintain or expand gas production capacity over the outlook period. We expect that total gas production from current GECF members will increase by more than half, reaching approximately 2600 bcm by 2050. This translates to a 1.4% annual growth rate over the outlook period, which will enable the GECF to keep its share of global gas production at around 47%.

Russia (41%), Iran (26%), Qatar (24.2%) and Nigeria (9.7%) are expected to be the largest contributors to incremental gas production volumes. Russia and Algeria are expected to contribute the most to unconventional gas production.

The Outlook also expects development in natural gas production among observer members. Iraq is expected to add more than 30 bcm in annual production by 2050, compared with 11 bcm currently, while Iraq will contribute around 7% to the GECF's total incremental gas production over the forecast period. Azerbaijan and Kazakhstan are also forecast to increase their gas production by 2050.

Figure 4.14. GECF Countries' gas production outlook (bcm)



Source: GECF Secretariat based on data from the GECF GGM







5. GAS TRADE AND INVESTMENT



KEY FINDINGS

- The global gas trade is expected to grow by 45% by 2050, at 1.5% per annum between 2020 and 2050 to reach 1,815 bcm and account for 1/3 of global gas demand.
- Regional natural gas markets are expected to become more integrated, interconnected and global over the long run.
- Global liquefied natural gas (LNG) trade will be the key driver underpinning natural gas exports, accelerating even more, compared to the previous forecast, overtaking pipeline trade before 2030 to reach 845 mt (1,150 bcm).
- Asia Pacific, the main destination of the world's LNG at present and by 2050, will represent the largest transformational challenge for the currently fragmented natural gas market. Asia Pacific with 70% share of LNG trade in 2020 will make up an even more impressive over 80% by 2050.
- Unsurprisingly, the top four largest LNG importers have emerged in Asia Pacific. China will become the biggest LNG importer in the near future, overtaking Japan as the leader in the consumption of liquefied gas, followed by South Korea and India. By 2050, the top four importers will remain the same, although India will overtake South Korea and Japan to become the number two LNG importer by 2050.
- Pipeline trade will see relatively modest growth, mainly due to a shift in the export focus from European to Asian markets, and the ramping up of exports from Russia and Turkmenistan to China.
- Trade of carbon-neutral LNG could play an important part in determining the role of natural gas in the energy transition.
- Between 2020 and 2050, total estimated upstream and midstream natural gas investment will decelerate slightly to USD 8.7 trillion (USD 1.3 trillion lower) due to lower global natural gas demand growth, resulting in 300 bcma less consumption by 2050 compared to the 2020 GECF GGO forecasts.
- The lion's share of the investment allocation will take place in upstream natural gas, streamlined mainly to Asia Pacific, Africa and Eurasia. Liquefaction will dominate gas infrastructure funding, and also be spotlighted on Asia Pacific region.
- Investment in the fossil fuel industry, including natural gas, will be challenging in the long run with tightened financial resources due to accelerated energy transition and climate change agenda pressures.

Introduction

Chapter 5 provides estimates of the natural gas trade and the prospects for global gas industry investments. The 2020-2050 outlook is based on the GECF Global Gas Model (GGM) using Reference Case Scenario (RCS) assumptions. The model first of all fulfils long-term contractual obligations, and the rest is allocated to spot market trades. The forecasts are based on optimisation using cost curve data for each delivery point, taking account of both production and transportation costs.

It contains three subchapters. The first subchapter examines the core current and future trends of the natural gas trade including the gas trade infrastructure prospects and natural gas pricing mechanisms. The second subchapter provides a regional projection of the international gas trade by pipeline and LNG, both contracted and spot traded. The third subchapter is devoted to the investment prospects and financing requirements of the natural gas upstream and midstream.

5.1 GLOBAL NATURAL GAS TRADE

The global gas trade is expected to grow by 45% between 2020 and 2050 to reach 1,815 bcma, around 1/3 of global gas demand. Of that total, LNG will overtake pipeline trade by 2030 and reach 1,150 bcma by 2050.

The share of Asia Pacific in global LNG trade will rise from 70% in 2020 to 80% by 2050. Around three-quarters of global LNG trade is tied to oil prices and it is expected that long-term oil-indexed contracting will be sustained in the global natural gas trade.

The growth in LNG trade is expected to be supported by the ongoing ramp-up of new LNG projects. Total liquefaction capacity rose from 271 mtpa in 2010 up to 454 mtpa in 2020 and is envisaged to reach 1,200 mtpa by 2050. Regasification capacity is expected to increase from 947 mtpa in 2020 to almost 1,400 mtpa by 2050, of which over 1,000 mtpa will be in Asia. As of end-2020, 108 mtpa of liquefaction capacity was under construction. Over the forecast period, the highest LNG export capacity additions are expected to come from the US, Australia, Qatar, Russia and Mozambique. It is forecast that Russia will overtake Australia as the world's third-largest LNG exporter (after Qatar and the U.S.) in the late 2030s.

While Asia will dominate LNG demand, the share between Asian countries will change significantly over the forecast period. The share of global demand met by the traditional markets of Japan, Korea and Taiwan will drop from 39% in 2020 to 18% by 2040. By contrast, South and Southeast Asia will increase their share from 14% in 2020 to over 40% by 2050. In the first half of 2021, China overtook Japan to become the world's largest LNG importer, and in 2020, China had almost 20% of global LNG imports. According to GECF forecasts, Indian demand for LNG could climb to 45 mtpa by 2030 and reach 110 mtpa by 2050.

The years 2020 and 2021 have seen extreme volatility in crude oil and regional gas benchmark prices. In April 2020, Brent reached a low point of USD13/bbl soon followed by TTF falling below USD 1/mmbtu and Asian LNG spot prices (JKM) dropping below USD 2/mmbtu. At the other extreme, in October 2021, Brent was over USD 80/bbl, TTF reached USD 54/mmbtu and JKM reached USD 50/mmbtu. This volatility has affected a broad array of industry stakeholders, and whether the current rebound in spot prices supports a wave of new LNG investments remains open.

While LNG has traditionally been traded under long-term arrangements, the share of spot and short-term trading has been growing steadily, reaching a record 40% in 2020. GECF members fully support the role of long-term gas contracts as well as gas pricing based on oil indexation, but the extent to which customers will share this view is less clear. Some legacy buyers in Asia, such as Japan, might seek increased flexibility, GECF believes that buyers from China, Pakistan and Bangladesh will continue to look for long-term contracts. There has also been a trend away from point-to-point trades towards a greater role for portfolio players and traders. Major LNG suppliers and buyers are also in the process of setting up LNG trading and optimisation arms.

LNG buyers are increasingly considering LNG's carbon footprint on top of price competitiveness. Asian buyers' interest in 'green' LNG continues to increase. Carbon emissions can either be reduced or offset with the purchase of nature-based carbon credits. Both approaches are leading to more rigorous measurement, verification and reporting of emissions along the LNG value chain.

The key challenge to future growth in natural gas trade (and in particular LNG) comes from the global energy transition. This may make it more difficult for project developers to lock in long-term contracts needed to finance the high-cost, capital-intensive, long payback projects. The high volatility in LNG prices increases uncertainty and is leading to a stronger drive for cost reduction. Many of the largest LNG importers in Europe and Asia have pledged to become carbon neutral – in many cases by 2050, and by 2060 and 2070 in the case of China and India respectively. The LNG industry must respond by increasing carbon mitigation efforts, including carbon capture and storage, and gas producers will need to diversify into lower carbon alternatives such as blue hydrogen and ammonia.

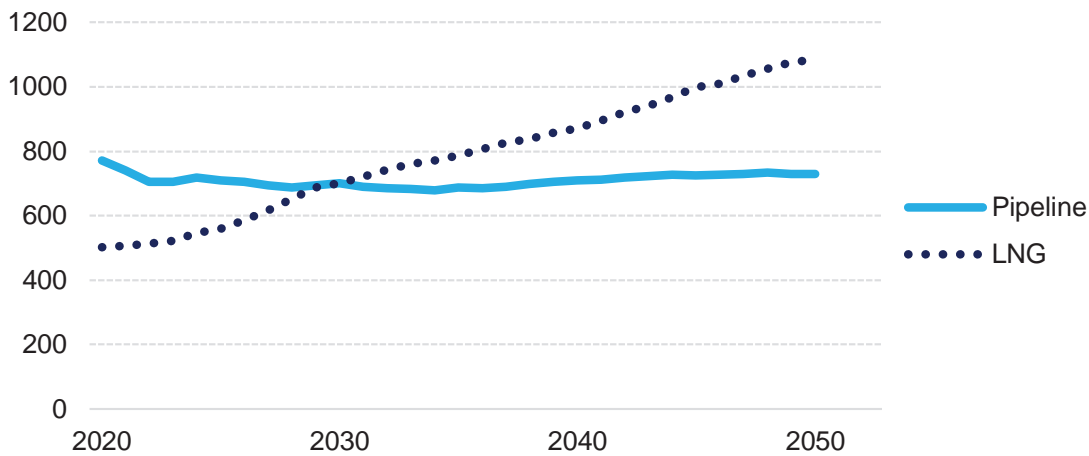


Long-term Outlook

The Outlook remains positive about the prospects of long-term natural gas demand and trade growth. The global gas trade is expected to grow by 45% by 2050, at an average growth rate of 1.5% per annum between 2020 and 2050 from 1,255 bcma in 2020 to reach 1,815 bcm, accounting for 1/3 of global gas demand. For the past 30 years, since 1990, natural gas trade has grown by an average annual growth rate of 5.1% due to pipeline trade development at an early stage (average annual growth of 8.3% in 1990 – 2000) with the more rapid growth of LNG trade at a later stage (average annual growth of 8.2% in 2000 – 2010).

While only 24% of all the natural gas traded worldwide consisted of LNG in 1990, it had increased to 40% in 2020. LNG trade is estimated to surpass the pipeline trade by 2030 at 50% share (700 bcma) and to account for 60% (1,090 bcma) of global gas trade by 2050.

Figure 5.1. Global natural gas trade by flow type (bcm)

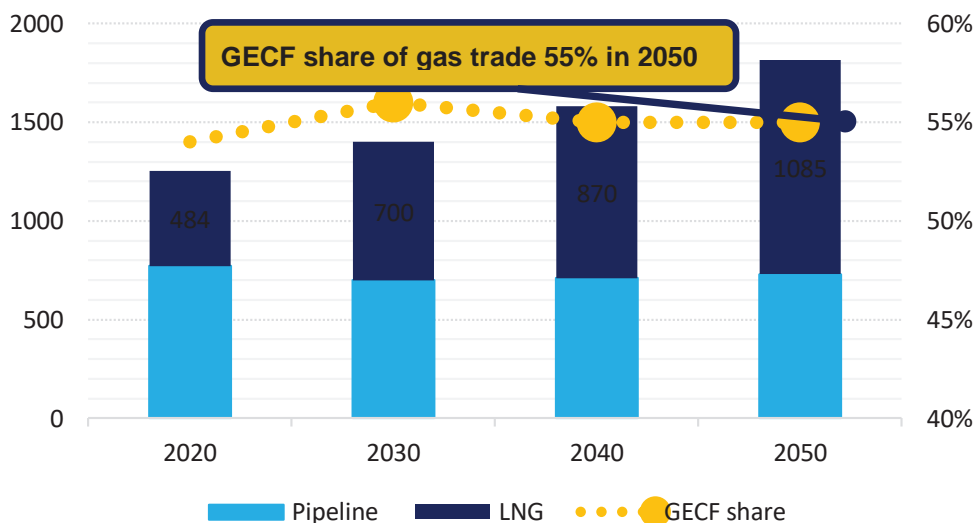


Source: GECF Secretariat based on data from the GECF GGM



The evolving scale and geographic scope of LNG trade will lead to a greater global gas supply security. By 2050, according to the GECF Global Gas Outlook forecasts, it is expected that the total number of LNG exporters will reach over 30 countries, while around 50 countries will be importing LNG.

Figure 5.2. Global natural gas trade by flow type (bcm) and GECF countries' share in global trade (%)



Source: GECF Secretariat based on data from the GECF GGM

By the end of 2020, 20 countries were exporting their natural gas as LNG, a significant increase from only 13 in 2005. In the last 15 years, an increasingly improved access to LNG was evident as the number of LNG importing countries has shown an impressive almost three-fold growth - from 15 countries in 2005 up to 43 countries in 2020. Therefore, the gas market will become increasingly more interconnected and less regionalised due to the extension of total gas exports according to LNG developments.

Over the long term, growth in LNG trade is expected to be supported by the ongoing ramp-up of new LNG projects and the associated growth in contracted supply. Total liquefaction capacity rose from 271 mtpa in 2010 up to 454 mtpa in 2020, with respective total regasification capacity from 572 mtpa up to 947 mtpa. By 2050, overall liquefaction and regasification capacity are set to reach 1,200¹ mtpa and almost 1,400 mtpa² respectively.

GLOBAL NATURAL GAS MARKET TRENDS

Natural gas price turbulence of 2020-2021

Though historically, crude oil and natural gas are inherently volatile commodities, it was an extreme roller coaster ride for crude oil and regional gas benchmark prices in 2020 and 2021. Although being at initially low levels on average through 2019, prices collapsed in all major gas-consuming regions in the face of sharp drops in demand in the first half of 2020 due to economic, social, and humanitarian impacts of COVID-19 as well as warmer than expected 2019-2020 winter in the Northern Hemisphere. Shortly after that world saw a 'magic' rapid turnaround. Natural gas markets – Asian and European in particular – are becoming increasingly interconnected, global and integrated. The recent price spikes at record-high levels are compelling evidence of the above.

Natural gas spot price volatility has affected a broad array of industry stakeholders. It 'touched' upon the short-term targets of the suppliers and portfolio players to optimize their trading strategies along with 2020 as well as reconsidering old and signing new long-term agreements at lower levels of oil indexation, between 10 and 11%, record low levels, compared to the earlier 14% slope contracts. The oil and gas majors have been seriously challenged by severe losses in earnings, negative cash flows leading to massive asset write-downs amid high leverage of 30% across the industry.

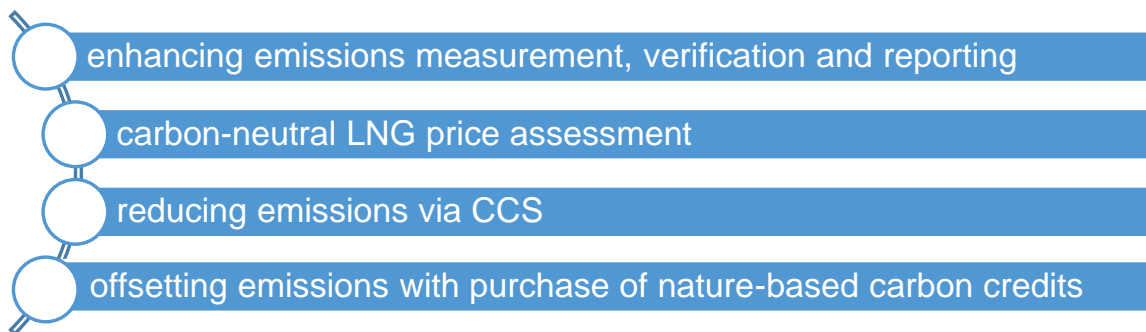
1 Liquefaction capacity includes existing, under construction, FID reached, FEED and proposed projects. It doesn't account for potential capacities for this reference.

2 Regasification capacity includes existing, under construction, potential, proposed, stalled and speculative projects.

On the contrary, 2021's high natural gas market environment has driven the long-term oil-indexed contracting market back on track. Especially, Asian LNG buyers have searched for a relative security of term contracts, with Chinese buyers leading the way. The TTF benchmark extreme volatility have been advocating in favour of Brent crude price linkage. The market for new oil-indexed deals is entering 2022 higher, into the 11-12% range.

'Greener' LNG to capture the minds of the industry stakeholders

Figure 5.3. Carbon-neutral LNG trends

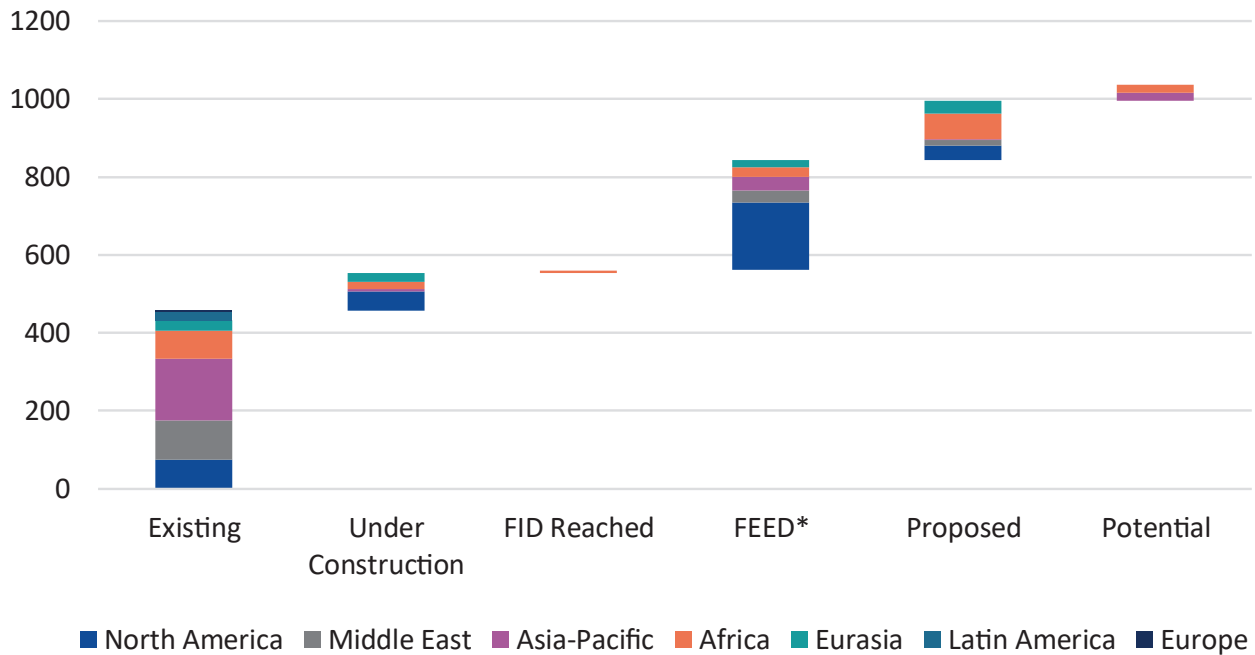


LNG buyers are increasingly considering LNG's low-carbon properties on top of price competitiveness. The market witnessed a spike in carbon-neutral LNG deals in late 2020 and early 2021 as increasing pressure came from the government changing policies and tighter regulations. Furthermore, the corporate sector's shareholders and investors are increasingly becoming more conscious of the LNG's carbon footprint. Asian buyers' interest in 'green' LNG continued to ramp up last year, crystallising a new sustainable trend of future LNG trading.

When carbon emissions couldn't be avoided, they can be either (i) reduced or/and (ii) offset with the purchase of nature-based carbon credits and verified carbon standard certificates. Both carbon emissions reduction strategies should imply more rigorous emissions measuring, verification, and reporting with enhanced and clear guidelines together with emissions transparency along the LNG value chain. Carbon-neutral LNG price assessment activity is also underway. S&P Global Platts, in mid-June 2021, announced the launch of the world's first daily carbon-neutral LNG price assessment (CNL). It tracks the cost of carbon credits purchased and retired to offset the carbon emissions for an LNG cargo on the world's most active trade route - from Australia to JKTC (Japan, Korea, Taiwan, China). The LNG industry is anticipated to further address the implementation of improved greenhouse gas (GHG) emissions quantification and reporting methodologies. A carbon-neutral LNG price assessment tool might be applicable to the broader universe of LNG trades. The industry will also continue walking along the 'lower emissions' pathway, optimising the reduction of GHG emissions, related to the production and consumption of LNG.



Figure 5.4. Global LNG liquefaction capacity outlook (mtpa)



Source: GECF Secretariat based on data from the GECF GGM
 Note: FEED* includes pre-FEED and FEED completed project status

GAS TRADE INFRASTRUCTURE PROSPECTS

LNG Supply

The 1,240 mtpa of liquefaction capacity projects by 2050, is higher than the expected LNG demand of around 845 mtpa, hence, LNG markets remain well supplied throughout the forecast period. Total liquefaction capacity rose from 271 mtpa in 2010 up to 454 mtpa in 2020.

LNG infrastructure will see a much faster build-up than pipelines, as it requires far fewer intergovernmental negotiations and is much less affected by geopolitical tensions. There were, as of the end of 2020, 108 mtpa of liquefaction capacity under construction, which will significantly ramp up the global LNG supply within the next five years. Another 240 mtpa of liquefaction projects are on fast-track for FID and are likely due over the next two decades. The highest LNG export capacity additions are expected to come from the US, Australia, Qatar, Russia and Mozambique.

The biggest liquefaction capacity additions are expected in North America, the Middle East, Eurasia, Asia Pacific and Africa. According to GECF projections, between 2030 and 2050, more liquefaction projects with approximately 520 mtpa of additional capacity have the potential to come online, the great majority of these are in the US (over 100 mtpa), which will be supported by shale developments. The US is expected to lead capacity growth in global LNG liquefaction and will be the third-largest LNG supplier in the world by 2050, after Qatar and Russia.

With lower-cost brownfield expansions, Africa, which has a further over 100 mtpa of liquefaction capacity proposals, could emerge as a key LNG production region. If these projects materialize, new exporters from Africa, such as Mozambique, Mauritania and Senegal, will join the LNG exporters.

In Russia, we expect a further slightly above 100 mtpa LNG expansion phases in the Arctic, in Qatar a 70 mtpa mega-trains project, while Canada will increase its capacity by 65 mtpa, Mozambique by under 60 mtpa with low-cost brownfield expansions, and around 40 mtpa that originates in Australia will also be expected to come online.

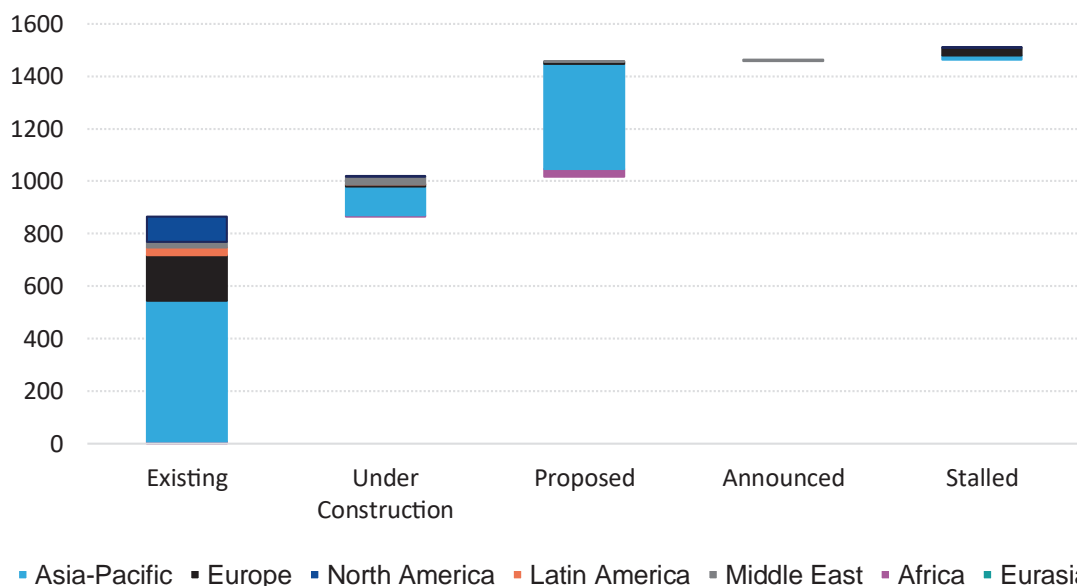
It is forecast that Russia will overtake Australia as the world’s third-largest LNG exporter in the late 2030s. Mozambique is expected to pass Nigeria in 2030 and become the world’s fifth-largest LNG supplier. Furthermore, Iran has a huge potential to emerge as an LNG supplier by the early 2040s and climb to be among the top ten LNG producers worldwide by 2050.

LNG Demand

LNG demand will more than double from 356 MT in 2020 to 800 MT by 2050, fuelled by solid demand from Asia and a rise in gas use for powering hard-to-electrify sectors.

The biggest regas capacity additions to 2050 are expected in Asia Pacific. Total regasification capacity rose from 572 mtpa in 2010 up to 947 mtpa in 2020. By 2050, regas capacity³ is projected to grow to 1465 mtpa, significantly outrunning the actual projected LNG demand. That will include, by 2050, almost 1050 mtpa in Asia, and 190 mtpa in Europe. China will top the list of regasification capacity by 2050 with almost 340 mtpa, followed by Japan with 210 mtpa, South Korea with over 150 mtpa and India with 100 mtpa.

Figure 5.5. Global LNG regasification capacity outlook (mtpa)



Source: GECF Secretariat based on data from the GECF GGM

8 new regasification terminals were commissioned in 2020 with a total LNG regas capacity of 26 mtpa, primarily in Asia Pacific region as well as Latin America (Brazil, Puerto Rico).

Gas infrastructure build-out, coal-to-gas switching and market deregulation are the main determinants for LNG demand growth. South and Southeast Asia are likely to drive LNG demand growth in the future as the countries are investing heavily in gas pipelines and regasification terminals. India offers the most demand growth potential in the region due to the scale of its infrastructure expansion. The South and Southeast Asia region might grow its share of global LNG demand from 14% in 2020 to over 40% by 2050.

Around 150 mtpa of new LNG regasification terminals are under construction, of which about almost $\frac{3}{4}$ or 110 mtpa is in Asia Pacific, where the top countries are China (over 50 mtpa), India (20 mtpa) and 28 mtpa in the Middle East, in Kuwait and Bahrain.

5.2 NATURAL GAS TRADE OUTLOOK BY REGION

By 2050, the majority of incremental growth in natural gas imports will be undoubtedly attributed to Asia Pacific with almost 650 bcm additions over 2020-2050.

Latin America and Europe, with total increases of 55 bcm and 35 bcm, respectively will follow. The underlying demand will be balanced out by supply increases from primarily Eurasia (285 bcm) Middle East (230 bcm) together with North America (160 bcm) and Africa (50 bcm) over the long term.

Asia Pacific will account for the highest share of global imports by 2050, while the share held by the European market will be

³ Regas capacity includes here existing, under construction, proposed and announced

Table 5.1. Global gas balance by region, [+] import, [-] export (bcm)

| Region | 2020 | 2030 | 2040 | 2050 |
|---------------|------|------|------|------|
| Africa | -75 | -115 | -155 | -125 |
| Asia Pacific | 220 | 455 | 670 | 865 |
| Eurasia | -225 | -390 | -490 | -510 |
| Europe | 310 | 365 | 355 | 335 |
| Latin America | 15 | 15 | 50 | 70 |
| Middle East | -145 | -210 | -245 | -375 |
| North America | -100 | -120 | -185 | -260 |

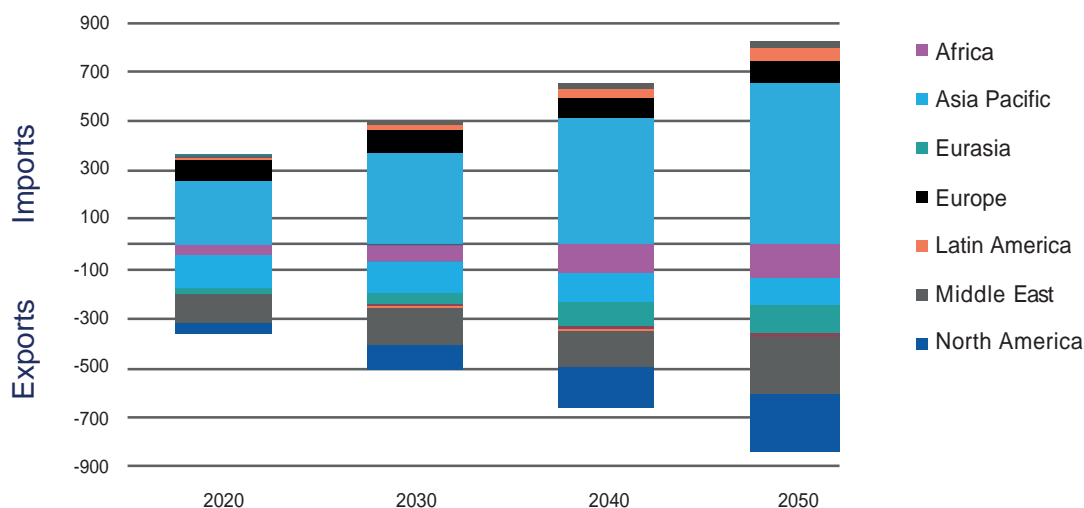
Source: GECF Secretariat based on data from the GECF GGM

gradually decreasing as import volumes increase slowly by 2030 due to a significant drop in domestic production but later slows down till 2050 due to overall natural gas demand in Europe is starting to decrease as decarbonisation and the 'green deal' efforts are seen to move gas out of energy mix.

LNG liquefaction investment decreased by more than a third in 2020 but is anticipated to go up by more than two-thirds in 2021 to over USD23 billion. Qatar, Russia, and the U.S. are leading the trend, whilst Mozambique's LNG future remains uncertain due to security issues. Qatar's project, with a final investment decision (FID) of USD29 billion taken in February 2021 on North East Field expansion, which will add 33 mtpa to the currently existing 77 mtpa, is a game-changer.

Asia Pacific, the main destination of the world's LNG at present and by 2050, will represent the largest transformational challenge for the currently fragmented natural gas market. Asia Pacific with 70% share of LNG trade in 2020 to make up for even more impressive over 80% by 2050.

Figure 5.6. Global LNG imports and exports by region (mt LNG)



Source: GECF Secretariat based on data from the GECF GGM

Naturally, the top 4 largest LNG importers emerged in Asia Pacific. China became the #1 LNG importer in 2021 overtaking Japan as the leader in the consumption of liquefied gas, South Korea, India to follow. By 2050, the top 4 importers will remain the same, just India will overtake South Korea and Japan to become the #2 LNG importer by 2050.

Slow LNG demand is seen in Africa, the Caribbean and partially in the Middle East. A very few import terminal projects are currently being built there.

Pipeline trade will see relatively modest growth, mainly due to shifting the export focus from the European to the Asian market, ramping up exports from Russia and Turkmenistan to China.

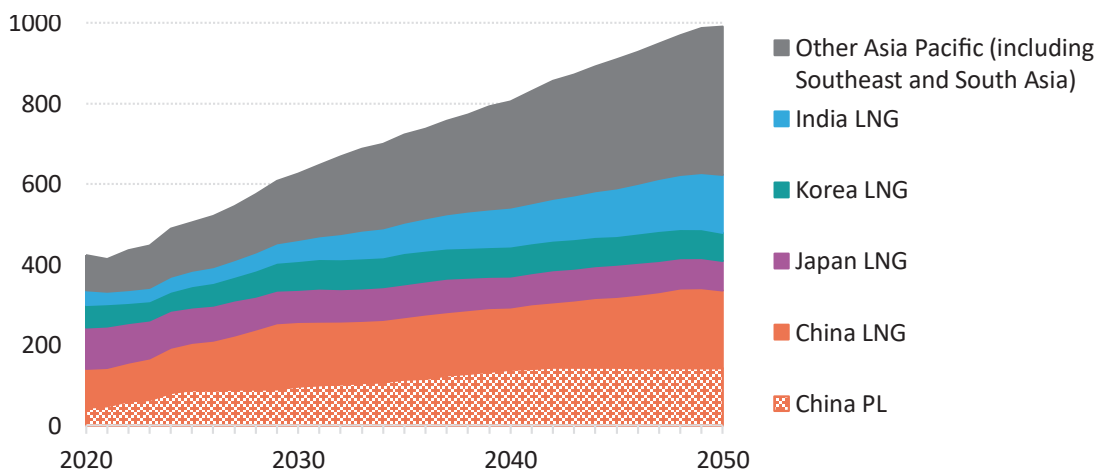
Asia Pacific

A rapid shift in demand for LNG from traditional markets to emerging markets will be envisaged in the coming 30 years.

Asian natural gas market is anticipated to stay the largest regional market over the 2020 - 2050 period, as more countries start importing natural gas with existing importers from predominantly developing Asia ramp-up the existing inflow trade. The incremental growth in Asian imports will be attributed to China (195 bcm) and India (107 bcm), 14 bcm by South Korea, with the balance taken by new importers from South and Southeast Asia and other developing Asia. Legacy importers such as Japan and Taiwan will slowly decrease gas imports.

The share of global demand met by the traditional markets – Japan, South Korea, Taiwan – will drop from 39% in 2020 to 18% by 2040, mainly due to lower gas demand for power generation in Japan.

Figure 5.7. Asia Pacific natural gas imports by country (bcm/a)



Source: GECF Secretariat based on data from the GECF GGM

On the contrary, South and Southeast Asia will increase their share from 14% in 2020 up to over 40% by 2050. China will be the single largest growth market between 2020-2030 but more than 2/3 of Asia’s LNG demand growth over the stated period will be generated from South and Southeast Asia.

South and Southeast Asian markets possess the biggest demand growth potential to be realized through the development of their LNG import infrastructure (regas and storage). Coal-to-gas fuel switching potential might be explored further, still with limited upside potential from Europe and potential constraints in North Asia.

The region’s key engines will be Pakistan and Thailand. India will take over as the biggest growth market after 2030, outperforming China. In absolute terms, China will remain the largest importer with demand nearly twice of India’s.

There is at present 947 mtpa of existing global regasification capacity vs. global demand of 356 mtpa in 2020. The existing global regas capacity is 2.7 times more than the current global demand. By 2050 the mentioned gap is anticipated to decrease. Although the global utilization rate of regasification capacities is low, more new capacities will continue to be built to accommodate the penetration of new markets.

Over 156 mtpa of capacity is under construction, 47% is in China and due to start in the next six years. Over 15% of the under-construction capacity is in South and Southeast Asia.

North America

2020 natural gas exports (intra- and inter-regional trade) from North America were around 200 bcm, of which nearly 48 bcm (34 mt of LNG) was exported as LNG, all from the US to consumer markets. Furthermore, in 2020 around 150 bcm pipe gas was traded between the US, Canada and Mexico.

By 2050, it is forecast that about 30% of all proposed LNG production capacity in the world will originate from North America, including the US (260 mtpa), Canada (90 mtpa) and Mexico (20 mtpa). Thus, the US is expected to lead capacity growth in global LNG liquefaction and will be the third-largest LNG supplier in the world by 2050, as long as US LNG prices remain competitive, in particular for the large Asian consumers.

US LNG exports started first in 2016, and since then the country has witnessed a tremendous expansion in LNG export capacity by turning into the world's third-largest LNG exporter only in four years, only behind Australia and Qatar. Once the new LNG liquefaction trains at Sabine Pass LNG in Texas and Calcasieu Pass LNG terminal in Louisiana are placed in service in 2022 or 2023, US LNG export capacity will become the world's largest. Given the ramp-up capability and speed of new US LNG projects commissioning, current high prices and the commercial momentum, a range of 20 - 30 mtpa of new US LNG projects might take FID in the next two years.

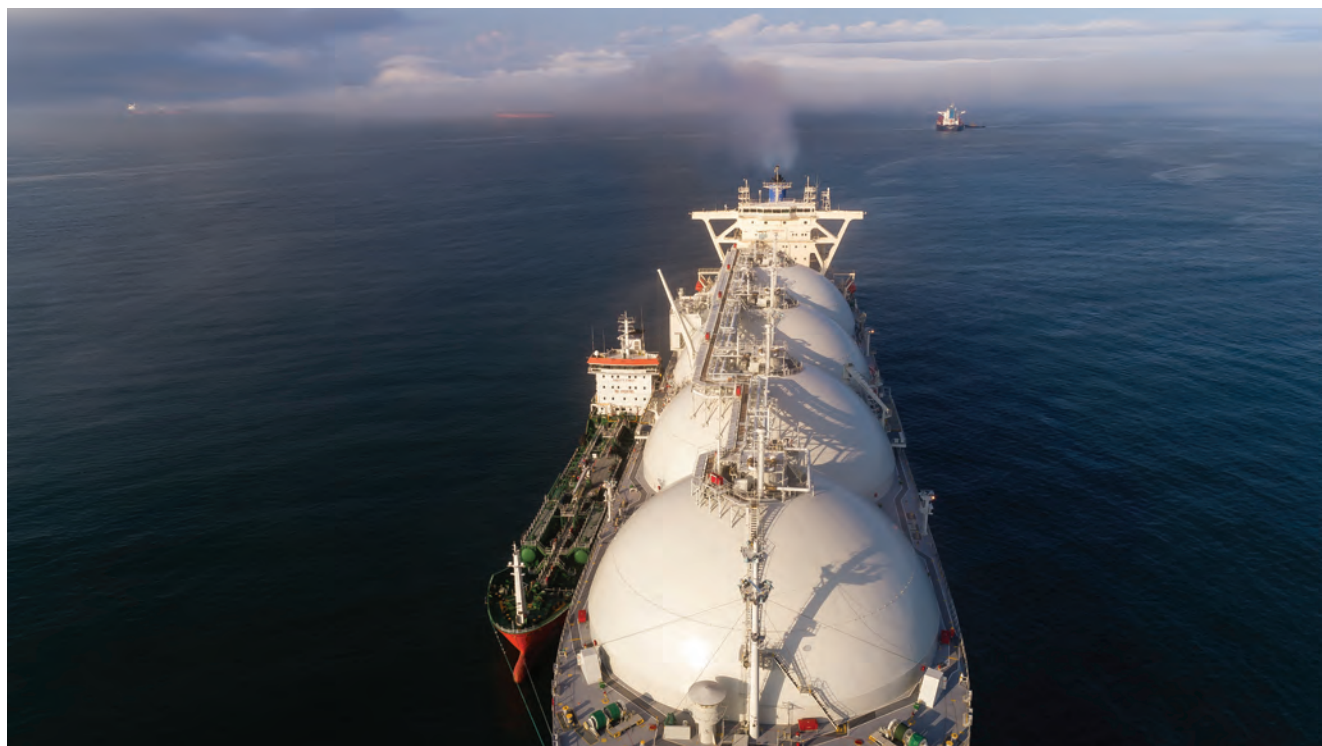
U.S. dry natural gas production supported by the development of tight and shale resources keeps growing, and accordingly, the US continues to add additional capacities to new projects and its existing LNG train facilities. Over the outlook period, the US is expected to be the key source of global LNG export growth. Hence, with around 260 mtpa LNG capacity, the US has great potential to become one of the largest LNG exporters, as long as US gas prices remain competitive, particularly in emerging Asian markets. On that premise, we forecast that US LNG exports will grow by an average growth rate of 3.5% p.a., from the current level to nearly 105 mtpa by 2050.

Eurasia

Eurasia is a net exporter of gas and exported about 340 bcm, mostly originating from Russia with around 250 bcm. The region exports more pipe gas than LNG. Last year the share of piped gas was around 80% of the region's total gas exports. Russia has the highest contribution of piped gas, at about 210 bcm, of which around 190 bcm is exported to Europe.

Azerbaijan, Kazakhstan, Turkmenistan and Uzbekistan together exported about 90 bcm, most of which was exported through Central Asia.

Central Asia could potentially supply much more gas, but uncertainty surrounds most of the new projects that could carry this gas to market. This is particularly true of the Turkmenistan-Afghanistan-Pakistan-India (TAPI) pipeline, which would export gas from Turkmenistan to Afghanistan, Pakistan and India. Following completion, the capacity of the pipeline would ramp up to 33 bcma, with the gas being supplied over 30 years to Afghanistan (5 bcma), Pakistan (14 bcma) and India (14 bcma). However, the completion date for TAPI remains very uncertain.



The Central Asia-China pipeline corridor is being used at close to its 55 bcma capacity. An expansion to 85 bcma is possible, by the construction of Line D from Turkmenistan via Uzbekistan, Tajikistan and Kyrgyzstan to China, but this is unlikely to go ahead until it is seen as strategically necessary by China.

Russia is the world's fourth-biggest LNG exporter after Qatar, Australia, and the US. In 2020, Russian LNG exports grew to 29.6 mtpa – a global LNG market share of around 8% – with Pakistan and Singapore becoming Russia's newest customers in Asia.

Nine projects and fifteen LNG trains are planned for a total capacity of 75.5 mtpa by 2026 in Russia.

Middle East

The region imported about 7 MT of LNG 2020 with overall gas imports accounting for over 40 bcma. The majority of the Middle East's gas imports were from within the region, as the main pipeline gas imports were from Qatar and Iran into their neighbouring countries. However, the volume of natural gas exported, around 160 bcm, was much higher than imports into the region.

Currently, the region has over 100 mtpa LNG liquefaction capacity: Qatar 77 mtpa, Oman 11 mtpa, Yemen 7 mtpa⁴, and the UAE 6 mtpa. Furthermore, around 130 mtpa capacity, including in different stages of FEED, proposed, speculative and stalled LNG projects is planned.

Currently, Qatar is the largest LNG exporter, and it is working to increase its liquefaction capacity to 126 mtpa by 2027. Post-2027, a further 55 mtpa of speculative LNG projects remain to be completed. It is forecast that Qatar will maintain its position as the top LNG exporter in the world by 2050.

The UAE both imports and exports LNG. In 2020, about 70% of the region's gas imports were supplied to the UAE, mostly from Qatar through the Dolphin gas pipeline.

The UAE is working on developing its gas resources to reduce its dependency on imports. These sources of supply would produce high-cost gas, and consequently, it would take time to effectively develop. Over the medium term, the UAE will continue to be one of the largest gas importers in the region, but the country is progressing towards a goal of gas self-sufficiency.

As the third-largest natural gas reserve holder, Qatar has been playing a meaningful role in the global natural gas trade that resulted from continuous and successful exploration in its giant North Field and investing in advanced LNG trains, employing the best practices in associated technologies. Qatar's North Field along with Iran's South Pars form one of the world's largest gas fields.

Qatar is the biggest LNG exporter worldwide with 77.1 mtpa, which accounted for 22% of global LNG production in 2020. The country is the major supplier to Asian and European markets. While in 2010 approximately 50% of Qatar LNG was streamed to Europe and the other 50% to Asia, in 2020, Asia already accounted for over 2/3 (68%) of Qatari exports.

The outlook for the future role of Qatar in global LNG trade is very promising since Qatar has a great potential to send its LNG cargoes into Asian markets with lower shipping costs compared to other LNG suppliers. Additionally, Qatar has a strong global business relationship with major European LNG consumers and is securing regasification capacity in countries such as the UK, the Netherlands, France and Belgium.

QatarEnergy, QE, (previously Qatar Petroleum) took the final investment decision, FID, for developing the North Field East Project (NFE) in February 2021. A USD29 billion project will raise Qatar's LNG production capacity by 43%, from 77 to 110 mtpa. A long-term breakeven price of slightly above USD4/mmbtu of the project is at the bottom of the global LNG marginal cost of the supply curve.

During 2021, moreover, QE has announced a new plan to reduce the emissions intensity of its LNG facilities by 25% and of its upstream operations by 15%. The company aims at accelerating the deployment of CCS in order to capture 7 mtpa of CO₂ and has set targets to completely remove routine gas flaring by 2030, and to reduce methane emission intensity to around 0.2% by 2025 for all its facilities. Qatar is currently one of the successful players worldwide in supplying the cleanest natural fossil fuel LNG. The country has many experiences in the reduction of methane emissions and CCUS technologies.

Europe

The European natural gas market is expected to remain the second largest, after the Asian Pacific market. Imports of nat-

⁴ Yemen LNG exports have been halted since 2015.

ural gas are expected to grow only incrementally in the medium-term due to declining indigenous production, and in the longer-term to decline with falling demand. Compared to 310 bcm in 2020, imports are projected to be 335 bcm by 2050, which is still over 20% of global gas imports.

In terms of infrastructure, the plans to connect European gas markets with a number of two-way flow pipelines are expected to be completed in the medium term, enabling consumers to access gas hubs far more easily in line with the new regulation. Also, more export pipelines have been connected to the European market, bringing more natural gas from Russia, Azerbaijan. Potentially new Mediterranean sources in Israel, Cyprus and Egypt can also supply gas to Europe even further allowing to diversify.

There are certain suppliers that would view the European market as easier to keep, primarily due to the position on the cost curve. The pipeline gas exports from Russia, North Africa and Norway are expected to persist because they have the lowest marginal costs. The differing sources of supply are expected to add to greater price flexibility on the European market, as is the further decrease in oil-linked contracting. On the downside, that will diminish the consumer options to withdraw more oil-linked gas in case of international gas price swings, and, in the case of smaller long-term supplier obligations, will significantly increase volume risks. The new situation on the market will require additional structural changes.

Between the gas source diversification policy and more available infrastructure, an increasing share of those imports will be from LNG. This is also due to the fact that Europe is the residual market for LNG shipments.

Natural gas demand in Europe is starting to decrease as decarbonisation and the 'green deal' efforts are seen to move gas out of the energy mix.

Africa

In 2020, natural gas exports from Africa were around 95 bcm, out of which 62 bcm (45 mt LNG) was exported as LNG from Nigeria, Algeria, Angola, Egypt, Cameroon and Equatorial Guinea. Hence, the continent supplied 13% of global LNG exports. Additionally, around 33 bcm pipeline gas was traded to Europe.

Africa has about 72 mtpa of LNG liquefaction capacity. There are ongoing plans to expand Africa's LNG production. There are currently projects amounting to 19 mtpa under construction, 25 mtpa in different stages of FEED, 66 mtpa of proposed projects, as well as 30 mtpa of potential and stalled projects that are expected to come online by 2050.

Africa has plentiful natural gas reserves. Nigeria, Algeria, Egypt, Mozambique, Tanzania, Ghana, South Africa, Senegal and Mauritania, as well as many other countries, all have their own remarkable resources that have already been developed. Some of the significant gas discoveries will be more likely to supply domestic gas demand (e.g. in South Africa), while certain major African LNG projects are designed to supply markets outside of Africa (e.g. Mozambique).

Overall, it is estimated that the total liquefaction capacity of the region will reach around 220 mtpa by 2050, more than tripling Africa's existing export capacity. Consequently, the region will become a major LNG hub over the long-term period. Accordingly, it is forecast that LNG exports from Africa will reach about 110 bcma (80 mtpa) by 2030 and 215 bcma (160 mtpa) by 2050.

Mozambique is one of the world's poorest countries, with a gross domestic product (GDP) per capita of below USD500 in 2020 and with about 45% of the country's 31 million people living below the poverty line. The International Monetary Fund (IMF) claims LNG can be a game-changer for the country's economic transformation in terms of sales, taxes, royalties and dividends. With a long-term LNG price of USD 8/mmbtu, supplied to European or Asian markets, the country can generate USD 12bn annually by exporting 30 MT from its three ongoing projects. Mozambique is expected to enter the LNG producers 'club' and emerge as the largest African LNG producer by the mid-2030s and retain its position throughout 2050.

In conclusion, according to GECF projections, the long-term outlook for Mozambique LNG looks fortunate with the potential of about 65 mtpa in LNG exports. Mozambique is anticipated to join the ranks of the world's biggest LNG exporters and to rank number five of LNG exporters globally in 2040 – 2050.

Latin America

In Latin America, natural gas is seen as doubly important: first, replacing crude oil in power generation, and, secondly, providing baseline power to complement the growing capacity of intermittent renewables.

Latin America is projected to turn into a net-importing region with around 70 bcm in net imports by 2050 from its current net-exporting status of 10 bcma and 6 bcma in net exports in 2019 and 2020, respectively. The GECF believes in the long run that the Latin American continent's natural gas trade will be dominated by LNG. All pipeline trade is conducted within the

region, mostly from Bolivia, and will remain at or below the current level of 12 bcma over the coming decades.

There is about 45 mtpa of existing LNG regasification capacity, and a further over 45 mtpa of regasification projects in Brazil, Chile, Colombia, The Dominican Republic, El Salvador, Bahamas, Nicaragua and elsewhere that will be developed over the outlook period.

LNG Trade. Latin American LNG demand is expected to have a record year in 2021.

So far, US LNG exports to Latin America have been modest, with the largest markets of Argentina, Brazil, Chile, Colombia, and Mexico importing from the US about 14.2 mcm/day of LNG in 2020, according to the US Energy Information Administration.

Overall, LNG heralds a new era for the region with the substitution of the more expensive and dirtier petroleum fuel for electricity generation along with hydropower. Furthermore, due to the rise in demand and decline in production, the region will gradually emerge as a net importer of LNG. It is forecast that LNG imports will increase at an average growth rate of 5.8% p.a. to about 77 bcma (56 mtpa) by 2050 from the current (2020) 14 bcma (10 mt), primarily sourced from the US.

5.3 NATURAL GAS INVESTMENT TRENDS AND FORECAST

Between 2020 and 2050, the total estimated upstream and midstream natural gas investment will decelerate to USD 8.7 trillion (USD1.3 trillion lower) due to the lower global natural gas demand growth contemplating 300 bcma less consumption by 2050 compared to the 2020 GECF GGO forecasts.

The vast majority of this is in upstream investment with USD 600 billion in gas trade infrastructure.

The lion's share of the investment allocation will take place in the natural gas upstream, streamlined mainly to Asia Pacific, Africa and Eurasia regions. Liquefaction will be dominating the gas infrastructure funding, also spotlighted on Asia Pacific region.

The scope of pipeline investment over the next 30 years will be less than the past 30 years, as many large-scale pipeline investments have already been made. Most new gas pipeline investment will be concentrated in Eurasia with new links to customers in Europe and Asia, notably Power of Siberia 1 and Central Asia-China line D.

For LNG, the rapid build-up of LNG supply capacity in the 2020s is widely expected to outpace demand growth. After the current wave of projects, investment is expected to subside for approximately 10 years as demand catches up with supply.

Existing and new LNG projects will be facing two major concerns: one relating to achieving adequate profitability and secondly the growing issue of environmental acceptability and more stringent 'greener' boundary conditions.

Investors to challenge the fossil fuel industry, including natural gas, in the long run with tightened financial resources due to accelerated energy transition and climate change agenda pressures.

Global energy investment

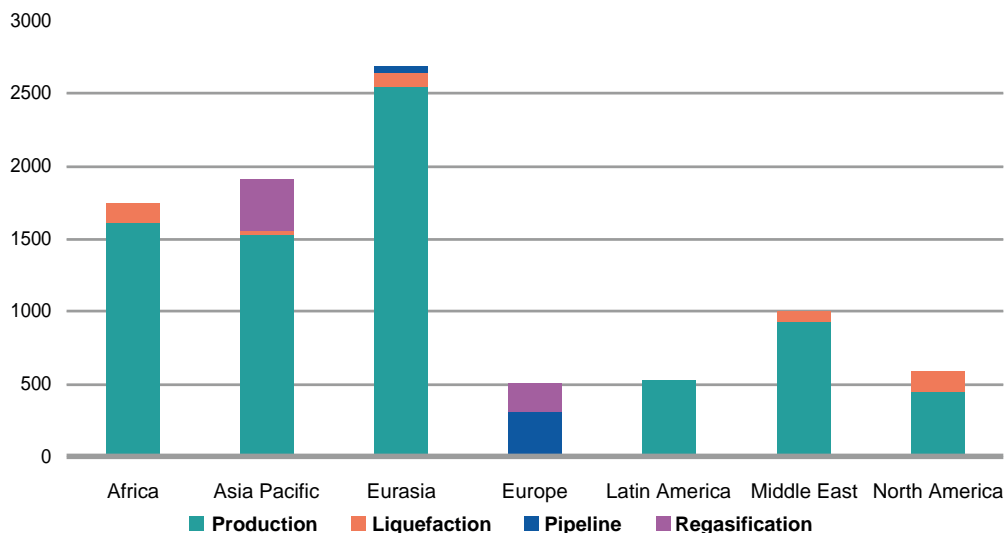
Global energy investments are expected to strongly regain to USD1.9 trillion in 2021 or by around 10% compared to the 2020 level, rebounding to the pre-COVID state. Climate agenda-induced world energy transition is increasingly setting 'the rules of the game' by streamlining more financing to be allocated the renewables and electricity at the cost of fossil fuels.

The power sector funding is trending to outperform the legacy oil and gas supply investments in the 6th consecutive year and to reach a record USD820 billion with renewables accounting for over 2/3 of it (USD530 billion) in 2021. Renewables investment expansion is backed by the rapid cost cuts and significant technological improvement as well as supporting regulatory frameworks in the key advanced and developing markets such as Europe, the US, and China.

Electrification investment by final consumers is also in the spotlight, primarily in the development and building of battery-powered electric vehicles (EVs) as well as the deployment of relevant charging infrastructure and grid capacity in the light of accelerated sustainable mobility. Global automakers might consider targeting over USD500 billion in investment commitments on EVs and batteries by 2030 to fit the weighing decarbonisation pathway, especially in large cities and urbanisation centres. The automotive industry during the last decade has attracted more than USD400 billion in investments aiming at electrifying mobility, connecting vehicles, and autonomous driving technology.

Although most of this projected USD8.7 trillion earmarked for gas investment is required in the natural gas exploration and

Figure 5.8. Natural gas investment by region 2020-2050 (real billion USD)



Source: GECF Secretariat based on data from the GECF GGM

production sectors, the trade infrastructure still requires over USD600 billion of capital in 2020 prices.

There is an expected growth in LNG consumption in future decades because of population growth, growing economic prosperity in developing countries (e.g. China and India), favourable government regulations and actions to reduce air pollution. Although the growth in demand drives an increase in gas investment, LNG development projects may be difficult to finance in the same way as before due to the prospect of market changes. It is less likely in coming decades that LNG projects will be financed by project-level debt, which requires long-term sales and purchase agreements.

LNG investment will have substantial government support in various countries such as the US, Qatar and Russia in order to meet the growing demand in Asia Pacific and European markets. Following global growth in LNG upstream and transportation investment, unlike the historical picture, North America will see a decline in upstream gas investments, while non-OECD Asia, Eurasia and Africa will be growing regions for gas investment.







6. ALTERNATIVE SCENARIOS

KEY FINDINGS

- In the GECF Energy Transition Scenario (ETS), CO₂ emissions will shrink significantly by 60% compared to the Reference Case Scenario (RCS), reaching around 11.7 Gt CO₂. Although the ETS trajectory remains incompatible with the 1.5°C target, it is consistent with the Paris Agreement objective to achieve a 2°C limit by the end of the century.
- In the GECF Hydrogen Scenario (HS), 2050 emissions will decrease by 2.6 Gt CO₂. The implementation of aggressive hydrogen development contributes to closing the gap between the RCS and the Paris-aligned trajectory.
- In the ETS, world primary energy demand starts to fall from 2025, ending up 5% lower in 2050 than 2020 levels.
- The ETS envisages a drop of fossil fuel's share to 38% by 2050. Natural gas will remain the most resilient fossil fuel, with 21% share in 2050. Demand will be peaked in 2027 at 4,250 bcm. However, gas usage will plateau in the later years and will decrease slowly by 2050.
- In the HS, natural gas production will increase to more than 5,200 bcm by 2050, which is almost 400 bcm less than what is forecast in the RCS.
- In the HS, demand for hydrogen is forecast to reach more than 620 Mt per year by 2050, which is 2.3 times more than the value forecast in the RCS and more than 6 times higher than the current value. Transport and industry will emerge as the most significant drivers behind this hydrogen demand expansion.
- In the HS, almost 46% of total hydrogen production will be sourced from blue hydrogen. However, the share of the total natural gas-based hydrogen generation, including other clean pathways such as turquoise hydrogen, is almost half of the global production.
- In the HS around 145 Mt of H₂ will be traded annually by 2050 accounting for more than 23% of the total hydrogen supply and demand by then. Europe and Asia Pacific will import the majority of the hydrogen while almost all regions will export this clean fuel.
- GECF countries have a solid potential to export almost half of the hydrogen trade, mainly from Eurasia, North Africa and the Middle East.

This chapter casts a critical eye over significant developments in the energy transition, analysing them from an oil and gas perspective and weighing up the opportunities they could present in the Energy Transition Scenario (ETS) and Hydrogen Scenario (HS).

The scenarios assess the energy transition drivers, their potential and possible developments over the long-term, their impact on global energy configuration and carbon emissions as well as the future role of natural gas.

6.1 OVERVIEW

The key climate-related objective agreed upon at the 2015 Paris Conference on Climate Change (COP21) was to restrict global warming to less than 2°C, ideally 1.5°C, by 2100 compared to pre-industrial levels. The main task for the Glasgow meeting (COP26) -held in November 2021- was to finalise the procedures for implementation of the COP21.

The Glasgow Climate Pact asks countries to accelerate efforts towards the phase-out of unabated coal power and inefficient fossil fuel subsidies. It recognises that limiting global warming to 1.5°C requires rapid, deep and sustained reductions in global greenhouse gas (GHG) emissions, including reducing global carbon dioxide (CO₂) emissions by 45% by 2030, relative to the 2010 level, and to net-zero around mid-century, as well as deep reductions in other GHGs. It also invites Parties to consider further actions to reduce by 2030 non-carbon dioxide GHG emissions, including methane (1).

According to the UN Climate Change, today, more than 130 nations have agreed to reduce emissions to net-zero by mid-century, together with companies, cities and financial institutions (2). Achieving net-zero energy needs a dramatic overhaul of the whole economy, from energy production to ultimate users, such as in road transportation, industry, residential and other hard-to-abate sectors (e.g., cement, steel, chemicals, container shipping and aviation).

Natural gas and LNG due to the varied benefits they have to offer, are projected to continue contributing in global energy mix in the next decades. However this bright future are subjected to uncertainty and deeply depends on removing the natural gas drawbacks such methane and CO₂ emission through the technology advancement and assorted carbon capturing measures.

6.2 STORY LINE SCENARIOS AND KEY ASSUMPTIONS

The GECF's ETS has a view of the energy transition and fundamental transformation of the global energy sector, induced by a pressuring climate change mitigation agenda and a call to deeply decarbonise the global economy by mid-century. There is no doubt that the above-mentioned transition will take place in the long term. The main debate that is underway currently is only about the multitude of pathways at regional and sectoral levels which could be chosen to achieve such a transformation.

Key modelling drivers in the ETS, including but not limited to:

- To reduce the final energy intensity of GDP,
- To apply high carbon prices per ton of CO₂,
- To increase the electrification of end-users,
- To increase the share of renewables in power generation led by solar and wind,
- To increase the share of EVs and HEVs in total vehicles sales,
- To apply widely carbon capture, use, and storage (CCS/CCUS) plants,

which illustrate what the world energy system might look like through to 2050 based on current trends. This has enabled us to account for variability in the rate of emissions reductions among some of the major sources of GHGs, such as generating power and transportation, without becoming predictive. It was noted that the scenario suggests the necessity for rapid, all-hands-on-deck measures to substantially cut GHG emissions.

The GECF's HS anticipates enhanced penetration of hydrogen into the energy mix by 2050 compared to the GECF's RCS. HS scenario avoids implementing the other decarbonisation pathways, such as efficiency improvement in order to assess the impacts of the possible and expectable hydrogen penetration into the energy system purely. The aim of developing a dedicated hydrogen scenario is that hydrogen is expected to be a decarbonisation pathway in which fossil fuels can play a role, especially natural gas. Natural gas with CCUS can serve the benefits of both energy consumers and producers. The HS will account for all the announced hydrogen strategies that mostly focus on the green hydrogen pathway as well as the relative ramp-up of blue hydrogen technologies and cost reduction. The HS will add to a higher uptake of natural gas decarbonisation with the use of pre-combustion CCS/CCUS.



The projections in all the GECF scenarios are projected up to 2050, with a common baseline year of 2020.

6.3 MAIN RESULTS

The future of energy can have numerous uncertain moving parts, including customer behaviour (either individually or in societies at large), innovation, global relations and climate change policy, to mention just a few. Every one of those assumptions will have a distinct influence in each energy scenario. It is crucial to note that each scenario is significantly distinct from the others, and that the capacity for radically diverse results can be observed across all four of them.

The scenario analysis reveals that there might be several paths to meeting the Paris climate objective and achieving a low-carbon future. Although it is postulated that renewables and other unconventional energy sources will account for a significant portion of the energy supply mix over the next 30 years, based on the GECF GGM’s calculation, GECF believes that some concerns may limit the pledge to fully replacing fossil fuels, particularly natural gas. The GGM demonstrates that committing to carbon-neutral objectives alone will not be enough to reduce GHG emissions, if not supported by rational and realistic measures.

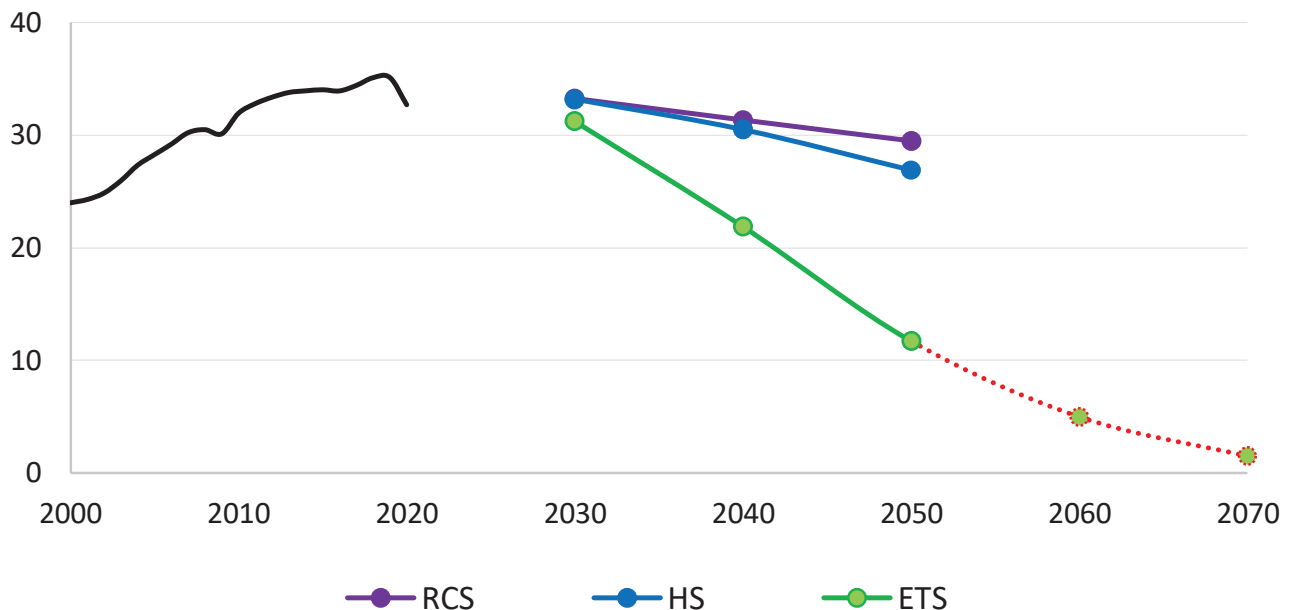
Energy-related CO2 emissions

The HS and ETS scenarios outline two potential carbon mitigation pathways for energy-related activities, with a much more aggressive emission reduction profile for the ETS. The latter scenario implements strengthened decarbonisation options, which are underpinned by the long-term net-zero targets and strategies announced by different countries.

In 2050, CO2 emissions will shrink by 60% in the ETS compared to the RCS, reaching around 11.7 Gt CO2. Although the ETS trajectory remains incompatible with the 1.5°C targets, it is consistent with the Paris Agreement objective to achieve 2°C by the end of the century. The ETS is therefore a Paris-aligned pathway, which assumes that the world will approach carbon neutrality by 2070, reflecting different decarbonisation speeds between developed and developing countries.

For the HS scenario, 2050 emissions will decrease by almost 9% compared to the RCS, which is equivalent to around 2.6 Gt CO2. The implementation of aggressive hydrogen development contributes, to some extent, to the reduction in the gap between the RCS and the Paris-aligned trajectory. It is a fact that the hydrogen pathway cannot solely solve the climate issue, as emission reductions resulting from only clean hydrogen deployment are not very significant. Hydrogen is not a game-changer in global energy decarbonisation, but hydrogen will complement other measures in decarbonising the hard-to-abate sectors. That means the supremacy of hydrogen is not the result of a very significant emissions abatement, but is more to do with the decarbonisation of sectors for which other pathways are impossible or extremely challenged.

Figure 6.1. Energy-related CO2 emissions (Gt of CO2)



Source: GECF Secretariat based on data from the GECF GGM

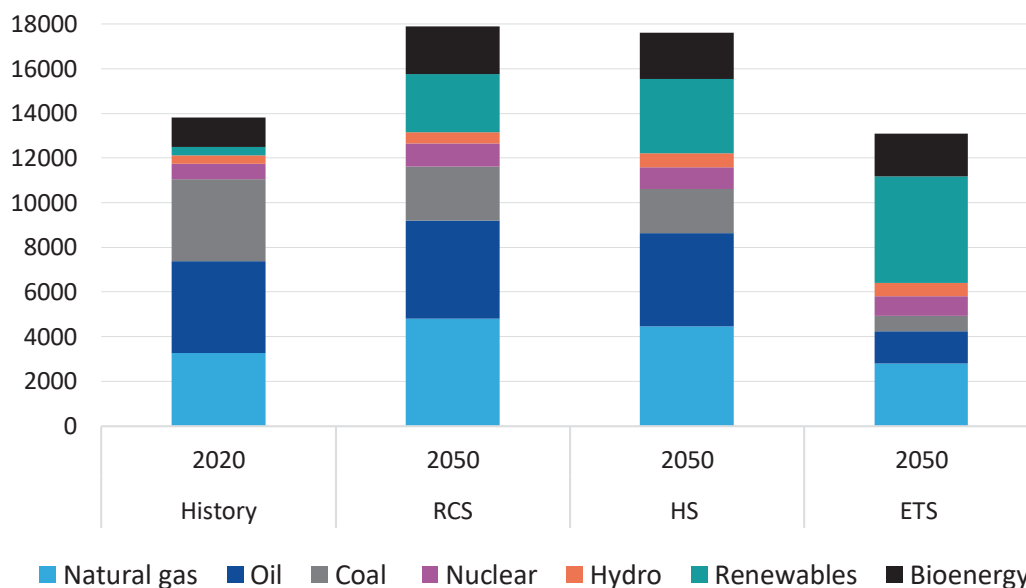
World energy mix

In the ETS each country will strongly implement aggressive energy efficiency, electrification and decarbonisation policies. The world will save more energy and the primary energy intensity of GDP between 2020 and 2050 will fall by 3.3 % p.a., much faster than the global average in the RCS.

As a result, while in the RCS there is no peak in world primary energy demand, in the ETS it starts to fall from 2025, ending up 5% lower in 2050 than 2020 levels. While assumptions regarding economic growth and population have not changed, the ETS indicates an efficient pathway to reach the required level of decarbonisation, based on countries' announced pledges to meet carbon neutrality and supported by the development and introduction of innovative technologies and the promotion of international technological cooperation.

A massive ramping up of renewables, pronounced contraction of coal usage and decline of other fossil fuel usage are the fundamentals to achieving the ETS. It is assumed that renewables will provide 36% of global energy demand in 2050, reaching 4,760 Mtoe by that date – almost two times higher than in the RCS – and their growth will be broad-based, while costs continue to fall rapidly. The use of bioenergy will also increase to 15% between 2020 and 2050 thanks to the growing use of modern biomass in the residential segment and as an alternative for thermal power plants. Conversely, traditional biomass is forecast to be nearly phased out.

Figure 6.2. World primary energy demand by fuel type (Mtoe)



Source: GECF Secretariat based on data from the GECF GGM 2021

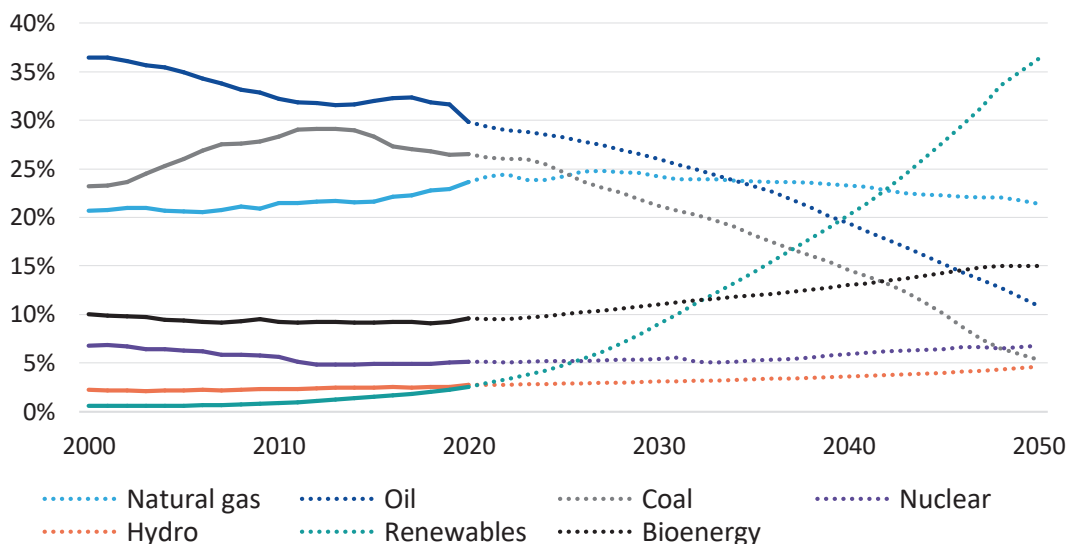
In the ETS, nuclear and hydro will have a continued presence in the global energy mix, accounting for a 7% and 5% share, respectively, partially due to nuclear's long lifetime, while extensions for existing nuclear reactors are acceptable. Given a huge build-out of electricity infrastructure and renewables expansion, stable and dispatchable low emissions sources will be in demand.

The ETS envisages a significant drop in the share of fossil fuels from 80% at present to 38% by 2050. Coal will be in retreat, and by 2050 this fuel will account for just 5% of the global energy mix, driven by structural changes in the power sector and industry. However, coal will remain important to several industrial processes, particularly in iron and steel and cement production, where fuel-switching opportunities are more limited. Oil demand will also see a strong decline and will be 65% lower than in 2020, mostly driven by the diffusion of EVs, plug-in hybrids, NGVs and fuel cell vehicles, as well as overall improvement in fuel efficiency in the transport sector. Oil will provide 11% of the energy mix in 2050 but will be persistent in plastics and petrochemicals despite increased recycling.

Natural gas will remain the most resilient fossil fuel, with its share falling from over 23% today to approximately 21% between 2020 and 2050. Moreover, the large-scale implementation of deep gas decarbonisation options through blue hydrogen and CCS/CCUS will improve the environmental credentials of this fuel. The ETS anticipates a drop in gas demand by 14%, compared to 2020.



Figure 6.3. Changing the structure of the world primary energy demand in the ETS



Source: GECF Secretariat based on data from the GECF GGM 2021

Natural gas and hydrogen demand

In comparison to the RCS, where natural gas demand reaches 5,625 bcm by 2050, demand in the ETS will experience a contrasting trend. Peaking in 2027 at 4,250 bcm, gas usage will plateau and in later years will decrease to 3,275 bcm by 2050. Reduced usage in advanced economies will offset continued growth in developing markets, with coal-to-gas switching and clean air policies supporting a resilient outlook.

From a sectoral perspective, significant declines are expected to come from the residential and commercial sector as well as from industry, amid increasing electrification and other decarbonisation options. Power generation, despite the fall in demand, will remain the largest consumer due to rising electricity demand, while natural gas fired power plants will continue to be a primary source of flexibility, even taking into account anticipated progress in storage technologies. At the same time, the transport sector and blue hydrogen generation will offer the best growth potential for natural gas usage.

Unlike the ETS and in line with the RCS, natural gas production in the HS will grow continuously over the outlook period. In the HS, natural gas production will increase to more than 5,200 bcm by 2050, almost 400 bcm less than what is forecast in the RCS.

There are both negative and positive drivers for natural gas demand in the HS. On the one hand, accelerating the hydrogen economy and its penetration into the energy sectors causes a reduction in demand for some other conventional fuels. Natural gas demand will be negatively affected as hydrogen is progressively introduced to the industry, power generation, residential and commercial sectors. On the other hand, a portion of lost demand for natural gas will be compensated for by producing clean natural-gas-based hydrogen mainly in the form of blue hydrogen. Therefore, the overall gap in natural gas demand between the RCS and the HS for the year 2050 is not very significant.

In the HS, the demand for hydrogen is forecast to reach more than 620 Mt per year by 2050, which is 2.3 times more than the value forecast in the RCS and more than six times higher than the current value.

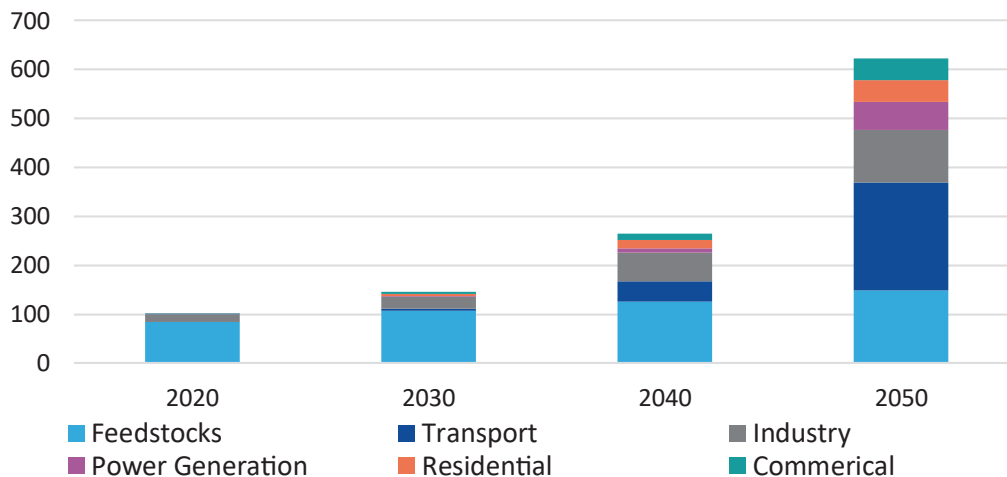
Transport emerges as the primary driver of hydrogen demand in HS, accounting for more than one-third of the total market. Hydrogen is assumed to substitute for petroleum products in almost all sub-sectors in transport. Heavy and long-haul road transports, trains, shipping and aviation are considered as hard-to-electrify energy sectors in which other measures for decarbonisation are highly challenging. Besides FCEVs, EVs are also assumed to contribute to the decarbonisation of passenger road transport and light commercial vehicles. But hydrogen supremacy in transportation is mainly focussed on sectors such as aviation and shipping in which currently no other options but hydrogen is presumed. Almost one gigatonne of CO₂ (more than the total energy-related CO₂ emissions of Germany and the UK combined) is estimated to be abated by the penetration of hydrogen in transportation in the HS.

The industry is the second-largest emerging consumer of hydrogen among the energy sectors. High-grade temperature industries such as steel, chemical, cement, etc., are also among the hard-to-decarbonise sectors. Post-combustion carbon-capturing is a possibility to decarbonise these industries but other than in industrial clusters, it is not considered

economically viable, leaving hydrogen as a valid option to deal with decarbonisation in this sector. In the HS, around 110 Mt of hydrogen is expected to be consumed in the industry as fuel, while almost 150 Mt is also needed as feedstock for the production of methanol, ammonia, etc. Refinery feedstock will also maintain a share in hydrogen use as feedstock.

Other sectors such as power generation and building will drive the rest of hydrogen demand, together accounting for 25% of hydrogen demand by 2050. Hydrogen can be used as a buffer for renewable power generation, reducing the disadvantages of intermittency and enhancing power security.”

Figure 6.4. Hydrogen demand by sector in the HS (Mt of H2)



Source: GECF Secretariat based on data from the GECF GGM

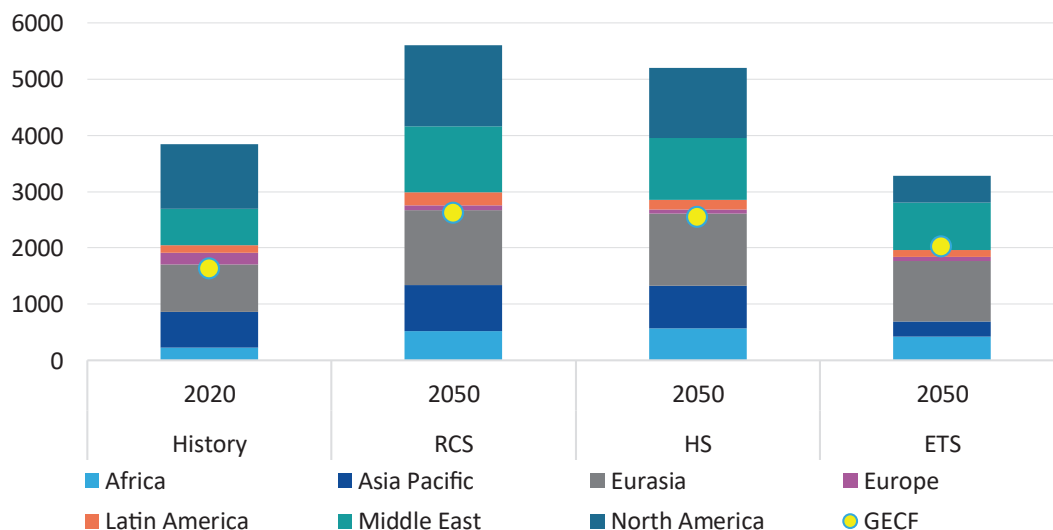
Natural gas and hydrogen production

As previously mentioned, demand for natural gas in both alternative scenarios is estimated lower than the RCS by 2050. Consequently, natural gas production is forecast to be less than what is expected in the RCS. The gap with the RCS for the global production of natural gas is around 2,350 bcm in the ETS, and 400 bcm in the HS. The lower decline in global gas production in the HS is due to blue hydrogen production that partially offsets the share lost by natural gas in total energy demand, primarily in the industry and power generation sectors.

Almost all regions in both the ETS and the HS will show lower natural gas production compared to the RCS by 2050. The only exception is Africa, which in the HS delivers around 50 bcm more production than in the RCS. This higher amount of gas production from Africa in the HS is due to the vast potential of blue hydrogen production, especially in North Africa, mainly from the GECF member countries Egypt, Algeria and Libya. In Africa, natural gas production is expected to be robust in the HS due to the solid increasing regional natural gas demand. Other regions, such as Asia Pacific, Eurasia, Latin America and the Middle East are seen with slightly lower gas production in the HS compared with the RCS by 2050, averaging around 60 bcm for each. North America shows the largest gaps for gas production under the different scenarios. In North America, natural gas production in 2050 is forecast to be around 1000 bcm less in the ETS than what is forecast in the RCS. As for the HS, this gap is much narrower at 190 bcm, thanks to blue hydrogen production in Canada and the US. However, this gap is the most significant regional gap between the HS and the RCS for regional gas production.

The natural gas production level within the GECF was found to be very resilient in all of the alternative scenario modelling. As mentioned in Chapter 4, the share of GECF countries in natural gas production will increase to 47% by 2050. This share is forecast to be higher at 49% and 62%, respectively, in the HS and the ETS by the Outlook horizon. Taking the aforementioned significantly lower global production in the ETS compared with the RCS of around 2,350 bcm, GECF countries are responsible for only a quarter of this gap (slightly less than 600 bcm). Similarly, in the HS, GECF countries are foreseen to account for one-sixth of the total gap in natural gas production compared with the RCS by 2050, amounting to 63 bcm out of more than 400 bcm. This is primarily due to the significant potential and competitiveness of the GECF countries in blue hydrogen production in the HS. This reason, besides other advantages, such as vast natural gas resources and the prospect of implementing CCUS and methane-abatement technologies, will enable GECF countries to preserve their market share of natural gas even in the very highly decarbonised future of the energy world modelled in the ETS.

Figure 6.5. Natural gas production outlook by region (bcm)



Source: GECF Secretariat based on data from the GECF GGM

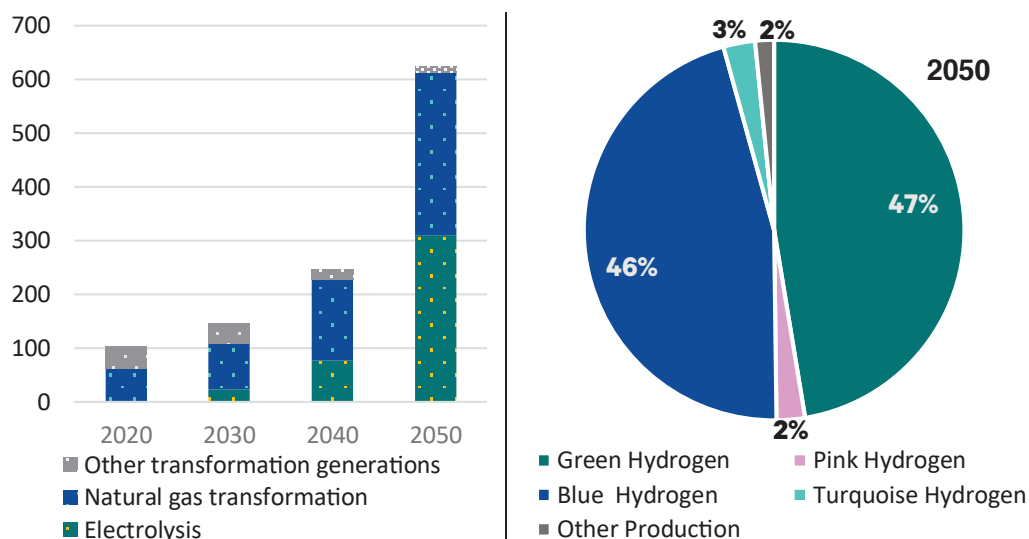
Natural gas is emerging as a crucial element in the hydrogen economy through blue hydrogen production and potentially turquoise hydrogen.

Currently, more than 60% of total hydrogen production comes from natural gas reforming, where the emitted carbon is not abated and instead released to the atmosphere, which is known as grey hydrogen production. The remainder of the hydrogen production today is mainly through the gasification of coal and transforming petroleum, and still falls in the category of grey hydrogen.

In the HS, only around 2% of the total hydrogen production by 2050 (10 mt of H₂) is assumed to be residual grey hydrogen production (but primarily through gas reforming with a very negligible amount from coal gasification).

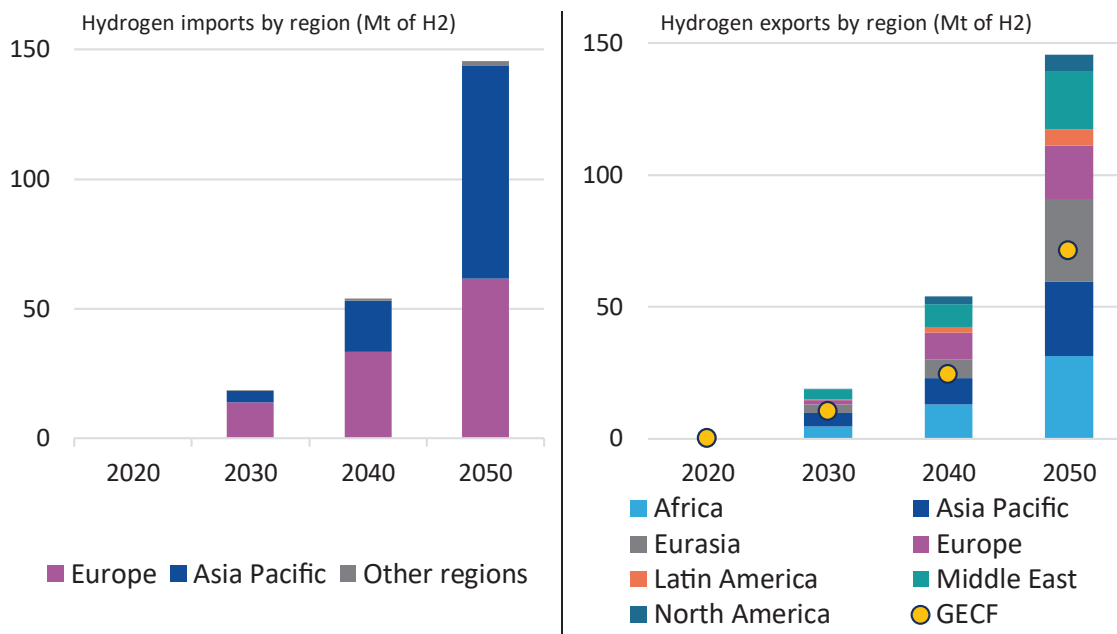
The results of the HS suggest that almost 46% of total hydrogen production will be sourced through blue hydrogen production, mainly through the transformation of natural gas with carbon-capturing measures. However, the share of total natural gas-based hydrogen generation, including other clean pathways such as turquoise hydrogen, is almost half of the total production. Nearly 47% of total hydrogen production is forecast to come from green hydrogen production, which refers to hydrogen produced via electrolysis with renewable electricity. A tiny percentage is derived from nuclear power, usually referred to pink hydrogen.

Figure 6.6. Hydrogen production outlook by source and technology in the HS (Mt of H₂, %)



Source: GECF Secretariat based on data from the GECF GGM

Figure 6.7. Hydrogen Trade Outlook (Mt of H₂)



Source: GECF Secretariat based on data from the GECF GGM

Natural gas and hydrogen trade

The ETS predicts natural gas trade will shrink considerably, together with a reduction in natural gas demand over the long term. At the same time, major trends articulated in the RCS, such as the further acceleration of LNG over the pipeline trade, and even more elevated focus of LNG trade flows in Asia and the emergence and rapid development of carbon-neutral LNG, will be observed in the ETS as well.

In the RCS, the global gas trade is expected to grow by 45% by 2050, at an average growth rate of 1.5% p.a. between 2020 and 2050, from 1,255 bcm per year in 2020 to reach 1,815 bcm per year in 2050, accounting for one-third of global gas demand. Asia Pacific, the main destination of the world’s LNG over the whole forecasting period which held a 70% share of LNG trade in 2020, will account for an even more impressive 80% of trade by 2050.

In the ETS, natural gas trade will rise by only 5% from 2020 to 2039 to peak at 1,344 bcma, afterwards decelerating to 1,300 bcma by 2050. There will be an overall gap in natural gas trade between the ETS and the RCS of over 500 bcma by 2050 (the ETS natural gas trade will be 28% lower than the RCS in 2050), thereby, representing a significant decline under the ETS, but this is more modest compared to the natural gas demand gap between the ETS and the RCS of 2,350 bcma by 2050 (the ETS natural gas demand will be 42% lower than the RCS in 2050). The EU and other developed legacy importers of natural gas will see a precipitous decline in demand due to an accelerated penetration of renewables in their power generation and other sectors. China, and later developing Asia, primarily India, will follow suit. The investment process in the full cycle of LNG (liquefaction, shipping and regasification) will be even more daunting and challenging compared to the RCS as uncertainties will strongly weigh on the suppliers as well as consumers of natural gas.

In the HS which allows for the deep penetration of hydrogen fuel into the energy sectors, hydrogen trade also plays an important role. It is not possible to significantly introduce a fuel into the energy system without developing the platforms and enhancing the possibility for its trade. The HS suggests that around 145 Mt of H₂ will be traded annually by 2050. This volume accounts for more than 23% of the total hydrogen supply and demand by then.

Net importer regions namely Europe and Asia Pacific, will import the majority of the hydrogen trade, however, there will be significant exporters within these regions such as Australia.

Countries in almost all regions will export this clean fuel. North Africa, the Middle East, Eurasia and Asia Pacific will be among the significant exporters of hydrogen in the HS by 2050. By 2050, Russia and Australia will emerge as the largest blue and green hydrogen exporters, respectively.

GECF countries have a strong potential to emerge as exporters of hydrogen, mainly in Eurasia, North Africa and the Middle East. This is due to the significant potential of blue hydrogen production in GECF countries thanks to vast gas reserves and CCS potential and the possibility of producing green hydrogen in some areas in the Middle East and North Africa.

Results from the HS suggest that by 2050 around half of the hydrogen exports will be sourced from the GECF countries, primarily in the form of blue hydrogen and, to a lesser extent, green hydrogen.



Annex I: Regional Groupings

Advanced economies: OECD regional grouping, plus Bulgaria, Croatia, Cyprus, Latvia, Lithuania, Malta and Romania

Africa: North Africa and Sub-Saharan Africa regional groupings

Asia Pacific: Afghanistan, Australia, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Chinese Taipei, Cook Islands, Democratic People's Republic of Korea, Fiji, French Polynesia, Hong Kong, India, Indonesia, Japan, Kiribati, Korea, Lao People's Democratic Republic, Macau (China), Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, New Zealand, Pakistan, Palau, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Timor-Leste, Tonga, Vanuatu, and Viet Nam

Caspian: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan

Developed Asia: Australia, Japan, South Korea and New Zealand

Developing Asia: Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Chinese Taipei, Cook Islands, Democratic People's Republic of Korea, Fiji, French Polynesia, Hong Kong, India, Indonesia, Kiribati, Lao People's Democratic Republic, Macau (China), Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Palau, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Timor-Leste, Tonga, Vanuatu and Viet Nam

Developing economies: All other countries not included in the "advanced economies" regional grouping

Eurasia: Caspian region and Belarus, Moldova, the Russian Federation and Ukraine

Europe: European Union and Albania, Bosnia and Herzegovina, Gibraltar, Iceland, Montenegro, Norway, Serbia, Switzerland, the Former Yugoslav Republic of Macedonia, the Republic of Moldova and Turkey

European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom

GECF Members: Algeria, Bolivia, Egypt, Equatorial Guinea, Libya, Islamic Republic of Iran, Nigeria, Qatar, Russia, Trinidad and Tobago, and Venezuela

GECF Observer Members: Angola, Azerbaijan, Iraq, Malaysia, Norway, Peru and the United Arab Emirates

Latin America: Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands (Malvinas), French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Pierre et Miquelon, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay and Venezuela

Middle East: Bahrain, the Islamic Republic of Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates and Yemen

Middle East and North Africa (MENA): Middle East and North Africa regional groupings

North Africa: Algeria, Egypt, Libya, Morocco and Tunisia

North America: Canada, Mexico and the United States

OECD: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States.

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam

Sub-Saharan Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo, Réunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia and Zimbabwe



Annex II: Abbreviations

| | |
|-----------------|---|
| ACE | Affordable Clean Energy Rule (US) |
| ADNOC | Abu Dhabi National Oil Company |
| AEMO | Australian Energy Market Operator |
| BCM | billion cubic meters |
| bn | billion |
| BC | British Columbia (Canada) |
| CAAGR | compound annual average growth rate |
| CAGP | Central Asia Gas Pipeline |
| CAPEX | capital expenditure |
| CBM | coalbed methane |
| CCGT | combined-cycle gas turbine |
| CCS | carbon capture and storage |
| PipeChina | China Oil and Gas Piping Network Corporation |
| CHP | combined heat and power |
| COVID-19 | a disease caused by a new strain of coronavirus. 'CO' stands for corona, 'VI' for virus, and 'D' for disease. |
| CNG | compressed natural gas |
| CNPC | Chinese National Petroleum Company |
| CO ₂ | carbon dioxide |
| CPP | Clean Power Plan (US) |
| CPS | carbon price support |
| EB | Executive Board (GECF) |
| EC | European Commission |
| ECB | European Central Bank |
| EIA | Energy Information Administration (US) |
| EOR | enhanced oil recovery |
| EPA | US Environmental Protection Agency |
| ETS | Emissions Trading System |
| EU | European Union |
| EU ETS | EU Emissions Trading System |
| EV | electric vehicle |
| FEED | Front End Engineering Design |
| FDI | Foreign Direct Investment |
| FID | final investment decision |
| FSRU | floating storage regasification unit |
| FYP | Five-Year Plan |

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|--------|--|
| GDP | gross domestic product |
| GECF | Gas Exporting Countries Forum |
| GGM | Global Gas Model |
| GGO | Global Gas Outlook |
| GHG | greenhouse gas |
| GIIGNL | International Group of Liquefied Natural Gas Importers |
| GTL | gas to liquids |
| HH | Henry Hub (US gas hub) |
| ICE | internal combustion engine |
| IEA | International Energy Agency |
| IED | Industrial Emissions Directive |
| IMF | International Monetary Fund |
| IMO | International Maritime Organization |
| INDC | Intended Nationally Determined Contribution |
| IGX | India Gas Exchange |
| ITGI | Interconnection Turkey-Greece-Italy |
| JCPOA | Joint Comprehensive Plan of Action |
| JFTC | Japan Fair Trade Commission |
| JKM | Japan Korea Marker |
| JOGMEC | Japan Oil, Gas and Metals National Corporation |
| JPY | Japanese yen |
| JVETS | Japan's Voluntary Emissions Trading Scheme |
| LCV | light commercial vehicle |
| LFPR | labour force participation rate |
| LNG | liquefied natural gas |
| LPG | liquefied petroleum gas |
| MER | market exchange rates |
| mn | million |
| mtpa | million tonnes per annum |
| NAFTA | North American Free Trade Agreement |
| NBP | National Balancing Point (UK gas hub) |
| NDCs | Nationally Determined Contributions |
| NEXI | Nippon Export and Investment Insurance |
| NGO | non-governmental organisation |
| NGV | natural gas vehicle |
| NOX | nitrogen oxides |
| NS 2 | Nord Stream 2 |



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|--------|--|
| OCS | Outer Continental Shelf |
| OPEC | Organization of the Petroleum Exporting Countries |
| PHEV | plug-in hybrid electric vehicles |
| PoS | Power of Siberia |
| PPP | purchasing power parity |
| PSPP | Public Sector Purchase Programme |
| PSV | Punto-di-scambio-virtuale |
| PV | photovoltaic |
| QP | Qatar Petroleum |
| R&D | research and development |
| RBI | Reserve Bank of India |
| RES | Reference Energy System |
| RPS | renewable portfolio standards (US) |
| SDGs | Sustainable Development Goals |
| SOX | sulphur oxides |
| SCP | Southern Caucasus Pipeline |
| TANAP | Trans-Anatolian Gas Pipeline |
| TAP | Trans Adriatic Pipeline |
| TAPI | Turkmenistan-Afghanistan-Pakistan-India Pipeline |
| TEC | Technical and Economic Council |
| TENP | The Trans Europa Naturgas Pipeline |
| TPES | total primary energy supply |
| TTF | Title Transfer Facility (Dutch gas hub) |
| UAE | United Arab Emirates |
| UK | United Kingdom |
| UN | United Nations |
| UNCTAD | United Nations Conference on Trade and Development |
| US | United States |
| USD | United States Dollar |
| VAT | value-added tax |
| WEF | World Economic Forum |
| WHO | World Health Organization |
| WTI | West Texas Intermediate |
| WTO | World Trade Organization |
| YPF | Yacimientos Petroliferos Fiscales |
| YPFB | Yacimientos Petrolíferos Fiscales Bolivianos |
| YTF | yet-to-find |

Annex III: Conversion factors and definitions⁶

| From\To | CM | mmBtu | toe | GJ | Therms | CF | T LNG | CM LNG | MWh | BOE | TC |
|---------|---------|----------|------------|----------|----------|----------|-----------|----------|-----------|---------|---------|
| CM (S) | 1 | 0.034 | 0.0009 | 0.035797 | 0.34 | 35.31 | 0.0007252 | 0.001639 | 0.009944 | 0.0066 | 0.0014 |
| mmBtu | 29.47 | 1 | 0.02519 | 1.0548 | 10.00 | 1040.59 | 0.021 | 0.048 | 0.293 | 0.1940 | 0.0420 |
| toe | 1169.59 | 39.69 | 1 | 41.868 | 396.93 | 41303.70 | 0.8481 | 1.917 | 11.63 | 7.700 | 1.667 |
| GJ | 27.94 | 0.9480 | 0.0239 | 1 | 9.48 | 986.52 | 0.0203 | 0.0458 | 0.2778 | 0.1839 | 0.03981 |
| Therms | 2.947 | 0.1000 | 0.0025 | 0.1055 | 1 | 104.06 | 0.0021 | 0.0048 | 0.0293001 | 0.019 | 0.0042 |
| CF | 0.02832 | 0.000961 | 0.00002421 | 0.0010 | 0.009610 | 1 | 0.000021 | 0.000046 | 0.00028 | 0.00019 | 0.0000 |
| T LNG | 1379 | 46.80 | 1.1791 | 49.36 | 468.00 | 48699 | 1 | 2.26 | 13.71 | 9.08 | 1.97 |
| CM LNG | 610.0 | 20.70 | 0.5216 | 21.84 | 207.02 | 21542 | 0.4423 | 1 | 6.066 | 4.02 | 0.87 |
| MWh | 100.57 | 3.413 | 0.0860 | 3.600 | 34.13 | 3551 | 0.073 | 0.16 | 1 | 0.66 | 0.14 |
| BOE | 151.9 | 5.155 | 0.1299 | 5.438 | 51.55 | 5364 | 0.1101 | 0.2490 | 1.5104 | 1 | 0.22 |
| TC | 701.8 | 23.82 | 0.6000 | 25.12 | 238.16 | 24782 | 0.5089 | 1.1504 | 6.9780 | 4.6199 | 1 |

| NATURAL GAS | | | | | | | | |
|--------------|----------------|---------|-------------|-------------|--------------|----------------|---------|-------------|
| MJ/Nm3 (GCV) | kCal/Nm3 (GCV) | kWh/Nm3 | (N)bcm/mtoe | (S)bcm/mtoe | MJ/Sm3 (GCV) | kCal/Sm3 (GCV) | kWh/Sm3 | Btu/Scf GCV |
| 41.959 | 10,022 | 11.66 | 1.1087 | 1.1696 | 39.775 | 9500 | 11.04 | 1068 |

⁶ Each of the gas production entities has its own calorific value so the specific value is used for these flows to convert into the energy content. For this reason, values that appear in the production entity tables and in the supply data tables that aggregate the volumes may be different from the production values using standard conversion factors.

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| Agriculture | Includes all energy used on farms, in forestry and for fishing [ISIC Divisions 01 – 03]. |
| Associated gas | Natural gas found in contact with or dissolved in crude oil in the reservoir. |
| Barrel of Oil Equivalent (BOE): | The term allows for a single value to represent the sum of all the hydrocarbon products that are forecast as resources. Typically, condensate, oil, bitumen, and synthetic crude barrels are taken to be equal (1 bbl = 1 BOE). Gas and NGL quantities are converted to an oil equivalent based on a conversion factor that is recommended to be based on a nominal heating content or calorific value equivalent to a barrel of oil. |
| Biofuels | Liquid fuels derived from biomass or waste feedstocks, including ethanol and biodiesel. |
| Biomass and waste | Renewable organic materials, such as wood, agricultural crops or wastes, and municipal wastes, especially when used as a source of fuel or energy. Biomass can be burned directly or processed into biofuels such as ethanol and methane. |
| Bunkers | Includes both international marine bunkers and international aviation bunkers |
| Coal | Includes primary coal (hard coal, lignite, coking and steam coal) and derived fuels (including patent fuel, brown coal briquettes, coke oven coke, gas coke, gas-works gas, coke-oven gas, blast-furnace gas and oxygen steel furnace gas). Peat is also included. |
| Coalbed methane | Natural gas contained in coal deposits. Coalbed gas, although usually mostly methane, may be produced with variable amounts of inert or even non-inert gases. [Also called coal-seam gas or natural gas from coal.] |
| Condensate | A mixture of hydrocarbons (mainly pentanes and heavier) that exist in the gaseous phase at original temperature and pressure of the reservoir, but when produced, are in the liquid phase at surface pressure and temperature conditions. Condensate differs from NGLs in two respects: (1) NGL is extracted and recovered in gas plants rather than lease separators or other lease facilities, and (2) NGL includes very light hydrocarbons (ethane, propane or butanes) as well as the pentanes-plus that are the main constituents of condensate. |
| Contracts for Difference | A mechanism of hedging the price of electricity for renewables between renewable generators and counter parties (for instance the Low Carbon Contracts Company in the UK). It allows the generators to receive a pre-agreed level for the duration of contracts (the strike price). |
| Conventional resources | Resources that exist in porous and permeable rock with buoyancy pressure equilibrium. The petroleum initially in place is trapped in discrete accumulations related to a localized geological structural feature and/or stratigraphic condition, typically with each accumulation bounded by a down dip contact with an aquifer, and is significantly affected by hydrodynamic influences such as buoyancy of petroleum in water. |
| Cost tranche | A set of production entities grouped according to a defined cost range. |
| Curtailed | According to National Renewable Energy Laboratory, curtailment is a reduction in the output of a generator of variable renewable energy from what it could otherwise produce given available resources like wind or sunlight. Variable renewable energy curtailment is usually used as a way to reduce the production of energy that cannot be delivered due to lack of power system flexibility. |
| Decommissioned LNG project: | Project is officially announced by owner as decommissioned (mothballed) or has been inactive for a significant period of time. |
| Distributed energy system | Includes systems which generate and deliver energy services (Power, cooking or heating services) independent of centralised systems. For renewable power, they include particularly off grid renewable generators such as home solar panels. |
| Domestic | The domestic sector includes energy used in the residential, commercial and agricultural sectors. Domestic energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment. |
| Dry gas | Natural gas remaining after hydrocarbon liquids have been removed before the reference point. It should be recognized that this is a resources assessment definition and not a phase behaviour definition. (Also called lean gas.) |
| Electricity generation | Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation. |

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| Energy sector | Covers the use of energy by non-energy sector and the energy losses in converting primary energy into a form that can be used in the final consumption sectors. It includes losses by gas works, petroleum refineries, blast furnaces, coke ovens, coal and gas transformation and liquefaction. It also includes energy used in the distribution network. Transfers and statistical differences are also included in this category. |
| Enhanced oil recovery (EOR): | The extraction of additional petroleum, beyond primary recovery, from naturally occurring reservoirs by supplementing the natural forces in the reservoir. |
| Existing LNG project | Existing capacity that has reached commercial start-up. Includes projects in temporary shutdown. For FSRUs, vessels are chartered at the port on a regular basis. |
| Feed-in premium | A renewable policy support mechanism which offers compensation based on market conditions. In this mechanism, electricity from renewable energy sources is sold on the electricity spot market and renewable producers receive a premium on top of the market price of their electricity production. No premium is paid if market prices are higher than the reference tariff level. |
| FEED completed LNG project: | Project that has finished front-end engineering and design (FEED) (for both the upstream and liquefaction segment). |
| Feed-in tariff | A renewable policy support mechanism which offers a fixed compensation to renewable energy producers, providing price certainty and long-term contracts that help finance renewable energy investments. The level of compensation is based on the cost of generation of each technology. |
| Feedstock | Includes refinery feedstocks and petrochemical feedstocks. |
| Final Investment Decision (FID): | Project approval stage when the participating companies have firmly agreed to the project and the required capital funding. |
| Gas exports (upstream volumes): | Gas volumes shipped by a gas-exporting country to an importing country including all the losses (pipelines, liquefaction, shipping and regasification). |
| Gas hydrates | Naturally occurring crystalline substances composed of water and gas, in which a solid water lattice accommodates gas molecules in a cage-like structure or clathrate. |
| Gas imports (end use volumes): | Net gas volumes delivered by an exporting country to an importing country, not including the losses during the shipment. |
| Heat energy | Obtained from the combustion of fuels, nuclear reactors, geothermal reservoirs, the capture of sunlight, exothermic chemical processes and heat pumps which can extract it from ambient air and liquids. It may be used for heating or cooling, or converted into mechanical energy for transport vehicles or electricity generation. Commercial heat sold is reported under total final consumption with the fuel inputs allocated under power generation. |
| Heat generation | Refers to fuel use in heat plants and combined heat and power (CHP) plants. |
| Heat Plants | Refers to plants (including heat pumps and electric boilers) designed to produce heat. |
| Hydropower | The energy content of the electricity produced in hydropower plants. |
| Industry | Includes fuel used within the manufacturing and construction industries. Key industry sectors include iron and steel, chemical and petrochemical, nonferrous metals, non-metallic minerals and other manufacturing. |
| In FEED LNG project | Project has started FEED (for either upstream or liquefaction segment). |
| International aviation bunkers: | Includes the deliveries of aviation fuels to aircraft for international aviation. The domestic/international split is determined based on departure and landing locations and not by the nationality of the airline. |
| International marine bunkers: | Covers those quantities delivered to ships of all flags that are engaged in international navigation. |
| Nationally Determined Contributions (NDCs): | Intended Nationally Determined Contributions (INDCs) after their ratification by individual governments. They include the countries' GHG mitigation and adaptation pledges submitted to the UNFCCC in the framework of the Paris Agreement. |



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| Natural gas liquids (NGLs): | A mixture of light hydrocarbons that exist in the gaseous phase in the reservoir and are recovered as liquids in gas processing plants. |
| Natural gas production capacity: | The potential volumes of natural gas ready to be produced by developed wells and processing units associated with a production entity. |
| Natural gas production | Marketed production including domestic sales and exports. |
| Natural Gas Proven Reserves: | Refers to existing reserves, new projects and unconventional (existing) gas resources. |
| Natural gas | Portion of petroleum that exists either in the gaseous phase or is in solution in crude oil in a reservoir, and which is gaseous at atmospheric conditions of pressure and temperature. Natural gas may include some amount of non-hydrocarbons. |
| New project gas production: | Fields that have been discovered but have yet to be developed or are in development. |
| Non-energy use | Fuels used for non-energy products excluding use as feedstock in petrochemical plants. Examples of non-energy products include gas works, cooking ovens, lubricants, paraffin waxes, asphalt, bitumen, coal tars, and oils as timber preservatives. |
| Nuclear | Refers to the primary energy equivalent of the electricity produced by a nuclear plant, assuming an average conversion efficiency of 33%. |
| Oil | Includes demand for crude oil both conventional and unconventional and petroleum products including refinery gas, ethane, LPG, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha and other oil products (white spirit, lubricants, bitumen, paraffin, waxes, and petroleum coke) and natural gas liquids but excludes biofuels and synthetic oil-based products. |
| Oil sands | Sand deposits highly saturated with natural bitumen. Also called “tar sands.” Note that in deposits such as the western Canada oil sands. |
| Petrochemical Feedstocks | The petrochemical industry includes cracking and reforming processes for the purpose of producing ethylene, propylene, butylene, synthesis gas, aromatics, butadiene and other hydrocarbon-based raw materials in processes such as steam cracking, aromatics plants and steam reforming. |
| Power generation | Refers to fuel use in electricity plants and combined heat and power (CHP) plants. |
| Pre-FEED LNG project | Project has officially announced that it has started pre-FEED (for either upstream or liquefaction segment). |
| Probable reserves | An incremental category of estimated recoverable quantities associated with a defined degree of uncertainty. Probable Reserves are those additional reserves that are less likely to be recovered than Proved Reserves but more certain to be recovered than Possible Reserves |
| Production entity | A gas field, or group of gas fields located in the same zone, or gas geological prospects from which marketed natural gas production is expected to be available and economically viable. |
| Production signature | A curve that models the rate at which the remaining recoverable gas reserves will be produced, without damaging the corresponding reservoir. |
| Proposed LNG project | Proposed and planned capacity that has not yet started FEED. Includes projects that have completed pre-FEED but not yet begun FEED. |
| Proved reserves | Those quantities that, by analysis of geoscience and engineering data, can be estimated with reasonable certainty to be commercially recoverable from a given date forward from known reservoirs and under defined economic conditions, operating methods and government regulations. |
| Refinery Feedstocks | Processed oil destined for further processing (e.g. straight run fuel oil or vacuum gas oil) other than blending in the refining industry. It is transformed into one or more components and/or finished products. |
| Renewables | Geothermal, hydropower, solar photovoltaics (PV), concentrating solar power (CSP), wind and marine (tide and wave) energy for electricity and heat generation. |
| Reserves | Those quantities of petroleum anticipated to be commercially recoverable by application of development projects to known accumulations from a given date forward under defined conditions. |

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| Residential | Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices and cooking equipment. |
| Shale gas | Although the terms shale gas and tight gas are often used interchangeably in public discourse, shale formations are only a subset of all low-permeability tight formations, which include sandstones and carbonates, as well as shales, as sources of tight gas production. |
| Speculative LNG project | Capacity that the GECF believes is a long-term possibility for future liquefaction supply based on available reserves, but which has not been officially proposed by a company. |
| Stalled LNG project | Project not officially cancelled but which has not made progress in recent years. |
| Tight gas | Gas that is trapped in pore space and fractures in very low-permeability rocks and/or by adsorption on kerogen, and possibly on clay particles, and is released when a pressure differential develops. |
| Total final consumption | The sum of consumption by the different end-use sectors. TFC is broken down into energy demand in the following sectors: industry, transport, domestic (including residential, commercial and agriculture), and feedstock uses. |
| Total primary energy demand: | Represents domestic demand only and is broken down into power generation, heat generation, refinery, energy sector, non-energy sector and total final consumption. |
| Transport | Fuels and electricity used in the transport of goods or persons within the national territory irrespective of the economic sector within which the activity occurs. |
| Unconventional gas production: | Fields that are associated with gas resources that are from either coal bed methane, tight shale or other resources that require special development techniques. |
| Unconventional resources | Such resources cannot be recovered using traditional recovery projects owing to fluid viscosity (e.g. oil sands) and/or reservoir permeability (e.g. tight gas/oil/CBM) that impede natural mobility. |
| Under construction LNG project: | Capacity that is currently under construction or going through commissioning. |
| Yet-to-Find (YTF) | Refers to the theoretical volume of undiscovered gas reserves, calculated based on the probability of finding reserves in certain geological areas. YTF also assumes that technological advancements will make it economically feasible to extract the gas in the future. |



Annex IV: References

Chapter 2

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Chapter 6

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