

2018 GLOBAL GAS OUTLOOK SYNOPSIS



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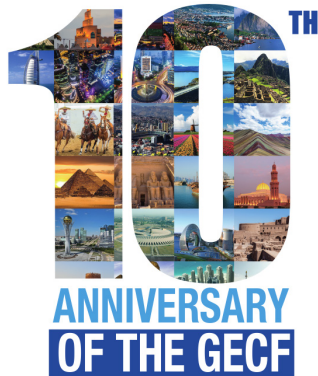
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ABOUT THE GECF

The Gas Exporting Countries Forum (GECF) is an intergovernmental organisation, whose objective is to increase the level of coordination and strengthen collaboration amongst its Member Countries. The GECF was established in May 2001 in Tehran, the Islamic Republic of Iran. It became a full-fledged organization in 2008 with the signing of the GECF Statute in Moscow, Russia.

The GECF is a gathering of the world's leading gas producers, with its permanent Secretariat based in Doha, Qatar. In accordance with the GECF Statute, the organization 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 cooperation in gas-related matters.

At the time of writing, the GECF includes nineteen countries comprised of twelve 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, the United Arab Emirates and Venezuela. Azerbaijan, Iraq, Kazakhstan, the Netherlands, Norway, Oman and Peru have the status of Observer Members. Angola joined the GECF as an Observer Member on 1 January 2019, becoming the sixth African country to join the Forum.

This year's publication of the GECF Global Gas Outlook Synopsis coincides with the Forum's 10th anniversary. Since its establishment, the GECF has become a well-respected authority for insights into global gas markets, and a trustworthy platform for the promotion or dialogue on key aspects of the gas industry.

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

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Foreword



This 2018 edition of the GECF Global Gas Outlook Synopsis was prepared by the GECF Secretariat to share our views on the developments that have been taking place in energy markets and on the multiplicity of factors and players which are resulting in shifting strategies and a new architecture shaping the world.

Our Outlook projects that global energy markets will continue to evolve in the coming decades. Energy demand will continue to drive these transformations and energy accessibility will become a top priority for policymakers, especially in Asia and Africa.

Global energy demand is forecast to increase by 26% by 2040. Natural gas will be the only hydrocarbon resource to increase its share in the global energy mix, from 22% today to 26% in 2040. These estimates were recently echoed at the 2018 G20 Meeting of Energy Ministers, who reached a consensus on the critical importance of natural gas and its capacity to expand significantly over the coming decades, supporting transitions towards lower emission energy systems.

Coordinated approaches to global energy market developments will contribute towards meeting the world's future energy needs, ensuring global sustainable development and responding to environmental concerns, in order to achieve the UN's seventeen Sustainable Development Goals (SDGs) and the Paris Agreement targets.

The GECF's calculations show that through proper investment in infrastructure, natural gas can meet the energy needs of these populations while improving air quality and achieving the targets outlined in SDG 7: access to affordable, reliable, sustainable and modern energy for all.

Despite natural gas' advantages, it is facing some key challenges, especially those related to energy policy. Firstly, the role of natural gas in reducing greenhouse gas emissions is not clearly highlighted in countries' National Determined Contributions (NDCs) submitted to the United Nations Framework Convention on Climate Change. Secondly, we observe some policy constraints in Europe with continuing changes of market rules and design, as well as the dominance of national policies and priorities over those of the UN. Thirdly, the policy remains unclear regarding the future role of natural gas and coal, particularly in some Southeast Asian countries.

The campaign for greater penetration of natural gas in the energy mix cannot be undertaken only by the owners of such resources or the producing companies; it should involve all stakeholders including producers, buyers, consumers, governments, environmental groups, and academia. Representing more than two-thirds of the world's proven gas reserves and almost half of global natural gas production, the GECF is open to dialogue with all parties interested in promoting natural gas to ensure global sustainable development and increase energy access to the world's most vulnerable populations.

Yury P. Sentyurin
Secretary General





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Executive Summary

This 2018 GECF Global Gas Outlook Synopsis highlights key challenges and opportunities for major gas exporting countries in the development of their natural gas resources. The next twenty years will be characterised by unprecedented transformations to global energy systems, as governments around the world seek energy to support economic development while treating environmental concerns.

Global primary energy demand is projected to rise by 26% through to 2040, as the population grows by an additional 1.7 billion people, mostly added to urban areas in regions with the lowest energy access. The global economy is expected to grow an average 3.4% per annum (p.a.) from 2018 to 2040, assuming that labour productivity will increase in parallel. While these demographic and socioeconomic trends will provide important opportunities for expanding gas' potential, the structure of the gas market is expected to stay geographically segmented over outlook period, despite some integration post-2025.

Natural gas will continue to be encouraged through supply-side policy measures promoting availability and accessibility to resources, and through demand-side measures including emissions standards, carbon pricing or mandated fuel switching. However, divergence and incongruence in national and regional energy policies will continue to pose challenges for producers. Market fundamentals may not provide adequate signals for developing costly gas supply chains or for enhancing gas demand against cheap coal and subsidized renewables, particularly in major and potential gas consuming markets.

Despite these challenges, natural gas will be the fastest growing fossil fuel, partially thanks to policy drivers concerning air quality. Global natural gas demand is projected to increase by 46% through to 2040, displacing other sources of energy in a range of sectors. The share of oil, the world's largest energy source, will decline from 32% to 29% by 2040. Coal's share will fall much more significantly, from 27% to 21%. Soaring renewable energy consumption of 6.7% p.a. will not be enough to displace CO₂ emissions from coal and oil, which will represent around 72% of global emissions in 2040. Large substitution potential between coal and natural gas remains, and can significantly contribute to emissions reductions given proper policy signals.

An abundance of natural gas resources will allow for production to grow by 1.7% p.a., with total output expected to reach 5427 bcm by 2040. This Outlook forecasts that YTF (yet-to-find) resources will begin contributing to gas production starting from 2021. In 2025 around 1% of total production will be obtained from undiscovered fields. This figure is projected to increase significantly by 2040, to around 21%. Global natural gas production from deep-water fields (including ultra-deep-water fields) will also accelerate over the forecast period, with approximately 15% of total production sourced from deep-water reserves in 2040, compared to only 4% in 2017.

Out of 5427 bcm of global natural gas demand in 2040, 1616 bcm will be imported, of which 960 bcm will come from GECF Members. The LNG segment will continue to see rapid expansion in the medium-term, with the share of LNG exports rising significantly. In order to meet growing demand and deliver new supplies to emerging import markets, the gas industry will require additional investments of \$7.9 trillion in natural gas production capacity and gas trade infrastructure.



Introduction and Scope

This 2018 GECF Global Gas Outlook (GGO) Synopsis is prepared in accordance with the resolutions adopted in the 18th GECF Ministerial Meeting. It aims to support the Long-term Priority Objectives of the GECF Long-Term Strategy and was developed within the framework of the Technical and Economic Council (TEC) created within the Forum, to guide and monitor extensive research on global gas markets.

The GECF Global Gas Outlook is unique, as it is the only energy outlook worldwide to focus solely on natural gas. It aims to be a global reference for insights into 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.

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, upstream production, pipeline, LNG and regasification capacity assumptions, as well as the corresponding investment figures. Chapter V is dedicated to global trade outcomes resulting from the equilibrium between supply and demand. 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 features two alternative scenarios devised by the GECF Secretariat: the Carbon Mitigation Scenario (CMS) and the Technology Advancement Scenario (TAS).

The GGO is quantified through the use of the GECF Global Gas Model (GGM), which is a unique energy model developed in-house at the GECF Secretariat, and which includes different sub-models with each one focused on one segment of the gas value chain (production, pipelines, LNG, shipping, regasification, contracts and demand). The GGM is characterized by its uniquely high granularity, encompassing: 113 country-level forecasts (with 60 regional aggregates and a global projection), complete energy balance estimates (covering 29 sectors and 34 fuels annually from 1990 to 2040), more than 4300 gas supply entities, and annual contracted and delivered volumes (including 600 contracts based on more than 1000 company-to-company contracts).

All of the sub-models have been calibrated and based on 2017 as the last available year of historical data. 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 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.

The starting year of our projections is 2018. Therefore, all data from 2018 to 2040 in the following analysis is considered a part of the GECF forecast, unless otherwise stated.



1

Global Economic and Energy Price Prospects



Key findings

- As population growth in the next 23 years will be two-thirds of the 2001-2017 rate, and 500 million fewer workers will join the labour force, labour productivity will need to increase at over 2.0% per year to sustain a GDP growth of 3.4%.
- Rapidly growing regions in Southeast Asia and India will remain the engines for the global economy up to the 2040s, despite significant deceleration to around 4.0% by 2040 for Southeast Asia and close to 4.9% for India in PPP terms.
- Chinese and Indian economies will experience difficulties shifting to knowledge-intensive GDP growth in the long-term, as China's labour force shrinks and India's stops growing.
- For the developed economies, growth prospects are balanced, as they are already both knowledge-intensive and driven by increasing labour productivity.
- Asian natural gas prices will increase in the long-term, fuelled by increasing demand, a policy push for air quality and expanding infrastructure.
- European natural gas prices will experience strong price pressure in the long-term, as carbon mitigation policies and global gas market integration increase competition between European and Asian consumers.

The assumptions of this Outlook are based on benchmark United Nations (UN) forecasts for population and urbanisation. The long-term macroeconomic, vehicle fleet and reference price projections have been developed in-house by the GECF Secretariat. Neither the qualitative or quantitative assumptions necessarily reflect the views of individual GECF Members.

Main energy demand drivers were strong in 2017 and 2018, although rising geopolitical risks have decreased security both for supply and demand in the short- and medium-term. After achieving its fastest growth in seven years in 2017, the global economy kept pumping on all cylinders this year. Growth is poised to hold the record for 2018-2019, as the global economy accelerates to 3.7%, the fastest seen since the post-Great Recession recovery in 2011. This growth is broad-based, as the strongest global trade recovery in eight years has helped to spread growth benefits among developing economies.

The financial risks both for developed and developing countries are at their lowest, and government debt levels are being brought to a sustainable level. Along with strong growth, there are some signs of overheating, but central banks have already started reacting by increasing interest rates in the US and by tapering the quantitative easing program in the Euro zone and Japan.

Although the global economy appears to be in good shape for growth, risks are heightening. For the first time in decades, these risks stem mainly from geopolitical trends. Tensions outlined in the 2017 GGO have not subsided, but instead appear to be increasing both globally and in several key areas. Global trade and investment risks increased when the US began to introduce trade barriers on the largest scale since World War II. Geopolitical tensions in Southeast Asia and the Middle East also escalated in 2017-2018, increasing risks to the security of energy supply. In Europe, the "hard Brexit" for the UK remains a possibility as the EU and UK parliaments may fail to agree on the deal.

There are background macroeconomic risks for the growth outlook as well. In the medium-term, growth in emerging markets will be put under pressure from tighter monetary policy and deceleration in the US, the test of EU budget and banking supervision put up by the Italian government, as well as increasing concerns about the mountain of local debt in China. However, compared to the situation in the past, the policies and the economies themselves are much better poised to avoid these risks.

The longer-term trends for the Outlook period remain unchanged from the last edition, with an average annual growth rate for GDP of 3.4%. The most important difference this year is the size of electric vehicle fleets which have been revised upwards, as climate policy challenges (1) put increasing pressure on carbon emitters and batteries become more affordable. However, if the geopolitical situation escalates, this will also impact longer-term perspectives.

1.1 Population growth and urbanisation

Population growth is the main driver of future energy trends. This Outlook is based on the projections outlined in the UN World Population Prospects Revision 2017 (2), medium fertility scenario, which sees the global population rising from 7.5 billion in 2017 to 9.2 billion by 2040.

Most population growth will take place in regions with the lowest energy access and almost no infrastructure, which could provide important potential for promoting natural gas demand in the future. Of this 1.7 bn increase, Sub-Saharan Africa is expected to provide 0.7 bn, and another 0.5 bn will come from Asia Pacific, with India alone accounting for 260 million, almost the size of the current US population. Population growth will slow over the projection period, moving from 1.3% p.a. growth between 2000 and 2017 to 0.9% p.a. from 2018 to 2040, in line with trends seen over the last three decades. The fastest growth will be experienced in Sub-Saharan Africa, with 2.4% p.a., followed by the Middle East and North Africa (MENA), with 1.3% p.a. As the GECF comprises ten Members from the Middle East and Africa, the combined population of GECF countries is expected to grow strongly at a rate of 1.3%, amounting to over 1 bn by 2040.

Urbanisation prospects used by this Outlook are based on UN World Urbanisation Prospects, Edition 2018 (3). As the push towards global urbanisation is strong, almost all the 1.7 bn population increase is expected to add to the urban population, with rural populations staying flat. The rapid pace of urbanisation is expected to transform rural societies in Sub-Saharan Africa (39% urban population) and developing Asia (with China still at 58% and India at just 34% urban population). This will lead to an 8% increase in world urbanisation levels to 62% by 2040, although this barely reaches the current urbanisation level of the GECF countries.

Urban energy consumption patterns differ from rural ones, and this affects energy demand. Access to gas, heating and power networks is much higher in cities, thus decreasing the need to use diesel or traditional biomass in the domestic sector. After a level of 65% urbanisation has been reached, the use of traditional biomass per capita decreases dramatically, with very low traditional biomass use after 80% urbanisation is reached.

1.2 Economic projections

Overall, the global economy is still expected to grow at 3.4% on average for 2017-2040. This growth will be concentrated in the power-hungry developing Asian market, with China growing by 4.7% on average and India at an average of 5.9% over the outlook horizon. With developed economies following a stable growth trend of 1.9%, and developing economies poised to grow by 4.3%, long-term global economic growth is expected to be broad-based and stable, while medium-term growth will follow cyclical patterns. For 2017-2025, the global economy is forecast to grow at a more modest pace of 2.8% as Eurasia, Southeast Asia and the Americas are expected to experience below average growth. For the current edition of the Outlook, there are several important developments in the global economy that have been taken into account.

First and foremost, the new trade policy of the US government is a downside risk for global growth, and it is already impacting the long-term expectations of investors. The downside of this impact is unclear, as there is no indication from the US on how much trade tensions could escalate. This unpredictability itself is one of the main risk factors for the long-term. Secondly, the growth of the Indian economy is estimated to be less than previously forecast, as previous and current years have not seen any progress on structural reforms after the semi-successful tax reform last year. Thirdly, in Europe the risks of a "hard Brexit" rose significantly in 2018 as the UK government and the EU were together unable to develop any meaningful solutions to their current impasse at the time of writing. This is reflected in the outlook for the EU.

However, all things considered, these developments will not affect aggregate global growth, as the outlook for non-UK Europe remains strong, as it is for global trade which will help spread growth more evenly to developing countries, especially in Sub-Saharan Africa and Southeast Asia.

The GECF economies are expected to grow strongly both in the medium-term (benefiting from a lasting rebound in the energy markets) and in the long-term based on strong labour force inflows, provided that enough investment is devoted to human capital (see Figure 1.1).

Figure 1.1. Projected GDP growth rates (%)



Source: GECF Secretariat based on data from the GECF GGM

The near-term prospects for the global economy appear bright, as the increasing geopolitical risks are not expected to stifle global economic growth until after 2020. The medium-term outlook is more clouded, however, as the deceleration in growth in the US, Japan, China and India is expected to outweigh recovery in Eurasia and Latin America.

For a few notable exceptions (such as the US), the global macroeconomic risks are low in the medium-term, allowing for a higher and more stable global GDP growth rate. Mounting geopolitical and structural challenges, however, could impact the outlook post-2020.

The risks of further sharp rises in US interest rates to curb inflation stoked by the Trump administration's late-cycle tax cuts and subsequent 'overheating' of the economy, could have dire consequences for developing countries with large dollar denominated debt. Additionally, the challenge between Italy, which is pursuing a budget in defiance of EU policy, and Brussels may destabilise the Eurozone banking system.

Main structural features of the long-term economic scenario

No more “Asian Economic Miracles” in the future

The theory of economic development states that a country should start by building and exporting the most basic things (raw materials, agricultural products, textiles) and subsequently move up the value chain to heavy industry, machinery exports and finally to the export of innovation, finance and professional services in a knowledge-based economy.

These assumptions are built into most authoritative global competitiveness rankings compiled by such organizations as IMD Lausanne and the WEF or instance, the WEF ranking weights three groups of competitiveness indicators differently based on the level of GDP per capita. The prospects of long-term growth change once an economy moves up to the next group, and the policy challenges are also different.

It is important to note that most upcoming technological advances erode this order, making the transition between levels a bigger challenge. Twenty years from now, for example, it will be much harder to base this transition on the wealth accumulated from the export of cost-competitive labour or natural resources to the premium consumer markets.

Automation is already affecting the demand for unskilled labour. This deprives developing countries from future labour export rent, and thus of future investment and development resources. Existing producers face human-robotics competition that further depresses producer margins and incomes in developing countries. Cleaner energy needs and carbon taxes will depress producer margins for coal and oil, decreasing export revenues for several developing nations, including Saudi Arabia, Iran, Iraq, Nigeria, Venezuela, Colombia, Indonesia and South Africa. They will also drive up costs and erode margins for energy-intensive products mostly produced in developing countries.

In the future, for those Asian and African countries which have not yet undergone an “economic miracle” or a windfall from petrodollars, it will be much harder to go down the same development path to achieve an “Asian economic miracle” of their own.

Geopolitics will cast a much longer shadow over economic development

In the new global architecture, economic development and foreign investment in several fast-growing regions will be affected by global and regional security shifts. While this Outlook assumes no global or major regional military conflict will take place in the foreseeable future, we assume geopolitics will influence economic development as global value chains get restructured in line with new geopolitical priorities. This will affect the global economy and energy along three main avenues.

First is the redistribution of global trade flows. There is a conflicting global trade policy agenda from the US, the EU, the UK and China, not to mention several new regional economic unions (like the Eurasian Economic Union, EEU) in the process of integration. Global trade growth will benefit developing economies less than before, as

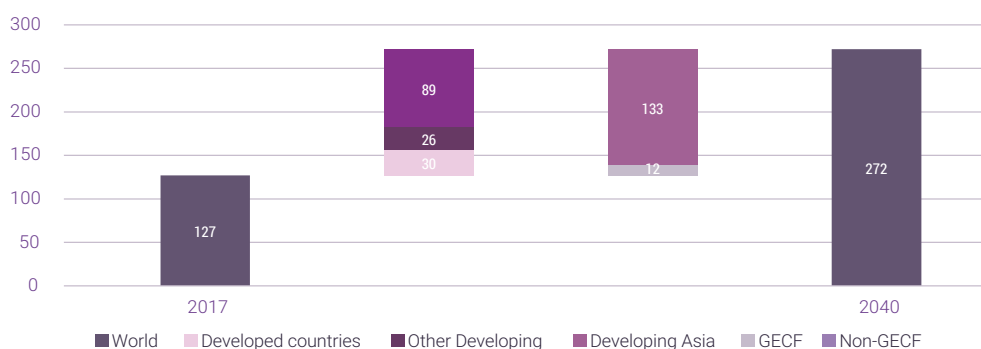
the value added will be eroded by stricter standards. The instruments are aplenty, including stricter intellectual property, environmental and ethical standards. A wider base for patent royalties, new green taxes and probably even Tobin taxes could also be used. Also, there will be stronger competition for the developed markets, including competition between human labour and robotic automation and increased South-South competition, as ASEAN and selected Middle East and African countries emerge as new production hubs.

The governments of large developing economies are already taking steps to protect their domestic markets. This typically takes the form of non-tariff barriers and indirect subsidies to national 'champions', but also the buildup of R&D, innovation systems and human capital. Some of these programs, like 'Made in China 2025', imply building competing value chains at home or within the region, aimed at the global market. This is what is currently happening with the shipbuilding, aerospace and electric vehicles industries in China.

The second consideration is the way that investment and finance flows are being limited for political reasons, which poses the risk of global financial market fragmentation. There is the capacity to limit investment and technology transfer from developed to developing countries by imposing sanctions. These political sanctions are treated as national security measures and are not covered by any trade and investment regulation or international arbitration. This makes it a flexible tool to stifle investment flows and to potentially destabilize the financial system in any particular country. In the long-term, it is likely that sanctions instruments will be used by more countries, and will cover a wider range of sectors. It is also likely that countries (most likely the EU and the UK) which are able to project financial power will impose sanctions and freeze the assets of certain entities as part of their geopolitical interaction.

The third issue is the increased risk of supply route disruptions, especially for energy supplies. Tensions are already mounting regarding Bab-el-Mandeb and the Hormuz straits, as well as South China Sea shipping routes. The risks for the East European gas corridor are also elevated.

Figure 1.2. Projected GDP growth composition to 2040 (2017\$ trillion in PPP)



Source: GECF Secretariat based on data from the GECF GGM

1.3 Vehicle markets outlook

The transport sector accounted for a little over 7.8% of global natural gas consumption in 2017, with just 0.5% coming from the road transport segment. Nonetheless, road transport's energy consumption is large, accounting for 22.2% of global energy consumption, a share that is expected to decrease just slightly to 2040.

The present structure of the car fleet is bound to change with new technology advances and shifting policy priorities. A number of recent policy initiatives in European countries, China and India, as well as from global industry leaders, means that electric vehicles, mostly battery-electric vehicles and plug-in electric vehicles, are expected to receive most policy support and investment at the expense of internal combustion engines (ICE) powered by petroleum products. There are two ways that natural gas demand could benefit from this process.

The first is through an increase in the natural gas vehicle (NGV) fleet, especially in the medium-term, as air quality policies in several developing countries are enacted. According to the World Health Organization (WHO) Global Urban Ambient Air Pollution Database, 91% of the global population lives in areas where air pollution exceeds WHO guideline limits.

A significant part of this pollution comes from transport emissions. According to the website of the Natural Gas Vehicle Association Europe (NGVA Europe), compressed natural gas transport emits 95% less PM-2.5, and 70% fewer nitrate oxides compared to the strict Euro IV vehicle fuel standards. This means ten times fewer polluting emissions as compared to the vehicle fuel standards (Euro III or less strict) used in most developing countries.

Both liquefied petroleum gas (LPG) and compressed natural gas (CNG) vehicles (as well as the rapidly developing sub-segment of LNG vehicles) are more affordable in cities once there is gas infrastructure in place. There is also potential for the government policy to increase usage of NGVs. So far, CNG vehicle markets will likely remain in the MENA and Latin America, with the only new market emerging in South Korea as a result of an announced program for replacing diesel vehicles with LPG, CNG and LNG vehicles. As the vehicle fleet in developing Asian countries grows by 570 million vehicles up to 2040, there is additional potential to increase the share of NGVs, especially in public transport and heavy goods vehicles sectors.

The second way in which gas demand could benefit is through an increase in demand in the power sector as a result of more electricity demand from the growing electric vehicles (EV) fleet. The global EV fleet is expected to rise by 300 million vehicles by 2040. Even though about 200 million of these new EVs are in developing Asia, where 55% of the power will still be generated from coal by 2040, there is a projected increase of over 1000 TWh for global electricity demand from the road transport sector. This will be an additional driver for natural gas demand in the power sector.

Vehicle fleet outlook

The global passenger car and light commercial vehicle (LCV) fleets are projected to grow by 770 million by 2040, at an annual rate of 2%. This forecast remains mostly unchanged from previous GGO editions. Out of these 770 million new vehicles, developing Asia fleets are to add 570 million vehicles to 2040, and Latin America fleets are

to add another 67 million. This reflects the growing population and urbanisation levels, and to a greater extent, economic growth rates and the corresponding increase in household wealth.

Despite the increasing well-being in developing countries, in terms of the total car fleet they will only overtake the fleet size in developed countries in 2025. Motorization levels in developing Asia will double, as measured by cars per capita, but for developing countries cars per capita will still be three times less than that of developed countries by 2040.

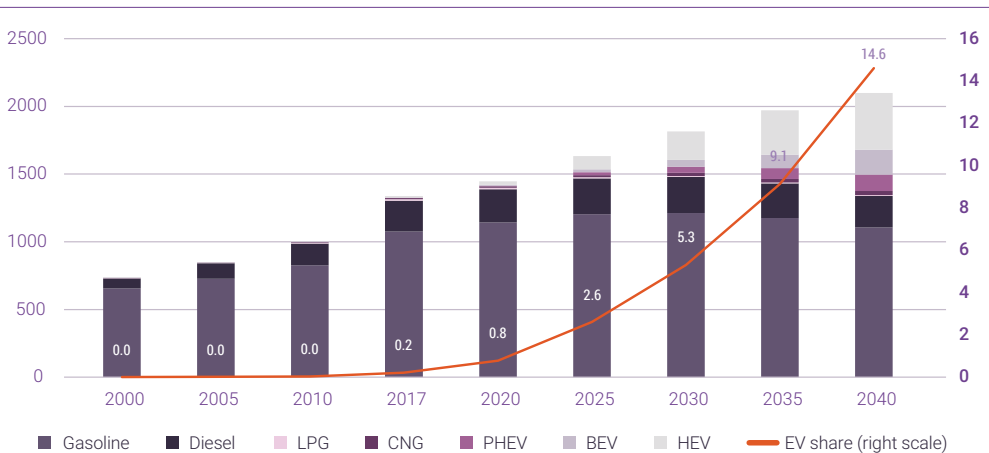
As for North America and the EU, the projections assume changes in the mobility industry that will cause a slight decrease in motorization levels, as penetration of autonomous cars will enable the wider use of car sharing and ride-hailing as a substitute to car purchases.

Fleet structure outlook

In 2016-2018, policy decisions to restrict the sales of new ICE vehicles have been announced at a national or large city level in 20 countries. The proposed deadlines are largely for the 2030-2035 period, and are expected to impact R&D investment and the bankability of new ICE powertrain projects. The global automotive industry has also announced several pledges to completely remove or significantly reduce ICE powertrains with new models.

Changes in passenger cars and LCV sales structures will impact the corresponding fleet structure with an average lag of 5 to 10 years, depending on the vehicle service life in a given country. Based on the sales structure trends outlined above, we assume a decrease in the share of vehicle fleets powered by gasoline or diesel from 98% in 2017 to 64% by 2040. NGVs will account just for 1.6% of the car fleet (mostly CNG vehicles), compared to 14.6% for EVs and 19.8% for hybrids.

Figure 1.3. Global car fleet structure (million)



Source: GECF Secretariat based on data from the GECF GGM

1.4 Natural gas price projections

We project that the structure of the natural gas market over the outlook period will remain largely geographically segmented, although integration processes will pick up from post-2025. Short-term price differences between regional markets will be increasingly eliminated via LNG shipments, although this requires a price differential of over \$5-6/mmBtu depending on transport costs, as well as supply and demand balance. The integrated market regions with the most natural gas turnover or liquidity will still be the American and European markets, as well as the Asian and Latin American markets.

Medium-term drivers and outlook

While all volumes traded within the US go through a gas-to-gas competition mechanism and are tied to the Henry Hub quotation, volumes exported to Asian and Latin American markets are largely oil-indexed (at least 84.1% and 70%, respectively, plus any hybrid pricing volumes). This difference in market structures is expected to persist for the outlook period. A majority of volumes (estimated at over two thirds) imported to the European market are currently priced using a hybrid oil and benchmark gas indexation mechanism (these are mostly classified as gas-to-gas competition by the IGU), and unless more regulation is enforced, this is expected to persist.

Notwithstanding the pricing structures described above, price will define the role of natural gas in the energy mix as a result of competition between fossil and non-fossil energy sources across the transformation, industry, domestic, transport and feedstock sectors in regional markets. These dimensions of competition determine the lower and upper bounds for natural gas prices. While the LNG market remains under pressure from projects started when the oil price was twice as high, there have been announcements that mean a significant number of those projects will be postponed indefinitely or cancelled. This backs up our projection that the natural gas market is expected to rebalance within two or three years, with the 2020-2025 period seeing a slow but steady upward price trend for all regional markets.

Long-term drivers and outlook

For the longer-term, increased capital cost of production, gas demand pressure from energy transition and power mix substitution, as well as the lack of new transportation projects coming after 2030 are expected to drive prices up. The important exception will be Latin America, where the growth in indigenous natural gas production and short distance for US LNG shipments will keep prices at a slight premium to Henry Hub. For the European market, the price is expected to edge up significantly following the new avenues for gas-to-gas competition with both LNG and pipeline supplies to Asia, as well as an increase in the carbon price and planned coal and nuclear capacity phase-outs.



2

Energy Policy Developments and Emissions Trends

Key findings

- The strong link that energy forms between the 2030 Sustainable Development Agenda and the Paris Agreement allocates responsibility to energy policies in supporting alignment of the two frameworks. Policies that support natural gas can achieve progress for both agendas.
- Market-based mechanisms, such as auctioning and tradable certificates, are increasingly contributing to renewables and energy efficiency. However direct government intervention and subsidies will continue to play a key role, especially in emerging markets.
- Natural gas continues to be encouraged through supply side measures promoting availability and accessibility to resources, and through demand side measures, including emissions standards, carbon pricing or mandated switching.
- Coal policy is expected to continue limiting coal's environmental impacts, either through mandated phase-out or through energy efficiency and emissions standards. Several countries, mainly in the Asia Pacific region, will continue to rely heavily on coal to meet growing energy demand.
- Countries with developed nuclear power systems will extend the lifetime of several existing projects to support energy independence and carbon mitigation commitments, but this will not counterbalance the long-term downward trend, since no large nuclear program will be adopted to replace the old fleet.
- Carbon pricing is assumed to progress in several countries, but large pricing disparities will persist, reflecting countries' conditions and climate commitments. Carbon markets are not expected to be globally integrated over the forecast period.
- CO2 emissions are expected to continue to grow, albeit at a reduced rate of 0.6% p.a., driven by economic growth and urbanisation in non-OECD countries.
- The Outlook sees the Paris Agreement target being missed by some margin and that coal and oil will represent around 72% of 2040 emissions. Increased gas use can contribute in closing the gap between emissions and the 2°C target.
- There is large uncertainty on methane emissions data from gas-related activities. Recent studies reported emissions ranging from 0.2% to 10% of the methane produced. Despite these uncertainties, the gas industry is taking this issue seriously through concrete actions and initiatives.

2.1 The role of energy policies in achieving sustainable development

The adoption of the United Nations 2030 Agenda for Sustainable Development in September 2015 marked the commitment of more than 190 countries to implement policy measures and initiatives that aimed to meet the UN Sustainable Development Goals (SDGs). Nearly three months after the 2030 Agenda was agreed upon by the UN General Assembly, the Paris Agreement was adopted, underpinned by countries' Intended Nationally Determined Contributions (INDCs)¹. While the SDGs reflect the holistic nature of sustainable development, the Paris Agreement specifically addresses greenhouse gas (GHG) emissions. Actions proposed under the 2030 Agenda and the INDCs are voluntary, necessitating the need to integrate the two frameworks coherently through well designed policies.

Energy at the crossroads of the 2030 Sustainable Development Agenda and the Paris Agreement

The efficient implementation of the 2030 Sustainable Development Agenda and Paris Agreement requires an understanding of the existing links and interdependencies between them and the discovery of ways that can consistently support both the SDGs and climate change mitigation and adaptation actions.

The most critical point of intersection between the SDGs and the Paris Agreement is energy. More energy-related actions outlined in countries' INDCs relate to SDG 7 (affordable and clean energy) than to other goals, but energy should not be restricted to only one SDG. Energy underpins all the economic, social and environmental aspects inherent to sustainable development, and actions specific to the energy sector play a dominant role in supporting country-level commitments under the Paris Agreement.

The strong link that energy forms between the 2030 Agenda and the Paris Agreement allocates responsibility to energy policies in supporting the alignment of the two frameworks. Energy policies establish priorities for the energy sector, affect preferences for particular energy resources, and define production, distribution, and consumption patterns. As such, energy policies can support progress towards achieving the SDGs and carbon mitigating actions which are outlined in countries' INDCs.

Promoting natural gas: a solution for a more balanced policy approach

Natural gas can be a balanced and viable solution that achieves progress toward climate objectives and the SDGs. The technical, economic, social and environmental advantages of natural gas enable it to contribute efficiently to the achievement of the SDGs through several channels. Natural gas contributes to reducing carbon intensity and the pollution effects which result from energy related activities; it supports access to modern energy; it improves the availability and reliability of supply; and it provides competitive and affordable energy. Natural gas can also be a vector for increased cooperation and the transfer of technologies between countries. Thanks to all these benefits, policies and measures which support natural gas can drive the implementation of both climate and sustainable development agendas.

¹ In the following paragraphs, INDCs include both countries that ratified the Paris Agreement, transforming their INDCs into NDCs, and those that have not yet ratified it.

Greater penetration of natural gas, especially when substituting for coal, has contributed significantly to mitigating CO₂ emissions. Between 2012 and 2017, China increased the share of natural gas in its primary energy mix from 4.4% to nearly 6% and decreased the share of coal from 67% to nearly 62%. Despite the fact that coal to gas switching was not the only factor affecting carbon intensity, it did contribute significantly to its decrease from 3.22 tCO₂/toe in 2012 to around 3.04 tCO₂/toe in 2017.

The US and UK are also relevant examples of where the shift to natural gas in the power sector and, to a lesser extent, in the industrial sector has significantly contributed to emissions reductions between 2012 and 2017, estimated at 3.5% for the US and 18.2% for the UK.

2.2 Global energy policy assumptions

2.2.1 Renewable policies

More than 170 countries have set renewables targets that drive their policy effort (4). The role of market-based mechanisms in the portfolio of measures considered by countries to support their targets has been increasing, specifically in countries that have achieved large renewables progress.

Market-based mechanisms can be a response to a reduction in the cost of subsidies and a way to incorporate market fundamentals in investment decisions, mainly by transferring the risk to project developers. However, higher risk and lower revenues for investors might lead to a significant slowdown in the installation of additional renewable capacities (5, 6). Auctioning of capacities has recently emerged as a popular market-based policy instrument, since it lowers the price of renewables capacity due to competition between bidders. However, it can also increase the risk of not achieving appropriate returns for investors (7).

This Outlook assumes that renewable support schemes will be a combination of instruments including subsidies as well as market-based instruments. Subsidies are assumed to continue to play a key role, especially in emerging markets, and also for some renewable options and technologies such as distributed renewable energy systems.

The integration of renewables is the main challenge for their progress, especially in markets hoping to achieve a high level of penetration. To deal with this challenge, the Outlook expects increased implementation of policy measures aimed at improving the flexibility of power systems and their capacity to accommodate a large share of intermittent renewables. Gas-fired power plants are expected to play a significant role in improving renewable integration.

Despite increasing policy attention being given to the deployment of renewables in other sectors such as heating and transportation, the Outlook is cautious regarding renewables progress in these sectors. This view is mainly supported by competition from other energy alternatives, such as oil and natural gas.

On a market level, this Outlook assumes that the adoption of more ambitious targets in the new EU renewable energy directive will encourage EU countries to implement measures aimed at accelerating the development of

renewables. However, differences are expected in terms of policy effort and outcomes depending on country-specific situations and constraints.

For China, the Outlook takes into account the recent government decisions to reduce subsidies for solar PV and onshore wind projects and to cap the development of solar PV projects. This decision is expected to slow down solar PV capacity development significantly, as well as onshore wind compared to recent trends.

This Outlook assumes that India's policy will contribute to accelerating renewables development, especially through capacity auctioning that has helped to achieve low prices. However, some key challenges will prevent India from reaching its ambitious renewables target, including funding constraints and competition from cheap coal.

2.2.2 Non-renewable policies

NATURAL GAS

Policies play a key role in supporting or constraining the progress of natural gas in countries' energy mixes. There is evidence that the adoption of measures favourable to natural gas could accelerate the penetration of this source of energy and achieve many economic, technical, social and environmental advantages. One case in point is China. The country adopted several measures to support the development of gas infrastructure and trade, and to encourage the penetration of gas at the expense of polluting and carbon intensive fuels, mainly coal; these measures resulted in an increase in the share of natural gas from 2.8% in 2007 to around 6.7% in 2017.

In this Outlook, it is assumed that natural gas continues to be encouraged through different measures that promote domestic production, the development of gas infrastructure, integration of networks, and the development of imports, particularly through LNG. Among the key measures that are expected to be adopted in this regard are: market reforms that aim to improve competition and attract gas investments in the upstream and midstream sectors; the facilitation of permits and administrative processes for gas project developments; and cooperation between countries to improve the availability and accessibility to natural gas and to enhance gas trade.

The Outlook also assumes the adoption of environmental policies that encourage the consumption of natural gas through strengthened emissions standards, pricing of carbon, or mandated fuel switching to natural gas from coal and oil. Gas is particularly promoted in power generation as a flexible option to balance the variable electricity that results from a large penetration of intermittent renewables.

The transportation and heating sectors will see strong policy attention to improve the penetration of natural gas. For transportation, one of the key policies is the support to infrastructure development in bunkering and gas refuelling stations, in order to cope with strengthened emission standards. Specifically, the development of bunkering is encouraged by expected implementation of the new International Maritime Organization (IMO) standards after 2020 (8).

On a market level, the key policy orientations featured in this Outlook are the following:

- ⊗ EU policy support to key gas infrastructure projects will continue, but economic and geopolitical uncertainties may affect the timing of their implementation.
- ⊗ China will face several challenges in meeting its announced target for natural gas (8-10% share of gas by 2020 and 15% by 2030), including a need to scale up domestic production, build extended infrastructure and storage facilities to manage seasonality and implement pricing and market reforms.
- ⊗ Policy measures in India will increase availability and accessibility to natural gas, especially in sectors where gas is in competition with oil, such as transport and industry. Gas will continue to observe difficulties in the power sector due to competition from coal and renewables.
- ⊗ Policy developments in many Asian countries show increased interest in promoting natural gas especially in the power generation sector. This interest is mainly driven by the willingness of governments to reduce pollution and carbon emissions, as well as to substitute gas for oil in the power, industry and transportation sectors.
- ⊗ The shale gas revolution in the US will retain its momentum, regardless of environmental and pending legal challenges affecting exploration and production activities.

COAL

Several countries have announced plans to phase out or limit the role of coal in their energy mixes. The launching of a new initiative, the "Powering Past Coal Alliance", supports these commitments with more than 25 countries which account for around 7% of global carbon emissions, deciding to move away from coal by 2030. Other actors are also playing a role in this dynamic and have pledged to undertake actions against coal, such as cities, institutions, banks, environmental agencies and business entities. (9, 10)

Despite these observed trends, other countries, especially in Asia and Eastern Europe, continue to rely on coal as an abundant, cheap and often domestically produced alternative. These countries have, though, deployed extended efforts to adopt cleaner and more efficient coal technologies.

In this context, the global coal policy orientation assumed in the Outlook is to limit the environmental impact resulting from coal-related emissions. This will occur either through the phasing out of coal or by adopting measures, particularly in emerging countries, which improve energy efficiency and support emissions reductions from coal-based technologies.

On a market level, the key policy assumptions in major coal consuming countries are as follows:

- ⊗ In China, despite an observed loosening of policy restrictions on coal in 2018, the government is assumed to be continuing to implement measures on limiting the consumption of coal, and accelerating the use of clean technologies as outlined in the 13th Five-Year energy plan.
- ⊗ For India, although the recent reduction in the coal tax is expected to drive growth in the usage of coal over the short to medium-term; the Outlook expects that this growth will be mitigated over the long-term by the implementation of policy measures which support efficiency in coal usage.

- ② For other Southeast Asian countries, this Outlook assumes that coal will remain a strategic option that contributes to meeting growing energy needs and security of supply. However, extended efforts to support gas, renewables and energy efficiency, especially in the context of ASEAN cooperation, is expected to mitigate coal demand growth compared to previous countries' projections and plans.

NUCLEAR

Despite the apparent resistance of the nuclear industry to the wave of opposition that followed the Fukushima catastrophe and the reluctance of many governments to significantly reduce the role of nuclear in their future energy mix, there are still large policy uncertainties and challenges affecting the future of nuclear at a global level.

In mature nuclear markets, one of the key challenges for policymakers is to deal with an old fleet and therefore with increased security risks (more than 60% of nuclear power plants are more than 30 years old). In many of these countries, there is still policy decision doubt over whether to proceed with large-scale nuclear phase out, to extend the plants' lifetime or to build new nuclear plants. These decisions have been complicated by factors such as the resistance from local populations, energy independence concerns and the government's fear of abandoning nuclear expertise and losing skilled employment opportunities.

For emerging nuclear markets, the main challenges are related to technology transfer, the complexity of projects and high development costs, financing issues, geopolitical concerns, resistance from local populations and constraints on fuel supply and skilled labour.

This Outlook assumes that nuclear policy will focus on supporting safety requirements and controls of nuclear power plants and operations along the nuclear fuel cycle, and that this will contribute to the increasing cost of nuclear power generation. The Outlook assumes that many projects in developed nuclear countries would benefit from lifetime extension, driven by the concerns about energy independence and carbon mitigation, but that this will not counterbalance the long-term decreasing trends of nuclear power in these countries, since no large nuclear program will be adopted to replace the old nuclear plants.

The Outlook assumes there will be policy support for nuclear in emerging and developing countries which have announced nuclear programs, driven by the willingness to diversify supply and meet the growing needs of baseload power generation. However the various challenges faced by these countries will result in slow progress towards the announced targets and ambitions. Furthermore, it is assumed that progress in renewables and natural gas will affect the prospects of nuclear and offer a less complex and more viable solution to meet both electricity needs and sustainability requirements.

2.2.3 Energy efficiency policies

Recent policy trends highlight an increasing number of mandatory energy standards being imposed by different countries, with a vision to strengthen them gradually in order to achieve energy savings and reduce the environmental impact. These mandatory standards target sectors including buildings, industry and transportation, and are usually associated with fiscal incentives, financial supports and price signals in order to improve their effectiveness in promoting energy efficient opportunities. There is also an emerging trend of

market-based instruments, such as white certificates and auctioning, to support energy efficiency, primarily in developed countries (11). In this Outlook, policy measures including standards, funding supports, price signals and the promotion of smart technologies are expected to support energy efficiency progress in different sectors.

The Outlook assumes that policy measures will focus on energy consumption in buildings and industry, including the consumption of electrical appliances and equipment as well as cooling and heating services. For heating, the penetration of gas-based boilers, as well as the combined production of heat and power are assumed to be supported as a cost efficient way to improve air quality and reduce carbon emissions. Energy efficiency policies will also support the energy performance of power plants, and the reduction of waste in power networks, particularly in emerging and developing countries. Gas power plants are expected to play an important role in energy efficiency improvements.

2.2.4 Climate policies

Climate policies and initiatives are mainly driven by the emission reduction targets pledged by different countries in the context of their INDCs, and these climate initiatives interact strongly with other measures and plans adopted in different domains including renewables and non-renewables as well as energy efficiency (as highlighted in previous sections). Climate policies are also underpinned by some specific measures targeting GHGs mitigation such as carbon pricing and carbon and methane emissions standards.

One of the key uncertainties surrounding climate policies is related to the evolution of GHGs mitigation targets and ambitions which are outlined in countries' INDCs, and which are still not in line with the Paris Agreement 2°C objective. The Agreement stipulates that countries should raise their ambitions and revise their INDCs' commitments upwards in order to keep pace with its 2°C temperature increase target, or even with a lower 1.5°C target as highlighted in the 2018 IPCC Special Report (SR15).

The Outlook assumes that the current INDCs' GHG mitigation targets will continue to drive climate efforts for a large number of countries. Policies and measures adopted in these countries are then not consistent with even reaching the 2°C target, and much effort will be needed to keep pace with this very ambitious objective.

Carbon pricing, either in the form of carbon markets or carbon taxes, is expected to make some progress in different countries, but large disparities will continue in the level of carbon price references and taxes applied in different countries, reflecting varying conditions and climate ambitions. For the EU, the carbon market reforms (EU ETS Phase III & IV) will reduce the excess of emission allowances and supports increasing trends in carbon prices.

Several challenges will persist and affect the functioning of carbon markets globally including market design issues, overlaps with other mitigation policies (e.g. support for renewables can affect demand for carbon emission allowances and then depress prices), as well as business competitiveness. In the latter instance, the UK has frozen its carbon prices after experiencing competitiveness issues in its economy (12). The Outlook assumes that carbon markets will not develop into an integrated emission trading system over the forecast period.

2.3 Energy-related greenhouse gas emission developments and trends

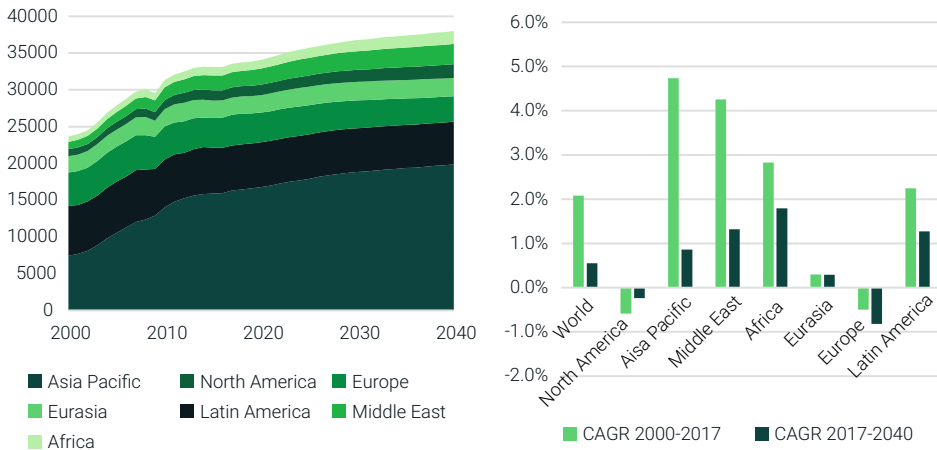
2.3.1 Energy-related CO2 emissions

In this Outlook, global energy-related CO2 emissions are forecast to exhibit increasing trends over the long term, despite an expected strong deceleration compared to the historical trajectory. The Outlook estimates an average annual growth rate at 0.6% between 2017 and 2040, bringing the overall level of emissions to around 38.2 GtCO2 in 2040.

Regional trends

The Outlook forecasts that the Asia Pacific region will take the lead in terms of CO2 emissions, accounting for around 53% of global emissions in 2040. This region will continue to see positive growth over the long term (CAGR 2017-2040: 1.1%) despite a net slowdown compared to historical trends. The GECF anticipates that the Middle East and Africa will experience the highest emission growth rates during the forecast period, which will increase the share of these two regions in global emissions from 9% in 2017 to closer to 12% in 2040.

Figure 2.1. CO2 emissions by regions (MtCO2) and annual growth rate (%)



Source: GECF Secretariat based on data from GECF GGM

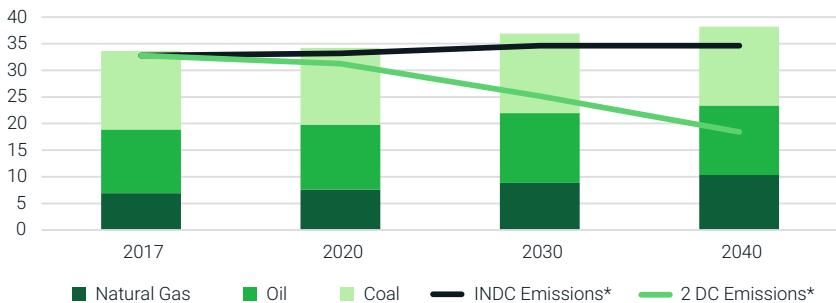
Conversely, Europe is projected to observe the highest emissions decline averaging around 0.7% between 2017 and 2040, followed by North America with a 0.2% average annual decrease over the same period. These forecasts reflect the fact that Europe, and particularly the European Union, will continue to be at the forefront of carbon mitigation efforts, with the implementation of strong climate and environmental policies. For North America, the decline of emissions is particularly expected in the US, driven by initiatives undertaken at a non-federal level (e.g. by states and businesses). Market fundamentals will also play a role in this region since they favour the penetration of abundant and affordable natural gas rather than more carbon intensive fuels.

Trends by fuel

The Outlook projects that the major part of energy-related CO₂ emissions in 2040 will result from burning coal which will represent 39% of global emissions, followed by oil with 34%. Natural gas will have the least impact on emissions despite the expected growth in its consumption between 2017 and 2040.

The important role of carbon intensive fuels, particularly coal, contributes to the forecasted mismatch between CO₂ emissions in the reference case and in the INDC and 2 DC scenarios. The INDC scenario reflects an emissions trajectory which is compatible with countries' pledges in their INDCs, while the 2DC scenario considers the emissions reduction required to meet the temperature increase target set by the Paris Agreement. As seen in Figure 2.2, natural gas can achieve more penetration in the energy mix, particularly against coal, and this will enable further mitigation of carbon emissions.

Figure 2.2. CO₂ emissions in the GECF reference case, INDCs and 2 DC scenario (GtCO₂)



Source: GECF Secretariat based on data from GECF GGM

Note: INDC Emissions: CO₂ emissions estimation based on aggregated INDCs targets (UNFCCC, 2016) - 2 DC Emission: based on IEA 450 scenario (WEO, 2016)

2.3.2 Methane emissions

There is large uncertainty on methane emissions data from gas-related activities. This uncertainty is reflected in the fact that a wide divergence in measurements exist between countries, and according to the methodology employed (bottom-up versus top-down). The challenge of measuring methane emitted from gas-related activities is also reflected in the huge number of potential sources of emissions worldwide. Recent studies reported emissions ranging from 0.2% to 10% of the methane produced (13). However, a large number of studies on methane are based on data from the US. There is, therefore, an important need to improve data availability, transparency and harmonization, especially outside the US, if emissions estimates are to be made more reliable and accurate.

Despite these challenges and realities, the gas industry is deploying efforts to address emissions of methane. In addition to the environmental and sustainability concerns, the methane mitigation effort of the gas companies is driven by: i) economic reasons to capture more value by saving natural gas; ii) safety reasons to avoid accidents due to methane leaks; and iii) the need to comply with methane emissions regulatory restrictions.



3

Energy Demand Outlook

Key findings

- Primary energy demand is projected to rise by 1% p.a., from 14144 Mtoe in 2017 to about 17829 Mtoe in 2040. This represents a slower pace than the historical average of 2% p.a. seen since 2000, thanks to increased energy efficiency measures.
- Fossil fuels will dominate the global energy mix with their share decreasing from 81% to 76% over the forecast period. Non-fossil fuels are expected to develop at a rate of 2.1% p.a., while fossil fuels will grow by an average of 0.7% p.a.
- The share of oil, the world's largest source of energy, will decline from 32% to 29% by 2040. Coal's share will fall much more significantly, from 27% to 21%, due to environmental concerns, with the Asia Pacific region accounting for the bulk of demand. Renewable energy consumption (excluding hydro and biomass) is forecast to soar by 6.7% p.a. and to reach 6% of the total energy mix by 2040.
- Natural gas will be the fastest growing fossil fuel, mainly thanks to policy drivers concerning air quality, and will displace other sources of energy in a range of sectors. Demand is expected to increase by 1.7% p.a., with gas share of the energy mix rising from 22% to 26% by 2040.
- Natural gas consumption will climb from 3709 bcm in 2017 to 5427 bcm in 2040. Asia Pacific, North America, the Middle East and Africa will lead this growth. Gas demand in Africa will grow most rapidly (3.1% p.a.) but from a very low base.
- From a sector perspective, the power generation (2.2% p.a.) and industrial sectors (1.2% p.a.) will be the biggest contributors to incremental gas demand. The transport sector (4.2% p.a.) will emerge as a significant new area with an overall increase of 160%, reaching 357 bcm in 2040.
- In the power sector, the advantages of gas over coal and oil will continue to drive fuel-switching. In addition, the increasing role of renewables will promote gas generation as a flexible back-up. Growth in electricity demand from 25613 TWh in 2017 to 42253 TWh in 2040 will also provide a boost for gas as a fuel input.
- In 2040, about 55% of electricity generation will come from fossil fuels and gas will represent 26% of the generation mix. Gas demand from the power sector is expected to grow by 67% to 2219 bcm in 2040.
- Under the assumption that the global urban population will reach about 5.7 billion by 2040, gas demand in the domestic sector will increase by 0.9% p.a. to about 924 bcm.

3.1. Primary energy demand trends: historical (2000-2017) and forecast (2017-2040)

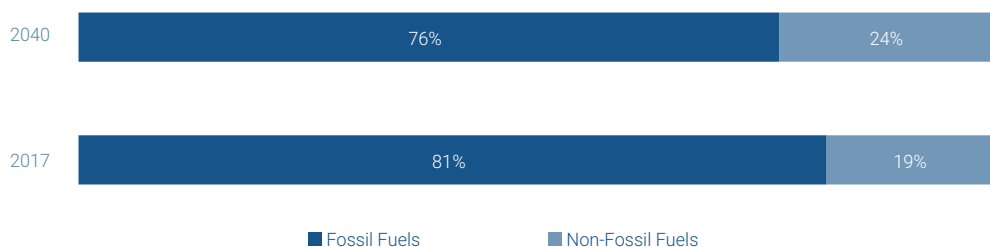
Global primary energy demand, as measured by Total Primary Energy Supply (TPES), grew by 2.0% per annum between 2000 and 2017, climbing from 10049 Mtoe in 2000 to about 14144 Mtoe in 2017. Last year, global primary energy demand increased by approximately 1.7% compared to 2016, as demand growth accelerated in China (+2.1%), India (+3.0%), South Korea (+3.0%), Japan (+1.0%), Germany (+0.2%), Iran (+4.3%) and Brazil (+1.8%). Conversely, primary energy demand growth in the US and Russia, decreased by 0.2% and 0.4%, respectively.

The GECF estimates that due to energy efficiency measures, global energy demand will grow by 1.0% per annum over the forecast period, a slower pace compared to the 1.1% indicated in the 2017 GGO, and demand will increase to approximately 17829 Mtoe in 2040. This corresponds to an overall increase of 26%.

Most of this growth is expected to come from key economies, where demand is driven by robust population and economic growth. In particular, Vietnam (145%), India (105%), Nigeria (97%), Egypt (96%), Indonesia (76%), Turkey (65%), Saudi Arabia (55%), Iran (50%), Pakistan (47%), Brazil (43%), Mexico (28%), and China (29%) will exhibit a surge in energy demand from 2017 through to 2040.

It is worth mentioning that due to energy efficiency measures, primary energy demand is expected to decline significantly in some countries, notably Japan (13%), Germany (21%), France (16%), the UK (8%), Italy (7%) and Spain (12%).

Figure 3.1. Global energy demand in 2017 and 2040 by fuel source (%)



Source: GECF Secretariat based on data from the GECF GGM

Fossil fuels accounted for 81% (approximately 11475 Mtoe) of global primary energy demand in 2017, with non-fossil fuels contributing 19% (approximately 2669 Mtoe). Despite the GECF forecasts that non-fossil fuels will grow at an annual average growth rate of 2.1%, faster than fossil fuels which have a forecast growth rate of 0.7% average per year, conventional fossil fuels will still dominate the global energy mix and will account for around 76% or almost 13546 Mtoe of the total world energy demand over the projection period.

Natural gas consumers are currently benefiting from a low-price environment, as well as ample reserves and supplies and fewer emissions than other fossil fuels. In 2017 global gas demand is estimated to have grown

by 2.5% year-on-year, slightly more than the 2.4% average annual growth rate seen from 2000 to 2017. Hence, demand for gas grew at a much faster rate than overall primary energy demand, increasing the share of gas in the global energy mix to a record 22% or 3161 Mtoe in 2017.

In line with last year's publication, the GECF expects that demand for all fuel sources will increase by 2040. Coal is the only exception, with demand dwindling as coal becomes increasingly replaced by natural gas and renewable energies.

As a result of environmental concerns and policy shifts toward low-carbon energy sources, natural gas is expected to not only become the world's fastest-growing fossil fuel, but also the fastest-growing source of energy, after renewables, increasing by an average of 1.7% annually over the projection period. The share of natural gas in the global energy mix is projected to rise to 26% or about 4633 Mtoe of total primary energy demand.

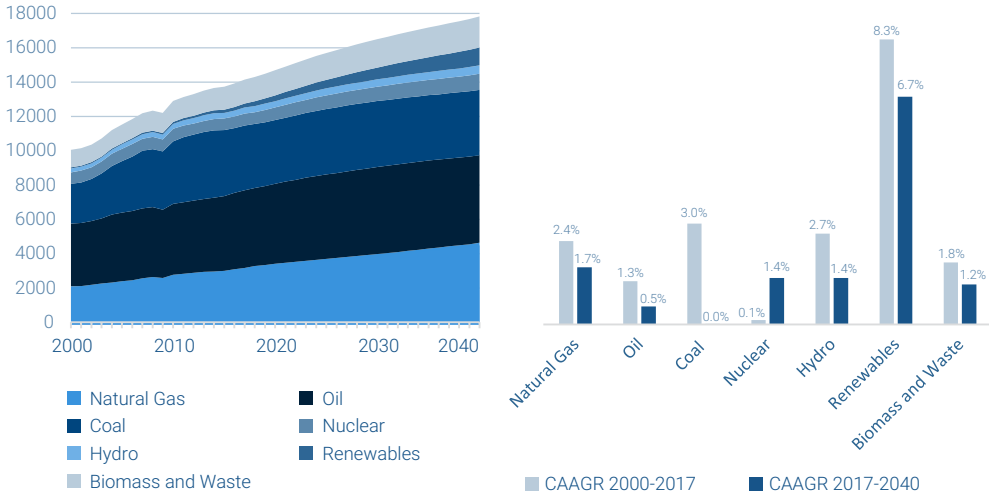
Oil contributed 32% or 4527 Mtoe to global primary energy demand in 2017 - more than any other fuel - and will remain the world's largest source of energy in 2040. However, its share is forecast to fall marginally to 29%, with an average growth rate of 0.5% per year. Oil is projected to contribute 5109 Mtoe to global primary energy demand in 2040, driven by the transport and petrochemical sectors.

Of total energy consumed in 2017, 27% or 3788 Mtoe came from coal. As previously mentioned, coal's decline is primarily attributed to increasing environmental concerns. By 2040 coal consumption will remain flat, and its share will drop sharply to 21% or about 3805 Mtoe of the global energy mix. Asian economies remain the largest consumers of coal, particularly India, where coal-fired power generation will continue to be a driving force of demand.

Renewable energies (geothermal, wind, solar and, to a lesser extent hydrogen) are projected to be the fastest-growing energy sources in the long-term. Demand for renewables is expected to increase by an annual average growth rate of 6.7%, from 2% or almost 237 Mtoe in 2017, to 6% or almost 1047 Mtoe of total primary energy demand in 2040. The wind and solar sectors are forecast to experience dramatic growth in coming years, and the US and China will remain the largest markets. The main driver behind this growth is likely to be cost reductions for both onshore and offshore wind and solar energies.

After renewables and natural gas, nuclear will see the third largest percentage increase in consumption. From 2017 to 2040, total primary energy consumption for nuclear energy is expected to increase by an annual average growth rate of 1.4%. In 2017, nuclear power represented nearly 5% or 692 Mtoe of the global energy mix. Its share, however, will remain relatively stagnant at 2017 levels, with a projected 943 Mtoe consumed in 2040. Clearly, policy changes driven by the Fukushima Daiichi nuclear disaster in March 2011 have not only slowed the development of nuclear energy around the world, but have resulted in many countries deciding to review their nuclear energy policies. The halt of nuclear power after the accident gave a major boost to the use of natural gas as an alternative energy source.

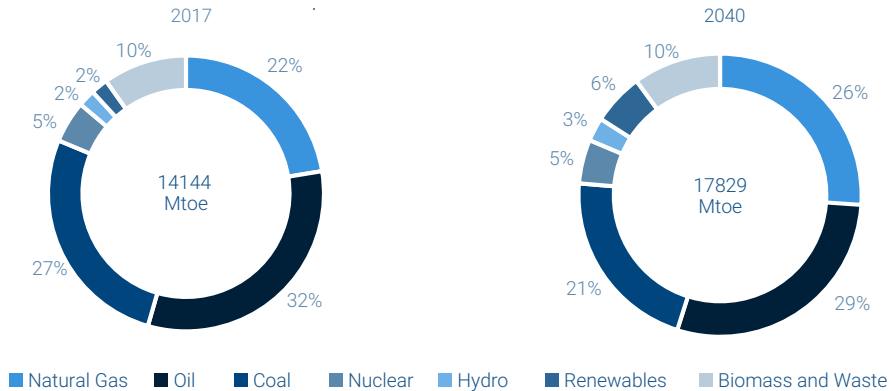
Figure 3.2. Global primary energy demand trends by fuel type (Mtoe), and associated CAAGR (%)



Source: GECF Secretariat based on data from the GECF GGM

Hydropower accounted for just 2% or 352 Mtoe of global primary energy consumption in 2017, with demand expected to increase slightly by an average of 1.4% per annum to 3%, or around 480 Mtoe in 2040. Hydroelectric plants accounted for 16% of global electricity generated in 2017, and the sector is expected to account for 13.2% of consumption by 2040. Due to environmental concerns and climate change, the actual amount of electricity which will be generated by hydropower will be much less than its potential.

Figure 3.3 Global primary energy demand in 2017 and 2040 by fuel type (%)



Source: GECF Secretariat based on data from the GECF GGM

Currently, China is the world's largest producer of hydroelectricity, with much of the remaining hydro potential existing in the developing economies of Africa and Asia. Although small-scale hydro power plants, as well as new hydro technologies such as wave, tidal and osmotic power, have great prospects, they are still under development. The high construction and installation costs associated with hydro-electric facilities also pose a barrier to their deployment.

Biomass (including wood burning) and waste contributed 10% or 1387 Mtoe to the global energy mix in 2017. Consumption will increase by an annual average growth rate of 1.2%, to approximately 1813 Mtoe in 2040. The share of biomass and waste in the global energy mix is projected to remain stable (at 10%) over the outlook period, due to firewood and charcoal burning for off-grid lighting and cooking purposes, mainly in Africa and Asia.

At the same time, future prospects of electricity generation from biomass and waste materials may face certain constraints, connected with technical issues, the availability of land and high fuel prices (particularly, advanced generation biofuels) in comparison with other sources of energy. In 2017 there was approximately 138 GW of biomass power plant capacity throughout the world.

3.2. Natural gas demand trends: historical (2000-2017) and forecast (2017-2040)

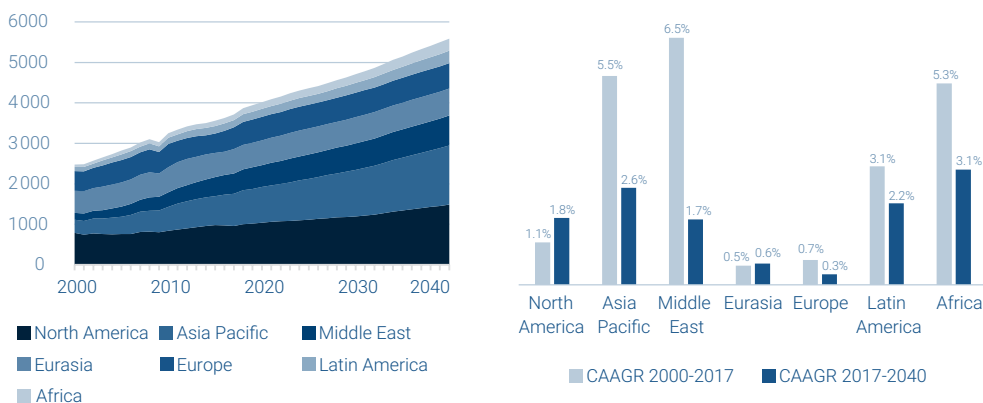
Global overview

Between 2000 and 2017 global demand for natural gas grew by 2.4% annually, from 2474 bcm to 3709 bcm, driven by consumption in the power generation sector. The GECF forecasts that global natural gas demand will rise at an annual average growth rate of 1.7%, representing an overall increase of 46%, and climbing to about 5427 bcm in 2040. The key changes to the projections are:

- ⊗ Strong policy efforts to improve air quality through coal-to-gas switching in key regions.
- ⊗ The acceleration of natural gas use in the power generation sector worldwide.
- ⊗ Policies include the phasing out of coal-fired electricity, and in some countries, nuclear-fired power generation, which will lead to greater reliance on gas-fired power plants.
- ⊗ On the assumption that the urban population reaches about 5.7 billion by 2040, the potential for the use of gas in domestic and residential sectors is high.
- ⊗ Stronger demand in the industrial sector as a result of economic and population growth will lead to an increased use of gas for exports of manufactured and industrial products.
- ⊗ In the transport sector, LNG is expected to become an important alternative to heavy fuel oil in the marineshipping sector in the long-term, which will enable ships to meet increasingly stringent international regulations on emissions.
- ⊗ North America is currently the largest consumer of natural gas, accounting for 26% of global demand. The region will continue to drive global gas consumption. This fact is primarily attributable to shale gas development in the US. Exploitation of abundant unconventional reserves has lowered prices and made natural gas an attractive alternative fuel for the power sector.

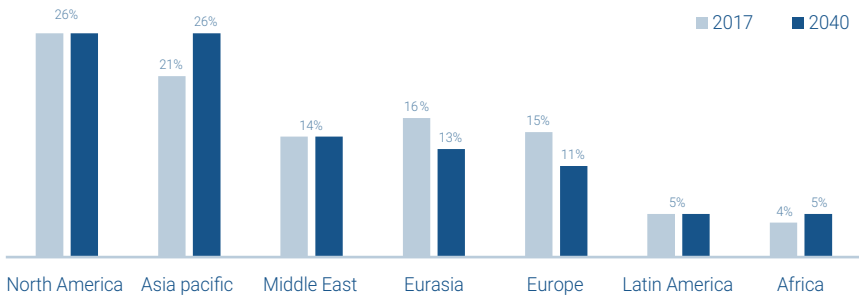
- ⊙ The Asia Pacific region accounts for 21% of the world's demand in 2017. Trends in this region are largely dependent on China and India; countries which are adopting policies in favour of gas in an attempt to improve air quality. While China and India are particularly significant to the global energy outlook, Asia's leading emerging markets (e.g. Bangladesh, Indonesia and Pakistan) are poised to make increasingly substantial contributions. The GECF expects demand in the Asia Pacific region to rise significantly by 79%, representing over a quarter of global gas consumption in 2040.
- ⊙ Over the historical period, the most dramatic rise in gas demand came from the Middle East. Countries in this region represented 14% of global gas demand in 2017, with Iran, Saudi Arabia and the UAE the primary drivers of consumption. As will be discussed in more detail, the Middle East will see demand for gas rising by 48% over the outlook period.
- ⊙ Gas consumption in Europe and Eurasia increased by 12% and 9% respectively, over the historical period. Russia, Germany, Turkey, the UK, Italy, France and Spain are among the largest consumers of gas in the world. Collectively, these countries will consume about 840 bcm of gas in 2040. Russia alone will consume more than half of this volume. By 2040, Europe and Eurasia will consume around 11% and 13% of global gas demand.
- ⊙ Latin America experienced a strong gas demand growth rate over the historical period, as a result of accelerated economic development coupled with high demand from the transport and power sectors. Various Latin American countries are looking at FSRUs to import LNG for the first time. Gas demand in Latin America will continue to be very weather dependent, given the massive role played by hydro in the region. Demand in the region is forecast to rise by 63%, representing about 5% of global gas consumption in 2040.
- ⊙ The largest growth in gas demand among all regions globally in the outlook period comes from Africa. Africa currently ranks bottom in the world in terms of gas consumption, responsible for only 4% of global gas demand in 2017. The main demand driver will be growth in the industry and power generation sectors. By 2040, Africa will account for 5% of the world total consumption.

Figure 3.4 Global natural gas demand by region (bcm), and associated CAAGR (%)



Source: GECF Secretariat based on data from the GECF GGM

Figure 3.5. Natural gas consumption by region in 2017 and 2040 (%)

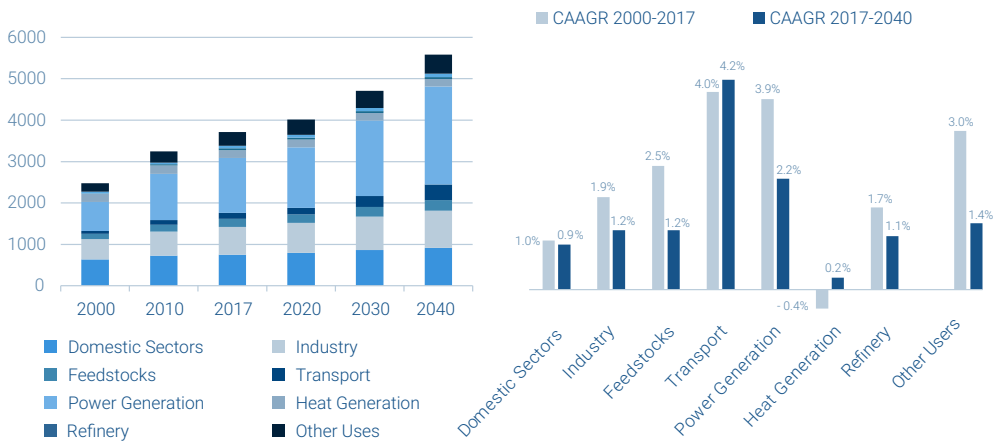


Source: GECF Secretariat based on data from the GECF GGM

Outlook by sector

As in the 2017 GGO, this edition forecasts that throughout the outlook period the transport and power generation sectors will be the main drivers of natural gas growth, with annual average growth rates of 4.2% and 2.2% respectively. These two sectors will account for about 48% of global natural gas consumption in 2040. However, the industrial sector still holds second place in terms of absolute consumption, after power generation.

Figure 3.6. Global natural gas demand by sector (bcm), and associated CAAGR (%)



Note: Data for the hydrogen sector is currently insufficient and has been omitted from these figures

Source: GECF Secretariat based on data from the GECF GGM

Power generation sector

Between 2000 and 2017 natural gas demand in the power generation sector saw significant growth at an average annual rate of 3.9%, from 700 bcm to 1332 bcm. The power sector increased its share of global consumption from 28% to 36% over the same period.

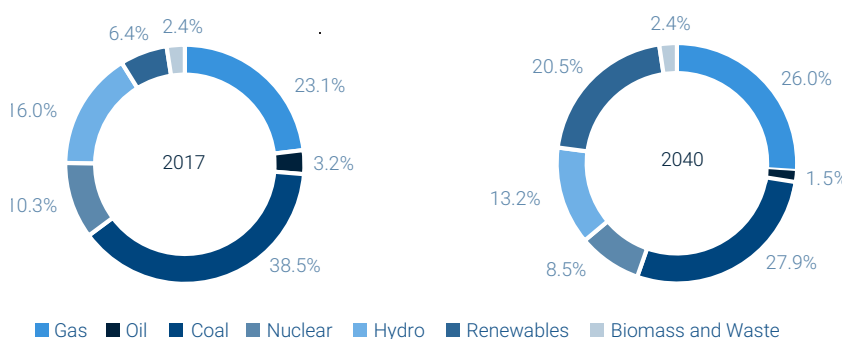
Natural gas has many advantages over oil and coal when it comes to power generation. Gas-fired generation is characterised by high thermodynamic efficiencies, lower heat rates and shorter construction lead times. Natural gas combustion produces fewer pollutants than other fossil fuels, such as nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon dioxide (CO₂) and particulate matter, and consequently coal-to-gas switching in the power generation sector has played a critical role in reducing emissions.

Natural gas consumption is closely linked with electricity demand in many countries. Developments in the power generation mix directly affect demand for gas. Hence, growth in electricity demand will increase the need for gas-fired power. This report forecasts that global electricity demand will grow faster than energy and gas demand, by an average of 2.2% annually, rising from 25613 TWh in 2017 to about 42253 TWh in 2040 (including the energy sector's own use, transmission and distribution losses).

In 2017 coal played a significant role in power generation, constituting 38.5% of the global power generation mix. Coal's contribution is expected to decrease as a result of air pollution concerns, and its share will drop significantly to 27.9% in 2040. The share of gas will continue to rise, from 23.1% in 2017 to 26.0% in 2040.

In 2017 the share of renewables in the global electricity mix was about 6.4%. Significant reforms in energy policies and government support for increased renewables penetration in many countries will propel renewable energies in the power generation mix to a share of 20.5% in 2040. This report expects that, over the outlook period, the share of nuclear in the global electricity mix will drop from 10.3% to about 8.5%. Additionally, the share of hydro will decrease from 16.0% in 2017 to 13.2% in 2040. These trends indicate that in 2040, about 55% of electricity generation will come from fossil fuels.

Figure 3.7. Global power generation mix in 2017 and 2040 (%)



Source: GECF Secretariat based on data from the GECF GGM

The GECF expects that global natural gas consumption will remain concentrated in the power generation sector. A key characteristic of renewable energies, particularly wind and solar, is their intermittency and their currently limited capacity for large-scale electricity storage. The flexibility and short start-up times associated with gas-fired power generation make it well suited to provide back-up energy for intermittent renewable electricity.

Demand for natural gas in the power generation sector is forecast to increase by an overall 67%, with an annual average growth rate of 2.2% per year over the outlook period, to about 2219 bcm, and it will account for a share of 41% of total global consumption in 2040. Policies to promote natural gas and/or phase out coal-fired power plants are the main drivers behind this growth.

Domestic sectors

Global gas consumption in the domestic sectors grew by an average of 1% per annum between 2000 and 2017, from 635 bcm to 751 bcm. The domestic sector currently accounts for over 20% of total natural gas demand. More than 68% (513 bcm) was consumed in the residential sub-sector, followed by 31% (229 bcm) in the commercial sub-sector, and just 1% (9 bcm) in the agricultural sub-sector. Variations in gas consumption within the residential and commercial sub-sectors are mainly weather related, as cooler temperatures boost demand for heating.

Under the assumption that the global urban population will reach about 5.7 billion by 2040, the potential for gas consumption in the domestic sector is large. At the end of the forecast period this sector will have increased consumption by 23%, growing modestly by an annual average rate of 0.9%. The domestic sector is projected to reach approximately 924 bcm in 2040, contributing 17% to global gas demand. Around 580 bcm will come just from the residential heating and cooling sectors. The main drivers behind the increase are population and economic growth, irrespective of energy intensity improvements.

Industrial sector

In 2017 almost 18% of global natural gas demand came from the industrial sector, where consumption is driven by iron and steel, chemical and petrochemical, non-ferrous metals and non-metallic minerals production. Gas is used to produce chemicals, fertilisers, methanol, urea and ammonia, as well as in the production of fabrics, textiles, manufacturing, paints and food and beverages.

Throughout the outlook period, global natural gas demand from the industrial sector will grow at a slower pace compared to the 1.9% recorded over the historical period. Industrial demand is projected to increase by 33%, from 671 bcm in 2017 to around 892 bcm in 2040, corresponding to an annual average growth rate of 1.2% and will constitute 16% of total global gas demand. Important drivers include economic growth and switching from coal-fired to gas-fired boilers in emerging economies. The positive outlook for the chemicals industry in regions such as North America and the Middle East, as well as the need to boost fertiliser production in populated countries such as China and India, also contribute to industrial demand growth.

Transport sector

Last year around 4% of global natural gas consumption came from the transport sector. A large portion of the energy used in global transportation networks comes from petroleum-based fuels, mainly gasoline and diesel. Although the transportation sector is slowly moving away from oil to alternatives such as CNG, liquefied petroleum gas (LPG) and other alternative fuels (e.g. biofuels), in 2017 this sector accounted for more than 24% of global GHG emissions. According to the latest data from the International Association for Natural Gas Vehicles, currently four countries together account for almost two-thirds of the world's NGVs. These are: China with

6.02 million (23.2% of the world's NGVs), Iran with 4.5 million (17.2%), followed by India with 3.09 million and Pakistan with 3 million NGVs. In Europe, Italy has the largest NGV fleet standing at approximately 1 million vehicles.

The UN's IMO adopted an initial strategy to reduce GHG emissions from ships, which are estimated to account for 3% of global GHGs emissions. Under IMO regulations, from 2020 ship owners will have to comply with a new 0.5% cap on the amount of sulphur in marine fuel, compared to the existing limit of 3.5%. LNG is expected to become an important alternative to heavy fuel oil due to its relatively low emissions of air polluting substances and GHG emissions, which will enable ships to meet increasingly stringent international regulations on emissions. Compared to heavy fuel oil, the use of LNG can significantly reduce emissions of SO_x, NO_x, CO₂ and particulate matter. Thus, it is expected that the move will give fresh impetus to the use of gas as a shipping fuel in the long-term.

These forecasts show that the transportation sector is the only sector with a robust gas growth rate in this outlook. Demand for natural gas as a transport fuel is projected to grow at an annual average rate of 4.2%, much faster than other sectors, with an overall increase of 160%, rising from 137 bcm in 2017 to about 357 bcm in 2040, constituting 7% of forecast global gas consumption.

Feedstock sector

Natural gas for non-energy uses is the most common energy feedstock used for agricultural chemicals, pharmaceutical products and petrochemicals. Butane, ethane and propane which are extracted from natural gas are used in fertiliser production, including ammonia and its derivatives (e.g. urea, methanol, nitric acid and ammonium nitrates). The surge in LNG usage has further resulted in additional gas demand for feedstock, driven by the US, Australia, Russia and Qatar. However, most of the growth in natural gas feedstock consumption over the outlook period is expected to originate from new methanol and ammonia projects in the US and the Middle East.

In this respect, the GECF expects gas consumption to grow at a slower pace compared to the 2.5% recorded over the historical period, at an average annual growth rate of 1.2%. Gas consumed as a feedstock will see an overall increase of 32%, rising from 195 bcm in 2017 to around 257 bcm in 2040. This will constitute approximately 5% of total global gas demand.

Other sectors

One of the main uses for gas is in the petrochemical sector, where it is used to provide hydrogen, methane, ethane, propane and butane for refinery processes. Hydrogen was introduced as a fuel source many years ago, but it has yet to play a significant role in global energy systems and a variety of uncertainties exist concerning its future contribution. There are a number of initiatives around steam reforming of methane and power to gas to create hydrogen by electrolysis (e.g. in Europe and Japan). Several fuel cells have been developed which can convert hydrogen into electricity, however hydrogen technologies have not reached the economies of scale necessary to achieve considerable market penetration. Gas used for refinery and hydrogen production is projected to grow at slower pace over the outlook period compared to that observed in the historical period, by

1.1% and 0.1% per year, respectively. Consumption in the refinery and hydrogen generation sectors will rise by 28% and 2%, from 58 bcm and 47.5 bcm in 2017, to roughly 75 bcm and 48.3 bcm in 2040, correspondingly.

However, these volumes are negligible given overall levels of consumption. The heat generation sector will only experience 0.2% growth per annum over the forecast period. Heating purposes vary depending on the consuming sector (e.g. space, water, cooking heating, high and low temperature processes etc.). Approximately 185 bcm of gas was consumed for heat generation in 2017 and this figure is expected to increase by 6% overall, to around 196 bcm, which constitutes 4% of global gas consumption in 2040. Increasing efficiency in residential heating, cooling and hot water systems will be the key drivers behind the slower growth.

Outlook by region

ASIA PACIFIC

Asia Pacific is currently the second-largest consumer of natural gas, accounting for 21% of global demand. Natural gas demand in the region is projected to increase at an annual average growth rate of 2.6%, from 794 bcm in 2017 to around 1422 bcm in 2040. The use of LNG in the power sector will be significant, supported by economic growth and strong coal-to-gas switching policies. In 2017, 317 bcm (40%) of gas was consumed in this sector. The absolute quantities of gas used in this sector will continue to rise, and it is expected that by 2040, around 509 bcm (36%) of gas will be consumed by the power generation sector.

NORTH AMERICA

In 2017 the North American gas market accounted for 26% of global gas demand. Between 2000 and 2017, gas consumption increased by 166 bcm at an average annual growth rate of 1.1%, from 792 bcm to 958 bcm. Almost 36% of this volume was used for power generation, particularly in the US. The GECF expects that gas consumption in the region will rise by 1.8% per annum, reaching 1435 bcm in 2040. This forecast shows that North America will continue to drive global gas consumption, which is not surprising given it comprises the largest countries in the developed economy. Similar to previous trends, gas-fired power capacity additions will boost gas demand significantly. Almost 50% (about 708 bcm) of regional gas consumption will be absorbed to produce electricity. Coal plant retirements, as well as surging electricity demand, will ensure a robust increase in gas demand.

MIDDLE EAST

Gas consumption in the Middle East is forecast to increase at an annual average growth rate of 1.7% over the forecast period, from 503 bcm in 2017 to around 747 bcm in 2040, substantially slower than the 6.5% recorded over the historical period. Incremental consumption in Iran, Iraq and Saudi Arabia is the main driver for the increase.

Demand will remain concentrated in the power generation sector. In 2017, 46% (233 bcm) of total demand from the region was consumed in this sector. Industrial demand came in second at about 23% (117 bcm) of total consumption.

EURASIA

Natural gas plays a significant role in the energy mix of Eurasian countries, which together consumed 16% (almost 600 bcm) of the world's gas volumes in 2017. Russia is the largest gas consumer in the region, accounting for 70% of demand. Gas consumption in Eurasia is projected to increase to 681 bcm by 2040 at an annual pace of 0.6%, slightly faster than recorded over the historical period. This minor growth in absolute terms will be driven by Russia (+47 bcm), Kazakhstan (+20 bcm), Turkmenistan (+8 bcm), Ukraine (+5 bcm) and Uzbekistan (+5 bcm). Belarus gas demand will also see a 5 bcm reduction, resulting from the commissioning of a nuclear power plant and a subsequent decrease in gas consumption in the power generation sector.

EUROPE

Gas demand in Europe increased at an average annual rate of 0.7%, from 482 bcm in 2000 to 538 bcm in 2017. The continent's natural gas demand saw strong growth driven by economic recovery, increased gas usage in the power sector, and unseasonable weather patterns that increased consumption in the heating and cooling sectors. From 2017–2040, demand is projected to increase by 35 bcm, and to grow at an average rate of 0.3% per year to reach about 573 bcm in 2040. This comparatively slow growth can be attributed to energy efficiency policies, declining energy intensity, supply security concerns, the use of renewable energy and a production decline in the Netherlands.

Natural gas usage for power generation accounted for approximately 24% (131 bcm) of total consumption in 2017. Growth in the power sector slowed during the historical period, by an average annual rate of 1.4%. The consumption of gas in Europe's power generation mix was highly dependent on fuel costs, the availability of hydro and nuclear energy, efforts to reform the Emissions Trading System (ETS) and apply more robust carbon prices, as well as policies that are making renewables more attractive. Over the forecast period, a 0.8% growth rate is expected in Europe's power sector, with natural gas consumption reaching 156 bcm in 2040.

LATIN AMERICA

Latin American countries have large natural gas reserves and have the potential to produce enough gas to satisfy the region's burgeoning gas demand. Natural gas demand in Latin America is forecast to increase at an annual average rate of 2.2% over the outlook period, an overall increase of 63%, from 178 bcm in 2017 to about 291 bcm in 2040. The main drivers for the growth are economic development, an increase in population and subsidised electricity prices that encourage consumption. Demand growth comes mainly from Chile (5.3%), Peru (3.9%), Brazil (3.1%), and Venezuela (2.0%) over the outlook period.

AFRICA

Africa's gas demand growth is expected to expand faster than that of any other region. Last year's GGO recorded a projected growth rate of 2.5%. This year, we expect gas demand to rise by 100% over the forecast period, at an average growth rate of 3.1% per year, from 139 bcm in 2017 to almost 278 bcm in 2040. Most of this growth is expected to come from Nigeria (+46 bcm), Egypt (+29 bcm), South Africa (+16 bcm) and Libya (+10 bcm). The rich gas reserves and developments in production from Egypt, Nigeria and Algeria, as well as population growth and the associated increase in electricity demand, are the main drivers behind this increase.

Natural gas demand trends in selected GECF (Members and Observers) countries

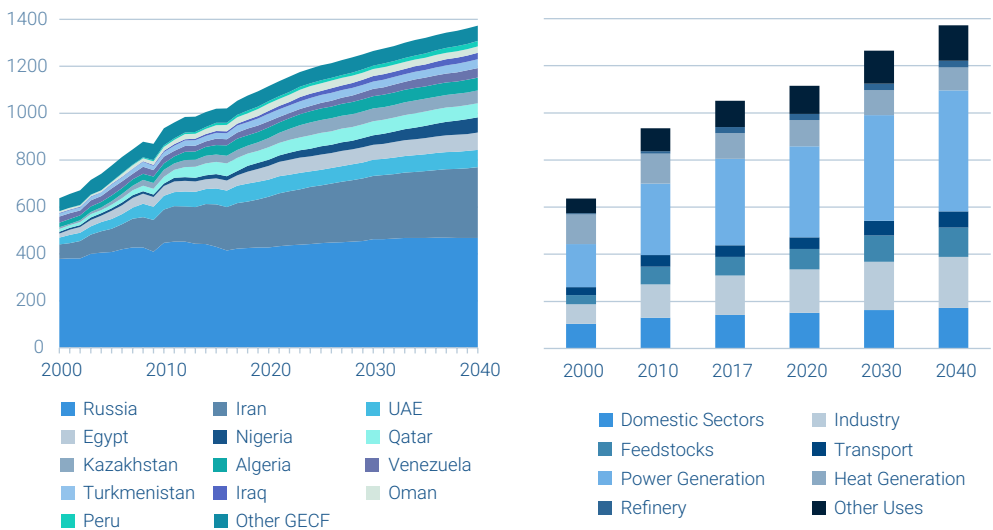
Natural gas consumption will reach 1373 bcm in the GECF countries by 2040, increasing annually by 1.2% on average over the forecast period, slower than the 3.0% recorded over the historical period. Iran (+106 bcm), Russia (+47 bcm), Nigeria (+46 bcm), Egypt (+29 bcm), Kazakhstan (+20 bcm), Iraq (+19 bcm), Venezuela (+15 bcm), and Peru (+14 bcm) will drive this incremental consumption. Most of the GECF countries will experience economic and population growth throughout the outlook period.

The feedstocks sector is the fastest growing in the GECF countries, rising by 2.0% per annum, from 80 bcm in 2017 to over 125 bcm in 2040. The main countries driving this demand are Russia, Iran and Egypt.

In line with global consumption trends of gas use in gas-fired power generation, the power sector in the GECF countries has the second-fastest growth rate of 1.5% per year. It is expected that consumption will rise by an overall 40%, from 367 bcm in 2017 to around 513 bcm in 2040, which is equivalent to 37% of total gas demand of the GECF countries.

The third largest natural gas consuming sector is industry. Emerging economies are key drivers, with a growth rate of 1.1% over the outlook period. Industrial consumption of natural gas in 2017 totalled 166 bcm, and the GECF expects that this will increase to almost 216 bcm in 2040. Demand for natural gas in the domestic and residential sectors is also considerable, increasing to about 172 bcm in 2040, up from 143 bcm in 2017.

Figure 3.8. GECF (Members and Observers) natural gas demand by country and sector (bcm)



Source: GECF Secretariat based on data from the GECF GGM



4

Natural Gas Supply Outlook

Key findings

- Overall growth in production of 1.7% p.a. is expected in the period to 2040, with total output expected to reach 5427 bcm by that date. Africa is expected to grow the fastest, albeit from a low base, while North America will be the largest contributor by 2040 with an overall share of 28% of global gas output.
- The US, Russia, China and Iran are the largest contributors to this expansion, accounting for 24.8%, 12.4%, 12.4%, and 10.5% respectively, of total change. The US, Russia and Iran will remain the largest individual gas producers, although Chinese gas production is expected to increase dramatically.
- With Iran and Qatar leading the way, Middle East will increase its annual gas production to more than 980 bcm by 2040, representing a growth of 52% or an annual average growth of 1.8%.
- Russia dominates Eurasian gas production, contributing three quarters of the total, while Central Asian countries also make major contributions. The area as a whole will remain the second largest global gas producer, increasing output by 300 bcm over the next two decades.
- Europe is the only region in the world with a declining production outlook. In particular output from Norway and the Netherlands will fall significantly.
- The Latin American region is a relatively small producer by global standards but is expected to show growth to 2040, mainly from Argentina, Brazil and Venezuela. Argentina will show significant growth in shale gas output, while much of Brazilian gas production will come from deep-water offshore fields.
- Africa is set to grow its share of global gas production from 6% to 9% by 2040, with Mozambique, Egypt and Nigeria making the biggest contributions to this growth.
- Unconventional gas production will play an increasingly important role in the increase of global gas output, in particular as costs fall across the world. By 2040 it is estimated that one third, or around 1800 bcm, of gas production will come from unconventional resources.
- Total gas production from current GECF members will increase by one third, reaching approximately 2250 bcm by 2040. This translates to a 1.25% annual growth rate over the outlook period, which will enable the GECF to keep its share of global gas production at more than 41%.

4.1 Global natural gas production outlook

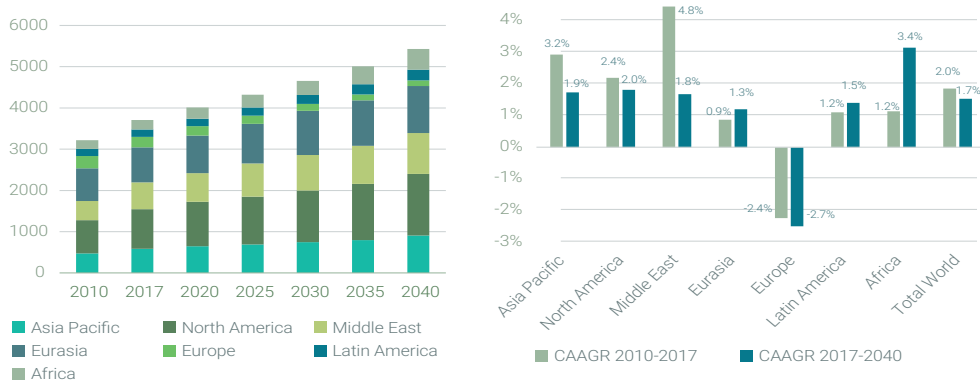
Global natural gas production¹ continued to ramp up in 2017 to reach more than 3700 bcm, around 100 bcm above 2016 levels. This overall increase masked a decline of more than 35 bcm in countries such as the Netherlands, the UK, Peru, Indonesia, Thailand, Vietnam and Mexico. This decline was offset by significant production increases in Norway, Australia, Iran and China.

Historical data shows that during recent years (from 2010 to 2017), with the exception of Europe, all regions have enhanced their gas production, with the Middle East demonstrating an annual growth rate of 4.8%, followed by the Asia Pacific region with 3.2%. Expansion in the Middle East has been driven by Iran and Qatar and, to a lesser extent, Saudi Arabia, adding 80 bcm, 53 bcm, and 19 bcm respectively to global gas production. In the Asia Pacific region, China and Australia were behind the increase, adding more than 55 bcm each to total production.

According to the latest results of the GECF GGM, global marketed gas production is anticipated to expand by around 1717 bcm over the forecast period, reaching over 5420 bcm in 2040, which is around 50 bcm above our previous forecast. The average annual growth rate is 1.7%, which translates into total growth of around 46.3% compared with the current value.

As Figure 4.1 shows, Africa is expected to have the largest annual average growth rate over the outlook period as a considerable amount of expansion in this region is forecast. In addition, the region's current volume of gas production is low, which makes the growth rate look more significant. Africa's gas production boom is expected to more than double output by 2040. Mozambique, Nigeria, Egypt, Tanzania, Libya and Algeria are the countries which will make the most impact.

Figure 4.1. Global natural gas production by region (bcm), and associated CAAGR (%)



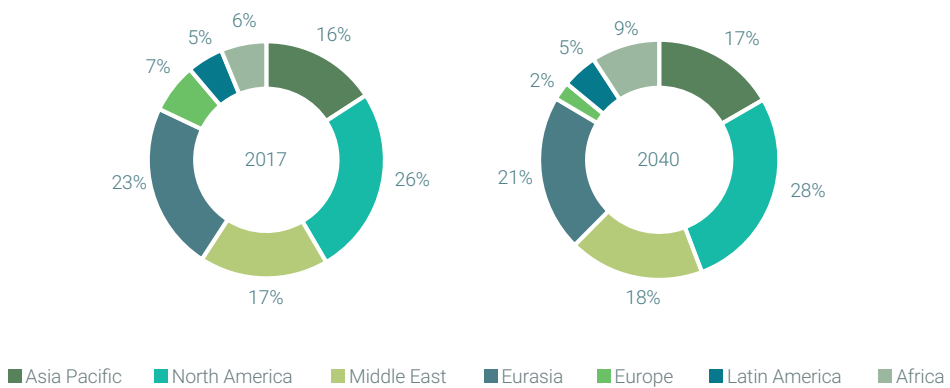
Source: GECF Secretariat based on data from the GECF GGM

¹ Unless otherwise stated, natural gas production and sales gas production both refer to marketed natural gas production

Europe is the only region to show negative growth in both historic and forecast figures in terms of natural gas production. Norway, the Netherlands and the UK, the three main natural gas producers in Europe, are forecast to reduce their annual gas production on aggregate by around 100 bcm by 2040 which will bring Europe's share of total gas production down from 7% in 2017 to 2% in 2040 (see Figure 4.2).

Figure 4.2 also indicates that Africa, Asia Pacific, North America, and the Middle East gain share in total gas production by 2040.

Figure 4.2. Current and future outlook of the regional share in global gas production (%)



Source: GECF Secretariat based on data from the GECF GGM

The US, Russia and Iran are currently the top three natural gas producers in the world. It is forecast that this ranking will remain unchanged by 2040, in line with our previous forecast. These giant gas producers will continue to expand their exploration and will together increase production by more than 820 bcm, which will comprise around 48% of the total global incremental volume that is forecast by 2040.

China will experience the third largest expansion of natural gas production in terms of absolute volume over the forecast period, and is forecast to add 213 bcm to its total gas production by 2040.

Norway will show the largest decline in natural gas production during the forecast period with production falling by more than 55 bcm, followed by Uzbekistan and the Netherlands.

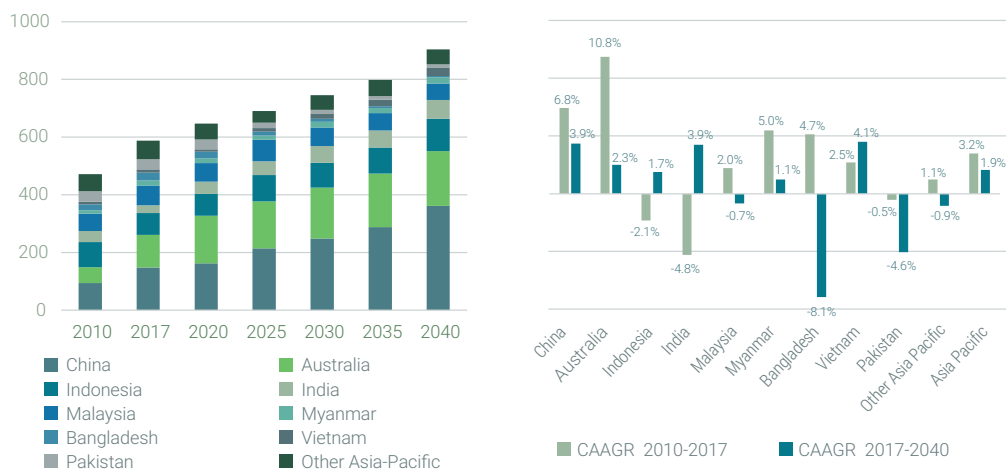
4.2 Regional natural gas production outlook

ASIA PACIFIC

One-fifth of total incremental gas production is anticipated to come from the Asia Pacific region. Australia and China are projected to drive incremental volume in the medium-term; India, Indonesia and, to a lesser extent, Vietnam and Myanmar will make their contribution in the longer-term. Three groups of countries can be identified in the Asia Pacific region based on their current and anticipated positions in global natural gas markets. The first group consists of countries that are trying to meet the largest possible share of domestic gas demand by increasing indigenous production. These countries, namely China, India and Vietnam, will contribute to slightly less than 15% of global growth during the forecast period. China alone will be responsible for an estimated 12% of the total increase in global gas production.

The second group comprises countries that are established gas exporters, such as Australia, Malaysia, Indonesia and Myanmar. These countries will try to maintain production to retain or strengthen their role in global gas markets. The last group covers other countries in the Asia Pacific region that are generally considered as natural gas importers. The group includes Japan, Korea and the Philippines - countries where only small-scale production is feasible over the forecast period.

Figure 4.3. Asia Pacific natural gas production (bcm), and associated CAAGR (%)

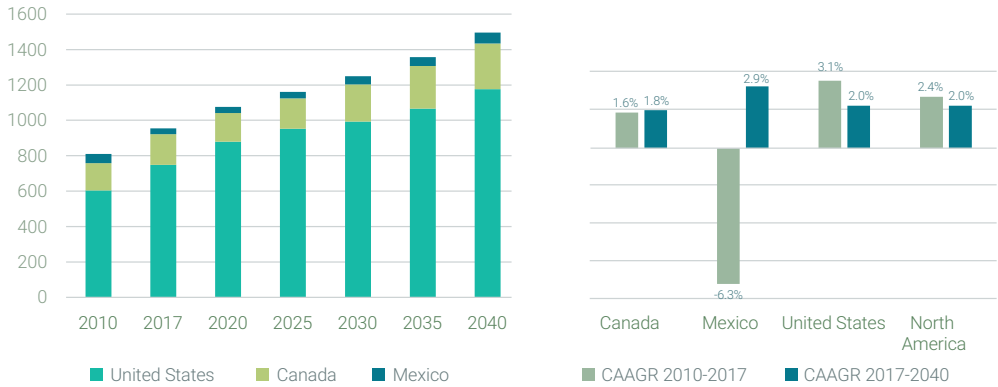


Source: GECF Secretariat based on data from the GECF GGM

NORTH AMERICA

More than one quarter (26%) of global natural gas production is currently based in North America. The US, the largest gas producer since 2011, is the main contributor to production in the region, currently accounting for 78% of the total. All three countries in the region are set to boost their production capacities, and all of them will maintain their shares of global production over the forecast period. The region is expected to achieve an annual growth of 2% which implies an expansion of 541 bcm or 56.7% compared with the current level.

Figure 4.4. North America natural gas production (bcm), and associated CAAGR (%)

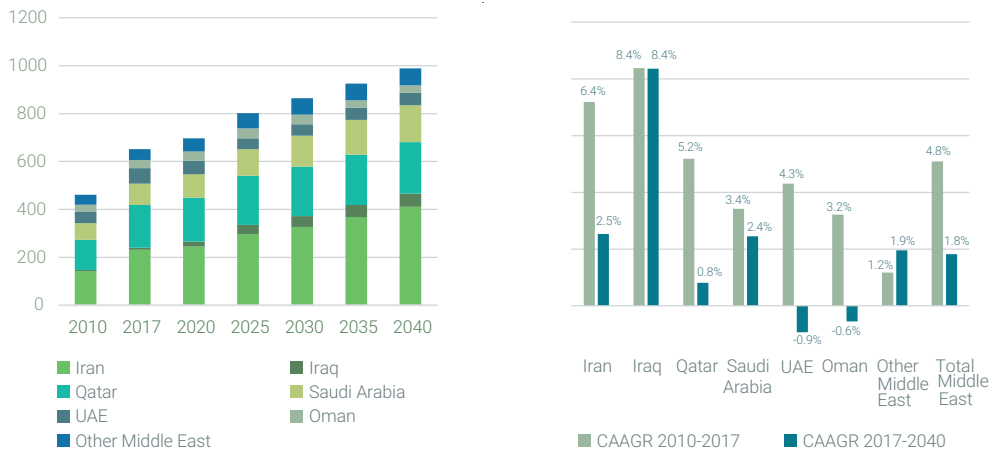


Source: GECF Secretariat based on data from the GECF GGM

MIDDLE EAST

The Middle East is the third biggest region in terms of natural gas production after North America and Eurasia. It contributed 17% of total produced gas in 2017, equivalent to slightly more than 650 bcm. The main gas producers in the region include Iran and Qatar with total marketed production of 400 bcm which accounts for more than 63% of the region’s production. The Middle East is expected to make very promising progress in terms of annual gas production over the forecast period. This Outlook suggests that the Middle East, with Iran and Qatar leading the way, will increase its annual gas production to more than 980 bcm by 2040, representing a growth of 52% or an annual average growth of 1.8%. On this measure, it comes third after Africa and North America.

Figure 4.5. The Middle East natural gas production (bcm), and associated CAAGR (%)



Source: GECF Secretariat based on data from the GECF GGM

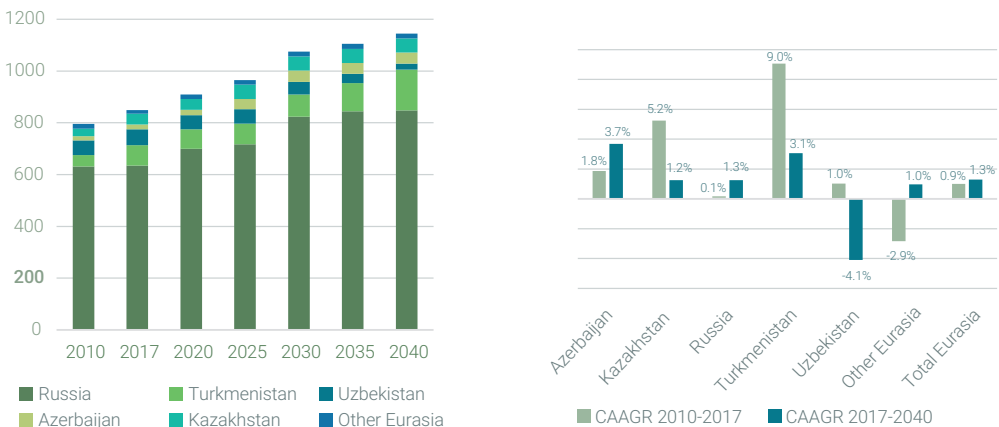
EURASIA

Eurasia is the second largest producing region after North America for natural gas output, with around 849 bcm in 2017. Three-quarters of total gas production in the region is sourced from Russia, with other contributors including Turkmenistan, Uzbekistan, Kazakhstan and Azerbaijan with shares of 9%, 7%, 5% and 2% respectively. It is forecast that all these contributors will improve their production capacity over the outlook period with the exception of Uzbekistan. The region is assumed to expand its gas production by 300 bcm to maintain its position as the second largest gas producing region in the world. Russia, Turkmenistan and Azerbaijan will be the main contributors to this expansion. Turkmenistan is expected to double its production to around 160 bcm by 2040 thanks to the expansion of pipeline export facilities that will enable the country to invest in extraction projects. Expansion in the Galkynysh field is also partly behind this increase. Azerbaijan is also expected to grow its production by commissioning other phases of the giant Shah-Deniz field as well as three phases of Absheron, located located offshore in the Caspian Sea. Total EP Absheron, a subsidiary of Total in partnership with SOCAR and Engie, is developing the field. This Outlook expects that the first phase will come online after 2023 and plateau at 4.8 bcm by 2025. Other phases are also expected to add another 7 bcm to total production by the end of outlook period.

In the long-term, the gas production outlook for the Russian Federation is very promising. This outlook forecasts that Russia will add around 212 bcm to its gas production by 2040, allowing it to maintain its position globally as the second largest gas producer. This expansion translates to a growth of 33.5% overall and an average annual growth rate of 1.3%.

In 2040, Russia is expected to account for 16% of the world's produced gas, slightly less than the current share of 17.2%. The country will contribute 12.4% of absolute growth in the world's annual gas production over the forecast period.

Figure 4.6. Eurasia natural gas production (bcm), and associated CAAGR (%)



Source: GECF Secretariat based on data from the GECF GGM

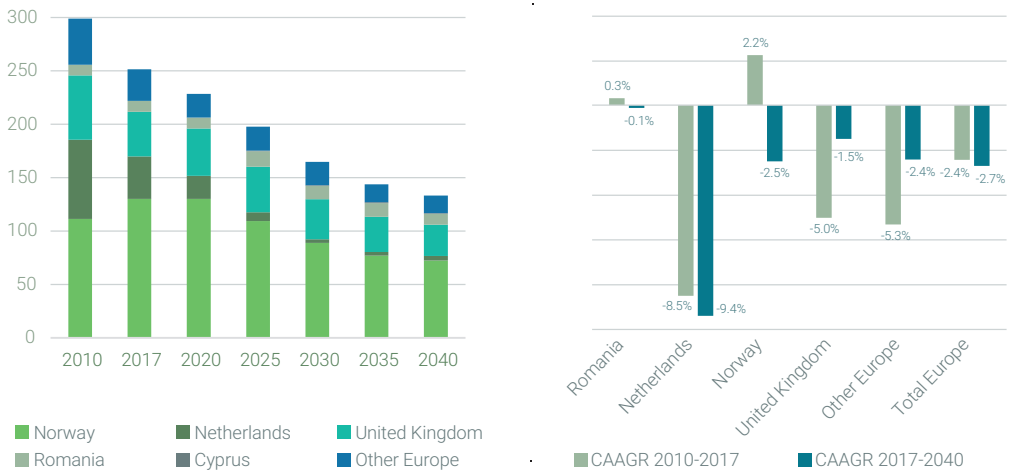
EUROPE

Europe is the only region with a bearish outlook for natural gas production across all regions. Almost all gas producers in the region are expected to see a reduction in their gas production over the outlook period. The biggest fall will be experienced by Norway, responsible for more than half of the gas produced in Europe, which will see a significant fall of around 50 bcm over the outlook period. However, Norway will remain the largest gas producer in Europe accounting for a slightly greater share of total European gas production. The Netherlands also will contribute to the overall negative trend for European gas production, with production there declining by around 35 bcm by 2040.

Total European gas production by 2040 is forecast to stand at about 130 bcm, less than half of 2010 production volumes. Historical trends in the last seven years have also been bearish in terms of gas production, with most gas producers in Europe seeing a decline over the period. Norway is an exception, marking a positive annual growth rate of more than 2.2% over the period.

Europe's share of global natural gas production is forecast to decrease to 2% compared with the current share of slightly less than 7%.

Figure 4.7. Europe natural gas production (bcm), and associated CAAGR (%)



Source: GECF Secretariat based on data from the GECF GGM

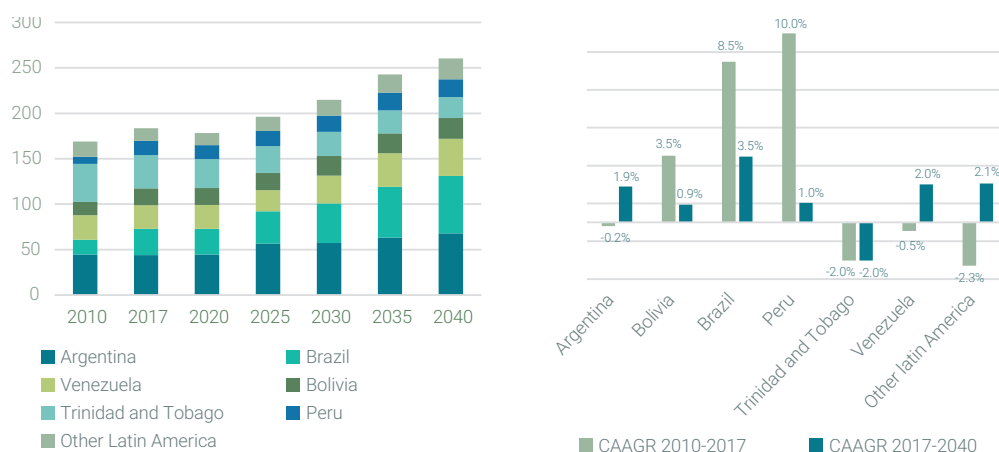
LATIN AMERICA

Latin America is considered a prosperous region in terms of almost all types of conventional energies. Apart from a very rich fossil fuel resource base, the region also has great potential from renewables thanks to the geological diversity of the region. For instance, well-developed hydropower has made this renewable energy a key source of power generation in some parts of the continent, specifically in Brazil.

Latin America, including Caribbean countries, is currently the smallest producer globally, with less than 190 bcm of natural gas production. This volume of production is mostly sourced from Argentina, Trinidad and Tobago, Brazil, Venezuela, Bolivia, Peru and Colombia in order of significance. Almost all of them, except for Trinidad and Tobago, are expected to increase their gas production over the forecast period. As a result, the region is expected to boost its gas production by 76 bcm to more than 260 bcm by 2040 which will enable the region to overtake Europe's gas production by then. According to the latest results of the GECF GGM, Latin America will expand its gas production by 41% over the forecast period and will produce 4.8% of global annual gas production in 2040.

Most of this expansion is forecast to be driven by Argentina, Brazil and Venezuela -totalling around 80% of regional expansion. Bolivia, Peru and Colombia will contribute to the remaining 20% of regional expansion by adding a total of 15 bcm to production from the region.

Figure 4.8. Latin America natural gas production (bcm), and associated CAAGR (%)



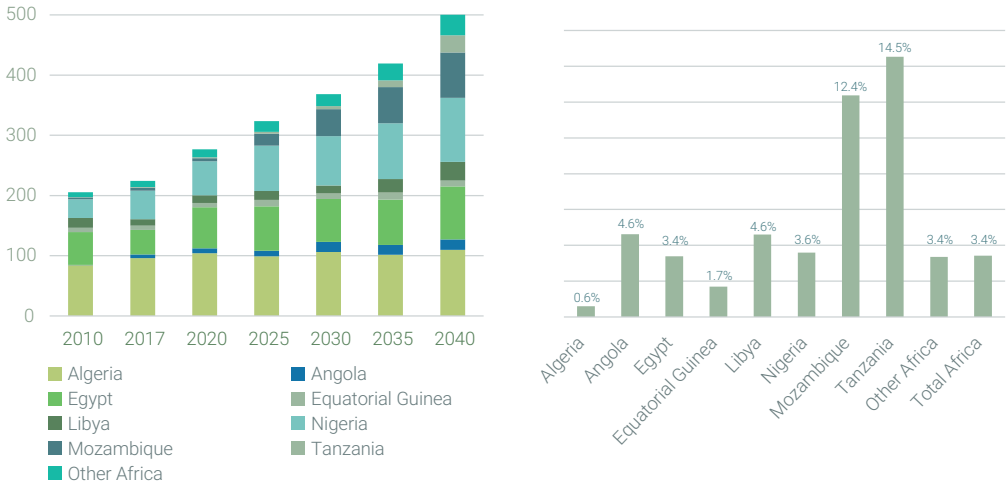
Source: GECF Secretariat based on data from the GECF GGM

AFRICA

The prospects for natural gas production in Africa are considerably promising. Africa is rich in energy resources, but oil and gas resources are relatively underdeveloped. Africa contributed only 6.2% to total marketed gas production in 2017; however, this Outlook suggests that this share could reach 9.2% by 2040. That means Africa's annual gas production will expand by around 270 bcm over the forecast period.

The GECF GGM projects that production in Africa will grow from 230 bcm in 2017 to more than 500 bcm in 2040. This corresponds to a 117% increase and a CAAGR of 3.4% over the outlook period. Mozambique, Egypt and Nigeria will contribute the most to this expansion, with 24%, 20%, and 15%, respectively. Libya, Algeria, Tanzania, Angola and Cameroon are also expected to develop their upstream sectors and expand the capacity of their natural gas production. Nigeria, Algeria and Angola contributed substantially to African production from 2010 to 2017, while Libya and Egypt experienced negative growth.

Figure 4.9. Africa natural gas production by country (bcm), and associated CAAGR (2017-2040) (%)



Source: GECF Secretariat based on data from the GECF GGM

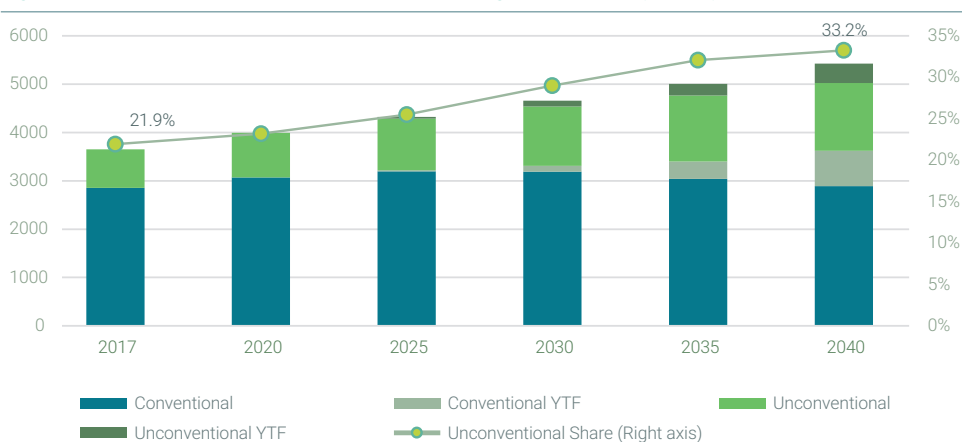
GECF countries have added substantial shares to their total gas production in Africa. Five GECF Member Countries are located in Africa (Algeria, Egypt, Equatorial Guinea, Libya and Nigeria). Collectively, they contributed approximately 206 bcm to marketed gas production in 2017 and accounted for slightly less than 90% of the total gas produced. With the rise of other market players in the region, namely Mozambique, Tanzania and Angola, the GECF market share is projected to decrease to 70% in 2040.

4.3 Unconventional and YTF gas production outlook

Advancement in shale gas extraction, as well as other types of unconventional gas resources, will result in a considerable reduction in production costs across the entire production chain. Figure 4.10 illustrates how the share of unconventional production develops over the outlook period. Currently, slightly more than one-fifth of total natural gas production is sourced from unconventional resources. This is mostly due to the significant production in the US and to a lesser extent in Canada, Australia and China. It is forecast that Argentina will contribute to the volume of unconventional production in the medium-term; in the longer-term Algeria, Oman, Russia and Saudi Arabia will become unconventional gas producers.

YTF unconventional resources will also take a vital role in developing this kind of production in some countries, specifically China, and to a lesser extent Saudi Arabia and Algeria. It is forecast that China will produce around 180 bcm from YTF unconventional resources in 2040, which will account for half of its total forecast production. Therefore we can see that the discovery and exploration of unconventional plays is a vital issue in expanding production in certain countries. It is forecast that slightly less than 1400 bcm of natural gas will be produced from existing proven unconventional plays by 2040 located in the US, Canada, China, Australia, Argentina, Oman and other producing countries. Also, around 400 bcm of production will be sourced from YTF unconventional resources by 2040.

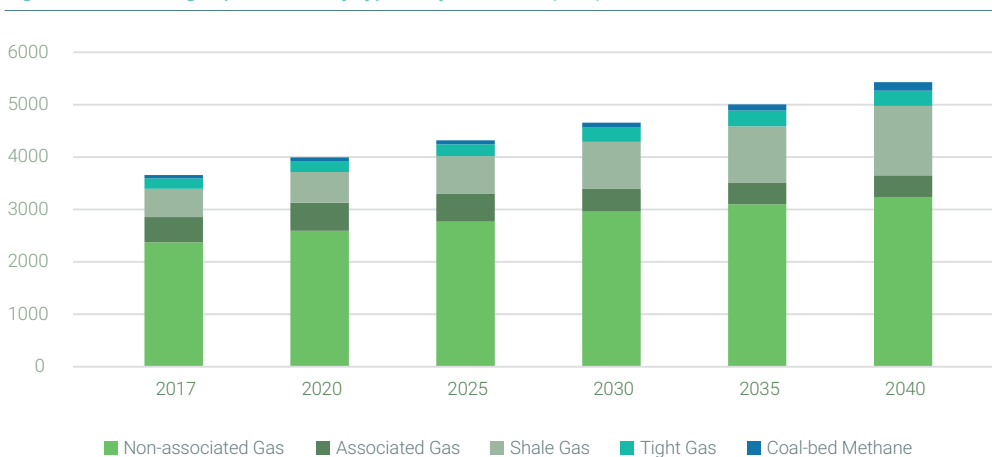
Figure 4.10. Global conventional and unconventional gas production (bcm, %)



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. Accordingly, these advancements in extraction technologies from shale such as hydraulic fracturing have resulted in reduced costs that enable economic production even with lower oil and gas prices. Figure 4.11 presents the outlook for gas production by type of hydrocarbon. Associated and non-associated gas is also illustrated by separate bars to show how these types of hydrocarbon are forecast to contribute to the total natural gas production over the forecast period.

Figure 4.11. Global gas production by type of hydrocarbon (bcm)



Source: GECF Secretariat based on data from the GECF GGM

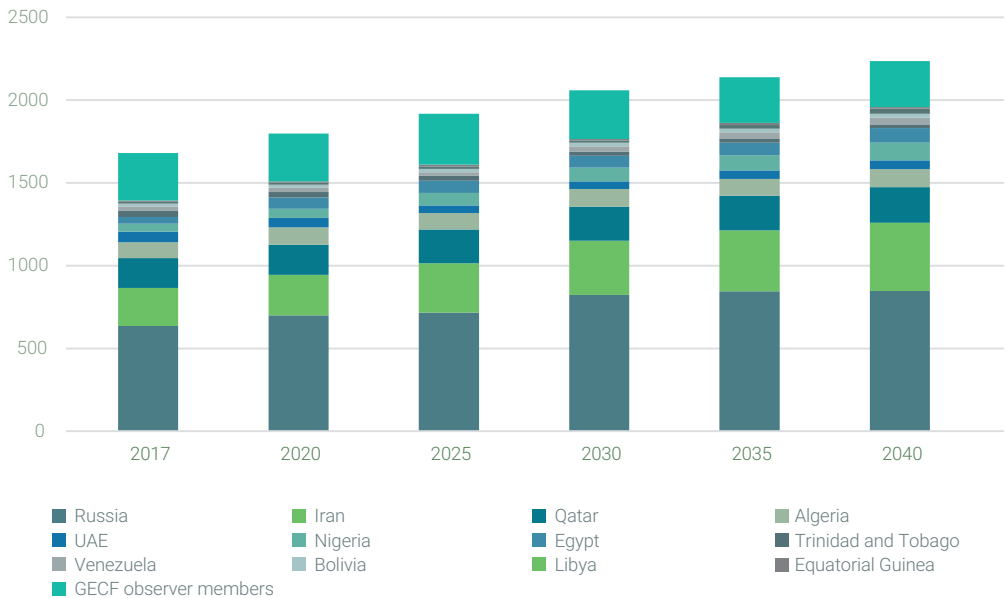
4.4 GECF Countries' gas production outlook

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 one third, reaching approximately 2250 bcm by 2040. This translates to a 1.25% annual growth rate over the outlook period, which will enable the GECF to keep its share of global gas production at more than 41%.

Russia (31%), Iran (26%) and Nigeria (8.7%) are expected to be the largest contributors to incremental gas production volumes. Russia, Oman 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 45 bcm in annual production by 2040, compared with 10 bcm currently. 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 2040.

Figure 4.12. 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 have grown by 38.6% by 2040, at 1.4% per annum, and reached 1616 bcm, sourcing 29.8% of global gas demand in 2040.
- The LNG sector will be more dynamic, growing at 2.5% to 729 bcm, while pipeline trade will expand more slowly at a rate of 0.7% per annum to reach 887 bcm.
- The natural gas export capacity increases that started in 2016 and will continue until to 2025 are expected to be the largest seen so far.
- Out of 1616 bcm imported in 2040, 878 bcm will come from the GECF Members, which corresponds to a market share of 54%.
- By 2040, we expect most of the additional import demand for natural gas to come from Asia Pacific and Europe, with total increases of over 300 bcm and 150 bcm respectively.
- Currently, 27 countries are net exporters of natural gas, but this could rise to up to 35 countries by 2030, including many African countries, and this total could then be maintained through to 2040.
- To meet growing demand for natural gas and avoid energy crises by 2040, there is a need to invest \$7.9 trillion in additional natural gas production capacity and gas trade infrastructure.
- LNG investment and capacity additions will slow down in the medium-term, but will continue for market entrants in Africa and Eurasia and for technologically developed projects in North America which can feed from a competitive gas market. Total investment into LNG and regasification is expected to accumulate to \$270 bn by 2040.

By 2040, the global gas trade is expected to grow by 38.6% to reach 1616 bcm, which corresponds to a growth rate of 1.4% per annum. We expect the LNG segment to be more dynamic, growing at 2.5% to 729 bcm, and pipeline trade to expand at a slower rate of 0.7% per annum to 887 bcm. The share of the GECF is expected to reduce from 62% to 54%, although this assumes no new members join the GECF.

The global investment requirements for 2018-2040 amount to \$7.9 trillion in 2017 prices, of which over \$7.5 trillion in 2017 prices is required for upstream gas projects as many countries, including GECF Members, are starting to produce from unconventional gas deposits at a higher marginal cost. This compares to \$2.9 trillion in 2017 prices invested in upstream gas over 1990-2017. The costs and capital intensity for the transport infrastructure, such as pipelines, liquefaction and regas plants, are expected to be in line with previous years.

5.1 Global gas trade

In 2017, out of 3709 bcm consumed to satisfy global natural gas demand, 1166 bcm was imported (including 720 bcm from GECF Members). The share of imports, comprising about 30% of total natural gas consumption, is projected to fluctuate slightly around this level for 2017-2040. According to the projection, out of 5427 bcm of global natural gas demand in 2040, 1616 bcm would be imported (including 878 bcm from GECF Members).

The demand and supply trends behind this outlook are different for each region. In Europe, the projected decrease in indigenous production would require more imports, as the demand for natural gas is expected to stagnate. At the same time, in Latin America, the assumed growth in indigenous production (such as Vaca Muerte field) would actually decrease the imported share while in Asia Pacific (mostly in Chinese unconventional gas plays), massive upstream investment would allow the share of imports to increase just slightly.

Trade infrastructure prospects

For the purposes of this Outlook, we consider only three types of natural gas export infrastructure: LNG facilities, export pipelines and regas facilities, all of which are key to shaping global gas trade flows. In the GECF GGM, infrastructure links points of production and consumption and is developed according to the assumptions outlined below.

The pace of development for LNG carrier fleets, both marine vessels and the emerging fleet of road trucks (especially in China), is expected to adapt to market needs and as such influences the gas trade only through cost elements. In recent years, road trucking of LNG has emerged as the last-mile infrastructure aimed at avoiding pipeline bottlenecks. However, due to very high marginal costs, this is expected to expand only for intra-country retail supplies (and predominantly in China, where it reached an estimated 18 mt in 2017). (14)

The global gas trade infrastructure will also see significant capacity increases in both pipeline and LNG by 2040. The global pipeline export network is expected to add over 450 bcm of capacity by 2040. This only refers to the capacity of pipeline projects which cross official state borders, and not to the supporting pipeline networks.

Of note is the record expected increase in pipeline export capacity from Eurasia to Europe and Asia, totalling 250 bcm, with half of that directed to the Asian market. When pipelines from the Middle East and Central Asia are included, the growth in pipeline capacity for the Asian market is expected to be more than 200 bcm, including intraregional export pipelines.

Project-wise, by 2030 this includes the completion of Central Asia-China gas pipeline D, the Turkmenistan-Afghanistan-Pakistan-India pipeline (TAPI), the Iran-Pakistan pipeline, and both routes for the Power of Siberia pipelines. In the same timeframe, for supplies to the European market, pipeline capacity is expected to be expanded with completion of the Southern Gas Corridor (via Transadriatic pipeline or TAP), Nord Stream 2 and 3, and the Turkish Stream pipelines. Also, several intra-EU gas pipeline interconnectors to be built in Europe are expected to make the European market significantly more integrated.

LNG infrastructure will see a much faster build-up than pipelines. An important factor which contributes to the faster development of an LNG export project is that it requires far fewer intergovernmental negotiations than a pipeline, and is much less affected by geopolitical tensions. For regas projects these drivers are even stronger.

Global regas capacity is estimated at 715 mtpa (970 bcm) as of 2017, as compared to 370 mtpa liquefaction capacity. By 2040, regas capacity is projected to grow to 1030 mtpa (1400 bcm) as liquefaction capacity grows to 695 mtpa (945 bcm).

The biggest regas capacity additions to 2040 are expected in Asia Pacific, while biggest liquefaction capacity additions are expected in the North America, Africa, Eurasia and Asia Pacific. This includes several 2018 project announcements such as Qatar's Ras Laffan facility expansion to 110 mtpa as well as the FID (final investment decision) taken on 14 mt of LNG Canada's first two trains. (15)

Global gas trade trends

By 2040, we expect most additional import demand for natural gas to come from Asia Pacific and Europe, with total increases of over 300 bcm and 150 bcm, respectively (see Table 5.1). This will be met in the medium-term via supply increases from Eurasia and the Middle East, and in the longer-term via new supply from Africa. Asia Pacific will account for the highest share of global imports from 2030 onwards, while the share held by the European market will progressively diminish. By 2040, Europe's share of global imports will decline by 10 percentage points.

However, in terms of share of imports in regional consumption, the biggest will be in Europe. Indigenous supply in the region is projected to follow a long-term decline and demand response will not be sufficient to reduce an almost 100% dependence on imports. The Latin American market, on the other hand, will be much less dependent on exports by 2040 as indigenous supply is expected to grow strongly. Vigorous growth in demand will increase the share of imports in the Asian region, while for the North American region supply growth will precipitate a further decrease in the share of imports.

Table 5.1. Global gas balances ([+] surplus, [-] deficit) (bcm)

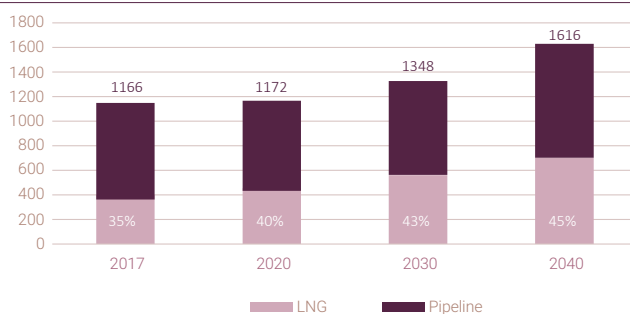
Region	2017	2020	2030	2040
Africa	93	110	138	206
Asia Pacific	-197	-207	-354	-510
Eurasia	227	302	409	464
Europe	-278	-349	-408	-439
Latin America	6	-18	-19	-31
Middle East	104	139	203	203
North America	15	23	30	107

Source: GECF Secretariat based on data from the GECF GGM

The main increase in LNG imports as a share of total gas imports will come from Asian market growth, as well as from increasing LNG supplies to Europe. We project that most additional gas demand will be met by the increase in supply from the same exporters, thus the diversification of gas imports will increase in Asia and stay constant or decrease in the rest of the world.

Currently 27 countries are net exporters of natural gas, but up to 35 countries could become net exporters by 2030 and hold that status through to 2040, including several African countries. The number of importers is also projected to grow, with many countries forming so-called "niche markets", typically with LNG imports well below 3 mtpa. In terms of regions, the biggest increase in the global share of exports is expected in Africa, which will increase its share of global exports from 9% to 14%. Eurasia is expected to increase its share by eight percentage points, while Europe's share of global exports is expected to drop from 17% to 4% over the next 23 years.

Figure 5.1. Global gas trade via pipeline and LNG (bcm) and share of LNG trade (%)

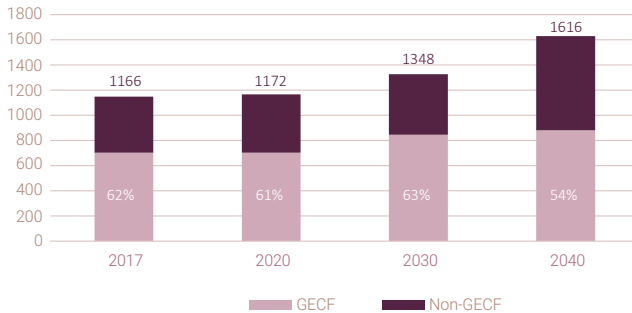


Source: GECF Secretariat based on data from the GECF GGM

GECF countries are already supplying most of these growing markets (except for North America), and will increase their exports by an additional 200 bcm over the outlook period (see Figure 5.2). The GECF's share of demand growth will potentially decrease as some new gas exporters emerge, especially in Africa. The GECF's share is calculated assuming the same member composition, and would materially change should countries join or withdraw from the GECF.

The share of exports comprising LNG will see some structural shifts as exporters are increasingly turning to this technology to speed up capacity build-up. There will be significant structural changes in Eurasia as its

Figure 5.2. Global gas exports (bcm) and GECF share in global exports (%)



Source: GECF Secretariat based on data from the GECF GGM

share of exports increases to almost 10%, in North America, where it rises to over 40%, and in Africa, where new exports will be predominately LNG.

Natural gas trade and pricing mechanisms

Investors and banks require predictable and manageable project revenue streams, and the pricing mechanism is one key component to this. The natural gas trade has historically featured long-term contracts with “take-or-pay” arrangements and oil-indexed natural gas export prices. Most of the industry still follows suit, although the push of European consumer countries to extend gas-to-gas competition to gas imports has led to a consistent expansion of hybrid gas pricing formulas. As of 2017, surveys (16) estimate the share of export volumes significantly linked to oil at 42-70% in Europe, 84% in Asia and 70% in Latin America in 2017.

Attempts at establishing gas trade hubs showed mixed progress globally in 2017. There was ample liquidity in European hubs (TTF trading volumes caught up the NBP in 2017-2018), with hub-traded volumes in 2017 more than ten times greater than the level of natural gas consumption in the EU. However, over 80% of the trade is over-the-counter (OTC), and thus there is no indication of how the price was calculated in those trades and whether it was benchmarked to an exchange index or some hybrid index. Additionally, for south-eastern European countries, the role of hubs on the gas market is minimal.

For the LNG market as a whole, the global LNG body, the International Group of Liquefied Natural Gas Importers (GIIGNL) indicated (17) that in 2017, 27% of global LNG volumes were traded on a spot or short-term basis (up to four years), as compared to 28% in 2015. LNG trade accounted for about 35% of global gas imports as of 2017, and the IGU indicates that 72% of LNG trade flows are oil-linked.

We expect that in the long-term, the increase in LNG exports and gas market reforms will precipitate a rise in uncontracted volumes. In 2018 about 87% of gas exports were supplied on the basis of existing contracts, but the share of supplies under existing contracts (obligated trade) will decline to 47% by 2040. This means additional natural gas export volumes will be offered on the spot and short-term market (non-obligated trade), even assuming existing contracts are renewed, extended or re-negotiated.

International trade prospects for the main regional natural gas markets

In total, 65 countries imported more than 0.5 bcm in 2017 and over 70 countries are expected to import more than that in 2040. The top 20 markets imported over 82.3% (960 bcm) out of the 1166 bcm imported in 2017. These markets are expected to cover 73.5% (1188 bcm) by 2040. Concerning the two largest natural gas markets, the biggest Asian buyers imported 330 bcm in 2017 and that volume is expected to grow to over 600 bcm by 2040. The largest European buyers imported 360 bcm in 2017 and are expected import 345 bcm by 2040.

The Asian natural gas market

There are new national markets emerging in Asia, including Bangladesh and Indonesia, which do not yet import gas but are expected to account for over 30 bcm by 2040. Some markets, such as Malaysia and Pakistan, will become full-fledged importers instead of niche markets and are expected to add 45 bcm by 2040. However, most new imports will be taken by China, totalling around 200 bcm. For India, infrastructure bottlenecks and energy policy uncertainty will most likely limit the rise of natural gas imports.

The gas trade is evolving in the Asian market and this will affect trade projections. The US is actively pushing for the new rules in the Asian gas market via the Asia EDGE (Enhancing Development and Growth through Energy) initiative and Japan is making efforts to build regas facilities in Asia. US-China trade tensions have already led to a 10% tariff on the US LNG and significant non-tariff restrictions. Meanwhile, new players will be entering the market as projects in Russia, Mozambique and the US will ramp up LNG production, and new pipelines from Iran, Turkmenistan and Russia will be completed.

China

Imports into China are projected to increase by over 240 bcm, from 87 bcm in 2017 to over 330 bcm in 2040. The increase is expected to be transported both via pipeline (over 110 bcm) and LNG (over 130 bcm), mainly from Russia, Qatar, Turkmenistan and Australia, but also Malaysia, Iran, Mozambique, and Indonesia.

The Chinese market currently lacks flexibility, as internal pipeline and storage infrastructure is underdeveloped. There is a planned increase in storage capacity in the country to over 15 bcm in 2020 and 35 bcm in 2035, reaching 5.9% of consumption compared to 4.9% as of 2017. While there are reports that Sinopec's storage projects are more ambitious and could provide storage for over 65 bcm, this would still provide just 9.2% of consumption, compared to almost 20% for the European gas system. The persistent lack of flexibility could lead to lower utilization rates in pipeline projects as the gas will have nowhere to go once it has arrived in China. In several cases, a rapidly increasing LNG trucking fleet can make up for the lack of flexibility in the pipeline system, but this will further increase the price of LNG. In this Outlook, we assume the flexibility of national pipeline and storage systems will be improved to levels consistent with the full utilization of future pipeline and LNG projects.

India

India is expected to more than double natural gas imports, from 27 bcm in 2017 to over 62 bcm in 2040. The increase in imports into India is projected to be sourced from both pipeline (about 16 bcm) and LNG (over 17 bcm), with total imports coming mainly from Mozambique, the US, Qatar, Iran, and Russia. With a strong build-up in indigenous production (mainly sourced from deepwater), import growth will be undercut after several production projects ramp-up volumes after 2030.

Additional pipeline supply of over 25 bcm will be transported by pipelines from Iran (via Oman) and Turkmenistan (via Pakistan and Afghanistan). The TAPI pipeline is currently under construction, and more capacity will be in place if planned pipeline projects from Myanmar and Bangladesh are launched. Talks of a giant 90-bcm Iran-Pakistan-India (IPI) project have stalled and the project is expected to be limited to an Iran-Pakistan pipeline for the time being. Internal connectivity will probably be provided by the JHBDPL project that will connect the western gas network with eastern Indian states and create gas distribution networks in eastern cities.

While regas capacity will ramp-up quickly, it is the connectivity that could prevent gas imports from reaching final consumers. Total regas capacity in India is expected to top 100 mtpa by 2020 and provide gas to the whole coastal area.

Japan

In Japan import volumes are projected to decline from 111 bcm in 2017 to less than 90 bcm by 2040 as a result of reduced demand. All imports come in the form of LNG, mainly from Australia, the US, Russia and Qatar. No additional pipeline or LNG infrastructure is likely to be constructed, as there is ample regas capacity in Japan (topping 190 mtpa or 255 bcm).

Japan is attempting to become a natural gas hub in the Asia Pacific region, and is planning to utilise the engineering and marketing capabilities of regional gas companies. These efforts were unveiled this year in a \$10 billion program to support regas and pipeline infrastructure in emerging gas importing countries. The mandates of NEXI (Nippon Export and Investment Insurance) and JOGMEC (Japan Oil, Gas and Metals National Corporation) were changed, allowing for export credit support for infrastructure projects.

Japan is also at the forefront of efforts to change the Asian LNG market structure in favour of shorter-term gas-to-gas competition. Japan's leading LNG importer company, JERA, spearheaded efforts in cooperation with CNOOC and KOGAS to create the world's largest gas importer consortium. While it is unlikely that Japan will use competition law to violate existing long-term contracts (like European countries did in 2011), the Japan Fair Trade Commission (JFTC) prohibited destination clauses starting from 2016. Japanese importers have announced that they will not accept destination clauses in the new contracts from 2019, enabling them to redirect the shipments globally and facilitate trading, including in the Asia Pacific region where shipments are still largely bound by destination clauses. Concerning the contract duration, the biggest LNG importer, JERA, has announced that it has a target below 42% for long-term contracts by 2030.

The European natural gas market

In Europe, natural gas imports are expected to grow slowly because indigenous production will decline over the outlook period and the accelerated penetration of renewables will slow down additional gas demand. With a lot of new pipeline capacity coming online before 2025 and ample regas capacity, most European countries are not planning significant additions up to 2040, with total expected additions of 33 mtpa (45 bcm), in addition to the existing 143 mtpa (195 bcm) of capacity. With a lot of competing projects proposed, some of the planned regas capacity might be cancelled.

While the imports are slowing down, a market transformation is still ongoing. European gas pipeline infrastructure upgrades, both recent and planned, will enable markets to be more integrated. Most upgrades are not limited to a single European country, but also connects main consumer markets, such as Germany, Italy, France and the UK. Market transformation also includes new gas hub and competition regulation that has severely impacted existing contracts, pending resolution between several natural gas exporters and the European Commission. The resolution (18) already mentions the removal of any destination and resale restrictions, and enables the transfer of export contracts to the “competitive Continental Western European gas markets.” This means indexation to the European gas hub-based prices and granting the European Commission authority over price mechanisms and EU arbitration.

5.2 Gas investment

To meet growing demand for natural gas by 2040, the GECF calculates that \$7.9 trillion is needed to invest in additional natural gas production capacity and the aforementioned gas trade infrastructure. This subsection details the estimates for the upstream and infrastructure investment required. All the subsequent investment estimates are provided at constant 2017 prices and are not discounted.

Although most of this \$7.9 trillion earmarked for gas investment is needed in the natural gas exploration and production sectors, trade infrastructure still requires investment of over \$325 bn in 2017 prices by 2040 (see Figure 5.3). The gas investment outlook is thus shaped both by trade infrastructure and upstream investment needs.

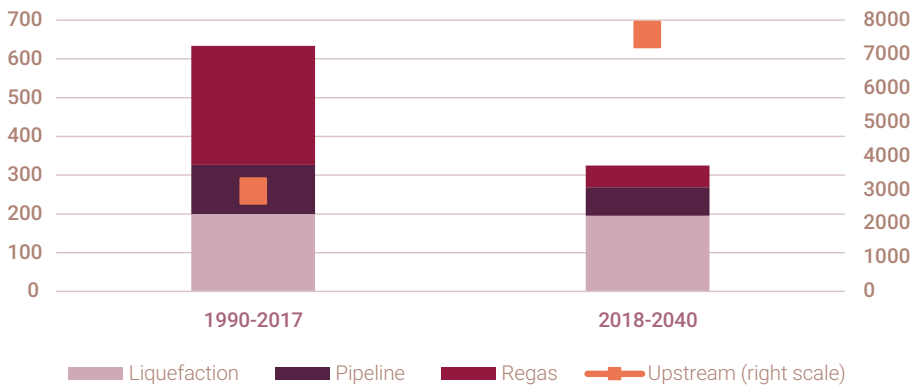
As production shifts to unconventional sources, the investment requirements from the gas industry will increase both in and outside the GECF. The developments already planned in Algeria and Mozambique will drive African investment while, after 2035, capital intensity for projects in Siberia is also expected to rise as the development of unconventional sources is anticipated.

Eurasian investment will additionally pick up being coupled with more pipeline investment, while in Asia Pacific and North America liquefaction capacity and unconventional production will be the main drivers of investment. Production projects aimed at the premium Asian market will be the most attractive, and are expected to break even for even the most expensive gas deposits such as unconventional gas production in China, which has the four times the capital intensity of US unconventional gas production. It is worth noting that in China, energy security considerations will drive production development in addition to the Asian gas premium.

As leading gas producers, GECF countries are expected to retain cost leadership even as supply shifts to unconventional and offshore sources. Figure 5.4 details the cost of investment per unit of overall gas production. The advantage of projects in the GECF countries is that they already have gas infrastructure in place, and thus upstream development in the same deposits requires much less investment than for most producers outside the GECF which have not yet developed a costly gas infrastructure.

The expansion of the gas trade infrastructure will see more LNG facilities in every region, while pipeline expansion will be focused in Eurasia and the Middle East. This current edition of the Outlook marks a moment when a

Figure 5.3. Global gas industry investment by purpose (2017 USD bn)

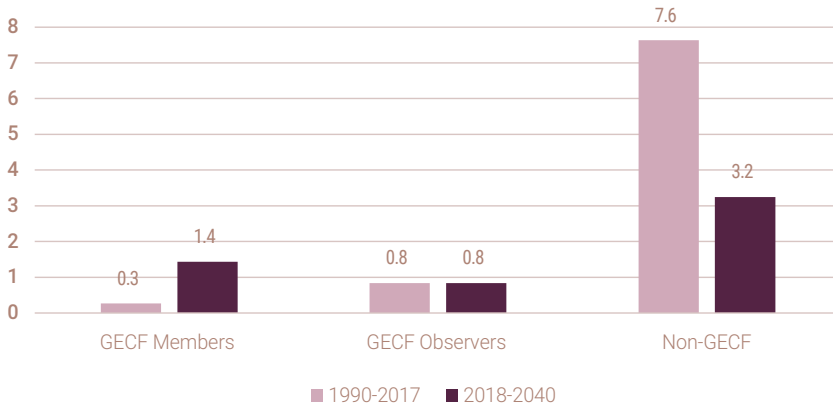


Source: GECF Secretariat based on data from the GECF GGM

significant part of investment into most Eurasian pipelines (SCP, TANAP, Nord Stream 2, Turkish stream and the Power of Siberia) has already been made, but supply from those projects is just beginning to flow. That is partly why future planned Eurasian pipeline investment is \$10 bn behind the historical value, amounting to just \$57 bn.

Investment into liquefaction and regas facilities will continue at a more modest pace. As additional piped gas enters Asian markets, the wave of liquefaction projects re-scheduled for the early 2020s will be further rescheduled, and cost and placement efficiency will increase as FSRU and FLNG penetration grows. LNG investment and capacity additions will continue for market entrants in Africa and Eurasia, as will technologically developed projects in North America with a feed-in access to a competitive gas market, amounting to \$325 bn globally by 2040.

Figure 5.4. Capital intensity of gas production, (2017 USD/mmBtu, not discounted)



Source: GECF Secretariat based on data from the GECF GGM



6

Alternative Scenarios

Key findings

- GECF has developed a Carbon Mitigation Scenario (CMS) and a Technology Advancement Scenario (TAS) that reflect accelerated energy transitions when compared to the Reference Case Scenario (RCS). TAS+ scenario assesses the combined effects of carbon mitigation policies in the CMS and technology progress in the TAS.
- Results from these scenarios' modelling suggest that natural gas could increase its share and play a central role in achieving the energy transition, by substituting for coal, being a partner to renewables and improving energy efficiency.
- By 2040, natural gas and renewables shares will respectively reach 27.7% and 7.8% in the CMS, increasing from 26% and 6% in the RCS. The consideration of technology advancement, as highlighted in the TAS+, will further improve these shares to 28.5% and 9.3% respectively. Conversely, coal's share is anticipated to decline strongly to 16.6 % in the CMS and 14.3% in the TAS+.
- The power sector is the main contributor to the global demand reduction in the CMS due to higher carbon prices and an improvement of average energy efficiency of power generation with the penetration of gas-fired plants and renewables. Average energy efficiency improvements in the CMS are due to the substitution effect in the power sector rather than technology advancement.
- Efficiency improvement related to technology progress in buildings, residential and commercial appliances, transport, power and industry sectors will drive an additional reduction in total primary energy demand in the TAS+ compared to the CMS. This reduction will offset the upside effect on energy demand due to increased electrification of final energy consuming sectors.
- Energy-related CO₂ emissions are expected to reach 34.2 GtCO₂ in the CMS by 2040, decreasing by more than 4 GtCO₂ compared to the RCS, and this level will drop to around 32.3 GtCO₂ in the TAS+.
- In the CMS, the bulk of emissions reduction is driven by changing the power generation mix with more renewables and natural gas penetration. The additional emissions decrease in the TAS+ is mostly achieved in industry and buildings, due to large energy efficiency improvements and electrification of these sectors. Aggressive electrification of final sectors due to technical enhancement and digitalization in the TAS+ will increase the prospects of electricity generated and then reduce the role of power in mitigating CO₂ emissions.

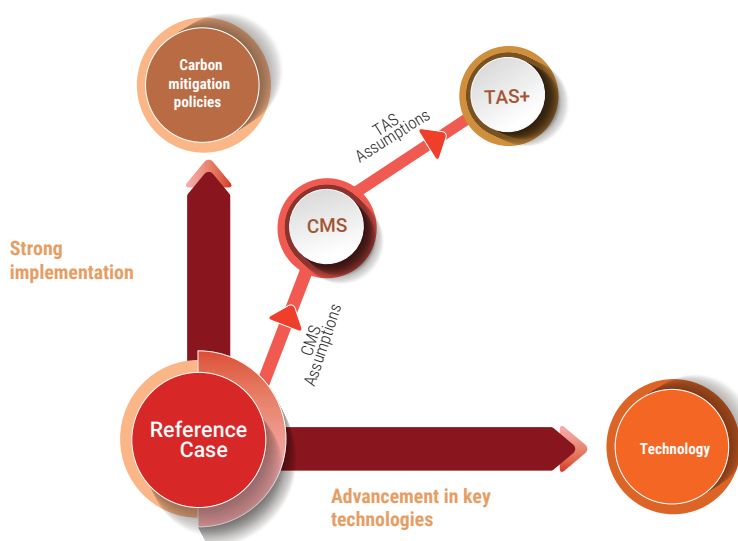
6.1 Methodology

The GECF has developed two alternative scenarios that reflect accelerated energy transitions when compared to the Reference Case Scenario (RCS). The Carbon Mitigation Scenario (CMS) aims to assess the effects that strengthened CO₂ mitigation policies have on global energy mixes. The Technology Advancement Scenario (TAS) takes into account expected progress in energy technologies across the energy supply chain.

The approach used to assess these two scenarios is to focus on critical parameters and driving forces that will support the changes in each scenario compared to the RCS. The CMS examines two shifts that are considered potential outcomes of carbon mitigation policies: i) a changing power generation mix that results from policy support for less carbon-intensive fuels and renewables and, ii) increased electrification in the transportation sector as a result of policy support for electric vehicles. In this scenario, technology advancement will mostly follow the current trends. The TAS focuses on technological progress in areas that are considered key to deployment potential. Technological progress is particularly reflected in the development of energy efficient technologies and cost improvements.

In order to contrast the two scenarios, compare their impacts on the global energy mix and assess their effect on the role of natural gas, the TAS builds upon the assumptions applied in the CMS, while the CMS builds upon the assumptions applied in the RCS (see Figure 6.1). This approach allows us to analyse the combined effects that carbon mitigation policies and technology advancement have on the energy mix and natural gas mix in particular. The scenario generated from both CMS and TAS assumptions, when subsequently applied to the Ref. Case, is called the TAS+.

Figure 6.1. Illustrative representation of the CMS and TAS+ compared to the GECF RCS



Source: GECF Secretariat

Table 6.1: Global assumptions in the CMS and the TAS

	RCS	TAS+*	
		CMS	TAS
Macro-economic drivers	<p>World real GDP growing 3.4% yearly on average over the outlook period</p> <p>Southeast Asia and India will remain the engines for global growth up to the 2040s, despite deceleration to over 4.0% by 2040 for Southeast Asia and over 4.9% for India in PPP terms</p> <p>Balanced growth for developed economies will continue as their growth is already driven by increasing labour productivity</p>	Macro-economic drivers are assumed to be at the same levels as in the RCS	Macro-economic drivers are assumed to be at the same levels as in the RCS
Carbon price assumptions	<p>Carbon pricing is expected to see progress in certain countries</p> <p>Large disparities persist in pricing levels, reflecting country-specific conditions and climate ambitions</p> <p>Implementation of EU ETS reforms Phase IV and UK carbon price (still connected to EU ETS)</p>	<p>Increased carbon price references are implemented in several countries (e.g. China, South Korea, Canada, US, and the EU ETS)</p> <p>Increase based on an assessment of policy ambitions and reforms that might support higher carbon price references</p> <p>Reference prices by 2040 in selected countries:</p>	

	<p>ETS reference price: \$40/tCO₂ (2030) – \$55/tCO₂ (2040)</p> <p>UK carbon price floor: \$63/tCO₂ (2030) – \$75/tCO₂ (2040)</p> <p>China carbon scheme: \$13.8/tCO₂ (2030) – \$17/tCO₂ (2040)</p>	<p>EU ETS: \$130/tCO₂</p> <p>UK: \$148/tCO₂</p> <p>China: \$40/tCO₂</p>	<p>No changes assumed for carbon prices compared to RCS.</p>
Renewables capacities	<p>Incremental capacities between 2017 and 2040:</p> <p>Solar PV: 2000 GW Solar CSP: 15 GW Onshore wind: 1000 GW Offshore wind: 250 GW Hydro: 440 GW Pump storage: 125 GW</p>	<p>Incremental capacities between 2017 and 2040 are increased due to policy support and renewable schemes: Solar PV: +80% Solar CSP: +30% Onshore wind: +50% Offshore wind: +30% Hydro: +30% Pump storage: +70% (assumed to play a key role in managing renewable intermittency)</p> <p>Renewable costs are assumed to follow the same trends as in the RCS</p>	<p>Advancement in on-shore and off-shore wind turbine technologies has been quantified by improving unit size, efficiency, and utilization rates, and by reducing the levelized cost of supply by 20% (compared with the CMS)</p> <p>Advancement in PV systems has been quantified similar to wind turbines (above)</p> <p>Batteries are implemented in the power sector, which can perform shifting peak demand and compensate for intermittency</p> <p>Digitization results in the introduction of smart grids, which can act as peak-shavers</p>

<p>Gas-fired capacities</p>	<p>Incremental capacities between 2017 and 2040:</p> <p>CCGT: 900 GW</p> <p>OCGT: 80 GW</p>	<p>Incremental capacities between 2017 and 2040 are increased due to policy support**</p> <p>Incremental CCGT capacities increased by more than 50%</p> <p>Incremental OCGT capacities increased by 30% (reflecting the higher need of peaking power plants to support renewables intermittency)</p>	<p>More potential for gas to power; increased demand could be captured through technology advancement:</p> <p>Advancement in CCGT has been quantified by improving efficiency, utilization rates, and plant factors, and by reducing the levelized cost of supply (compared with the CMS)</p>
<p>Coal and oil-fired capacities</p>	<p>Incremental capacities between 2017 and 2040:</p> <p>Total coal capacities: +70 GW</p> <p>Large Scrubbed Steam Turbine: +100 GW</p> <p>Large Un-Scrubbed Steam Turbine: -190 GW</p> <p>Integrated Gasification Combined Cycle (IGCC): +70 GW</p> <p>Fluidised Bed Combustion (FBC): + 80 GW</p>	<p>Coal retirement pace accelerated in countries announcing phase-out or strong limitations to coal (e.g. France, the UK, Korea, China)</p> <p>Total coal capacities between 2017 and 2040 are decreased by around 400 GW</p> <p>Retirement pace is higher for the un-scrubbed and scrubbed coal power plants and there is less development of IGCC and FBC</p> <p>Oil-fired capacities assumed to halve (especially in Asia, Latin America and the MENA region)</p>	<p>Clean coal technologies are assumed to have advanced (e.g. greater efficiencies and lower costs) resulting in greater deployment, especially in Asia</p>

<p>Transport sector</p>	<p>Share of electric vehicles: 14.6% by 2040</p>	<p>Larger penetration of electric vehicles (around 20% of the car fleet by 2040)</p>	<p>Advancement in Battery Electric Vehicles (BEVs)</p> <p>EVs are deployed in greater numbers, especially in OECD countries and China</p> <p>Advanced fleets are introduced in the marine sector; greater penetration of LNG as a bunker fuel</p>
<p>Domestic sector</p>	<p>Significant improvement in domestic energy efficiency due to policy support (strengthened performance standards, building codes and price signals, such as a reduction in energy subsidies)</p> <p>For instance: CAAGR (2017-2040) for the energy consumed by households = 0.004% (world) and -0.3% (OECD countries)</p>	<p>This scenario does not implement carbon mitigation assumptions in the domestic sector (such as higher efficiency)</p> <p>The only carbon mitigation action modeled is strengthened carbon taxation in some countries (e.g. in European countries)</p> <p>Energy efficiency improvements follow RCS assumptions</p>	<p>Newly constructed homes feature energy efficiency improvements (e.g. insulated windows, reflective roofing) for a 10% increase in efficiency gains</p> <p>Efficiency improvement of new (not existing) equipment and home appliances is assumed to be around 10% for selected countries, mostly in OECD and developing countries</p> <p>Development of off-grid or stand-alone power plants; off-grid power plants assumed to be more available in remote areas, with a 5% increase in selected countries</p>

* TAS+ is an abbreviation of TAS + CMS

** For instance: Extended US policy support to gas infrastructure development and upstream projects is assumed to improve the availability of domestic gas at relatively low prices and to support gas in power sector.

6.2 Carbon Mitigation Scenario

The CMS aims to assess the effects that strengthened CO₂ mitigation policies will have on the global energy mix. It also attempts to highlight the role of natural gas in supporting countries' climate commitments, especially after the adoption and ratification of the Paris Agreement. The CMS assumes that CO₂ mitigation will be primarily achieved through stronger implementation of measures that will favour the development and penetration of the less carbon intensive and cost efficient options. It also assumes that these measures will recognize the key role of natural gas in meeting countries' commitments.

The focus on the power sector is motivated by the fact that it still represents a big share of CO₂ emissions (around 35% of total emissions in 2017). The power sector is also expected to significantly contribute to emissions reductions, given the large spectrum of proven technologies and options that can be used to produce electricity with fewer carbon emissions. Moreover, a large proportion of CO₂ mitigation policies target the power generation sector, making it central to future decarbonisation efforts.

Main policy assumptions in the CMS

Renewable energy policies

In the CMS, renewables, in particular solar and wind, are expected to see continued policy support, which allows many countries, especially those announcing renewable targets, to achieve more progress with renewables compared to our RCS.

Renewable support schemes and power market design will be improved in many areas in order to tackle the integration challenge of large intermittent renewable power supplies, and also to achieve greater cost efficiency for renewables development. Synergies between gas and renewables will be significantly promoted, since gas allows for improved power system flexibility and can efficiently balance intermittency. In this scenario, natural gas will contribute significantly to the renewables integration challenge.

Non-renewable energy policies

The CMS considers extended policy support for gas infrastructure development (e.g. the LNG supply chain), network integration and upstream projects, which will contribute to improving gas availability and accessibility. In this regard, many supporting instruments are considered which will stimulate the gas value chain, such as investment incentives and strengthened cooperation frameworks.

The environmental qualities of gas are being promoted in many countries which are experiencing pollution in urban areas. Countries announcing gas penetration targets, especially China and India, are assumed to make progress in line with their announced targets and to significantly increase gas-fired capacities in the power sector, which is the major focus of the CMS. Other countries that have potential for greater penetration of gas (over more carbon-intensive energy sources), such as countries in Southeast Asia, are expected to make progress in mitigating CO₂.

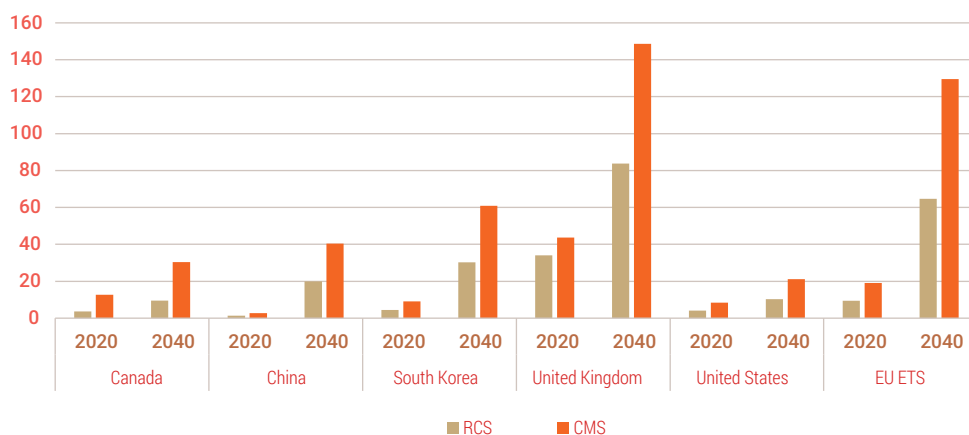
The CMS considers the strengthened implementation of air pollution emission standards and taxes on coal, which will increase the cost of producing electricity and support the decommissioning of coal-fired capacities. Additionally, phasing out of coal or limitations on coal use will be strongly applied in countries having made announcements in this regard. Table 6.4 displays the main coal policy assumptions in the RCS and the CMS.

The CMS considers no additional policy support to nuclear compared to the RCS, where nuclear is expected to see non-negligible growth (around 1.4% between 2017 and 2040). This assumption is motivated by the fact that more aggressive penetration of nuclear remains constrained by high investments costs (due to safety requirements), waste treatment issues, availability of skilled labour, and fuel availability challenges in some emerging economies.

Carbon pricing

As highlighted in Figure 6.2, under the CMS, carbon reference prices are assumed to double in Europe, China and the US between 2020 and 2040 when compared to the RCS. (For the US, we take the average carbon market prices in California and the Regional Greenhouse Gas Initiative). For Europe, the average EU ETS reference prices are expected to reach around \$20/tCO₂ in 2020 and \$130/tCO₂ in 2040. Chinese carbon prices are assumed to reach around \$40/tCO₂ in 2040. In the UK, the reference price is expected to reach \$148/tCO₂ in 2040, reflecting aggressive mitigation policies.

Figure 6.2. Carbon prices in the RCS vs. the CMS



Source: GECF Secretariat based on data from the GECF GGM

Electrification of the transport sector

Electrification of the transport sector is one of the key drivers behind carbon mitigation. Several countries, especially China, India, Japan and some European countries, are undertaking measures to increase electricity usage in transport, mainly by supporting the penetration of EVs. Some countries have also considered the introduction of binding targets and mandates for car makers to produce and sell low-emission vehicles, including EVs (zero emission vehicle mandates). These mandates have already been enforced in some US states, such

as California, while China and the EU are considering the possibility of introducing them within the framework of their decarbonisation policies. India has announced its support for electricity usage under the framework of an ambitious plan (the National Electric Mobility Mission Plan 2020). The CMS assumes that policies will significantly support the penetration of EVs. These policies will result in a 20% EV share in the CMS by 2040, compared to a 15% share in the RCS.

6.3 Technology Advancement Scenario

Energy balance projections are highly dependent on economic, technological, social and political circumstances. Among these, technical innovation is partially driven by complex drivers and feedback mechanisms between the other three factors. Policy measures which alter the economic environment through financial incentives and supports, can propel technological advancements and intentionally promote the development of specific technologies.

Putting supporting policies in place and improving the financial circumstances surrounding technological development are the best ways to ensure the deployment of clean and efficient technologies across the energy supply chain and in end-use sectors. The most feasible way to deal with the negative and inevitable consequences of climate change is to introduce advanced technologies and to improve current conventional technologies through wise and supportive policy measures.

The TAS explores the impact of technological advancement across the energy supply chain, as well as in consuming sectors. It considers the implementation of new and innovative technologies, as well as the advancement of conventional technologies that are readily available. The objective of the TAS is to examine how technology can affect the future energy system and to evaluate the impact of technologies on energy markets.

The definition of advanced technologies used in this scenario includes those technologies which are still under development but promise to deliver significant value or those which have yet to gain substantial market shares. It is important to note that there is unevenness in the pace at which advanced technologies are commercialized and transferred, as well as in the distribution of technology possession across developed, emerging and developing economies.

Energy systems are not only affected by innovative technological breakthroughs, but also by enhancements in conventional technologies, like power-plants, CCS, and CHP technologies. While these technologies have been around for decades, recent and ongoing developments have focused on reducing energy consumption (and therefore the marginal cost of production), as well as increasing thermal efficiency and decreasing associated GHGs.

These and other advancements may have significant effects on the rate and scale at which technologies are deployed and, consequentially, their role in final energy consuming sectors. Technologies which are specifically applied to mitigate GHG emissions are also subject to policy interventions. Therefore, their development reflects the political and economic landscape.

The TAS considers these complex interactions by assuming which technologies are most likely to develop, as well as predicting their impact on final energy balance projections. The TAS applies these assumptions to the CMS in order to simulate the impact of specific advancements in energy sector technologies.

Methodology

The objective of the TAS is to identify technologies that are most likely to advance and to assess whether they are beneficial or competitive for natural gas. An attempt has been made to conceptualize a scenario that considers new parameters in sectors that are expected to see rapid development on an anticipated scale, like renewable energies. In order to explain how various assumptions were applied in the model, it is first necessary to describe the structure and limitations inherent in the GECF GGM. Because the GGM is the central modelling tool applied in this analysis, understanding the model's design will allow for a better understanding of how the TAS is implemented and processed.

The GGM is a modular modelling tool that benefits from a variety of methodologies, such as linear programming and econometric time-series. The energy price and macroeconomic sub-models feed end-use energy demand. End-use demand includes, but is not limited to, the commercial, residential, agricultural, industry and transportation sectors. The final consuming sectors encompassed in the demand sub-model estimate energy needs, such as the demand for heat, electricity and other intermediate fuels (like petroleum products, hydrogen, etc.). Some final sector technologies, such as vehicles, industrial machinery and residential appliances, affect energy demand and, consequently, the modelling results generated for this sector.

Based on projections of activity from transformation technologies, primary energy demand is determined. Some technologies in this sector, like power plants, refineries and other conversion technologies, are included in this sub-model. Because econometric time-series methodologies are utilized in the transformation sector energy demand sub-model, any set of assumption on these technologies impacts overall results and, accordingly, the gas supply and trade sub-models. The resulting projections generated for primary energy demand need to be met with indigenous supply or trade.

The trade sub-model utilizes linear programming. All technology advancement assumptions along the natural gas supply chain must be imposed into the optimization process. This means that the GGM is very sensitive and responsive to any changes in the gas sector. For instance, any supply discoveries (in production from both conventional and unconventional resources) can change the results dramatically.

Based on the iterative progress of the GGM, after running linear programming, the marginal cost of supply feeds into the price sub-model and we can see an iterative circuit. The model runs a series of iterations until it converges to a set of consistent prices, as well as demand and supply projections based on the assumed acceptable difference between the two latest iteration results. The converged energy balance projections by fuel, sector and technology are then used to calculate CO₂ emissions. In this sub-model, technologies such as CCS can have an impact on the total system. The TAS considers technologies that are likely to be deployed from 2018 through to 2040.

The functioning of the GECF GGM affects the assumptions imposed in the TAS. The following key areas are considered:

- ④ As previously mentioned, technologies utilized along the natural gas supply chain can significantly affect the model results, and are therefore very important for the development of the TAS. The TAS considers technologies being used in the power generation sector, as they affect demand for electricity and the need for new power capacities.
- ④ Moreover, the TAS will consider the implementation of renewable energy technologies, such as wind turbines. These technologies are considered due to the rapid scale at which they are developing and being deployed, with projections showing that renewables will become the fastest growing energy sources through to 2040. As these technologies are expected to have a significant impact on energy balance projections, they have been included in this analysis despite being competitive to natural gas in the power generation sector.

6.4 Scenario Results

World primary energy demand

Compared to the RCS, primary energy demand in the CMS is expected to observe less growth momentum over the 2017-2040 period, estimated at around 0.83% annually (compared to a CAAGR of over 1% in the RCS over the same period). Lower growth prospects in the CMS reduce global primary energy demand by around 720 Mtoe in 2040, corresponding to energy savings of more than 4% compared to the RCS (see Figure 6.3).

Figure 6.3 shows that even more energy demand reductions are anticipated in TAS+. When all the assumptions from the CMS and TAS are implemented, total primary energy demand in 2040 is estimated at around 16870 Mtoe. This is 240 Mtoe less than what is projected in the CMS and approximately 1000 Mtoe less than what is projected in the RCS. This significant reduction in total primary energy is equivalent to 5.4% of the energy savings in the RCS. Cumulative energy savings over the 2017-2040 period are estimated at more than 9500 Mtoe.

TAS+ considers technology advancement assumptions in addition to the policy assumptions already considered in the CMS, in order to contrast the two scenarios (see Section 6.1). The CMS forms the base case for the TAS+, to which technology-related assumptions, particularly energy efficiency and cost improvements, are implemented.

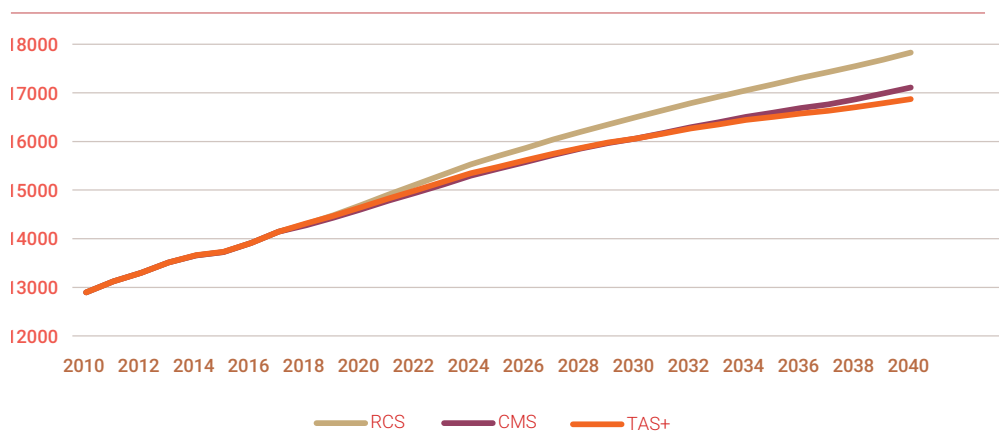
The power sector is the main contributor to global demand reductions in the CMS, with around 560 Mtoe conserved through to 2040. The two driving forces behind this reduction are: i) higher carbon prices which affect energy demand in power generation, and ii) the closure of coal-fired power plants (to the benefit of gas and renewables) which improves average energy efficiency. Efficiency improvements result from fuel substitution, as opposed to technological development (which is incorporated in the TAS). In the transportation sector, policy support to EVs in the CMS is expected to reduce oil consumption by approximately 90 Mtoe in 2040 when compared to the RCS. This occurs because oil is substituted by electricity.

Results from TAS+ suggest that efficiency gains stemming from technological improvements in buildings, residential and commercial appliances, transport, electricity generation and industry will drive additional

reductions in total primary energy demand when compared to the CMS. This reduction will compensate for increasing electricity demand in final consuming sectors, which is driven by electrification of appliances and industrial equipment, as well as by further expansion of EVs.

When compared to the RCS, TAS+ forecasts higher electricity demand and an additional 3400 GW of power capacity by 2040. This is 28% more than the RCS, indicating that electrification will significantly and positively impact the power sector, while total primary energy consumption is reduced.

Figure 6.3. Total primary energy consumption outlook in different scenarios (Mtoe)



Source: GECF Secretariat based on data from the GECF GGM

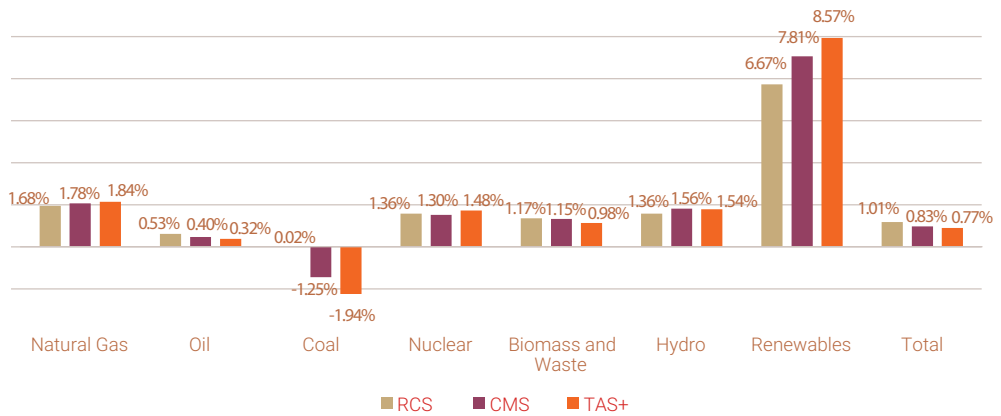
Primary energy demand by fuel

Figure 6.4 depicts average growth rates for primary energy carriers in the RCS, the CMS and the TAS+. Natural gas demand annual growth between 2017 and 2040 is expected to rise from 1.68% in the RCS to 1.78% in the CMS, and further to 1.84% in the TAS+. Coal is projected to decline by around 1.3% and 2% annually in the CMS and the TAS+, respectively, after exhibiting stable long-term evolution in the RCS.

The significant decline of coal in the CMS is mainly driven by Asia Pacific, Europe and North America. China is expected to lead this decline, with a demand reduction of more than 700 Mtoe between 2017 and 2040, compared to an anticipated reduction in the RCS of around 340 Mtoe. China will also lead gas demand growth in the CMS, with incremental gas demand totalling nearly 450 Mtoe (estimated at 390 Mtoe in the RCS). This growth will be supported by coal to gas substitution in the power sector. Coal is expected to see further demand reductions in the TAS+, totalling approximately 2% average annual decline over the outlook period, and driven by progress in renewables and gas-fired power generation technologies.

Renewables are an important focus in the CMS, which aims to assess their potential impact on global energy systems and the transition towards low-carbon economies. The CMS projects that renewable energies (excluding hydro and biomass) will grow at an average annual rate of 7.8% between 2017 and 2040. This corresponds to a 1.1 percentage point increase compared to the RCS. Asia Pacific, particularly China and India, will drive

Figure 6.4. Primary energy consumption CAAGR (2017-2040) in different scenarios (%)



Source: GECF Secretariat based on data from the GECF GGM

the acceleration of renewables, especially solar. Demand for renewables will increase by more than 450 Mtoe between 2017 and 2040 in China and India, which is 150 Mtoe higher than incremental demand in the RCS. This increase is driven by continuous policy support and cost declines.

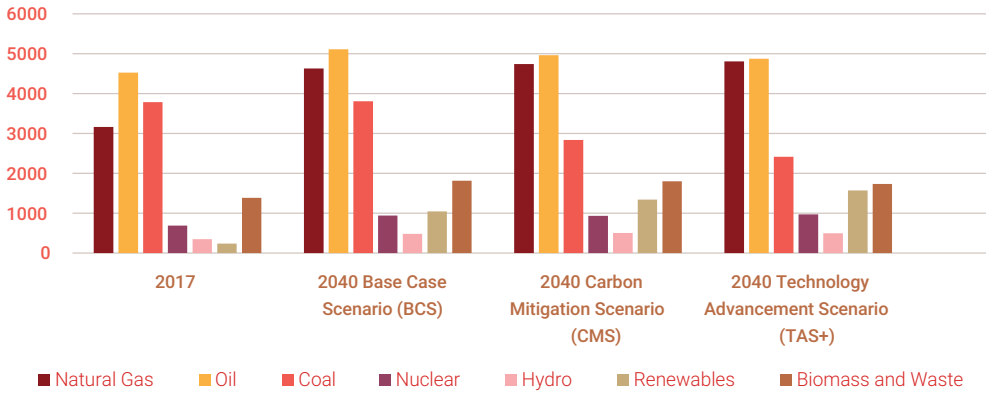
TAS+ also sees a promising future for renewables. Anticipated technological advancements in wind turbine, solar PV and CSP technologies will contribute to their accelerated deployment. Policy support for renewables in China and India will be implemented through a combination of market-based mechanisms (including auctioning and tradable certificates) and through direct government intervention in the form of funding incentives and subsidies. The CMS also assumes that these two countries will be able to significantly reduce the curtailment of renewables through reinforced grid networks and improved flexibility of power systems. Gas-based power plants will play a key role in supporting this flexibility.

Oil demand growth is expected to decrease at an annual rate of 0.4% in the CMS and 0.32% in the TAS+, compared with 0.53% in the RCS. Oil demand reductions in the CMS and TAS+ are driven by greater penetration of EVs (representing a respective 20% and 23% of the passenger vehicle fleet in the CMS and TAS+ by 2040), as well as by the decreasing role of oil-fired power generation, mainly in emerging and developing countries.

The CMS does not expect further policy support for nuclear energy and additional nuclear capacities are not imposed on the RCS. As a result, the progress of other alternatives to nuclear in producing power, especially renewable energies and gas, contribute to the decrease in the average annual growth rate of nuclear from 1.4% to 1.3% over the forecast period. The growth prospects of renewables, natural gas, coal and oil in the CMS and TAS+ will lead to significant changes in the primary energy mix by 2040 (see Figure 6.6).

In the CMS, demand for natural gas and renewables is expected to be 110 Mtoe and 290 Mtoe higher respectively than in the RCS. Conversely, demand for coal and oil is expected to be 960 Mtoe and 162 Mtoe lower respectively. The substitution momentum in the power sector, coupled with the progress of EVs, is anticipated to be favourable for natural gas and renewables.

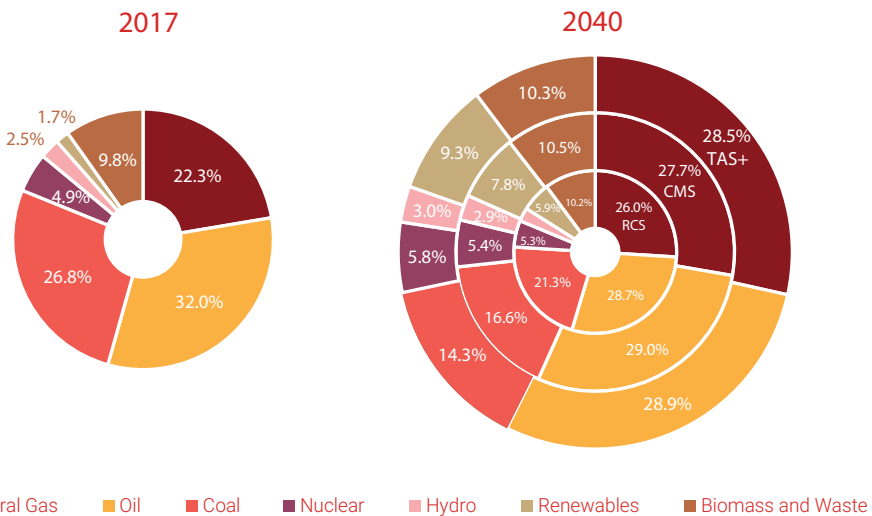
Figure 6.5. Global primary energy demand trends by fuel type in all scenarios (Mtoe)



Source: GECF Secretariat based on data from the GECF GGM

Adding the technology advancement assumptions to the CMS (as highlighted in the TAS+) increases natural gas demand by 65 Mtoe, amounting to more than 4800 Mtoe by 2040. The share of natural gas in total primary consumption will reach 27.7% and 28.5% respectively in the CMS and the TAS+ by 2040 (compared with 26% in the RCS). The share of renewables will also rise from 6% in the RCS to 7.8% in the CMS and 9.3% in the TAS+. If we include hydro and biomass/wastes, renewables' contribution will reach 21.3% in the CMS and 22.6% in the TAS+, significantly surpassing the share of coal. The role of coal in primary energy is, therefore, anticipated to decline significantly and reach 16.6% in the CMS and 14.3% in the TAS+ by 2040 (its share was 21.3% in the RCS).

Figure 6.6. Global primary energy mix in 2017 and 2040 by fuel type in all scenarios (%)



Source: GECF Secretariat based on data from the GECF GGM

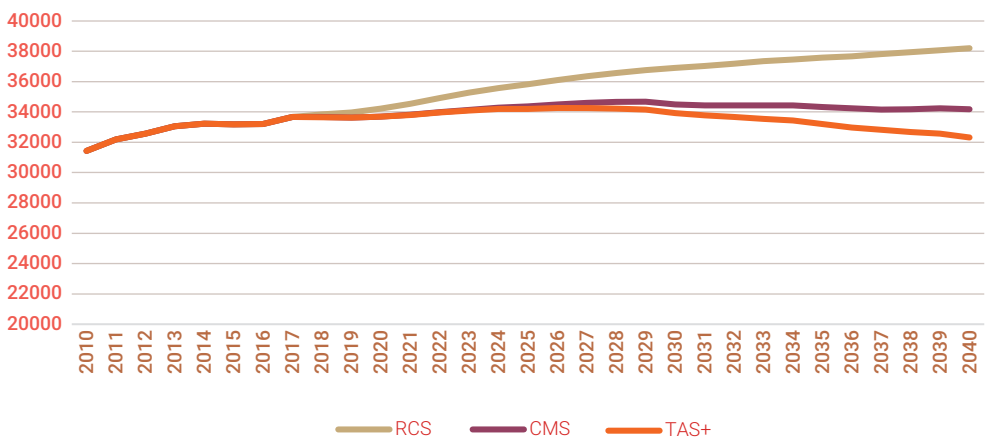
Global energy-related CO₂ emissions

Energy-related CO₂ emissions are expected to reach 34.2 GtCO₂ in the CMS by 2040. This will drop to around 32.3 GtCO₂ in the TAS+, which accounts for technology advancements in some carbon reduction options (e.g. efficiency improvement or electrification of final sectors), in addition to expected carbon mitigation efforts in the CMS. These 2040 emissions figures translate to non-negligible reductions compared to the RCS, estimated at 4.1 GtCO₂ in the CMS and nearly 6 GtCO₂ in the TAS+. The total CO₂ emission trajectory shows that emissions are expected to peak by 2030 in the CMS and by 2026 in the TAS+, meaning that emissions trends will be affected by anticipated technological developments in carbon-free and carbon mitigating technologies.

In the CMS, the bulk of emissions reductions comes from a changing power generation mix with renewable and natural gas penetration. This sector is expected to reduce its emissions by around 3.5 GtCO₂ amid the total 4.1 GtCO₂ reduction forecast for 2040 in this scenario. However, for TAS+, additional reductions (around 2 GtCO₂ by 2040) are expected to be achieved, with main contributions from the industrial and residential sectors, due to energy efficiency improvements and electrification. Reductions from the industry and buildings sectors are expected to compensate for increasing emissions from the power sector (Power related emissions are more than 1 GtCO₂ higher in TAS+ compared to the CMS by 2040). The aggressive electrification of final sectors due to technical enhancements in the TAS+ will accelerate electricity generation and reduce the efficacy of the power sector in mitigating CO₂ emissions.

In CMS, the transportation sector is anticipated to reduce emissions by nearly 300 MtCO₂, mainly as a result of the reduction of oil products demand in this sector. The consideration of further penetration of EVs in TAS+ due to improved technology and reduced costs is expected to further reduce emissions by around 150 MtCO₂. Although the TAS in this outlook assumes moderate technical advancements in CCS when compared to the RCS,

Figure 6.7. Prospect of global energy related CO₂ emissions (MtCO₂)



Source: GECF Secretariat based on data from the GECF GGM

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, Korea, 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, the United Arab Emirates, and Venezuela
GECF Observer Members: Azerbaijan, Iraq, Kazakhstan, Netherlands, Norway, Oman, and Peru

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 of America

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)
ADGSM	Australian Domestic Gas Security Mechanism
AEMO	Australian Energy Market Operator
AI	Artificial Intelligence
AV	Autonomous vehicle
BEV	Battery electric vehicles
BLM	United States Bureau of Land Management
bn	Billion
CAAGR	compound annual average growth rate
CBM	coalbed methane
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CH ₄	methane
CHP	combined heat and power
CNG	compressed natural gas
CNPC	Chinese National Petroleum Company
CO ₂	carbon dioxide
CPP	Clean Power Plan (US)
CPS	carbon price support
DOI	United States Department of the Interior
EAU	emission allocation unit
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
EU	European Union
EV	electric vehicle
FID	final investment decision
FSRU	floating storage regasification unit
FYP	Five-Year Plan
GCP	Global Carbon Project
GDP	gross domestic product
GECF	Gas Exporting Countries Forum
GGM	Global Gas Model
GGO	Global Gas Outlook

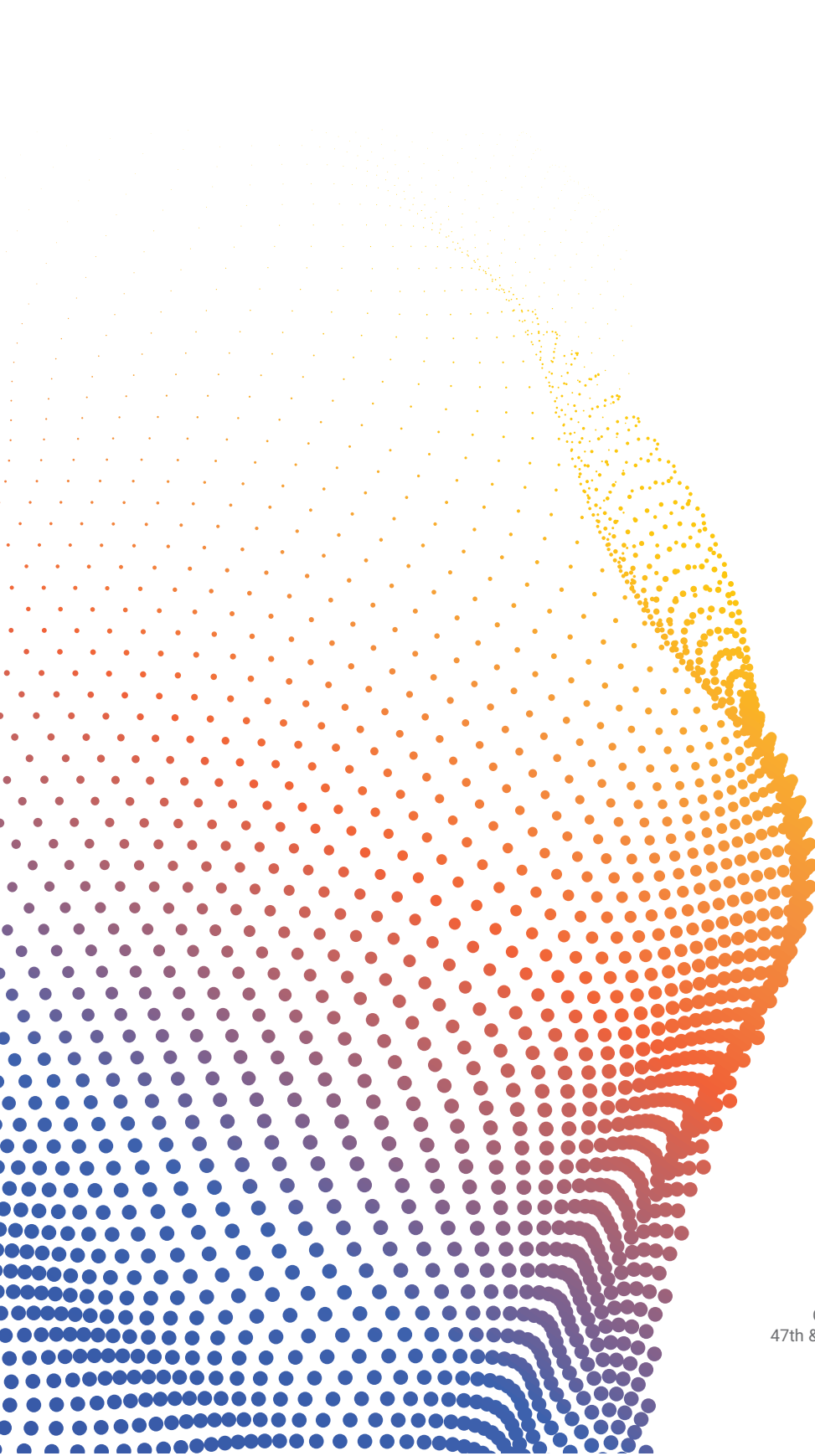
GHG	greenhouse gas
GIIGNL	International Group of Liquefied Natural Gas Importers
GTL	gas to liquids
ICE	internal combustion engine
IEA	International Energy Agency
IED	Industrial Emissions Directive
IMF	International Monetary Fund
IMO	International Maritime Organization
INDC	Intended Nationally Determined Contribution
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
LCV	light commercial vehicle
LFPR	labour force participation rate
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MER	market exchange rates
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 vehicles
NOx	nitrogen oxides
OCS	Outer Continental Shelf
OPEC	Organization of the Petroleum Exporting Countries
PHEV	Plug-in hybrid electric vehicles
PPP	purchasing power parity
PSPP	Public Sector Purchase Programme
PSV	Punto-di-scambio-virtuale
PV	photovoltaic

R&D	research and development
RBI	Reserve Bank of India
RES	Reference Energy System
RPS	renewable portfolio standards (US)
SDGs	Sustainable Development Goals
SOx	sulfur 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
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
YTF	yet-to-find

ANNEX III: REFERENCES

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