



Gas Exporting  
Countries Forum

# Global Gas Outlook **2050**

Synopsis

2022 Edition



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Synopsis

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2022 Edition

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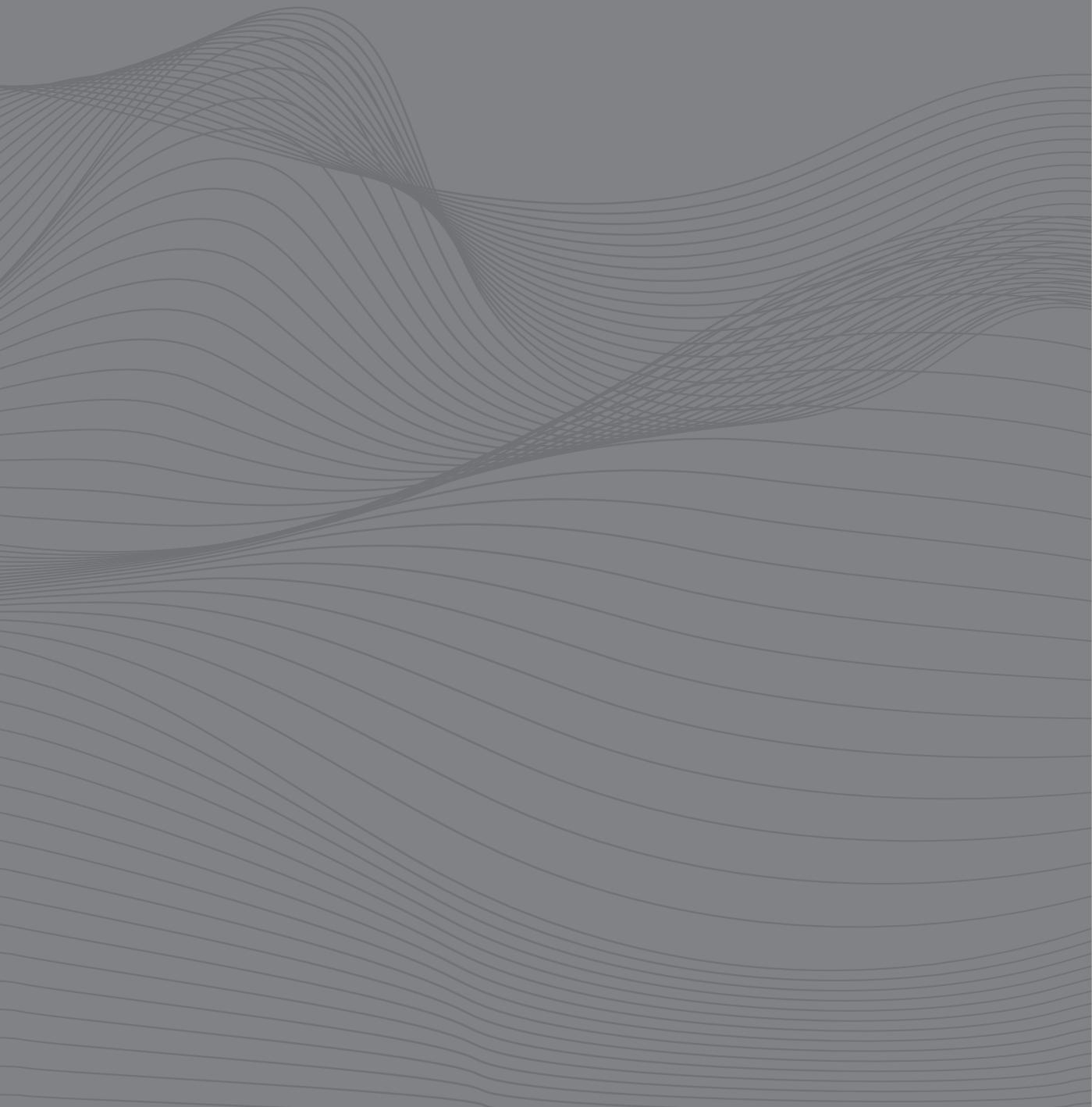
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## About the GECF

The Gas Exporting Countries Forum (GECF or Forum) is an intergovernmental organisation established in May 2001. It became a fully-fledged organisation in 2008, with headquarters in Doha, the State of Qatar.

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

Cooperation has been extended to technology with the establishment of the Gas Research Institute in 2019, headquartered in Algiers, the People's Democratic Republic of Algeria.

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

In accordance with its Long-Term Strategy, the vision of the GECF is "to make natural gas the pivotal resource for inclusive and sustainable development", and its mission is "to shape the energy future as a global advocate of natural gas and a platform for cooperation and dialogue, with the view to support the sovereign rights of Member Countries over their natural gas resources and to contribute to global sustainable development and energy security".

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## Foreword

This edition of the GECF Global Gas Outlook is developed at a special juncture, one of profound challenges, as the world faces a multifaceted crisis encompassing the economy, energy, trade, health, environment, and geopolitics.

The global energy system has been on a roller coaster in the last three years: coronavirus pandemic, economic recession, chronic energy underinvestment, and geopolitical tensions. As a result, there have been drastic transformations in natural gas markets in ways that deeply affect physical flows, investment, trade, and market functioning.

Furthermore, geopolitical conflicts and the ensuing energy supply deficit have prompted policymakers to place energy security at the top of the priority list. The price discovery and risk management functions of a main natural gas exchange have also been altered, with potentially damaging consequences, notably on investment and financial stability.

Against this background, the uncertainties have never been so large and the challenges so profound. What is nevertheless clearer, and more crucial, is the energy trilemma: how to ensure a secure, affordable, and sustainable energy system over the short to long term? What steps should be taken to ensure that energy is available for socio-economic development, while concurrently protecting the environment?

The Global Gas Outlook seeks to answer these pressing questions by examining the global and regional economic growth prospects, demand and supply of energy, natural gas trade and investment, the effects of policies, technological developments, and various other drivers.

The key message of the Outlook is that all energy sources and technologies will be required to satisfy the world's growing energy needs, while improving air quality and reducing greenhouse gas emissions. There is no one-size-fits-all model. Future energy pathways must be nationally determined and based upon the circumstances and priorities of each country, such as geography, natural resources, population, financial and technological capabilities, and people's choices.

Another key message is that natural gas, along with renewables, is expected to play a pivotal role in the future. For example, its use in replacement of wood and dung for cooking will mitigate indoor air pollution and deforestation. As the cleanest burning hydrocarbon, natural gas improves air quality and reduces greenhouse

gas emissions. It is a partner of variable and intermittent renewables, providing backup and stability to power grids. Last but not least, it is a key ingredient in the production of petrochemicals and fertilisers.

The Outlook's accelerated energy decarbonisation scenario demonstrates the need to rapidly scale up many of the existing clean energy sources and technologies: wind and solar, coal-to-gas switching, carbon capture, utilisation and storage, blue and green hydrogen, and modern biomass. This could more than halve carbon dioxide emissions from the energy sector by 2050 compared to the reference case. Besides solar and wind, the low-hanging fruit in mitigation is coal-to-gas switching. Carbon capture, utilisation and storage, at scale, could contribute to reduce dioxide carbon emissions by up to 8.7 GtCO<sub>2</sub>eq. Natural gas also contributes to expanding the use of blue hydrogen in hard-to-abate sectors. All these mitigation pathways require policy support, fiscal and monetary incentives, and appropriate market design.

The Outlook has a special focus on Africa. On this continent, 900 million people still lack access to clean cooking fuels and 600 million to reliable electricity. African communities suffer from the adverse impacts of climate change, despite being the least responsible for it. Africa's population is set to rise from 1.4 to 2.5 billion in 2050. A doubling of the continent's average GDP per capita by 2050, a rather modest objective, would increase energy demand by around 150%.

It is thus clear that there is no alternative to Africa but to use its natural resources to alleviate poverty and pursue socio-economic development. The narrative that Africa should not develop its natural resources, particularly natural gas, is misguided. A prosperous Africa will be more capable to protect the environment. The right of Africa to develop its vast natural resources shall thus be preserved, and its access to finance and technology shall be facilitated.

The recent past has shown that investment in natural gas is critical for the stability of global energy systems. By 2050, the cumulative upstream and midstream investment required to satisfy global gas demand will reach a hefty US\$ 10.5 trillion. In an industry characterised by a natural decline rate of 4%-5% per annum, a lack of investment can only lead to higher prices, which, coupled with higher carbon prices, will result in high inflationary pressures as seen today. This will trigger people's resistance to energy transition policies in developed countries. The ripple effect of these undercurrents will be even more dramatic in developing countries.

The policy re-think underway now, on the back of the realisation that natural gas is required for decades to come, is a positive development for the attainment of the UN Sustainable Development Goals and the Paris Agreement's long-term goal.

I wish to express my appreciation to the GECF team who worked on this report with dedication despite the challenging circumstances. I extend sincere gratitude to our close partner, OPEC, for its contribution. My deepest thanks also go to S&P Global, which provided data services for the GECF Global Gas Model, and to Energy Intelligence for peer reviewing this latest edition of the GECF Global Gas Outlook.

**Eng. Mohamed HAMEL**  
Secretary General



## Executive Summary

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## Executive Summary

The GECF Global Gas Outlook explores various energy pathways through 2050, underpinned by population growth, economic expansion, policies, and technology. It addresses economic growth prospects, energy demand and supply, trade, and investment. It is based on a multi-sector, multi-energy hybrid model.

### **1.8 billion additional people in 2050 with most of that growth in Africa and the Asia Pacific**

The world's population is expected to increase by almost a quarter from 7.9 billion people in 2021 to 9.7 in 2050. Africa and the Asia Pacific will account for around 90% of the total population growth.

Declining population growth rates in every region of the world, aging global population, accelerated urbanisation, and expanded migration are the key demographic characteristics.

### **Global GDP will more than double by 2050**

The global GDP is expected to more than double over the forecast period, from US\$95 trillion to US\$210 trillion in real terms.

Yet, the shift in balance of economic power to developing countries is the more dramatic factor as non-OECD countries continue to catch up in multi-factor productivity. Non-OECD economic growth will surpass OECD countries in 2043, with the non-OECD raising its share in overall global output from 39% to over half in 2021-50.

The Chinese and Indian economies will witness the most dramatic transformation, with combined GDP of US\$70 trillion in 2050, or the equivalent of the US and EU combined, compared to only 45% today.

### **Energy security, affordability and reliability become top priorities**

The growing pressure for scaling up emission mitigation ambitions in 2021 was suppressed by the energy crisis in 2022, when energy security and affordability became policymakers' priorities.

The main pillars in the released policy plans in 2022 were centred on increasing domestic energy production, diversifying energy sources to ensure energy security, and pivoting energy systems toward a new one to fulfil emission mitigation targets. Natural gas received policy support as a balancer of energy transition and energy

security even in developed countries with aggressive emission mitigation targets. It was seen as a partner of renewables, providing support to power grids. In addition, natural gas will play a paramount role in the sustainable development of Africa, given its large resources and energy needs.

### **Energy demand is expected to rise and natural gas will raise its share in the energy mix from 23% to 26%**

Global primary energy demand will rise by 22%, reaching 17,865 million tonnes of oil equivalent (Mtoe) by 2050. The structure of the energy mix is becoming more diversified thanks to the growing needs for clean energy, led by natural gas and renewables. Natural gas will come out on top, raising its share by three points to 26% by 2050.

Climate change policies will continue to play a crucial role. However, energy security, affordability and sustainability shall remain equally important. In this context, a multi-dimensional approach should be the way forward to deal with long-term energy and climate targets. Natural gas, the cleanest burning hydrocarbon, will form the bedrock of a realistic, cost effective and just energy transition. Natural gas will overtake coal in around 2025 and become the most utilised fuel just after 2040.

Natural gas demand is projected to increase by 36% to 5,460 billion cubic meters (bcm) in 2050. Policies aimed at air quality improvements, and coal- and oil-to-gas switching are among the main drivers. Natural gas paired with CCS/CCUS, both in power generation and industry, will become an important mitigation option, supporting long-term gas use.

Power generation will take a frontline place, accounting for 43% of additional volumes between 2021 and 2050. This is underpinned by a strong growth in electricity needs and policies to phase down coal-fired capacity. Meanwhile, the increasing role of renewables will make gas-fired generation a critical source of system flexibility.

There will be new avenues for natural gas demand, particularly through the growing use as a source for blue hydrogen generation. The transport sector will emerge as an important demand centre on the back of stricter environmental regulations and supportive policies.

Asia Pacific, the Middle East, and Africa will be responsible for the bulk of future gas demand growth. Asia Pacific will represent the largest growth engine, contributing to half of the global net demand increase during the outlook period. Europe will be the only region to experience an evident declining trend, as REPowerEU plan implementation will have a strong impact.

### **Natural gas supply to increase by 36%**

Global natural gas production will continue to rise by an average of 1.1% per annum, from 4,025 bcm in 2021 to 5,460 bcm in 2050, representing a total of 36%.

The Middle East will contribute the largest growth share, accounting for one-third of the total, followed by Africa and North America.

North America, the world's largest gas producer, will maintain its position until the end of the outlook horizon. The region natural gas production is forecast to grow by 285 bcm to reach 1,420 bcm by 2050. However, the region's share will decline from 28% in 2021 to 26% in 2050.

The Middle East will become the world's second-largest natural gas producer, supplying almost 22% of natural gas globally by 2050, compared to 17% now. Gas output in the Middle East is expected to jump by 520 bcm to 1,190 bcm by 2050.

Eurasia is the second-largest regional natural gas producer, the source of almost a quarter of global output. Its share will decrease to 20%, and it will become the third-largest producer by 2050. The region is expected to add more than 155 bcm to its current production, driven by Russia, which will contribute more than 59% of this growth. Eurasian gas production is expected to increase by an average of 0.5% annually by 2050.

Africa will be responsible for the second-largest volumetric growth, gaining more than 11% share of global gas supply by 2050, compared with slightly more than 6% in 2021. Africa is the only region where gas production growth will more than double, from 260 bcm in 2021 to 585 bcm in 2050.

Europe is still expected to be the only region in which natural gas production is forecast to fall. The average annual decline is of 2.9% over the forecast period, lowering the region's share of global production to only 2%.

Natural gas output in Latin America is expected to grow by 46% (65 bcm) by 2050, or 1.3% annual growth contributing to 4% of global gas production.

### **Natural gas trade to expand by more than a third, led by LNG**

Global natural gas trade is expected to rise by 36% between 2021 and 2050, reaching over 1,700 bcm, almost a third of global gas demand. Global LNG trade will accelerate overtaking long-distance pipeline trade by 2026 and reach 1,170 bcma by 2050.

LNG demand will increase continuously over the forecasted period and more than double in volume between 2021 and 2050. With domestic production declining in some of the Asia Pacific countries and Europe, and with pipeline exports to Europe also declining, LNG is gaining momentum and becoming the preferred natural gas supply source.

The Asia Pacific will retain its leading role as the key LNG importer with emerging Asian countries – primarily South and South East Asian nations – driving the growth. The current share of 72% of Asia Pacific in the world's LNG trade will be sustained over the long term and will account for 67% by 2050.

Presently, the EU is planning to have LNG 'at the heart' of its diversification strategy and is set to ramp up its LNG imports and expand its liquefaction capacities together with resolving the existing gas infrastructure bottlenecks.

By 2030, the natural gas trade looks very promising for all the world's regions. As the global energy crisis exacerbates and key natural gas importing countries are set to secure reliable supply, investments in new LNG infrastructure are anticipated to surge. In particular, this will be applicable for the coming decade - 2021-30 - due to a sharp short-term increase in LNG demand in Europe and Asia Pacific.

In contrast, after 2030, diverging trajectories of energy transitions for each region and sub-region might be challenging. In the 2030s and 2040s, the LNG industry investment – LNG liquefaction and regasification – is expected to decline substantially.

Total liquefaction capacity over the past decade has grown from 270 mtpa in 2010 up to 462 mtpa at the end of 2021. In the coming 30 years, LNG liquefaction capacity is set to more than double to 1,026 mtpa by 2050.

Global regasification capacity rose from 630 mtpa in 2010 up to 993 mtpa in 2021. By 2050, global regasification capacity is projected to almost double to around 1,840 mtpa, more than twice larger than the expected LNG demand of 850 mt. By 2050, 1,060 mtpa or almost 60% of total LNG regasification will be in Asia Pacific, and 380 mtpa or 20% of all regas capacity in Europe.

### Natural gas investment huge and crucial to market stability

To meet the growing natural gas demand, the upstream investment required over the forecast period to 2050 is a hefty US\$9.7 trillion.

Africa, the natural gas-rich continent, needs to invest US\$1.7 trillion in the upstream gas sector to increase its gas production to 585 bcm in 2050. The strong rise in

natural gas supply from the Middle East would require US\$1.11 trillion of upstream investment to increase production by 520 bcm and reach 1,190 bcm in 2050.

From 2021 to 2050, the total forecasted midstream natural gas investment will reach US\$775 billion due to the higher global LNG demand growth, particularly in 2021-30 in Europe, and to the elevated LNG appetite from the developing Asia Pacific region.

While the major share of investment will be streamlined to the capital-intensive natural gas upstream, midstream funding - the gas infrastructure including pipelines, LNG liquefaction and regasification facilities - will be dominated by LNG liquefaction capacities' allocation mainly in North America, Africa, the Middle East, and Eurasia.

Between 2021 and 2050, the largest natural gas infrastructure spending will be in the Asia Pacific region – almost US\$200 billion or 25% of total global midstream investment. The lion's share - 80% or US\$160 billion - will be attributed to LNG regasification infrastructure.

In the short to mid-term, the European and global energy crisis will define the trends for accelerated LNG - liquefaction and regasification capacities - infrastructure development, especially by 2030.

### Africa energy resources and needs are huge and the development of its natural gas reserves shall be facilitated

Africa has the youngest and fastest-growing population in the world. Africa's population is set to grow at 2.1% per annum on average between 2021 and 2050, faster than any other region of the world and more than three times the global average growth rate of 0.7%.

Africa's real GDP is forecast to grow almost threefold from US\$2.5 trillion in 2021 up to US\$7.1 trillion in 2050.

In Africa, the projection for the primary energy mix is centred on natural gas, with a growing contribution of renewables due to the continent's enormous gas reserves and the worldwide trend toward greater climate ambition. Many African countries have developed energy strategies based on natural gas and renewables.

The region's energy demand is projected to increase by 82% from today's level of 860 Mtoe to 1,565 Mtoe by 2050. Natural gas will make the most significant inroads, responsible for around 30% of the total energy demand increase in Africa. Gas demand growth will be concentrated in the power generation sector. Going

hand-in-hand with the development of renewable energy projects, natural gas will become an essential element towards improving electricity access while substituting oil-fired generation and constraining the expansion of coal-fired generation.

Traditional use of biomass remains elevated in the region, constituting over 60% of residential energy demand in 2050. This represents an additional potential for clean energy sources, including natural gas, to meet energy needs while helping to eradicate energy poverty.

Africa's natural gas production is projected to increase from 260 bcm in 2021 to 585 bcm in 2050. Monetisation of the continent's natural resources will ensure the availability of investment for energy and social development projects, increase energy access, and accelerate economic progress.

### Alternative scenarios

This edition of the GECF Global Gas Outlook considers two alternative scenarios; The Energy Sustainability Scenario (ESS) and the Accelerated Energy Decarbonisation Scenario (AEDS).

The outlook's ESS envisions even more robust economic, income, energy, natural gas, and electricity demand growth in Africa through 2050. Africa is a diverse region with substantial human and natural resources that can potentially contribute to inclusive growth and alleviate energy poverty. However, more than 600 million people lack access to reliable electricity and over 900 million do not yet have access to clean cooking fuels in Africa.

Under the ESS, Africa's economy is set to rapidly expand. It is assumed that by 2050 Africa's GDP per capita will reach US\$5,000. This translates to Africa's economy reaching US\$4.3 trillion in 2030, and US\$12.4 trillion by 2050.

In the ESS, primary energy demand in Africa is expected to increase by 154% from 860 to 2,180 Mtoe by 2050. More than 85% of this growth will originate in Sub-Saharan Africa (SSA). Accordingly, primary energy intensity is set also to decline by 2.2% per annum over 2021-50, compared to a reduction of 1.4% per annum in the Reference Case Scenario (RCS).

Natural gas will play an important complementary role, along with the development of renewables, to fuel industries and climate change resilience infrastructure. Renewables and natural gas, combined with established decarbonisation technologies, would boost energy security and reduce CO<sub>2</sub> emissions in Africa. Furthermore, promoting access to electricity and clean cooking energy is widely recognised as a vital driver of economic development and critical to encouraging

equitable growth to bring SSA countries out of poverty. Therefore, electrification becomes a priority in the ESS, and natural gas and renewables will make up 51% of the energy mix of the region.

The second alternative scenario, the Accelerated Energy Decarbonisation Scenario (AEDS), explores a wide range of decarbonisation means in the energy system. Natural gas, as the cleanest hydrocarbon fuel, can play a prominent role in the decarbonisation of energy systems by 2050, especially when it is coupled with CCS. AEDS considers various pathways, with their penetration level and the pace at which they can be implemented in the energy system.

Results from AEDS suggest a robust potential carbon mitigation pathway for energy-related activities, with a much more aggressive emission reduction profile compared to RCS. According to the results of the scenario modelling, almost 14 Gt of energy-related CO<sub>2</sub> will be actually emitted by 2050, which is half of that for RCS.

In AEDS, CCS is a key instrument in future energy decarbonisation. In this scenario, both post- and pre-combustion of CO<sub>2</sub> are considered. Post-combustion carbon capture is mostly implemented in power and industry, and pre-combustion carbon capture is primarily in blue hydrogen production. According to the results of the scenario, almost 8.7 Gt of CO<sub>2</sub> can be abated in AEDS.

The share of fossil fuels in the primary energy mix will decline from almost 80% in 2021 to 49% in 2050. Coal will see the most significant drop, driven by coal-to-gas switching and structural changes in the power sector and industry. Its share is expected to shrink to just 7% by 2050. Oil demand will also witness a strong decline and will be 38% lower than in 2021 amid overall improvement in fuel efficiency in the transport sector and increased diffusion of EVs and hydrogen fuel cell vehicles. Oil will provide 17% of the energy mix in 2050 and will remain persistent in petrochemicals.

In AEDS, natural gas will remain the most resilient fossil fuel. Its share is forecast to rise to 25% by 2050, as the large-scale implementation of deep gas decarbonisation options through blue hydrogen and CCS will improve the environmental credentials of this fuel. Nevertheless, the absolute volume of natural gas demand is forecast to be almost 730 bcm lower than that in RCS.



# 01

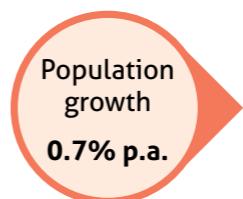
## Key Macro and Energy Policy Assumptions

## Key findings:

- The global population is expected to increase from 7.9 billion people in 2021 to 9.7 billion in 2025. This represents an average growth rate of 0.7% per annum. Africa and the Asia Pacific will account for around 90% of the incremental growth in population.
- Even though the era of population-driven economic growth is ending, persistently high levels of urbanisation and productivity gains will drive global sustainable development and wealth creation. Improving opportunities and demographic shifts will drive migration patterns, which in turn enhances income and economic growth.
- Although short-term global economic headwinds persist, this year's outlook assumes nevertheless a 2.9% average annual growth through 2050. Over 75% of economic growth over this period will be attributable to labour productivity gains.
- The global gas market will remain regionally segmented, but will become strongly integrated after 2035.
- The growing pressure for scaling up emission mitigation ambitions in 2021 was suppressed by the energy crisis in 2022, when energy security and affordability emerged as policymakers' priorities.
- The main pillars in the released policy plans in 2022 were increasing domestic energy production, diversifying energy sources to ensure energy security, and pivoting energy systems toward a new one to fulfil emission mitigation targets.
- Energy transition has been accelerated, and natural gas is enjoying policy support globally as a balancer of energy transition and energy security, even in developed countries with aggressive emission mitigation targets. For example, the EU's REPowerEU Plan, the US Inflation Reduction Act and China's 14th five-year plan attempted to align energy systems with net-zero pledges, while ensuring energy security. Natural gas has a place in all of these policies.
- New and additional support for renewables has been enacted in many countries, with a focus on the power sector. Furthermore, electrification of end uses such as heating and road transport has emerged as a new area of interest for policymakers.
- Despite significant efforts in the past years to phase out coal, record-high gas prices and constrained supply in 2022 have prompted countries to consume more coal.
- The number of countries considering hydrogen in their energy sector strategies grew rapidly last year.

## 01 Key Macro and Energy Policy Assumptions

2022 GGO Reference Case Key Assumptions	
Base year	2021
End year	2050
Population, billion people	7.9 (2021) 9.7 (2050)
Population growth rate, %	0.7% p.a. (2021 - 2050)
% Urban in total population	69% in 2050
Number of households	3.0 bn in 2050
Global economic growth rate, % real GDP	2.9% p.a. (2021 - 2050)
Long-term Brent oil price	US\$75/bbl
Carbon prices	2050: US\$166 per tonne (EU)



Global economic growth decelerated in 2022 on the back of surging inflation, fiscal and monetary tightening in a challenging post-COVID recovery process. China's Zero COVID Policy was curbing the country's economic reopening. The world is living through one of the worst energy crises in recent decades, exacerbated by the Russia - Ukraine conflict. European economies have slowed down due to the surge in the cost of energy prices and increasing interest rates. The risk of global recession is skewed to the downside.

Quantitative assumptions such as population and urbanisation trends, economic prospects, energy and carbon prices are central to the analysis. Qualitative assumptions are equally important as they capture social, economic and environmental policy formation. This includes policy response to the COVID pandemic and recovery, global economic and financial challenges pertaining to supply chain disruptions, high inflation and surging energy and food prices; an aggravated geopolitical situation, as well as technological development.

## CHAPTER 1

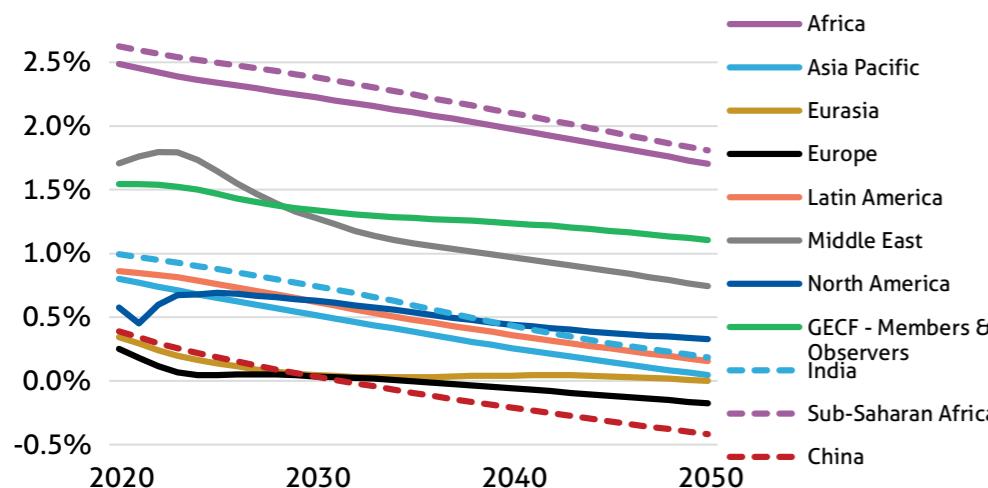
Demographic assumptions underlying the 2022 Outlook are based on the United Nations (UN) forecasts for population and urbanisation. Short-term and medium-term macroeconomic assumptions are based on the International Monetary Fund (IMF) April 2022 World Economic Outlook projections and GECF Secretariat estimates. The long-term macroeconomic and reference energy price assumptions have been developed in-house by the GECF Secretariat (1).

### 1.1 Population and demographics

Demographic trends are shaping global economic development, structural productivity growth, living standards, unemployment rate, as well as consumption and investment among many more macroeconomic indicators. They will have profound implications on the national, regional, and global economies. Yet, the era of population-driven economic growth is coming to an end (2).

Population growth will slow in all regions over the Outlook period, moving from 1.2% annually from 2000-20 to 0.7% from 2021-50, in line with trends seen in recent decades. Declining fertility rates in developing regions will drive a slowdown in global population growth. The largest reductions in regional population growth are expected in North America, Asia Pacific and Latin America, while European and Eurasian populations will simply decline.

**Figure 1.1. World population growth rates (% p.a.)**

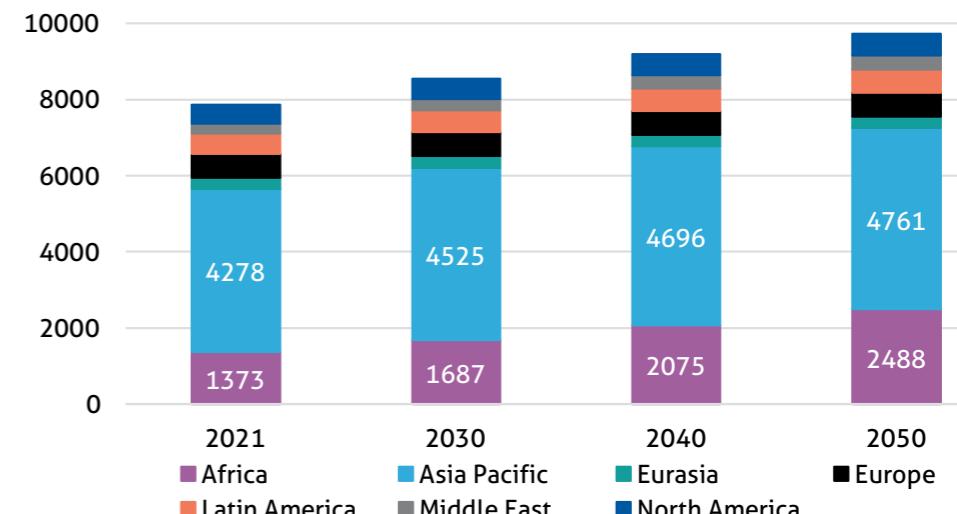


Source: UN 2019 Revision of World Population Prospects

The global population will grow by 1.8 billion people by 2050. The world was home to 7.9 billion people in 2021, a figure that will grow to 8.5 billion in 2030, 9.7 billion in 2050 and 10.4 billion in 2100. The medium variant of the UN projections serves as the basis for the GGO 2022 (3). The world's population grows by around 83 million people every year, equivalent to Germany's inhabitants.

## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

**Figure 1.2. Population by region (million people)**



Source: 2019 Revision of World Population Prospects

Africa and the Asia Pacific region will account for around 90% of the total.

**Africa.** This region will drive most of the world's population growth. Some 1.2 billion people, or two-thirds of the global increase to 2050, is attributable to Africa. By 2050, over a quarter of the world's people will be living in Africa, compared to 17% now (and less than 10% in 1950) (4). Africa's 54 nations will almost double their population in the next 30 years, from 1.3 billion to 2.5 billion. The continent's unprecedented population growth will impact almost every aspect of life, from geopolitics to global trade, migration, and technological development (5).

Africa will have the highest long-term average population growth of 2% per year over the forecast period. Furthermore, it will be the last remaining region projected to deliver strong population growth through the end of the 21st century. Nigeria's population is set to reach 400 million by 2050, overtaking the US as the world's third-most populous nation. The median age in most African countries is under 20, while 40% of all Africans are under the age of 14 (5).

**The Asia Pacific region** is home to 4.3 billion people or 53% of the world's population. Population will grow by 0.5 billion people, or by 28%, from 2021-50. The demographic trends here will be defined by rapid demographic transition with declines in both fertility and mortality rates, particularly in Eastern Asia, speedy urbanisation and considerable migration flows. The strong beneficial effect of demographics on developing Asia's economic growth is gradually fading away as the region's population aging affects growth through savings, capital accumulation,

## CHAPTER 1

labour force participation, and total factor productivity (6). From 2021-50, the number of people aged 60 and above will more than double, reaching 1.3 billion. By then, over 25% of the population will be 60 or older, compared to only 10% today. The Asia Pacific region will be supplying 40% of all international migrants across the globe.

**China.** China's population is expected to decrease by 109 million between 2021 and 2050 from 1.4 billion people now (3). The country's birth rate of 1.7 births per woman is considerably below the 2.1 replacement rate. The UN sees its population peaking in 2024. A shrinking working-age population pressures the country's wages, resulting in more costly output. Hence, demographic challenges will pressure China's economic growth long-term despite improved productivity. In August 2021, China formally endorsed the three-child policy, a major policy shift aimed at preventing a steep decline in birth rates. China's two-child policy was introduced in 2016, replacing a one-child policy that had been effective for 35 years and now poses a major demographic challenge.

**India.** India accounts for 18% of the global population. It is forecast to surpass China to become the most populous country in 2023. India's population will reach 1.668 billion by 2050, some 350 million higher than the Chinese population projection of 1.317 billion. India's median age is 28, 10 years younger than China, where half the population is below 38 years. In India, the workforce is just beginning to take off - 65% of its population is currently aged 35 years and below (7).

North America, European and Eurasian population growth rates will slow over the coming decades as aging challenges mount. Fertility rates in these regions are generally below 2.1 births per woman, the level at which populations remain stable at constant mortality rates.

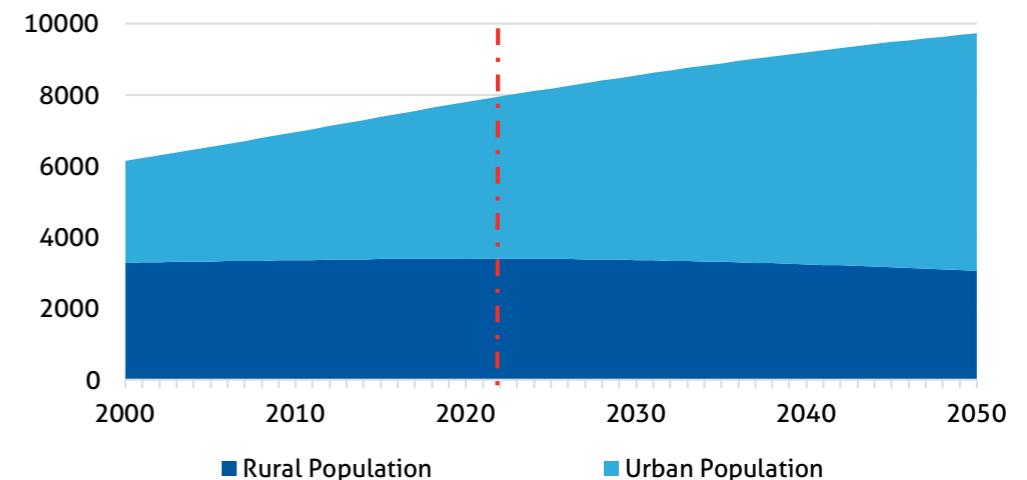
### Urbanisation

Persistently high levels of urbanisation drive global sustainable development and wealth creation. There is a strong relationship between urbanisation and income. Countries become more urbanised as they develop wealth. Urban populations are inclined to have more elevated living standards compared to their rural brethren. Rapid urbanisation is underway, supporting almost all additional population growth. Africa and developing Asia - specifically India - elicit the most upside potential.

Some 4.5 billion people, or 57% of the world's population, live in urban areas. By 2050, almost 70%, or 6.7 billion, will dwell in cities. This is up from only 29% in 1950. Still, urban residents surpassed the rural population in 2007.

## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

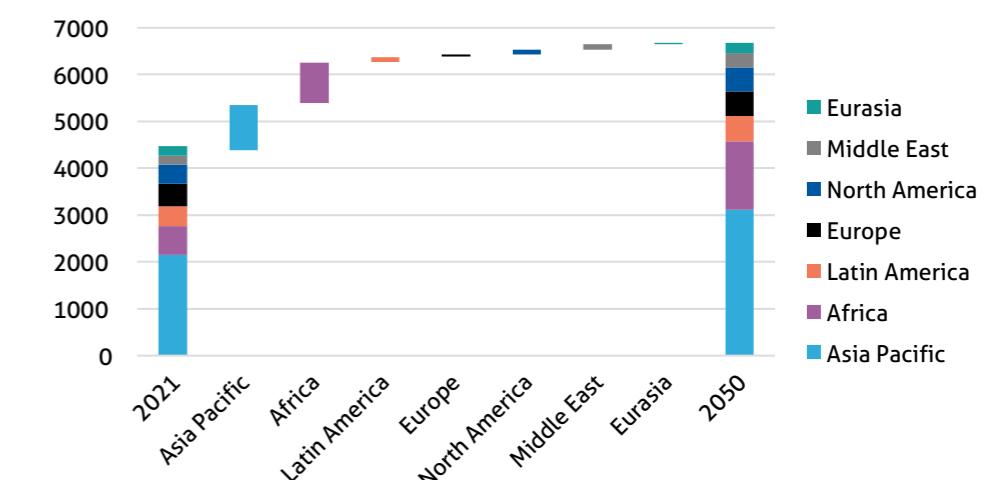
Figure 1.3. Global population by urban and rural population (million people)



Source: UN 2019 Revision of World Population Prospects, 2018 Revision of World Urbanization Prospects

The rapid pace of urbanisation is expected to transform rural societies in Africa, with the 44% urban population forecast to increase to 59% in 2050. Africa's urban population is forecast to triple to 1.3 billion by 2050.

Figure 1.4. Global urban population growth by region (million people)



Source: 2018 Revision of World Urbanization Prospects

Developing Asia will vary in urbanisation levels. Chinese urbanisation will grow from 63% to 80%, while India will jump from 35% to 53% by 2050. Globally, urbanisation suggests that per capita electricity use rates will grow considerably. The new infrastructure required to support this global urbanisation will translate into a surge in energy demand.

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## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

### International migration

International migration is a structural driver of demographic trends. Population increases in high-income countries between 1980 and 2000 were primarily the result of organic growth (+104 million people) and to a much lesser extent by net international migration (+44 million people) (8). The significance of international migration in high-income countries surged over the following 20 years, almost doubling (+81 million) and exceeding the natural population growth (+66 million).

Growing international migration from less wealthy countries will be the key population growth driver in high-income countries. Conversely, population increases in lower and middle-income countries will continue to be driven by an excess of births over deaths. About two-thirds of the world's migrants are voluntary workers pursuing socioeconomic opportunities, while refugees fleeing conflict or instability might start growing following the escalation of recent global conflicts.

Migration enhancement over the long term is set to factor into economic growth. Migrants can generate economic gains for destination countries through increases in labor, human capital, and entrepreneurship. It can provide countries of origin with remittances that improve socioeconomic development.

### 1.2 Economic growth and productivity

#### Short-term economic outlook

The global economy faces many headwinds, such as slowing growth, high inflation, tightening financial conditions, trade tensions and the adverse effects of the energy crisis and COVID-related lockdowns.

Recovery from the COVID-19 crisis is slow and uneven as the world rebounds at different speeds. According to the October 2022 IMF World Economic Outlook, global GDP growth in 2022 will reach 3.2%, compared to 6.0% in 2021. The forecast was revised downward by almost one percentage point since the beginning of 2022, amounting to almost US\$1 trillion. With a few exceptions, employment and output will typically remain below pre-pandemic trends through 2026. Recovery in developing economies will be slower than in advanced economies, reflecting more limited policy support, generally slower vaccination rates and more exposure to high energy prices.

According to recent World Health Organization data (9), there have been 660 million confirmed cases of COVID-19 (around 8% of the global population), including 6.7 million deaths. This is the equivalent of the population of New Zealand, Bulgaria or Lebanon. The world is in a better position to end the COVID-19 pandemic (10), with around 13 billion vaccine doses administered by mid-October 2022. Most of the world is now moving beyond the emergency phase.

Still, there are concerns over the security of supply chains. In 2022, rising geopolitical divisions, including the Russia-Ukraine conflict as well as growing US-China tensions, constrain trade and heighten strategic concerns over the security of the supply of key components and materials, particularly energy and food. The Russian-Ukrainian crisis has exacerbated inflation driven by post-pandemic food and energy costs.

Global inflation is expected to reach 8.8% in 2022, compared to 4.7% in 2021. It is also expected to remain elevated longer than in the previous forecast, declining to 6.5% in 2023 and 4.1% in 2024. Persistent fiscal and financial constraints, particularly in developing countries, remain a challenge. Record government debt and rising interest rates constrain consistent public investment in infrastructure, social support and education.

Persistent fiscal and financial constraints, particularly in developing countries, remain a challenge. Record government debt and rising interest rates constrain consistent public investment in infrastructure, social support, and education.

Global trade will remain one of the most important drivers of sustainable growth. But the outlook remains subdued even though the pandemic may now be under control. Its impact across the global economic value chain is still noteworthy, however. It might cause more significant impediments for emerging markets, which could become less competitive as advanced economies benefit from colossal government stimulus packages and better access to vaccination - in addition to superior medical services.

#### Medium-term and long-term economic outlook

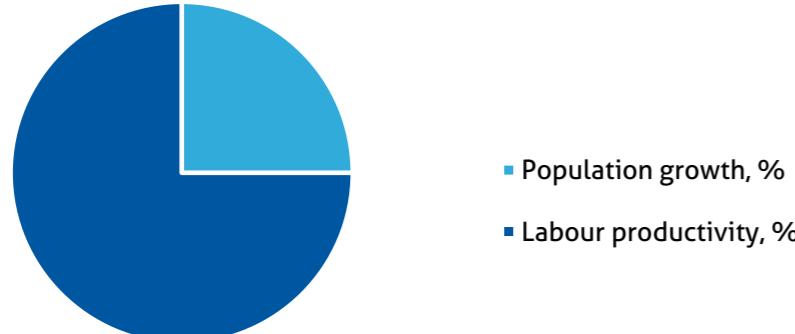
Average global economic growth of 2.9% from 2021 to 2050 underpins GGO 2022 assumptions. Importantly, 2021 was an exceptional post-COVID recovery year, as the global economy expanded by 6.1%. The 2022 forecast is an upward revision from last year's projection of 2.7% annual long-term growth. Primarily, it removes 2020, which was an outlier year when the global economy contracted by 3.1% given the widespread pandemic impact. While global GDP more than doubles over the forecast period from US\$95 trillion to US\$210 trillion in real terms, the non-OECD Asia economy will expand from US\$26 trillion to US\$86 trillion. India will grow almost five-fold to reach US\$15 trillion.

The Asia Pacific GDP will almost triple from US\$35 to US\$99 trillion, accounting for almost 50% of the total global GDP by 2050. Uneven and challenging post-COVID recovery process as well as elevated post-pandemic trade frictions are driving medium-term and, to some extent, longer-term economic risks. Such risks include trade disruptions due to the Russia-Ukraine conflict as well as persistent US-China trade tensions and broader de-globalisation factors prominently as well.

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## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

Figure 1.5. Global real GDP growth 2021-2050 by contribution



Source: GECF Secretariat based on data from the GECF GGM

Rising geopolitical tensions are elevating sustainable economic development risk. Governments will continue to play an increasingly important role in navigating these challenges.

Population growth, mainly driven by Africa and developing Asia, coupled with strong urbanisation and labour productivity trends, will continue to remain the key engines behind economic development and primary energy demand. Over 75% of global real economic growth will be attributed to labour productivity over the long run until 2050, while population growth will drive the remainder.

COVID-19-accelerated changes in consumer and supplier behaviour patterns provide opportunities for more innovative, cost-efficient businesses. This includes, but is not limited to, hastening adoption of digital technology and creating and expanding new industries. COVID-19 has prompted companies to boost supply chain resilience.

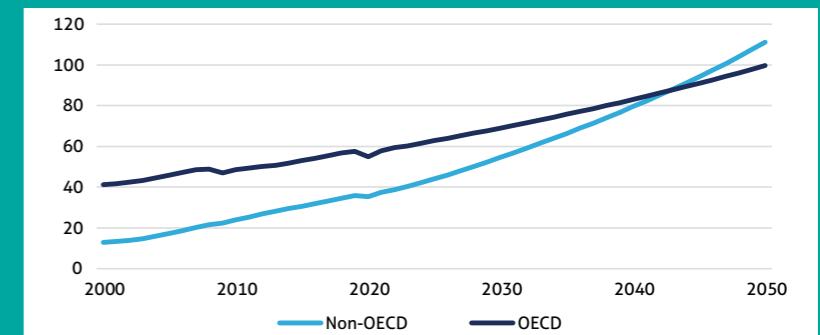
Both technological and demographic trends follow a much longer cycle. Digitalisation of the economy, evolution towards more flexible markets and developing economies' transition to knowledge-based economic growth will remain key innovative forces.

Medium- to long-term global economic growth will be resilient and appear to be more positive relative to the previous forecast. Strong labour productivity growth is expected to anchor an average of 2.9% annual growth in real terms from 2021-50. The burgeoning middle class will help drive the Chinese and Indian economies, which will grow by 4.1% and 5.7% annually, respectively, by 2050. The projection of 3.2% annual growth from 2021-30 is a small increase compared to 3.0% from 2000-19. Additionally, growth will reach 2.8% annually from 2031-40, while slowing to 2.6% from 2041-50.

### BOX 1.1. Economic growth in OECD countries versus non-OECD countries

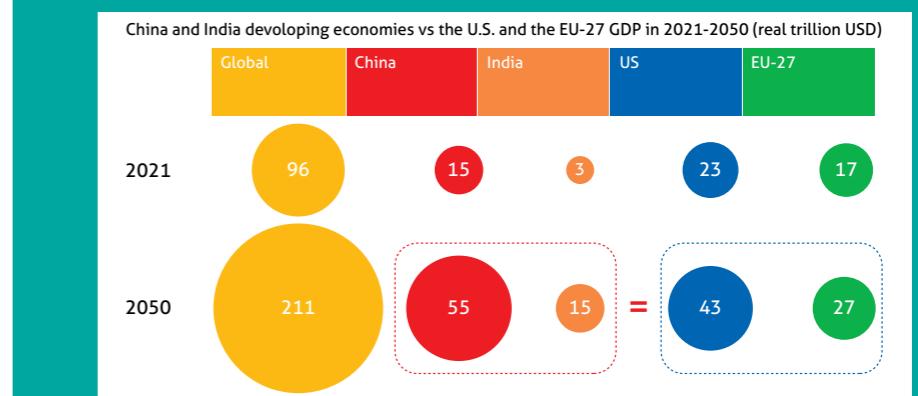
The balance of global economic power will dramatically shift by 2050. GDP growth in the OECD area is projected at around 2% annually to 2050, with declining rates in many high-income countries. At the same time, emerging countries' growth rates are expected to continue outpacing developed nations. But they will decline from the 6% average over 2000-19 to around 4.5% in 2021-30 and 3.4% by 2050. Such growth patterns will lead to fast-growing emerging economies increasing their share of global output, driven mainly by catching up in multi-factor productivity. However, the gap narrows substantially over the long run. Non-OECD economic growth will surpass OECD countries in 2043, with the non-OECD raising its share in overall global output from 39% to 53%.

Figure 1.6. OECD and non-OECD GDP (real trillion US\$)



Source: GECF Secretariat based on data from the GECF GGM

By 2050, two-thirds of global GDP will be concentrated in China, the US, India and the EU-27. The Chinese and Indian economies will encounter the most dramatic transformation, with combined GDP of US\$70 trillion in 2050, or the equivalent of the US and EU combined. The Chinese and Indian economies currently account for only 45% of the US and EU combined.



Source: GECF Secretariat based on data from the GECF GGM

China and India will dominate global growth. India is projected to grow faster as China's population will be declining by 2050.

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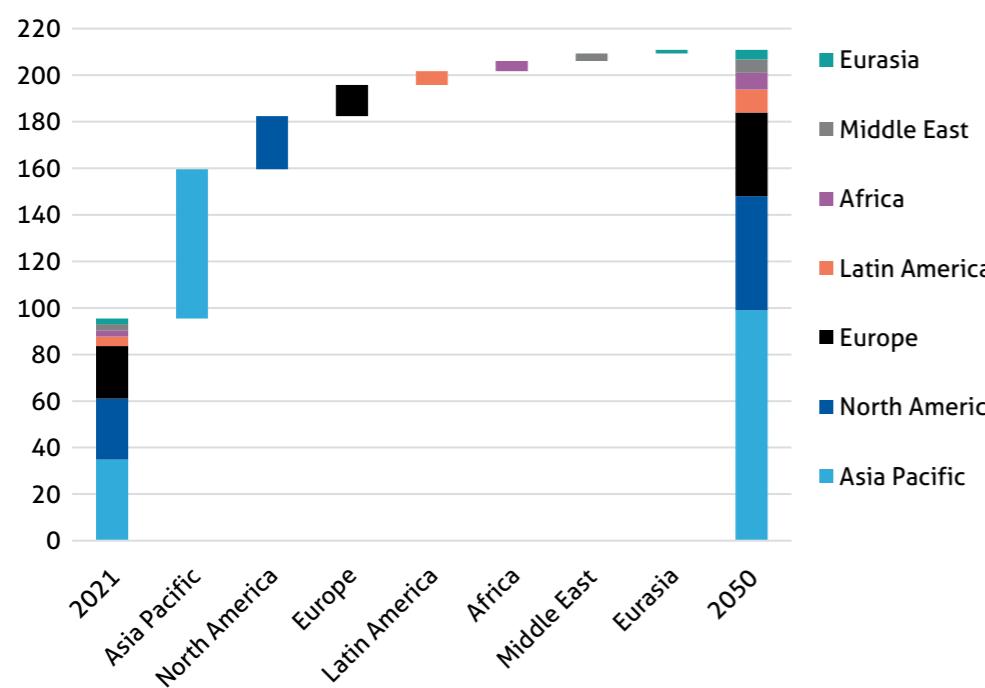
## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

Economic prosperity is the most effective headwind for population growth. Countries encountering the demographic transition model of economic growth - how a country's economic development is linked to its population - often see a sharp decline in birth rates as they become wealthier. Japan and South Korea experienced rapid economic growth along this pattern and achieved high-income status before their fertility dropped sharply. For China, lack of a clear solution for its soon-to-be-shrinking population will likely be met with slower growth rates: Its population is "growing old before it grows rich" (11).

### Regional prospects for economic growth

Long-term growth will largely originate from the developing economy expansion, especially throughout Asia. The Asia Pacific region, particularly South and Southeast Asia, will lead global economic expansion, contributing 60% of real GDP growth over the 2021–50 period. North America and Europe will be the second and third respectively contributors to the global GDP over the long run.

**Figure 1.7. GDP growth composition by region (real trillion US\$)**



Source: GECF Secretariat based on data from the GECF GGM

Growth in most of the developing Asia Pacific region rebounded in 2022 from the impact of COVID-19. However, China has lost momentum (12) because the government continued to implement emergency containment measures in its most economically dynamic cities, including Beijing, Guangzhou, Shanghai, and Shenzhen.

The region is set for faster growth and lower inflation in 2022 than other regions. The strong rebound in private consumption from the Delta variant in 2021 is key, along with sustained global demand for Asia Pacific commodity and manufactured goods exports; limited tightening of fiscal and monetary policy, compared to the United States (US) and the European Union (EU), are driving improvement in growth. Beyond 2022, the probability of global recession, policy distortions and surging debt could be a drag on regional growth (13).

**Asia Pacific** GDP growth is forecast to average 3.8% in 2021–50, compared to a higher average of 5.2% p.a. during 2000–19. Commodity exporting countries will account for additional upside due to the momentum of elevated commodity prices. Growth rates for the major economies of the region for 2021–50 are forecast as: Indonesia (4.6%), Malaysia (3.8%), the Philippines (4.4%), Thailand (3.2%), Vietnam (5.3%) and Bangladesh (4.9%).

**China**, which previously led recovery in the region, is projected to grow by 3.2% in 2022, a sharp decline from 8.1% in 2021. For Asia Pacific, growth is forecast to slow to 3.6% in 2022 from 6.2% in 2021 before rebounding to 4.3% in 2023. China's growth rate is expected to slow to 4.1% p.a. between 2021–50 as opposed to the impressive 9% p.a. growth seen for almost two decades (2000–19). **India** will grow at an average of 5.7% p.a. between 2021–50, compared to an average of 6.4% p.a. between 2000–19.

The **European** economy is forecast to grow by 1.9% in 2022, constrained by disrupted supply chains, tightening monetary policy, increased borrowing costs, and severe commodity market shocks, exacerbated by the Russia-Ukraine conflict. The European economy is at risk of slipping into a recession in 2023 as major economies continue to slow sharply. Growth projections for 2023 have been downgraded throughout most of the region. Higher energy prices have translated directly into larger import bills and wider current account deficits. They have also levied significant fiscal costs in several countries because of fossil fuel subsidies, price caps, and support to households and firms.

The outlook for Europe is predicated on persistently elevated energy prices. But a global environment characterised by tighter global financing conditions, softening external demand, and easing supply chain bottlenecks are relevant as well. Europe's output could be weakened with fragmentation in regional trade and investment disintegration if Russian energy exports are disrupted further.

Europe's economic growth over the 2021–50 period is forecast to reach an average of 1.8% p.a., a similar pace that it witnessed in 2000–19 of 1.7%.

**The US** economy, together with the European Union (EU) and China, will continue to slow down in 2022 and 2023. The potential for recession in 2023 is considerable.

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Annual real GDP growth in the US is anticipated to reach only 1.6% in 2022 and 1.0% in 2023. The US economy has strongly rebounded from the COVID-19 pandemic, with GDP growth reaching 5.7% in 2021. Unprecedented policy support, combined with early vaccination rollout, led real GDP to recover to its pre-pandemic level by mid-2021. The rebound in employment was very strong, though the cost of labour supply and demand is mismatched. Hence, the US labour market remains tight and wages are rising, especially for low-income earners, causing inflation to surge. Structurally, goods and services inflationary pressures are broadening together. As a result, global external financing conditions have tightened, and risk premiums have edged up following rapid US monetary policy tightening.

Long-term US economic growth will be challenged by the fiscal burden engendered by an aging population. Reforms to offset aging costs are required in order to stabilise the gross general government debt-to-GDP ratio. Additional revenue and improvements in public spending efficiency will be needed. Low economic mobility and rising inequality continue to shrink the middle class. Income and wealth distributions have grown more polarised since the 1970s, while childcare affordability and enrolment for the US middle class is low (14). North America's economic growth is forecast to reach 2.3% annually through 2050, similar to the 2000-19 period (2.1%).

### 1.3 Energy and carbon prices

#### Crude oil

Crude oil prices have jumped due to tightening supply and demand conditions, exacerbated by the Russia-Ukraine conflict. Prices might ease back below US\$90/bbl in 2024-25 as more supply emerges, particularly US barrels, and demand growth slows. We anticipate the crude oil market will stabilise over the medium term.

From 2026 through 2050, the average long-term Brent price is assumed at US\$75/bbl, subsiding from US\$80/bbl in 2027 towards US\$70/bbl in real terms by 2050.

Several drivers support a higher Brent breakeven outlook:

- *Higher upstream capital costs.* Higher steel, offshore and land rigs, equipment and labour costs will remain critical throughout the forecast period.
- *Higher internal rate of return (IRR) assumption.* IRR has increased from 10% to 20% due to financial market pressure for greater profitability after a decade of poor returns and greater uncertainty about future oil demand. Net-zero commitments and the energy transition are increasingly weighing on the oil and gas industry cost of capital.
- *Shifting marginal crude barrel.* This will shift by 2050 due to declining Russian output.

## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

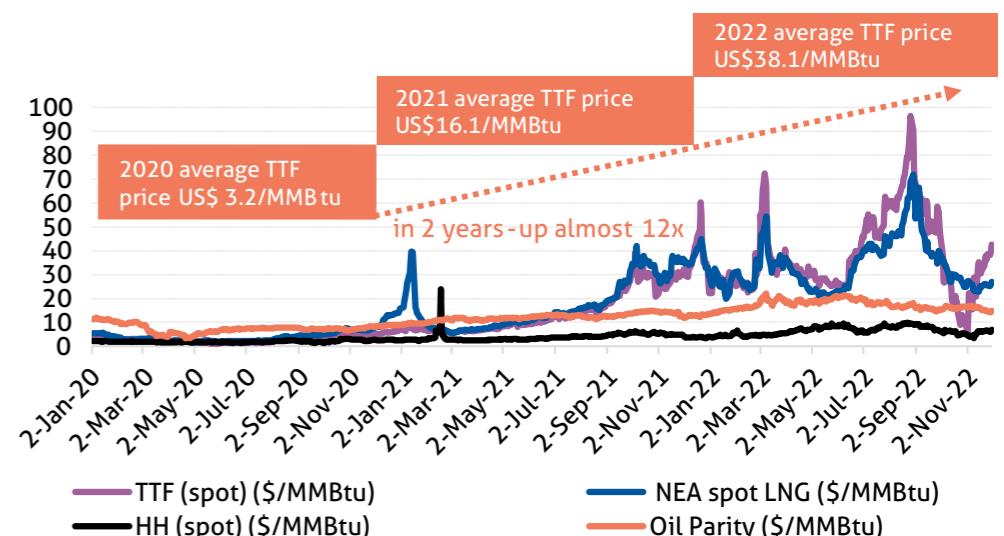
Global oil demand from gas-to-oil switching jumped significantly in 2022 after soaring prices for natural gas and LNG push more power producers, refiners, and industrial users to burn fuel oil and other liquid fuels.

The OPEC+, which comprises the Organization of the Petroleum Exporting Countries (OPEC) and allies including Russia, has reclaimed the status of swing producer, which has contributed to market stability over the last seven years. After a severe supply disruption in the spring of 2020 and a well-orchestrated market rebound in 2020-21, it is obvious that OPEC+ spare capacity can, to a significant level, guarantee oil market stability in the medium term.

#### Natural gas

Global gas prices have rebounded with recovery in natural gas demand and limited incremental supply. The Russia-Ukraine conflict exacerbated an already tight market situation.

Figure 1.8. Daily spot natural gas prices in 2020 - 2022 (US\$/MMBtu)



Source: GECF Secretariat based on data from Argus, RefinitivEikon and OANDA

European gas prices were set to surpass coal and oil on an energy equivalence basis. Some countries in Europe and the Asia Pacific were forced to switch to oil and back to coal. Gas-to-oil switching was more common in the Asia Pacific as these countries had to live with the consequences of LNG cargos being diverted to Europe in response to its high gas prices. At the same time, fuel oil cracks have also considerably decreased in Asia due to the larger availability of crude oil cargos.

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## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

In 2022, Europe to a large extent is replacing lower priced Russian pipeline gas imports by increasing LNG supply, turning Europe into a premium market by redirecting LNG cargoes from the Asia Pacific to Europe. The Asian gas market, de facto, is becoming a swing market with spot natural gas traded at discount to the European market. Europe will be in a better position starting from 2026 when the global tight gas market will be alleviated and rebalanced and natural gas prices will be brought down as a lot of new significant LNG capacity will come online, primarily from Qatar and the US.

In the short to mid-term, gas prices are expected to remain elevated due to a slower rebound of natural gas supply relative to gas demand growth. Volatility will continue due to the investment cycles for LNG. The global arbitrage window will ensure that high-value markets – the European and the Asian - attract supply. The challenge of decarbonisation will have an important impact on Europe and the Asia Pacific region, while putting downward pressure on longer-term natural gas demand and prices.

Over the long term, the natural gas price level is anticipated to be structurally higher and volatile at the same time as both key gas markets - Asian and European – are set to compete for LNG with less market flexibility space available for Europe. Over 2022-50, we see increasing regional natural gas market integration and European, Asian and Latin American price convergence.

The structure of the natural gas market over the outlook period is expected to remain geographically segmented. LNG shipments will be used increasingly to eliminate intra-regional price arbitrage as storage capacity grows and gas grids expand. Regional gas markets, which have weaker connectivity, are expected to become strongly integrated after 2035 as rapid LNG capacity development, transportation and trading networks -including large-scale export pipeline projects- support market integration. Thus, we expect that American and European markets, as well as the Asian and Latin American markets, will remain integrated market regions with the most natural gas liquidity. After 2035, a global gas market will start emerging, with regional differences diminishing in significance.

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

- Growing capital intensity. Gas production is expected to become increasingly capital-intensive, despite technological advancement. Increasing demand will encounter a higher long-run marginal cost of supply (LRMC).
- Carbon taxation and methane abatement policies. Climate concerns will translate directly to additional natural gas cost pressure after coal-switching benefits have been exhausted.
- LNG investment wave. Undersupply is and will continue driving an investment surge, helping balance the LNG market after 2026 and bringing the spot prices back to normal.

### Carbon

A significant rise in EU ETS carbon prices over the past few years will have long-lived repercussions. Carbon prices in the range of US\$80-US\$160/t CO<sub>2</sub> will impact other regional and country-level emissions trading marketplaces as well.

Carbon prices hit records in the EU, California, New Zealand, and South Korea. The EU ETS encountered record trading activity, with prices increasing almost threefold in 2021.

Global carbon markets derived revenue increased by almost 60% in 2021 to around US\$84 billion (15). With reduced allocation and strong commodities market, carbon price revenues surpassed carbon tax revenues for the first time – 67% vs 33%.

Worldwide, there are 68 Carbon Pricing Instruments (CPIs), with 23% of total GHG emissions covered by such CPIs.

At COP26 in 2021, Parties to the UNFCCC agreed on the rules that will govern international carbon markets. The agreement could also foster growth in voluntary carbon markets where companies buy carbon credits to help meet their net-zero goals. At COP27 in Egypt, Parties decided to establish a Loss and Damage Fund to help vulnerable countries deal with the consequences of climate change. Such creation of the Loss and Damage Fund might have a positive impact on the adoption of the carbon market in some of developing countries. They might be considering participating in the carbon market as an additional avenue for climate finance, resulting in increased carbon credit supply and improved global participation in the carbon market.

EU carbon prices are expected to increase with implementation of its REPowerEU Plan, while the US outlook remains largely unchanged.

US prices remain regional and avoid convergence with other markets, until 2050. Global carbon market convergence is more evident beyond 2050, catching up with the EU ETS.

Carbon price assumptions affect inter-fuel competition, especially the process of coal-to-gas switching. As the carbon market is expected to support the competitiveness of natural gas, we assume it will make coal more expensive to use while keeping the coal-gas price ratio within the affordability range.

## 1.4 Energy policy

### Global policy developments and trends

Energy policy was on a roller-coaster in the recent past. The COVID-19 pandemic was a stress test for the resilience of energy systems. In the run-up to COP26 in Glasgow, climate change was in the driving seat: pledges of net-zero emissions by mid-century flourished and pressure to limit financing of fossil fuels increased. At the same time, affordability became an issue as rapid post-pandemic recovery and years of chronic underinvestment led to rapidly rising energy prices in the second half of 2021. In 2022, geopolitical developments brought energy security back to the top of the policymaker priority list. Structural changes affected energy systems regarding investment, physical flows, trading and market function.

### Scaling up GHG-emission-mitigation ambitions

The International Panel on Climate Change (IPCC) Sixth Assessment Report—Working Group I underlined that limiting global warming to 1.5°C above the pre-industrial level by the end of the century requires rapid, deep, and sustained reductions in GHG emissions (16). At COP26, countries agreed to reduce global carbon dioxide emissions by 45% relative to the 2010 level by 2030, aim to achieve net zero emissions around mid-century, and severely reduce other GHG emissions.

The Nationally Determined Contribution (NDC) Synthesis report revealed that the estimated aggregate GHG emission level, considering all submitted NDCs, would be 13.7% above the 2010 level in 2030 (17). This led to a work programme initiative to urgently scale up mitigation ambitions. Furthermore, the UNFCCC parties agreed to revisit and strengthen their 2030 climate plans before COP27, phase down unabated coal power, and phase out inefficient subsidies for fossil fuels (18).

However, the 2022 energy crisis has led energy security and affordability to become policymakers' priorities. In response to soaring energy bills, governments have deprioritised pledges to end inefficient fossil fuel subsidies and are effectively supporting the sector through energy bill relief for consumers. Governments, including in Europe, have set aside the negative narrative surrounding coal due to its abundance and affordability while ramping up production and use. Only a few major GHG emitters have responded to the call to update and strengthen their NDCs for 2030. Furthermore, the dialogue between China and the US on climate change has been stalled as geopolitical and trade tensions have risen.

### BOX 1.2. Primary outcomes from COP27

The 27th session of the Conference of the Parties of the UNFCCC (COP27) convened in the Egyptian coastal city of Sharm el-Sheikh in November 2022. Under the slogan "Together for Implementation", 112 world leaders and delegates from 190 countries discussed how to advance the global climate agenda and ensure implementation of climate commitments. The results were mixed, focusing more on climate change impacts than causes, with the Sharm el-Sheikh implementation plan an overarching cover decision. Some of the key outcomes are highlighted in the following points.

- **Loss and Damage:** Parties reached a historic decision to respond to loss and damage caused by the adverse impacts of climate change. A loss and damage fund was set up for the first time, with the details to be figured out over the next year. This landmark decision was a great success, particularly for the most vulnerable developing countries.
- **Mitigation:** The Sharm el-Sheikh implementation plan reiterated the long-term goal of limiting the temperature increase to 1.5 °C above the pre-industrial level and phasing down coal from the Glasgow Climate Pact achieved the previous year. References to renewable energy were replaced with language referencing "low-emission and renewable energy", which may be interpreted as a positive sign for natural gas. Also, countries were asked to "revisit and strengthen" their 2030 climate targets by 2023 – if they have not already done so. However, some parties were concerned that the results of the efforts might not be enough to "keep 1.5°C alive".
- **Climate Finance:** The need for a "transformation of the financial system and its structures" was acknowledged for the first time. Multilateral development banks and international financial institutions were asked to modify their practices and priorities in response to the "global climate emergency". Furthermore, the "Sharm el-Sheikh dialogue" was launched to align financial flows with global temperature targets. However, no new finance target was set, even in the most crucial climate finance negotiations, which aimed to replace the \$100 billion target with a new, higher threshold that would take effect after 2025.
- **Methane emission reduction:** Methane was once again a popular topic of discussion. At a side event, it was announced that Global Methane Pledge members had reached 150 countries. China, the world's largest annual methane emitter, which is not party to this pledge, proclaimed its national methane plan.

### More energy policies to promote renewables

The recent energy crisis demonstrated that renewables are not yet sufficiently reliable unless backed up by dispatchable sources of electricity, notably natural gas. Still, countries have continued to enact renewable-supportive policies to support longer-term energy security. It is now fully recognised that natural gas paired with renewables is a realistic, cost-effective, and secure mitigation pathway in most countries and regions.

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The cost of solar and wind electricity generation has declined considerably in the past decade. According to the International Renewable Energy Agency (IRENA), the cost of electricity from solar PV and onshore wind has declined by 88% and 68%, respectively, since 2010 (19). As a result, renewables are competitive with fossil fuels in the power sector and attract the bulk of global investment in this sector. Moreover, the recent run-up in fossil fuel prices has created an opportunity for faster renewable rollout.

Many countries have enacted new and additional support for renewables, focusing on the power sector. Furthermore, electrification of end uses such as heating and road transport has emerged as a new area of interest for policymakers.

In the US, the landmark Inflation Reduction Act of 2022 (IRA) aims to encourage investment in renewable projects. In Europe, the REPowerEU plan outlines measures to accelerate the transition to clean energy by scaling up renewable use in power generation, industry, buildings, and transport. In China, the 14th Five-Year Plan for the energy sector and sub-sector plan on renewable energy were adopted in the spring of 2022.

Still, renewables development faces serious obstacles. Primarily, the current energy system remains compatible with fossil fuels. Adapting the structure for renewables requires a deep transformation, with substantial effort in overhauling systems and habits, plans, policies, and fiscal regimes, together with massive investment in both new capacity and enabling technologies and infrastructure. For example, despite good global progress in the deployment of renewables in the power sector, end-use sectors (such as industrial processes and domestic heating) still rely heavily on fossil fuels.

Another challenge is the variable and intermittent nature of renewables, which determines their need to be integrated with alternative sources, such as natural gas, to create a reliable system. Finally, investments associated with the penetration of renewables, such as the expansion of transmission and distribution grids, are substantial and difficult to bear, especially in highly indebted countries. The environment is further complicated by an inflationary and high interest-rate environment.

### Policy support for natural gas

Since 2015, policy focus has favoured sustainability to the detriment of security and affordability. Low natural gas prices and ESG-related pressures on financial actors to cease financing natural gas projects led to a dramatic decline in investment. Years of underinvestment in the gas sector fostered a situation in which a growing supply deficit triggered a sharp rise in prices to balance the market in the second half of 2021.

## KEY MACRO AND ENERGY POLICY ASSUMPTIONS

Geopolitical tensions in Eastern Europe and the subsequent decline in Russian gas flow to Europe have further exacerbated the situation. Europe became the preferred market for LNG cargoes instead of the market of last resort as in the past. High prices have eroded demand in several Asian countries, with severe and protracted effects on energy availability and costs for billions of people. In addition, despite European coal phase-out policies, its consumption and the subsequent GHG emissions have increased sharply. This highlights the paramount role of natural gas in balancing energy transition and energy security.

For the world to meet the 1.5°C long-term temperature goal, the use of natural gas should be scaled up rapidly, particularly through oil and coal substitution. The upscaling of mitigation ambition and 'phasing down' of coal could encourage increased gas use, primarily because of increasing demand in fast-growing emerging economies as they continue to industrialise and reduce their reliance on coal. Global carbon markets and the Global Methane Pledge could incentivise the scale-up of methane emissions reduction, carbon capture (CCS/CCUS), and blue hydrogen, all of which will give natural gas an expanded role in the energy transition.

In the US, the IRA provides support to the oil and gas industry, including expedited access to federal land leases for both onshore and offshore developments and streamlined project permitting. In addition, the legislation provides financial incentives for CCS/CCUS.

Moreover, the Complementary Climate Delegated Act, published in the EU Official Journal on July 2022, includes specific nuclear and gas energy activities in the list of economic activities covered by the EU Taxonomy. This green classification system identifies economic activities that are environmentally sustainable, leading to more confident investment and financing.

### The coal industry struggling in an increasingly carbon-constrained world

According to the IPCC, GHG emissions from coal should have peaked in 2020 to limit the temperature increase to less than 1.5°C. Furthermore, coal used to generate electricity should be 80% lower than 2010 levels by 2030, with OECD countries entirely ceasing coal use by 2030 and shutting all coal-fired power plants by 2040 (20).

The Glasgow Climate Pact includes the provision for 'accelerating efforts towards the phasedown of unabated coal power'. Also, more than 40 countries have agreed to stop using coal-fired power, and more than 100 financial institutions and other groups have decided to stop funding coal development. Furthermore, major coal-consuming countries (such as Canada, Poland, South Korea, Ukraine, Indonesia, and Vietnam) pledged to stop using coal to generate

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electricity. The largest economies committed to ceasing using coal power by the 2030s, while the other economies pledged by the 2040s. However, some of the largest coal-dependent economies (such as Australia, China, and India) were not part of the deal.

Furthermore, the US joined European nations in pledging US\$8.5 billion to help accelerate South Africa's transition from coal to cleaner energy. More broadly, donor countries the UK, US, Germany, France, and Japan are focusing attention on South Africa, Vietnam, Indonesia, India and Senegal.

But these efforts are proving difficult in the current environment where record-high gas prices and constrained supply have prompted countries to consume more coal. Price sensitivity in Asia has been a critical driver. Europe has also restarted coal plants as well in an effort to shore up energy sources. As a result, the global coal phase-out is slowing. Still, the prospect of new coal investment is dim. Banks and other financial institutions are averse to backing coal projects, while their customers are committed to net-zero emissions—most of them by 2050.

### Accelerating hydrogen developments

Hydrogen offers opportunities to simultaneously contribute to decarbonisation targets and enhance energy security. It will be used increasingly to decarbonise hard-to-abate processes and activities, especially in industry and transportation. Green and blue hydrogen are the primary low-carbon hydrogen sources, with blue hydrogen benefitting from a significant cost advantage compared to green hydrogen.

The number of countries considering hydrogen in their energy sector strategies has grown rapidly during the last year (2022). Europe's REPowerEU initiative outlined a plan to produce 10 million tonnes per annum (mtpa) of renewable hydrogen within the member states and import another 10 mtpa by 2030. The UK's Energy Security Strategy doubled its ambition for low-carbon hydrogen production to 10 GW by 2030, with at least half coming from electrolytic hydrogen, and China's Hydrogen Industry Development Plan targets the production of 100-200 kilotonnes (kt) of renewable hydrogen by 2025.

Several gas-exporting countries such as Oman, Russia, and Trinidad and Tobago, have published national hydrogen strategies and roadmaps in the last year. Others, including the US, Algeria, UAE, and Egypt, are currently preparing theirs. Oman's green hydrogen strategy aims to produce 1 mtpa of green hydrogen by 2030, while the UAE is targeting 25% of the global hydrogen market. Russia aims to export 0.2 million tonnes (mt) by 2024, 2 million by 2035, and 15-50 million by 2050.

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The world's first shipment of liquefied hydrogen from Australia to Japan in February 2022 was a milestone in the development of an international hydrogen market. Still, the adoption of hydrogen as a clean industrial feedstock and energy vector is still nascent enough to elicit wide variability in possible long-term outcomes for the fuel, along with its energy security and energy transition roles.

### Policy drivers and developments in the key markets

#### United States (US)

##### *Energy transition speeds up*

President Joe Biden has altered the US energy transition direction following a pause implemented under the previous administration. Important legislation such as the IIJA and IRA followed a new NDC unveiled in 2021 (21), all propelling the US toward its climate goals.

The convergence of market, regulatory, and technology forces helped public and private sector leaders converge toward the net-zero pledge. The new laws include many initiatives to enhance the energy transition, bolster energy security, and accelerate efforts to tackle the climate crisis. As a result, the US is expected to likely stay on track to reduce its GHG emissions by 26%-28% below 2005 levels by 2025.

The bipartisan IIJA focuses on upgrading physical infrastructure (such as power grids and transportation systems) to integrate a higher share of renewable energy. This includes investment in the building and expansion of a national electric vehicle charging network, along with investment in zero- or low-emissions school buses and funding for CO<sub>2</sub> emissions reduction in power generation.

The IRA legislates the country's largest-ever investment aimed at addressing climate change. It is expected to reduce GHG emissions by 40% from 2005 levels by 2030 and could be a game-changer for the power sector. Over the next ten years, the IRA will fund US\$369 billion for projects that promote clean energy and could trigger a boom in decarbonisation technologies. The IRA targets energy efficiency, electric vehicles (EVs), low-carbon hydrogen production, CCS/CCUS, methane emissions reduction, and both transportation and building electrification. The legislation will also provide tax credits for renewable energy developers, as well as initiatives supporting nuclear energy and even fossil fuels.

##### *Renewables may gain the most from the Inflation Reduction Act*

The IRA will provide investors with more confidence to invest in renewable projects by lengthening production and investment tax credits and setting up

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new technology-neutral credits. The law considers different types of renewable energy, including wind, hydroelectric, biomass, geothermal, and solar, along with the equipment made for energy storage, EVs, grid modernisation, and energy efficiency. As such, the cost of renewables will likely decline. The solar and wind industries will benefit significantly from the IRA, which also unlocks a remarkable market for energy storage.

### *Electrification and energy efficiency will grow fast*

We expected electrification to raise US annual electricity demand by about 30% by 2050 prior to IRA passage. Now, the legislation will make this change larger and faster. New tax incentives and rebates will drive massive electrification investment in buildings while encouraging heat pumps and heat pump water heaters in residential structures. Considerable funding also has been devoted to developing and electrifying maritime ports, heavy-duty vehicle fleets and related infrastructure.

### *Natural gas continues to receive support*

The IRA helps the oil and gas industry as well, including easier permitting for projects and accelerating the acquisition of federal leases for both onshore and offshore projects. Also, the law provides oil and gas companies with financial incentives to use CCS/CCUS. These incentives recognise a long transition development period and that natural gas will remain a transition fuel for decades.

Importantly, aspects of the IRA are less favourable to traditional oil and gas. The IRA includes a minimum tax of 15% on oil and gas companies with income greater than US\$1 billion. In addition, it doubles rental fees on leases and increases royalty rates from 12.5% of the value of extracted oil and gas products to 18.75%.

Moreover, the legislation levies a price on methane emissions for both offshore and onshore producers, natural gas processing, transmission, and compression, along with underground gas storage, LNG facilities, and gas gathering and boosting stations.

CCS/CCUS funding in the IIJA – and incentivised by the IRA – will benefit the oil and gas industry. It will likely result in more liquidity options for project developers and significantly increased investment in CCS/CCUS.

### *The time limit for hydrogen subsidies accelerates development schedules*

Clean hydrogen tax incentives (known as 45V) are the key IRA initiatives. The 45V subsidises low-carbon hydrogen production with tax credits based on the carbon emitted during the production process and the project's start date. To

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obtain the maximum credit of US\$3/kg, a facility must have begun construction or modifications of existing facilities no later than one year after the enactment of 45V. As a result, project developers seeking 45V tax credits will need to act quickly to start construction within the next year.

Therefore, many announced hydrogen projects will be accelerating their development schedules to be eligible for the 45V tax credit, and additional announcements are expected. While the 45V incentive favours hydrogen production projects with the lowest carbon intensity, it still offers credit to hydrogen projects using CCS.

### *Nuclear plants will survive*

The US now sees nuclear energy as important to meeting emissions reduction goals, even though electricity markets have been difficult for nuclear operators and retirement announcements have proliferated. Nuclear plants will have three avenues for financial support: IRA credit at a base value of US\$3/MWh, with a maximum value of US\$15/MWh if certain requirements are met, a fund allocated through the IIJA, and state zero-emission credit programs.

### **European Union (EU)**

#### *EU seeks fossil fuel diversification despite transition goals*

The EC's European Green Deal, released in December 2019, outlined its long-term growth plan to reach carbon neutrality by 2050. In 2020, this plan became a legally binding obligation for 55% GHG emissions reduction from 1990 levels by 2030, along with the long-term carbon neutrality target. The bloc's 2021 "Fit for 55" laws were passed to achieve these goals.

Europe has long sought to phase out its dependency on Russian energy sources. In 2022, the EU decided to accelerate efforts to transform Europe's energy system to achieve both this goal and advance emissions reduction initiatives. Its May 2022 REPowerEU plan outlines steps and investments needed to wean the region off of Russian fossil fuels by 2027. Renewables, low-carbon energy sources and energy efficiency will offset most Russian gas demand. The remaining gas requirements will be covered by diversified suppliers.

The REPowerEU initiative contains three primary goals:

**Energy conservation:** The initiative increases long-term energy efficiency measures, including the binding Energy Efficiency Target (EET) under the "Fit for 55" package, from 9% to 13%. Energy efficiency measures and faster deployment of heat pumps may lower gas demand in the residential and commercial sectors by 37 billion cubic metres per year (bcm/year) by 2030.

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**Supply diversification:** The EU is working on importing gas and LNG from a greater number of sources. LNG, which provides a significant opportunity for supply diversity, is expected to provide the most incremental gas (+50 bcm), but pipeline gas (+10 bcm or more) will also be needed. The EU Energy Platform will help facilitate diversification goals by promoting partnerships among EU members and with external suppliers. Investment of €10 billion in new pipeline and LNG infrastructure through 2030 will also augment the opportunity for gas supply to originate from a growing number of sellers.

**Accelerating renewable energy penetration:** This plan aims for faster and greater renewable energy in power generation, industry, buildings, and transportation. Current energy prices pushed the EC to reconsider boosting the renewable ambitions under the Fit for 55 package from 40% to 45% by 2030. This expansion creates a framework for other renewable energy programmes. This includes the Solar Rooftop Initiative, which will mandate the installation of solar panels atop new buildings, and the EU Solar Strategy doubling solar power capacity by 2025. It also includes doubling heat pump use, along with the Biomethane Action Plan to increase production to 35 bcm by 2030 and boost renewable hydrogen production and imports to 20 million tonnes by 2030.

The EU External Energy Strategy plans for negotiation with different countries for additional gas and hydrogen supplies, including Algeria, Angola, Azerbaijan, Canada, Egypt, Japan, Korea, Nigeria, Norway, Qatar, Senegal, and the US. Also, the EU announced the "You collect/we buy" scheme, providing technical assistance to partners to capture methane from leaks, venting, and flaring sustainably and cost-effectively and supply it to the EU.

### Box 1.3. EU proposal on price caps and its potential impact on the gas market

In 2022, the European Commission (EC) proposed several regulations to tackle gas supply shortages and unsustainable gas prices in the region which include REPowerEU Plan (proposed on 18 May 2022), Gas Storage Regulation (entered into force on 30 June 2022), Save Gas for a Safe Winter (entered into force on 6 August 2022), Emergency Market Intervention on High Electricity Prices (proposed on 14 September 2022).

The latest EC proposal on new energy emergency measures was made on 18 October 2022. The EC published two documents: Communication entitled "Energy Emergency: Preparing, Purchasing and Protecting the EU Together" and Proposal for a Council Regulation entitled "Enhancing solidarity through better coordination of gas purchases, exchanges of gas across borders and reliable price benchmarks". The key proposals of the draft regulation cover, inter alia, the following topics:

- New LNG-based price benchmark – creation of a new complementary LNG-based price benchmark which would be reflective of actual LNG transactions.
- Temporary EU framework to cap the price of gas in electricity generation – introduction of a price cap on electricity prices at the EU level.

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- Joint gas purchasing – aggregation of demand at the EU level which will allow companies to form a European gas purchasing consortium to purchase gas jointly.
- Energy solidarity measures – creation of a set of default solidarity rules that will apply to Member States in the case of emergency.

However, the focus of the draft regulation was made on temporary dynamic price corridor for transactions on the TTF hub, which envisages the implementation of two mechanisms to prevent extremely high volatility and prices which are the intra-day market volatility management system and market correction mechanism.

**Intra-day market volatility management system (Article 15 of proposed regulation):** The intra-day market volatility system aims to prevent excessive fluctuations of prices within a trading day by setting upper and lower price boundaries where any price above or below would not be executed. The price boundaries will be calculated relative to a reference price and will be renewed at regular intervals during trading hours. This mechanism is used in other exchanges where there may be price limits or price bands.

**Market correction mechanism (Article 23 of proposed regulation):** The market correction mechanism will apply to all gas transactions taking place on the TTF trading hub. Other EU trading hubs may be linked by a dynamic price corridor. The proposal specifies several conditions to be held if this mechanism is implemented including that it should be without prejudice to over-the-counter (OTC) trades, should not lead to an overall increase in gas consumption and should not affect the stability and orderly functioning of the energy derivative markets. Furthermore, Article 24 stipulates that the Council can decide to suspend this mechanism if the justification for it is no longer valid or if unintended market disturbances occur.

These market interventions by EU authorities are likely to have a significant impact on the inherent functioning of the market. The intra-day volatility limit and market correction mechanisms, in particular, can manipulate the price discovery function of the exchange and introduce a somewhat indirect price cap on the TTF price.

The TTF price may decline in alignment with the variable price limit. It may also impact other European hub prices as the markets are interlinked. Furthermore, Asian spot LNG prices have closely tracked European hub prices over the past two years, therefore, there may potentially be a downside impact on Asian LNG prices as well. Furthermore, if Asian LNG demand increases, there will be increased competition for cargoes. In this regard, any TTF price limit may incentivize sellers to divert cargoes away from Europe, which may result in a deficit of gas in Europe.

The TTF price cap could disrupt efficient trading on exchanges and over-the-counter (OTC), which market participants, including traders and end buyers, currently use, inter alia, for hedging to manage risks and reduce volatility. In the EU gas market, traders often purchase gas during the shoulder months and summer season, when prices are lower, and inject it into underground storage. At the same time it is sold as futures to the end buyers for delivery in winter when prices are higher. The price cap could reduce the winter season spot gas price below the futures price in winter, which was previously contracted in the summer season. That may result in the end buyers declaring force majeure and refusing to receive physical gas and make payment for it under previously concluded futures contracts. In the meantime, if the traders sell the gas in the spot market at lower prices, driven by the price cap, they may incur a financial loss. As such, the trader may choose to keep the gas in storage until it is profitable to sell the gas in the market, which could lead to gas shortages, in particular during the winter

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season. However, it should be noted that such a negative impact of the price cap on the functioning of the market may only be of the short-term nature, while in the long term the market may adapt to the new conditions, with the futures market reflecting the price cap.

In this context, market correction mechanisms may jeopardise financial stability in the euro area by increasing volatility and related margin calls, challenging central counterparties' ability to manage financial risks and incentivising migration from trading venues to the non-centrally cleared over-the-counter market. These risks were outlined by the European Central Bank in a special note, prepared in December 2022 at the request of the Council of the European Union.

The bottom line is that if the proposed legislation on price caps is adopted by the EU authorities, it may affect the global gas market, leading to market distortions, lower investment, diversion of gas/LNG supply away from EU, deficit of gas in EU and ultimately, regional gas demand destruction.

As of 14 December 2022, the discussions on the proposed price cap were still ongoing at the EU level and it was uncertain as to when the regulation would be adopted, since there was support and objections from EU member states.

### China

#### *China aims to balance energy security and achieve its climate change goals*

China's energy priorities include increasing renewable power, maintaining crude oil output, boosting natural gas production and tackling rising emissions. In March 2021, the Chinese government released a general policy document outlining the main goals and guidelines of the 14th Five-Year Plan (FYP) for 2021-25. This was followed by more detailed plans in 2022, including the 14th FYPs for a modern energy system, renewable energy, the first Medium-Term Plan for Hydrogen, and a roadmap for energy storage.

#### *The 14th Five-Year Plan for energy is a shift toward a modern energy system*

The 14th FYP for a Modern Energy System, published in March 2022, was the first energy-focused plan to be announced after China's carbon pledges. The policy shifts the focus of China's energy sector toward long-term transition goals and the construction of a modern energy system to solve both sustainability and supply security concerns. It lays out strategic goals in supply security, system transition, efficiency, and innovation for the energy sector by 2025. The plan also indicates targets for the primary energy mix, flexible power sources, the electrification rate, and new technologies.

The plan calls for China to maintain annual crude oil output at 200 million tonnes, boost annual natural gas production to more than 230 bcm, and develop a comprehensive energy production capability of over 4.6 billion tonnes of standard coal equivalent (bn tce) by 2025.

The plan reiterates several major objectives from the overall FYP and China's NDC, including an 18% CO<sub>2</sub> intensity reduction, 13.5% energy intensity reduction, and an approximately 20% increase in the share of non-fossil energy in total energy consumption, all by 2025.

The plan is not expected to slow coal-fired power plant development. It only calls for a "clean and efficient use of coal" with trading mechanisms to reduce energy use and cut CO<sub>2</sub> emissions and more tax credits to support low-carbon development. Prior to COP26, the country pledged to stop building new coal-fired power projects abroad.

The 14th FYP foresees an increase in nuclear capacity to 70 GW by 2025. The National Development and Reform Commission (NDRC) expects China to reach 200 GW of nuclear capacity by 2035.

#### *Hydrogen receives more policy support in the first medium-term plan for hydrogen*

The National Development and Reform Commission published China's first medium-term plan for a clean and green hydrogen industry in March 2022. It aims to have around 50,000 fuel cell vehicles on the road and produce 100,000-200,000 tonnes of hydrogen annually from renewable sources by 2025.

#### *The 14th Five-Year Plan for renewable energy*

China released its 14th FYP for renewable energy in June 2022. It indicates that 25% of China's energy will come from non-fossil sources by 2030. Renewables will cover at least half of the increase in electricity demand. The new plan targets total renewable energy output of at least 1,000 million tonnes of coal equivalent by 2025.

#### *The 1+N policy framework for carbon neutrality*

The country's Long-Term Low Greenhouse Gas Emission Development Strategy, announced in September 2020, includes a 2060 carbon neutrality target. China also submitted its updated NDC to the UNFCCC ahead of COP26 in October 2021. China aims to reach peak CO<sub>2</sub> emissions, reduce carbon intensity by 65% compared to 2005 levels, increase the share of non-fossil fuels in primary energy consumption to around 25%, and install 1.2 billion kilowatts of wind and solar energy capacity — all by 2030.

China is implementing a '1+N' policy framework for carbon peak and neutrality. The "1" refers to the long-term approach to combating climate change, which is documented in a guideline issued in October 2021 (22). The "N" refers to the "carbon peaking action plan" – a 10-point plan that sets out China's expectations on the actions that key sectors are required to implement to achieve peak emissions by 2030.

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### India

#### *Coal remains dominant, while natural gas and renewables are gaining ground*

India's energy policy includes quadrupling renewable electricity capacity by 2030, more than doubling natural gas share in the energy mix, improving energy efficiency and transport infrastructure, enhancing domestic coal production, and decreasing dependence on imports.

India is pursuing its gas-supportive strategy to switch to a gas-based economy. It aims for natural gas to account for 15% of the country's primary energy demand by 2030, which includes increasing domestic production and importing LNG. Also, the government's draft LNG policy, announced in 2021, focuses on regasification facility development. It is targeting 70 mtpa by 2030 and 100 mtpa by 2040.

#### *A just, smooth, sustainable and all-inclusive approach to the energy transition*

India increased its emissions intensity target in its updated NDC submitted in August 2022. The NDC includes an unconditional commitment to reduce the emissions intensity to 45% below 2005 levels by 2030, compared to the 33%-35% cut in the 2015 NDC. It also contains a conditional commitment for approximately 50% of its installed electricity generation capacity to be run on non-fossil fuel sources by the same year if finance and technology transfer are provided by other countries. This is a 10% increase from the first NDC target, which aimed for a 40% share by 2030.

India introduced the Energy Conservation (Amendment) Bill in August 2022. This bill requires industries such as mining, cement, steel, textile, chemicals, and petrochemicals, as well as the transport sector and commercial buildings, to use non-fossil energy sources with different consumption thresholds. It also enables the central government to specify a system for exchanging carbon credits while promoting energy efficiency and conservation by setting new regulations for the energy consumption of equipment, appliances, buildings, and industries.

The National Hydrogen Mission of India was initiated in August 2021 to make the country a global hub for producing and exporting green hydrogen. With the Green Hydrogen/Green Ammonia Policy on February 2022, the government increased the green hydrogen production target to 5 million tonnes by 2030. The government has also introduced a mandatory 'green hydrogen purchase obligation' for certain sectors.

At COP26, the country announced its target to achieve carbon neutrality by 2070 and submitted its "Long-Term Low Emission Development Strategy" to

the UNFCCC during COP27. This strategy focuses on the rational utilisation of national resources regarding energy security. Accordingly, India will adopt "a just, smooth, sustainable, and all-inclusive manner" to transition from fossil fuels. Some of India's goals are fast green hydrogen production growth, domestic electrolyser manufacturing expansion, tripling nuclear capacity by 2032, and overall development of the power sector.

#### *Electricity Plan based on the growing role of renewables*

According to India's new Draft Electricity Plan released after the NDC update in September 2022, around 228 GW of incremental capacity is required to meet electricity needs by 2026-27. Some 18% will be conventional sources, including coal and lignite, natural gas, and nuclear, while 82% will be renewable sources, such as large hydro, solar, wind, biomass and pumped storage plants.

The share of incremental conventional capacity will decline to 7.5% by 2031-32. According to this plan, apart from 25 GW of coal-based capacity under construction, additional coal capacity may vary from 17 GW to around 28 GW. The total incremental capacity projection is consistent with the country's goal of reaching 500 GW of non-fossil-based installed capacity by 2030.

## 02

### Energy and Gas Demand Outlook

## Key findings:

- Global primary energy demand is forecast to rise by 22%, reaching 17,865 Mtoe by 2050. Most of the increase will come from fast-growing economies of Asia Pacific and Africa.
- The energy transition is underway and the rapid growth of renewables will contribute to a more diversified structure of the global energy mix. Still, fossil fuels will maintain their leading role, accounting for 63% in 2050.
- Natural gas will come out on top, raising its share to 26% by 2050. Natural gas will overtake coal in around 2025 and become the most utilised fuel by around 2043.
- Natural gas demand is projected to increase by 36%, from 4,025 bcm in 2021 to 5,460 bcm in 2050, with no peaking expected. Policies aimed at air quality improvements, and coal- and oil-to-gas switching are among the main drivers. Nascent technologies such as blue hydrogen and CCS/CCUS will support a sustained demand trend.
- Asia Pacific, the Middle East, and Africa are projected to be where the bulk of future gas demand growth will take place. Europe is the only exception due to REPowerEU plan implementation, with demand contraction in the region accelerating in the long term.
- The power generation sector will be the driving force, accounting for 43% of total gas demand growth amid a strong increase in electricity needs and the phase-down of coal-fired capacity. In addition, gas-fired generation will become more important for providing flexibility due to renewables scale-up in power systems.
- Industrial gas demand retains significant, contributing 17% to incremental volumes between 2021 and 2050. Policy-driven fuel switching will be the key factor. Moreover, gas demand will rise as a feedstock for the production of petrochemicals and fertilisers.
- Gas in road and marine transport will take off, driven by policy initiatives aimed at abating emissions. LNG use in shipping and heavy goods vehicles presents the main opportunity.
- Blue hydrogen generation will be an additional vector for increased gas use, given countries' efforts to scale up the deployment of low-carbon hydrogen in energy systems. Blue hydrogen will be attractive due to the maturity of the technology, lower cost, and synergy with natural gas infrastructure.

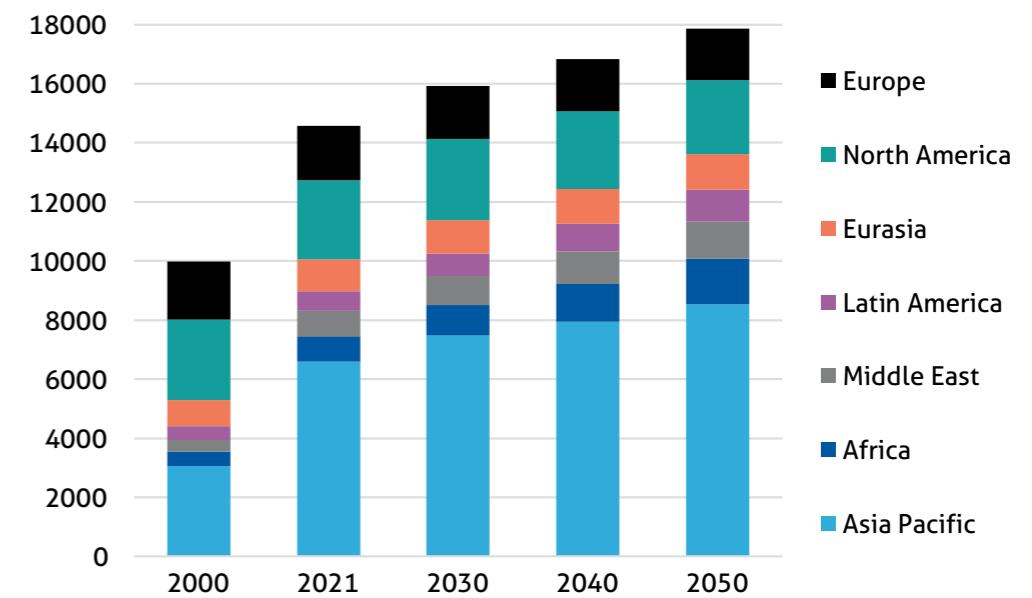
## 02 Energy and Gas Demand Outlook

### 2.1 Global primary energy demand outlook

According to the RCS, energy markets are expected to go through a significant transformation over the next three decades. Global primary energy demand is forecast to rise by 22%, reaching 17,865 Mtoe by 2050, up from 14,585 Mtoe in 2021. Based on policies and actions implemented to achieve a low-emission transition, this forecast sees increasing use of renewables in the power generation sector, expanded and swift coal-to-gas switching (specifically in the power generation and industrial sectors), progress in energy efficiency and greater electrification of end-use activities. The Outlook projects that electricity will meet 29% of global final energy consumption in 2050, compared to 21% in 2021. Additionally, the service sector will dominate global GDP growth, resulting in a faster decline of global energy intensity. The latter decreases by 2.4% per annum over the 2021-50 period, compared to a reduction of 1.5% per annum between 2000 and 2021.

The regional breakdown of primary energy demand shows that the Asia Pacific region will account for 1,955 Mtoe, or 60% of the increase between 2021 and 2050. Fast-growing Chinese, Indian and Southeast Asian economies, with large and growing populations, will drive this trend. We expect Africa to be the next largest source of incremental energy demand, adding 690 Mtoe through to 2050 or 21% of the increase.

**Figure 2.1. Global primary energy demand trends by region (Mtoe)**



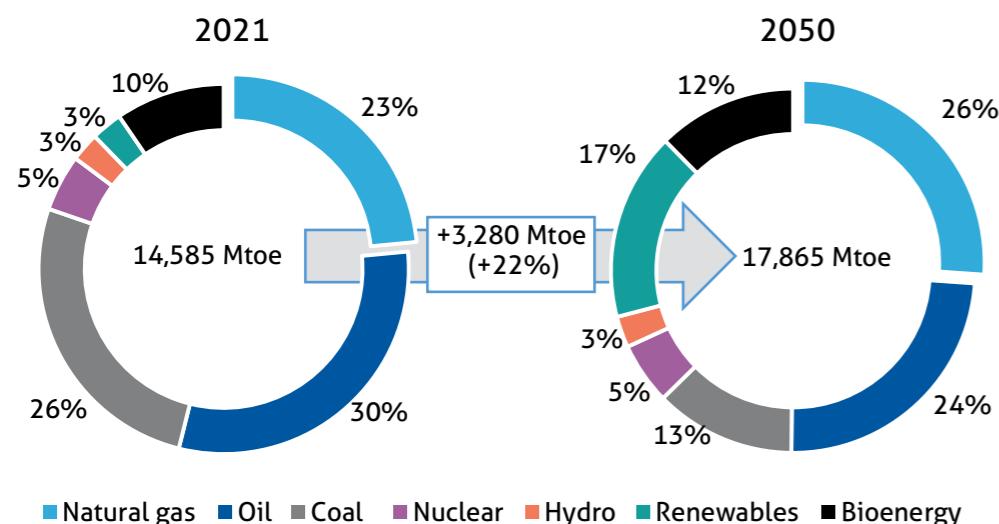
Source: GECF Secretariat based on data from the GECF GGM

Latin American and Middle Eastern demand will increase by nearly 410 Mtoe and 400 Mtoe, respectively, in response to significant energy supply and economic expansion. Eurasian regional demand will grow by 115 Mtoe due to the significant potential in energy efficiency. North American energy consumption will decline by 175 Mtoe, with the US accounting for most of the reduction due to slowing population growth, road transport fuel efficiency improvements, and increasing renewables use. Energy demand in Europe will also decline, underpinned by policies targeting energy sector decarbonisation.

In the context of the energy transition and countries' nationally determined contributions to climate mitigation under the UNFCCC, natural gas, which satisfies today 23% of the world's primary energy demand, is set to play a critical role in meeting the growing needs for clean energy. Natural gas will overtake coal in around 2025 and become the most utilised fuel by about 2043. It will also be the only hydrocarbon to increase its share, from 23% in 2021 to 26% in 2050. Increasing supply availability and policy support in many countries will drive natural gas to the top of the global primary energy mix.

The benefits of growing natural gas use are well established, including carbon intensity and pollution reduction, along with expanded access to modern energy fuels. As decarbonisation activity gains additional traction, the deployment of low-carbon technologies, such as blue hydrogen generation and CCS/CCUS, will enhance the resilience and competitiveness of natural gas in the long term.

**Figure 2.2. Global primary energy demand in 2021 and in 2050 (%)**



Source: GECF Secretariat based on data from the GECF GGM

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

The global energy mix structure is becoming more diversified. Progress in renewables is central as its share rises from 3% in 2021 to 17% in 2050. Nuclear and hydropower share will remain stable at 8%, although volumes will grow. Global bioenergy demand will also rise with increasing usage of modern forms of biomass. Driven by natural gas increases, fossil fuels overall will maintain their leading role, but their share in the energy mix will decline to 63% by 2050, compared to almost 80% in 2021. Oil will remain an important fuel, but its share will decline from 30% to 24%. The share of coal will drop by half, accounting for only 13% of the future primary energy demand by 2050.

#### Demand outlook by fuel

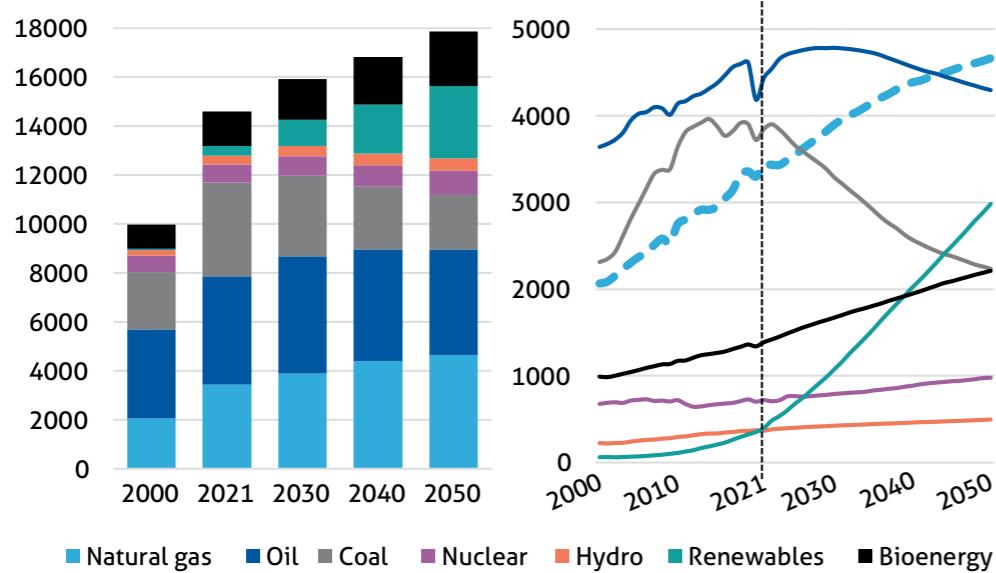
Global oil demand will expand this decade, reaching around 4,785 Mtoe by 2030 (8% growth compared to the 2021 level). Heavy trucks and aviation fuels as well as petrochemical feedstock will drive growth in oil use. However, the pattern will change: oil demand will plateau from around 2030 through 2035, before starting to decline thereafter. This trend is mainly attributed to efficiency improvement in the transport sector and policy actions aimed at greater penetration of EVs, natural gas vehicles (NGVs) and hydrogen fuel cell vehicles. Oil demand in the power generation sector will also continue its long-term decline. These bearish drivers will outweigh continued oil consumption growth in petrochemical manufacturing.

Still, the oil demand outlook differs widely by region and country. Developing markets including India, Southeast Asia and Africa will propel growth, while the US, EU, Japan and South Korea will lead the decline. China will become the world's largest oil consumer in the first half of the 2030s, taking over from the US, and will retain its leading position over the outlook horizon.

Coal demand outlook reflects the world's resolve to combat climate change. Coal use is enjoying a temporary revival in some regions due to soaring natural gas prices and energy security concerns. Nevertheless, the structural decline will return as energy markets stabilise, while efforts to reduce emissions and improve air quality intensify. Global coal demand will drop to 2,235 Mtoe by 2050, a 42% decline from 2021. The most pronounced contraction will be in power generation and industry, driven by natural gas-supportive fuel-switching policy and renewables scale-up. However, coal will remain important for several industrial processes, particularly in iron, steel and cement production, where opportunities for substitution are more limited.

Coal will encounter a more mixed outlook at the regional and country level. China will dominate the decline in demand, compounded by sizeable weakening in the US, Japan, South Korea, Germany, and South Africa. In contrast, Indian coal use will jump due to growing electricity demand. Affordability and energy security concerns suggest this fuel will remain critical throughout South and Southeast Asia.

Figure 2.3. Global primary energy demand trends by fuel type (Mtoe)



Source: GECF Secretariat based on data from the GECF GGM

Nuclear energy will rise by 36% to 980 Mtoe in 2050. As a response to the current crisis, many historical users support lifetime extensions of operating fleets and consider this fuel as a viable option to provide reliable and carbon-free electricity. Particularly, the EU has included nuclear power in its Taxonomy Regulation, while South Korea has reversed its phase-out plans. Japan is working to bring its fleet of reactors back online. Several countries, such as Egypt, Bangladesh, Saudi Arabia, Türkiye, and Poland are planning to pivot towards nuclear power.

At the same time, a number of factors will hinder stronger nuclear power growth. These include rising capital costs and long construction lead times due to increased safety concerns, as well as nuclear waste treatment and storage issues. There is a growing interest in small modular reactors, but this technology is still maturing. North America and Europe will see declines in demand amid decommissioning of aging capacities, while the centre of gravity shifts towards the Asia Pacific region. Ambitious Chinese and Indian nuclear programmes will lead regional developments, while China is on track to become the nuclear power leader by the early 2030s.

Hydropower demand is forecast to rise by 35% to 495 Mtoe by 2050. Growth will be less promising than its global potential as environmental concerns associated with the protection of biodiversity and climate change, along with high construction costs, constrain development. Climate-related events, such as unpredictable rainfall patterns, which are increasingly reducing the availability of water resources in many regions, also raise questions about its resilience.

However, rising electricity demand will ensure that hydropower projects continue to attract interest. Large-scale hydropower developments, such as conventional reservoirs, will be prioritised. Pumped hydro, a mature storage technology, is also set to increase, becoming more important for providing flexibility. The Asia Pacific region (particularly China, India, Pakistan, and Indonesia) will be the largest contributors. China, which has been investing heavily in hydropower capacity, will drive this growth, remaining world's leading producer of hydroelectricity. Hydropower will also grow in Latin America (Brazil, Venezuela, and Paraguay) and several sub-Saharan Africa countries.

Global renewables energy demand (solar, wind, geothermal, and tidal) will surge by over 650% to 2,985 Mtoe by 2050. Solar PV, along with onshore and offshore wind installations, will gain traction in many regions as countries plan to devote significant resources to meet increasingly ambitious renewables targets. Supportive policies encouraging carbon neutrality and measures to expand and modernise power grids will be key drivers.

Yet, large renewables scale-up elevates both the challenge of intermittency management and the requirement for back-up generation such as natural gas-fired power plants and energy storage. Longer term, further diffusion of renewables will be, to some extent, isolated from political swings due to continued cost reduction, technological advancement, and the development of supply chain for critical minerals. From a country perspective, the growth in renewable energy demand will embrace all markets, led primarily by China, India, and the US.

Bioenergy demand, including traditional and modern biomass, will grow by 59% to 2,210 Mtoe by 2050. Advanced use of biomass (such as modern solid bioenergy, biofuels, and biogases) will drive the increase. It will double to about 1,570 Mtoe by 2050, pushed by decarbonisation policies and, to some extent, energy security goals. Power generation, including biomass co-firing in thermal power plants, will be the main contributor, although residential and transport demand will also demonstrate noticeable increases.

Particularly, the use of biofuels in road transport will develop amid wider adoption of blending requirements, while it is also viewed a promising option for aviation due to limited availability of alternatives. Given currently high natural gas prices, biomethane is gaining attention as well. Ambitious production targets are increasingly evident, especially in the EU. Overall, demand for modern biomass will grow in many markets, with China, India, the US, and European countries in the lead.

Demand for traditional biomass, which currently accounts for around 45% of total bioenergy demand, will remain broadly stable over the outlook period, albeit with

regional variations. The traditional biomass use will fall in China and India driven by national programmes to improve air quality by eliminating polluting cooking and heating fuels.

However, this will be offset by rising demand in sub-Saharan Africa amid growing populations and limited progress on universal access to clean cooking. In the RCS, traditional forms of biomass remain elevated in the region, constituting over 60% of residential energy demand in 2050. This represents additional potential for clean energy sources, including natural gas, to meet energy needs while helping to eradicate energy poverty, alleviate the adverse impacts of indoor pollution, and reduce deforestation.

## 2.2 Natural gas demand outlook: global overview and sectoral trends

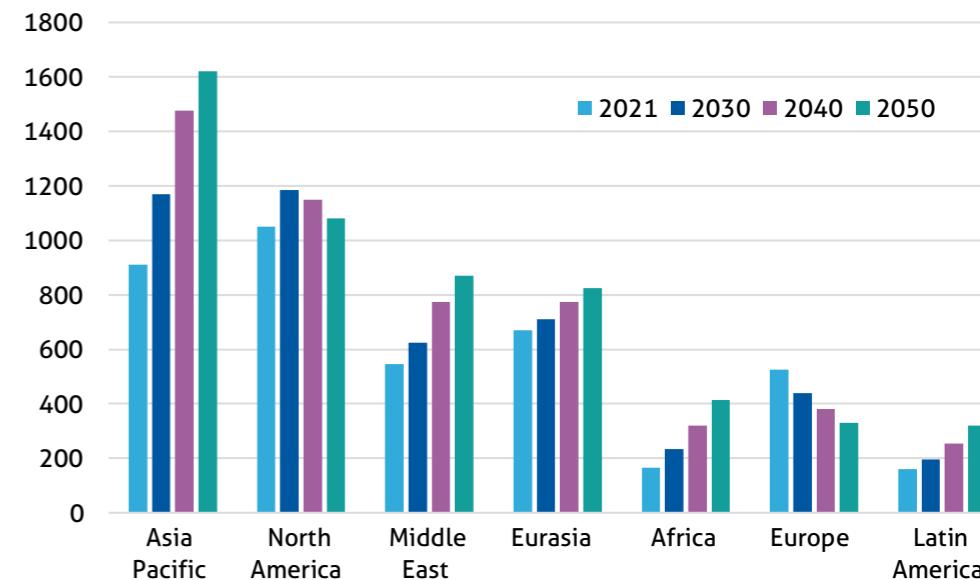
### Global overview

Natural gas demand is projected to increase by 1,435 bcm by 2050 – 36% higher than the 2021 level, with no peaking expected. Sustained demand growth in Asia Pacific, Middle Eastern, and African countries is underpinned by rising population, urbanisation and economic activity. In addition, an increase in electricity demand and policies aimed at air quality improvements, and coal- and oil-to-gas switching are key drivers. Proven technology, such as CCS/CCUS, will lower the carbon footprint of natural gas use in power and industry. Blue hydrogen is also an important pathway toward decarbonisation.

Nevertheless, looking at the long-term trend, natural gas demand growth will slow after 2035. The US is committed to achieving carbon neutrality by mid-century, while Europe's REPowerEU plan is already expected to negatively impact natural gas demand much sooner. Increased policy support for renewables and alternative decarbonisation options, such as pervasive electrification and energy efficiency, along with biomethane and green hydrogen deployment, will be central to this effort.

**Asia Pacific** will represent the largest growth engine of natural gas demand, contributing to half of the global net demand increase during the outlook period. Goals for air quality improvement and greenhouse emissions, as well as the focus on cutting coal dependence, will remain key priorities. In this context, natural gas is set to play a frontline role, whilst driving the energy transition strategy for the majority of countries in this region. Gas consumption will grow by 78% to 1,620 bcm by 2050 and will expand across all sectors, supported by surging electricity needs, broader economic and population dynamics, policy measures encouraging coal- and oil-to-gas switching, extensive gas infrastructure buildout, and efforts to liberalise gas markets. China, India and Southeast Asia will be the primary growth centres.

Figure 2.4. Global natural gas demand trends by region (bcm)



Source: GECF Secretariat based on data from the GECF GGM

In **North America**, gas demand will continue to increase this decade before reaching a plateau in the early 2030s and declining thereafter to 1,080 bcm in 2050, remaining almost unchanged, compared to the 2021 level. However, changes in countries' consumption trajectories are meaningful. Mexico will lead gas demand growth, driven by significant expansion of gas-fired power capacity. Conversely, demand in the US will peak and contract after 2030 as the anticipated boom in decarbonisation technologies, spurred by the Inflation Reduction Act, will have an impact. Still, natural gas is well protected and forecast to maintain a strong position in the US energy mix. An additional push for gas use in North America will originate in the transport sector and blue hydrogen generation.

The **Middle East** is the second-largest contributor to global gas demand growth, responsible for around 23% of incremental volumes. Demand in the region will rise by 60% to 870 bcm by 2050. Growing availability of domestic gas supply for both the power and industrial sectors, along with the scope to displace oil products use, will be the key factors. In addition, the region will see a strong renewables deployment drive in power systems that will both augment gas availability and support economic diversification. Blue hydrogen generation will be a promising area, underpinned by countries' plans to develop export markets, while state funding and state-owned companies are already engaged in hydrogen projects, built on natural gas capacity.

In **Eurasia**, gas demand will rise by 23% to 825 bcm by 2050. Stronger growth in gas use will be constrained due to huge energy saving potential, especially in power and heat generation sectors, although growing household gas connections and the expansion of gas-to-chemicals, petrochemicals and non-metallic minerals production will balance increased fuel efficiency. Incremental gas demand will also come from the development of NGV markets, supported by low gas prices and active promotion of this fuel. Blue hydrogen generation will be an additional vector for increased gas use. Russia will lead due to strategic initiatives to export and consume low-carbon hydrogen in various spheres of the economy.

Natural gas demand in **Africa** will expand by 152% to 415 bcm by 2050, driven by accelerated economic activity and a rising urban population, accompanied by an unprecedented increase in electricity demand. The upbeat outlook for indigenous production offers significant prospects for domestic use. Natural gas has already reached a high share of the energy mix in mature North African markets. Conversely, in sub-Saharan Africa, gas accounts for just 5% today, but it will make remarkable progress due to the push for industrial and social development. The power generation sector will lead, given significant scope for natural gas to displace oil-fired generation, constrain the expansion of coal-fired capacity, and bridge the substantial power deficit. The GGO features a special focus on Africa (Chapter 6), providing a detailed view on the region's gas demand dynamics.

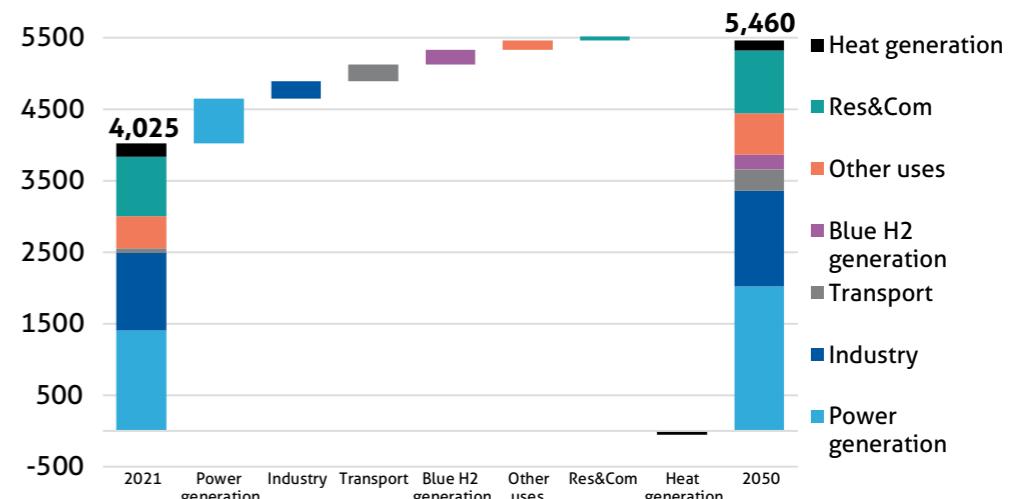
In **Europe**, natural gas demand will drop by 37% to 330 bcm by 2050, driven by REPowerEU plan implementation. Decarbonisation efforts through energy efficiency gains, electrification, renewables advancement, and the scaling up of green hydrogen will gather pace, resulting in considerable gas demand contraction. The transport sector and blue hydrogen generation will present the best growth potential, partially offsetting drops in other sectors. Blue hydrogen will be attractive, especially in the early phase of low-carbon hydrogen uptake due to the maturity of the technology, lower cost, and synergy with natural gas infrastructure. In addition, natural gas paired with CCS/CCUS, both in power generation and industry, will become an important solution in the region.

Gas demand in **Latin America** will double to 320 bcm by 2050. Countries' strategies to exploit domestic gas resources, infrastructure development, and government policies promoting gas in power generation, industry and road transport will be key drivers. Full-fledged gas integration in the region will be challenging due to the lack of pipeline connections, therefore LNG imports will become critical for meeting energy needs and building a more sustainable energy system. Gas-fired generation development, including based on LNG, will gain momentum as a part to displace oil-fired generation and reduce dependence on currently indispensable hydropower. However, gas use will fluctuate over the outlook horizon rising in dry seasons and declining during months with greater rainfall.

### Sectoral trends

The power generation sector will represent the primary area of natural gas demand expansion, accounting for 43% of additional volumes consumed between 2021 and 2050. The industrial sector will come in second, accounting for 17% of the total growth. There will be new avenues for natural gas demand, particularly through growing use as a source for blue hydrogen generation, along with greater penetration as a bunker fuel. The transport sector (including road and marine transport) will emerge as an important demand centre given stricter environmental regulations and supportive policies.

**Figure 2.5. Global natural gas demand trends by sector (bcm)**



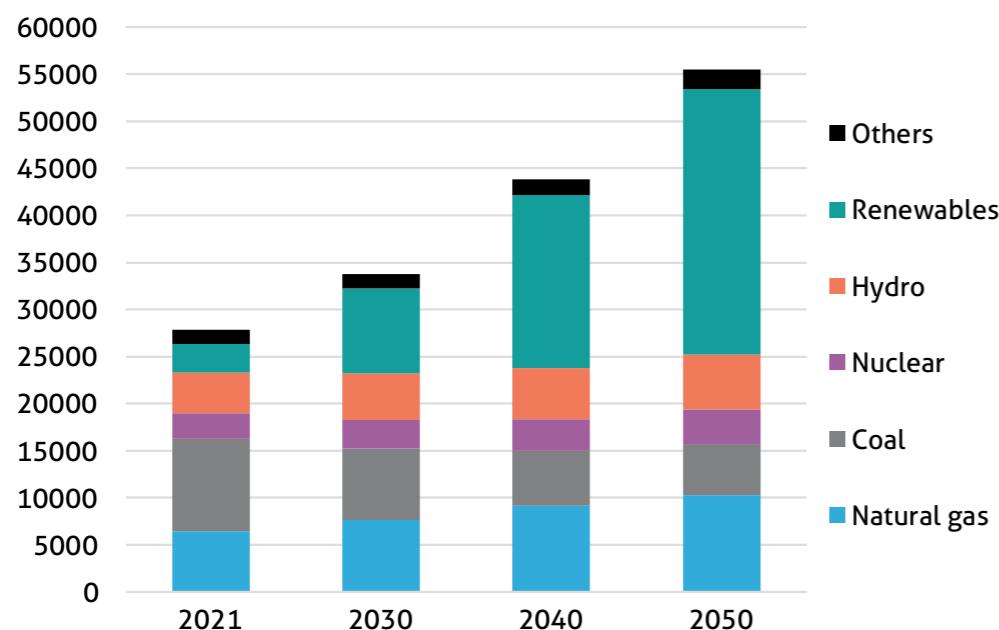
Source: GECF Secretariat based on data from the GECF GGM

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

In the **power generation** sector, natural gas demand will increase by 620 bcm, or 44%, reaching 2,025 bcm in 2050. This is underpinned by strong growth in electricity needs and policies to phase down coal-fired capacity. At the regional level, Asia Pacific and Africa will lead in power sector demand expansion, although the Middle East and Latin America will also see sizeable increases. In North America, gas in power is expected to retain a considerable role but will begin declining in the mid-2030s due to strong renewables growth. Europe will be the only region to encounter declining gas use in power over the entire outlook period. Short-term energy security leads to a temporary delay in the scheduled closure of some coal-fired and nuclear power plants, while long-term pressure will intensify from renewables in line with REPowerEU targets.

Global electricity generation is projected to double from 27,820 TWh in 2021 to 55,500 TWh in 2050, stemming from greater electrification of end-use sectors (led by the residential segment and industrial sector) and rising green hydrogen production. Renewables are set to become the dominant source of electricity worldwide, with their share advancing from 11% in 2021 to over 50% in 2050. Consequently, coal will lose the most ground. It will decline to 10% in 2050 from 35% in 2021 as governments fulfil their announced phase-out pledges. The shares of nuclear and hydro will also decline, despite rising output in absolute terms, and will provide 7% and 10% of the global generation mix, respectively, in 2050.

**Figure 2.6. Global electricity generation growth (TWh)**



Source: GECF Secretariat based on data from the GECF GGM

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

Gas-fired power generation will maintain its current share of 23% over this decade, overtaking coal by around 2030. But it will fall to about 19% by 2050 as solar PV and wind shares rise. Growing electricity needs and the limitations of renewables intermittency will drive demand for greater power system flexibility. Storage technologies, such as batteries, along with demand-side response, will cover that role to some extent. But they are unlikely to offer seasonal and long-duration storage. In this context, low-emission generating capacity is expected to remain the bedrock of flexibility, with natural gas-fired generation serving as a critical source of power supply stability and security in many countries.

Natural gas demand in **industry** will rise by 250 bcm, or 23%, by 2050, led primarily by Asia Pacific, Middle Eastern and Eurasian markets. Gas will be used increasingly to provide heat and steam across energy-intensive industries, retaining its place as the key fuel suited for medium- and high-temperature processes. This includes chemical and petrochemical production, non-metallic minerals, and a broad range of light manufacturing. Strengthening policies intended to curb emissions will augment traditional drivers such as developing country industrialisation and population growth. This will favour oil- and coal-to-gas switching, primarily in China and India. Moreover, industrial demand will rise for non-energy uses, underpinned primarily by the need for fertilisers, which will contribute to agricultural sector productivity and food security.

There will be strong incentive to decarbonise assets through the adoption of new technologies at scale and on a cost-competitive basis. Many natural gas-consuming industries will use CCS/CCUS. Primary applications will emerge in hard-to-decarbonise industries such as steel, cement, glass, and fertiliser, while deployment at a much greater scale will be in industrial clusters.

In the **transport** sector, gas demand is forecast to rise by 233 bcm, or almost 350%, to around 300 bcm by 2050, predominantly in the form of LNG as bunker fuel and in heavy goods vehicles (HGV). Stricter environmental regulations and air pollution reduction targets will be key drivers. Road transport will account for most of gas demand growth in this sector, rising by over 150 bcm between 2021 and 2050. Mature CNG and LNG technologies may represent a longer-term bridge to more sustainable and decarbonised mobility. Favourable government policies, regulatory frameworks and the expansion of refuelling infrastructure will be the driving forces, encouraging higher NGV uptake. Asia Pacific will lead demand growth in road transport, followed by Eurasian countries.

LNG in marine transport presents an important opportunity for natural gas penetration. Many of alternative fuels, such as hydrogen and ammonia, are in a nascent stage of development and have commercial and technical limitations. But LNG is in a good position to comply with requirements for reduction in the major emissions types, improve air quality, and offer enhanced competitiveness given existing gas infrastructure and supply chains. Introduction of the International Maritime Organization's (IMO) global cap of 0.5% sulphur content has already accelerated the adoption of LNG. Simultaneously, the shipping industry is increasingly focused on meeting the IMO's 2030 and 2050 targets, and switching to LNG appears as a viable option for shipping decarbonisation. Rising orders for LNG-powered vessels will sustain high expectations in terms of fuel use globally.

**Blue hydrogen generation** will be another major avenue for gas demand expansion given countries' efforts to scale up deployment of low-carbon hydrogen in energy

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systems. Gas demand in this sector is forecast to grow by 205 bcm between 2021 and 2050. Middle Eastern and European countries will be responsible for more than 55% of the total increase. Growth opportunities will originate from development of an internationally traded hydrogen market, while substitution of grey hydrogen with blue hydrogen in existing industrial applications will also materialise. Commercialisation of CCS/CCUS and development of a corresponding full-scale value chain will further support the economics of blue hydrogen.

In the **residential and commercial** sector, gas demand will rise by 50 bcm, or 6%, by 2050. Increased gas use will be less significant compared to other consuming areas, as electricity will fuel much of the additional household and commercial space energy demand. Energy efficiency improvements, building retrofits and alternative heating options, such as biomethane, hydrogen, or renewables, will further limit the scope for gas to develop. A structural decline will materialise in Europe, but it will be offset by growth in other regions, primarily in the Asia Pacific region, amid switching away from coal and city gas distribution development.



## 03

### Natural Gas Supply Outlook

## Key findings:

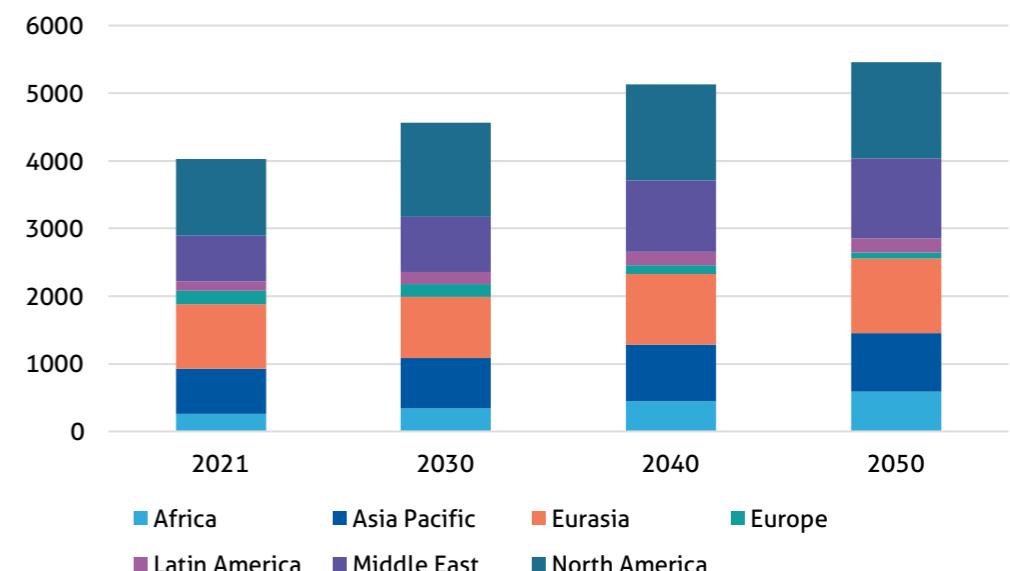
- Global natural gas production is expected to expand from 4,025 bcm in 2021 to 5,460 bcm in 2050, corresponding to an increase of almost 36% over the period and an average growth rate of 1.1% per annum.
- The Middle East will contribute the largest growth share, accounting for more than one-third of the total, followed by Africa and North America.
- Almost all regions expand their production over the outlook period except Europe, which is expected to show around 57% decline.
- Africa is the only region where gas production more than doubles, from 260 bcm in 2021 to 585 bcm in 2050.
- Gas production in the Asia Pacific region will expand by almost 30% to reach around 870 bcm by 2050. However, the region's share of global natural gas supply will slightly decline from 17% in 2021 to 16% in 2050.
- Around 74% of annual production by 2050 will be sourced by sanctioned and new projects as well as by developing yet to find (YTF) resources.
- YTF resources will contribute to around 27% of total production by 2050. This suggests that the current proven reserves are not sufficient to accommodate rising demand and that exploration projects and new discoveries are crucial.
- Associated gas output will decline from more than 430 bcm in 2021 to around 350 bcm by 2050, contributing to about 9% of total conventional gas production.
- Offshore production will grow by around 2.3% per annum on average, adding more than 1.1 tcm, mostly from deepwater. By contrast, onshore output will reach a turning point around 2030 and decline to around 3.15 tcm by 2050.
- Almost 30% of total gas production will be sourced by unconventional production by 2050, with the shale gas leading the way at 14% of total output.
- The Outlook expects the GECF share of gas production to slightly decline from 43% to 41% by 2030 due to expansion in non-GECF countries. However, its share will rebound to 46% by 2050 due to growth among many GECF countries.

## 03 Natural Gas Supply Outlook

### 3.1 Global natural gas production outlook

Global natural gas production will continue to rise by 1.1% annually from 4,025 bcm in 2021 to 5,460 bcm in 2050, a total of almost 36%. The Middle East will contribute the largest growth share, accounting for more than one-third of the total, followed by Africa and North America. Advancement in upstream sectors, such as technological enhancement in deepwater production and progress in natural gas supply chain infrastructure, will stimulate the expansion of supply needed to meet growing demand.

Figure 3.1. Global natural gas production outlook by region (bcm)



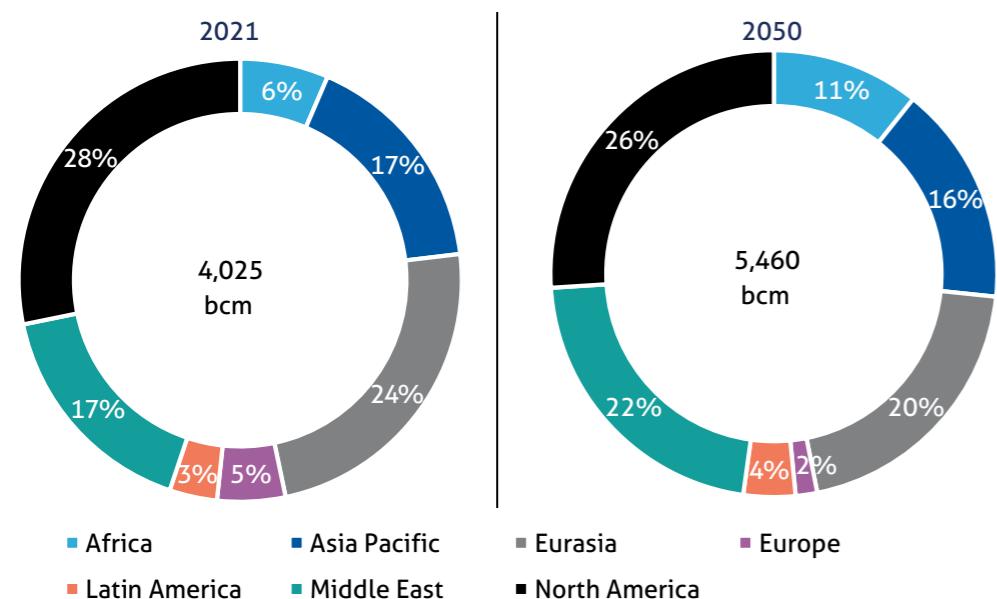
Source: GECF Secretariat based on data from the GECF GGM

North America, the world's largest gas producer, will maintain its position until the end of the outlook horizon. However, the region's share will decline from 28% in 2021 to 26% in 2050. The Middle East will become the world's second-largest natural gas producer, supplying almost 22% of natural gas globally by 2050, compared to 17% now. Eurasia is the second-largest regional natural gas producer, the source of nearly a quarter of global output. Its share will decline to 20%, and it will become the third-largest producer by 2050.

Africa will be responsible for the second-largest volumetric growth, gaining more than 11% share of global gas supply by 2050, compared with slightly more than

6% in 2021. Europe is still expected to be the only region in which natural gas production is forecast to fall in the long term.

**Figure 3.2. Regional share in global natural gas production**



Source: GECF Secretariat based on data from the GECF GGM

### 3.2 Regional natural gas production outlook

#### Africa

Africa is expected to contribute substantially to global gas supply given its massive onshore and offshore reserves on both the continental shelf and in deepwater. However, most of these resources have not yet been developed due to a lack of investment, transport and export infrastructure, along with technological issues in deepwater exploration technology and inadequate pipeline network. Still, the outlook is promising. This is the only region where gas production growth will more than double, from 260 bcm in 2021 to 585 bcm in 2050. This 125% jump is the equivalent of 2.8% annual growth.

Given the important role natural gas will play in the continent, we have dedicated a chapter and scenario in this Outlook to focus on Africa.

#### Asia Pacific

In contrast to its role as a global demand centre, gas exploration and production in the Asia Pacific region is mature. But it will be an area of massive expansion.

Countries will work to expand their gas output to meet as much demand as possible. However, prospects for production growth in most countries are limited.

China is one exception, where output is expected to more than double by 2050 in an effort to limit the need for growing imports. Annual regional production growth will reach only 0.9%, similar to our previous forecast of 1.0%. Other exceptions include Australia, one of the largest LNG exporters, and other traditional gas exporters like Indonesia and Malaysia.

However, even these countries are not expected to increase their exports significantly over the long term, though production may grow. China will be responsible for almost 71% of incremental Asia Pacific production, followed by Australia, which is forecast to deliver a 7% share, while Vietnam, India, and Indonesia are among the other countries expected to increase gas output over the long term.

Australia, Malaysia, Indonesia, Papua New Guinea (PNG), Myanmar and Brunei will work to maintain production to retain or strengthen their exporter roles. However, only Australia and Indonesia are expected to increase their natural gas output. And in the case of other countries in this group, incremental gas will mostly feed domestic demand. As a result, the increased output is not expected to impact exports over the outlook period.

China, India and Vietnam are among the countries chasing domestic demand with growing gas production. They will not be exporters, but their output growth is meaningful. These countries will contribute around 17.5% of global natural gas supply growth over the forecast period. China alone will be responsible for an estimated 15% of the global gas supply output change.

Pakistan, Thailand, Bangladesh, and the Philippines are existing gas importers that will encounter declining gas production and growing import requirements.

Japan, Singapore, and South Korea are meaningful gas importers with little or no domestic output and equally constrained prospects for changes to their production profiles.

#### Eurasia

Eurasia is the second largest gas producer after North America. In 2021, the region produced almost 950 bcm, which accounted for 24% of global output. This is almost 100 bcm more than in 2020, which registered a 22% share. The region is expected to add more than 155 bcm to its current production by 2050, driven by Russia, which will contribute more than 59% of this growth. Eurasian gas production is expected to increase by around 0.5% annually by 2050.

Eurasia is the only region where the declining output will rise again after 2030, driven by Russia. In the longer term, Russia, Turkmenistan, Kazakhstan and Azerbaijan will increase output.

#### **Europe**

Europe is the second smallest natural gas producer region after Latin America, accounting for only 5% of global output. However, the Outlook forecasts that Europe will be the smallest producing region by 2050. The significant decline is expected to reach 2.9% annually to 85 bcm over the forecast period, lowering the region's share of production to only 2%.

In 2021, the gas output in Europe continued its decade-long trend, declining by almost 8 bcm from 2020. This was evident in almost all major European producers, including Norway, the UK and the Netherlands.

The Outlook expects a regional production rebound in 2022 following curtailment of the Russian gas supply, with Norway taking on a more expansive role as it limits maintenance.

#### **Latin America**

Latin America contributed 3% of global gas production in 2021, the smallest regional share. The region's output is expected to reach 205 bcm by 2050, a 65 bcm increase over 2021.

The region holds various types of gas resources, including conventional, shale and tight gas, along with coalbed methane. Yet, much of this resource base, particularly unconventional gas, has not been meaningfully developed—with the Argentinean Vaca Muerta a key exception.

But the region can potentially enhance both associated and non-associated production. We expect that associated gas will constitute around 20% of incremental output over the outlook horizon, 80% of which will be extracted from the Brazilian pre-salt.

Major field development will drive the region's gas production over the longer term. However, effective asset development requires the expansion of pipeline networks and transmission infrastructure, along with improvement in both policy and market conditions. We expect that regional gas output will grow by 46% by 2050, or 1.3% annually.

#### **Middle East**

The Middle East is the world's third-largest gas-producing region, accounting for almost 17% of global output. Annual production has been growing at a rapid 6%,

jumping from 190 bcm in 2000 to 670 bcm in 2021. By comparison, Asia Pacific and African production grew by only 4.1% and 3.7%, respectively over that period.

Iran, Qatar, and Saudi Arabia, supply slightly less than 78% of the total output in the region. These three countries will remain production hotspots through 2050, with Qatar delivering 2.6% annual growth—the fastest of the three countries. Gas production in Iran and Saudi Arabia will grow by 2.1% and 1.5%, respectively, on an annual basis over the long term. Their share of regional production will reach almost 82%, while accounting for 18% of the world's gas output.

This Outlook expects regional production to grow by 140 bcm by 2030. This will represent around 24% of global growth, driven by Qatar's North Field expansion projects, along with Iran, UAE and Saudi Arabia increases as well. But longer-term growth will be even more substantial. Output will jump by 520 bcm to 1,190 bcm by 2050. Share of global output will reach 22%, while the region will account for more than 33% of global growth.

#### **North America**

North America is the world's leading natural gas play, given its mammoth, 15 tcm reserve base, competitive production costs, high demand, extensive gas network, and more recently, expansion of export facilities. It has managed to expand output despite lower investment, backed by high demand and export developments. All three countries will deliver increased gas output, with production growing by 285 bcm to reach 1,420 bcm by 2050.

The region produced 1,135 bcm in 2021, accounting for 28% of the global output. Roughly half was sourced from the Marcellus, Permian, and Haynesville Basins in the US and the Montney basin in Canada. The Marcellus shale formation in the northeastern US alone supplied almost 250 bcm. Production has grown by 365 bcm, or 3.6% annually, since 2010, the most rapid growth among regions globally. Unconventional gas production development has been at the centre of this growth.

North America is forecast to grow more rapidly than other regions, adding 230 bcm by 2030 and accounting for almost half of global growth. The production increase will be front-loaded this decade, accounting for 64% of growth to 2050. Part of this expansion is the result of near term European gas needs, as well as requirements from other importing regions.

The regional output will grow by only 50 bcm from 2031-50, a much slower pace than the previous decade. Lower internal natural gas demand growth and reduced demand from export markets such as Europe will play a role as decarbonisation policies are implemented.

### 3.3 Outlook for the changing profile of gas production resources

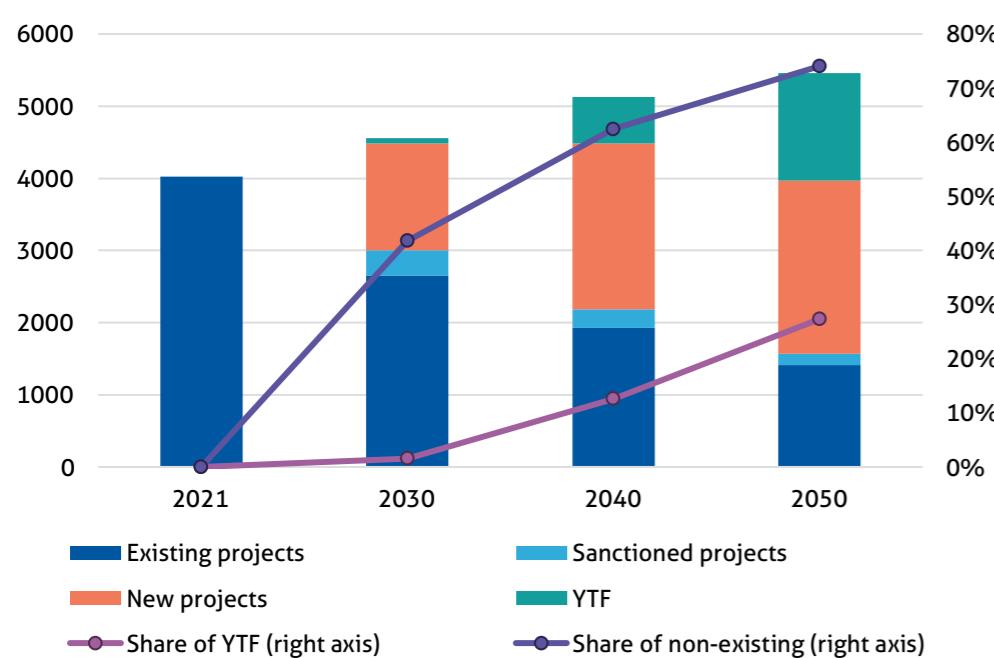
#### Production from YTF resources and new projects

YTF resources will play a promising role in meeting the rising demand for natural gas over the forecast period. In this Outlook, the production from YTF resources is distinctly projected along with the volume of output from existing, sanctioned and new projects.

Base year gas production is sourced from **existing projects**. Typically, this production category declines over the outlook period in line with maturing field evolution, and other projects will be called upon to offset this output loss. **Sanctioned projects**, or projects approved to move forward either during or before 2021, will be important in this regard –launching in the short term and enjoying longer lives than existing projects. **New projects**, which have yet to be sanctioned, will be critical for optionality as the market environment warrants.

YTF resources will contribute around 27% of total production by 2050, implying that the current proven reserve level is insufficient to supply rising demand. The Eurasian, Asia Pacific and African regions are expected to contribute more than 75% of production from YTF conventional resources.

**Figure 3.3. Global natural gas production by project status (bcm, %)**



Source: GECF Secretariat based on data from the GECF GGM 2020

We expect that 74% of production expected by 2050 will be sourced from non-existing projects. This considerable share highlights the importance of investment along the natural gas supply value chain, particularly upstream.

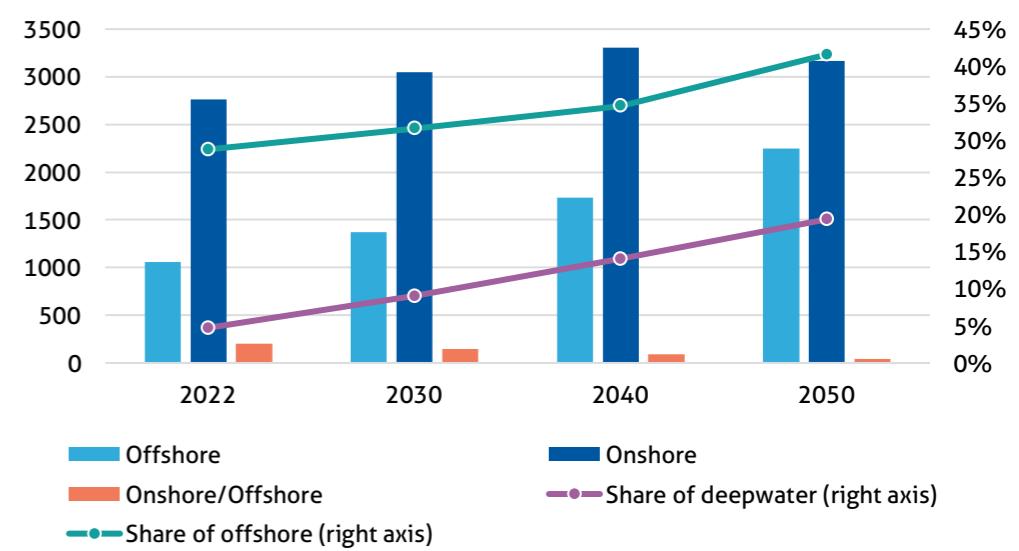
#### Offshore and onshore production

Roughly 85% of offshore production has been on the continental shelf. Advancements in technology used in upstream activities, communication, process, operation control, on-site power generation and logistical support have supported growth. Expectations for additional technological gains will drive even further production increases over the outlook period. Deepwater sources are poised to benefit.

An estimated 26 tcm of proven reserves are located offshore in deepwater areas, of which approximately 4 tcm have been explored. Additional sanctioned projects will target another 2.5 tcm. Much of the remaining deepwater gas reserves are forecast to be developed by sanctioning new projects.

Significant YTF reserves are estimated to reside in deepwater locations in remote areas that remain untouched. Deepwater YTF gas resources are estimated at around 80 tcm. Technology solutions, including advanced discovery methods, floating platforms and information technology, will aid in unlocking this potential.

**Figure 3.4. Global natural gas production by project location (bcm, %)**



Source: GECF Secretariat based on data from the GECF GGM 2020

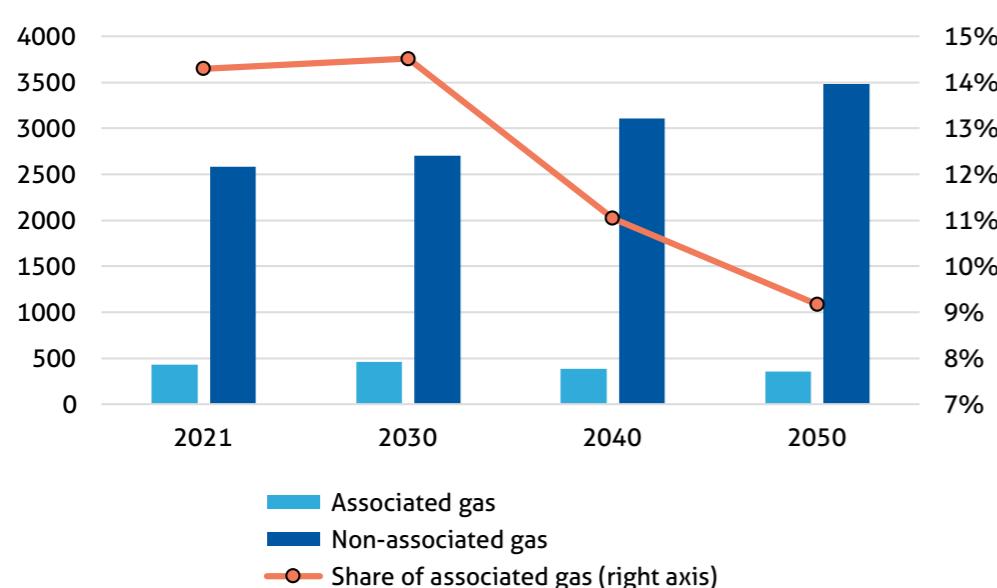
Almost 30% of global gas production is currently sourced from offshore resources. Deepwater production accounts for almost 5% (or 16% of total offshore production).

Offshore production will grow by around 2.3% annually, adding more than 1.1 tcm — mostly from deepwater. By contrast, onshore output will reach a turning point around 2030, reaching almost 3.15 tcm by 2050. Deepwater production is forecast to gain 860 bcm to achieve slightly less than 20% share of global output. By 2050, almost 47% of offshore production will be sourced from deepwater fields.

#### Outlook for associated gas production

Associated natural gas has always been a considerable share of total gas production, especially when crude oil production is rising. Technological advancements and other infrastructural developments have enabled projects to utilise associated gas rather than flaring it. However, flaring is still a challenge with remote projects where the collection and initial gas treatment are not economical. Associated gas can be found as free gas or in solution with crude oil (referred to as dissolved gas). Almost 430 bcm of gas output is sourced from associated gas, excluding volumes from unconventional crude oil production.

**Figure 3.5. Conventional gas production from associated and non-associated gas (bcm, %)**



Source: GECF Secretariat based on data from the GECF GGM 2020

COVID-19 negatively impacted associated gas production over the last two years (2020 and 2021). However, recovery, along with the tight market for fossil fuels, is expected to drive the upstream project activity and a medium term increase in associated gas production. Almost 14% of the conventional gas production was associated gas in 2021. This share is expected to increase to 15% by 2030 due to increased upstream

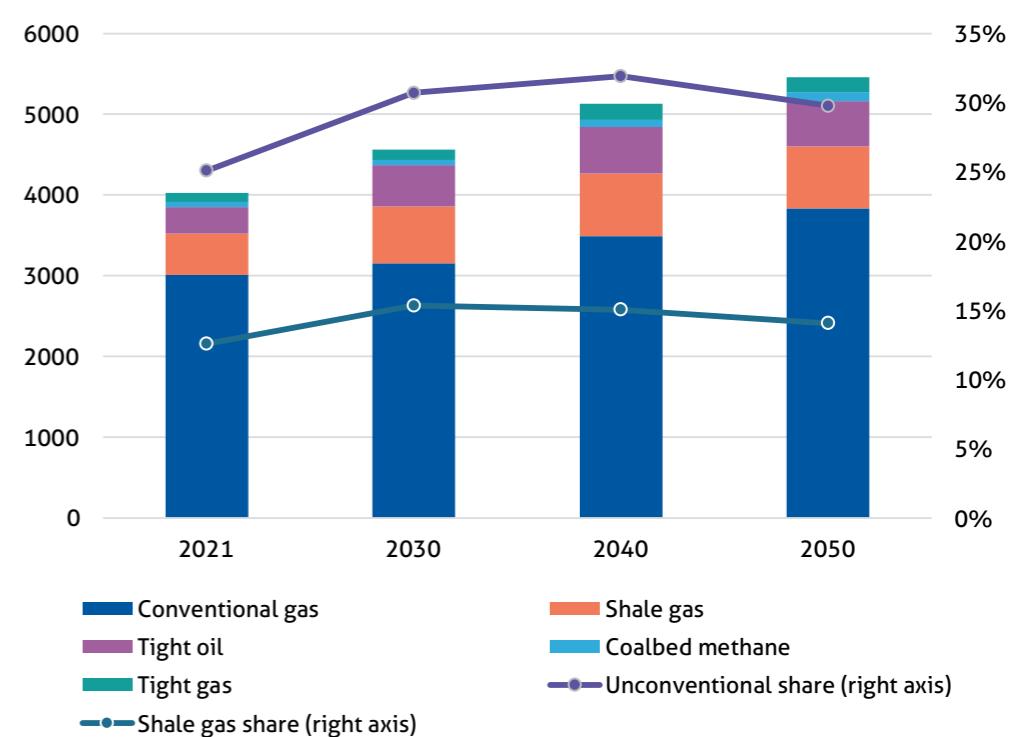
oil activities and efforts to avoid gas flaring. After 2030, the associated gas production is forecast to decrease due to decarbonisation pledges that stabilise or reduce oil production and consequently impact associated gas volumes.

The Outlook forecast that associated gas output will decline to around 350 bcm, contributing to about 9% of total conventional gas production by 2050. Russia, Saudi Arabia, the US, Brazil, Nigeria, UAE, Venezuela, Mexico, Indonesia and Kazakhstan are the primary contributors.

#### Unconventional gas production outlook

Unconventional resources, particularly shale gas output, have already benefited from advancements in drilling cost reduction and fracturing technologies, among processes to control climate impacts across the value chain. This supports unconventional gas growth over the longer term.

**Figure 3.6 Global conventional and unconventional gas production (bcm, %)**



Source: GECF Secretariat based on data from the GECF GGM

More than 80% of global unconventional gas production is sourced from North America, of which almost 86% originates in the US. Canada is also prospective for unconventional resources mainly from shale gas plays. North American share

is forecast to decline to 70% by 2050 as other regions, including the Middle East, expand their production from unconventional resources.

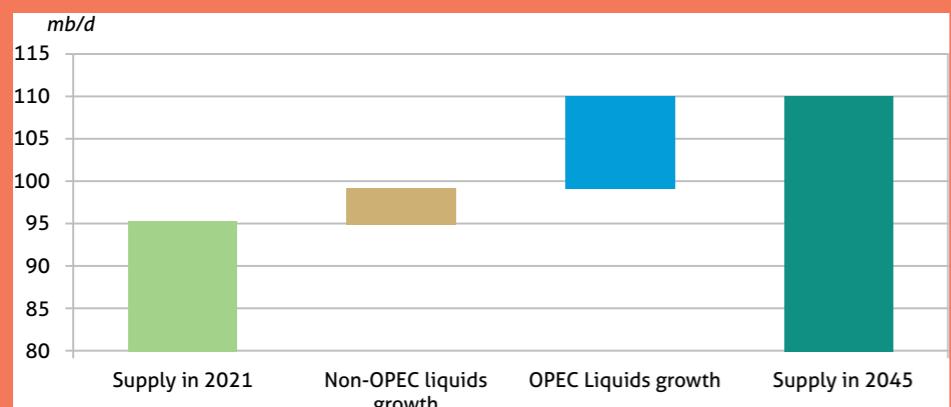
Asia Pacific is the second-largest unconventional gas region, driven primarily by China and Australia. Output includes shale gas and coalbed methane, respectively. Chinese unconventional output is expected to add an additional 200 bcm by 2050.

#### BOX 3.1 Global liquids supply: Steady growth ahead

(Prepared by the Organization of the Petroleum Exporting Countries (OPEC) Secretariat)

Global liquids supply (including crude oil and non-crude liquids) is projected to grow in line with future oil demand, rising from 95 mb/d in 2021, to around 110 mb/d in 2045. Of this, OPEC's share is anticipated to rise from 33% in 2021 to 39% by 2045. This comes largely as a result of non-OPEC's projected peak in supply at just over 72 mb/d by 2030, as US supply reaches its zenith.

Figure 3.7. Composition of global liquids supply growth, 2021-2045



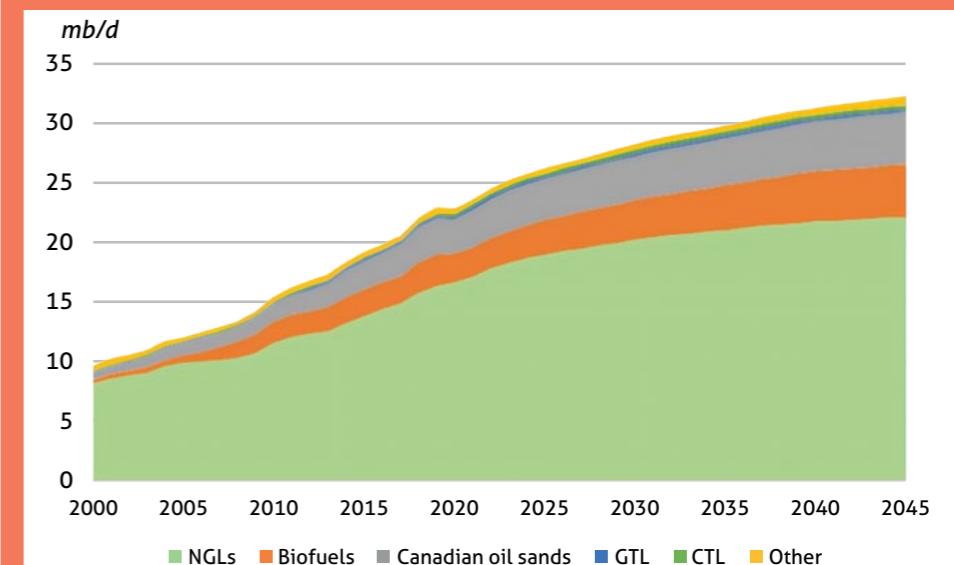
Source: OPEC World Oil Outlook (WOO 2022)

But even while crude production in non-OPEC countries declines from the late 2020s, supply of other types of liquids continues to rise. So-called non-crude liquids have emerged as a pivotal complement to crude oil in recent decades. From a mere 6% share of total liquids in 1980, they grew to 12% in 2000, and to 24%, or 23 million barrels a day (mb/d) out of a global liquids supply of 95.2 mb/d by 2021.

Encompassing natural gas liquids (NGLs), fuel ethanol and biodiesel, gas-to-liquids (GTLs), coal-to-liquids (CTLs), refinery additives, extra-heavy oil and kerogen, the growth momentum of different non-crude liquids has been mainly supported by favourable government policies. In the case of NGLs, they emerged essentially as a by-product of expanding natural gas supply.

The contribution of non-crude liquids towards the global oil market is set to continue its rise, with projections in OPEC's World Oil Outlook (WOO 2022) seeing volumes increase to nearly 32 mb/d, or 30% of global liquids supply by 2045.

Figure 3.8. Global non-crude liquids supply



Source: OPEC World Oil Outlook (WOO 2022)

NGLs, which make up the largest share of non-crude liquids, have benefited from steady natural gas production growth since the early days of the century. NGLs supply has increased by slightly less than 3.6% per annum on average at the global level from 2000 to 2021. Consequently, supply has more than doubled from 8.1 mb/d to nearly 17 mb/d in 2021. This significant jump is heavily supported by both energy-related and environmental policies favouring gas over coal, along with rising demand for natural gas in the petrochemical sector.

Geographically, significant NGLs growth has recently been driven by the increasing volumes of tight oil, and consequently associated gas, as well as shale gas in the US and Canada, which contain more liquids relative to conventional gas. Furthermore, the commissioning of deep water gas fields in the Gulf of Mexico has also contributed to the increasing wetness ratio, as this gas normally has higher liquid content relative to conventional onshore production.

OPEC Member Countries are another major source of NGLs, with supply increasing strongly in recent years in line with rising gas production. NGLs rose from just below 3 mb/d in 2000 to just over 5 mb/d in 2021.

Viewed over the long-term, NGLs production is anticipated to grow the most, adding almost 4.9 mb/d from 2021 to 2045 by 2045 to reach 21.7 mb/d. The growth of NGLs is noticeable throughout the long-term projection. OPEC, with significant domestic gas resources, drives the projected growth in supply. In the US, another key driver is the expansion of production due to the continuous increase of US shale gas. Other regions of production include Canada, Mexico, Norway, UK, Brazil and Guyana.

The Canadian oil sands is also expected to gradually raise its share of non-crude liquids. Different Cold Lake projects, along with the expansion of Foster Creek within Alberta

drive medium-term growth, with further expansions set to increase output from around 3 mb/d to 4.3 mb/d by 2045.

In terms of GTLs and CTLs, their development stems from a desire to find crude oil alternatives, minimise associated financial risks from stranded assets, as well as energy security concerns.

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

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

Elsewhere, biofuels largely emerged as an alternative to fossil fuel-based liquids as a result of government policy, with a view towards reducing emissions and making fuels more sustainable. As shown in Table 1, the global supply of biofuels is forecast to grow significantly. The US, for instance, led the way with its Renewable Fuel Standard, implemented in 2005-2007, which established blending mandates. Today, it has resulted in the production of around 1 mb/d of fuel ethanol as part of the US's liquids fuel mix.

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

China has ambitions for non-crude liquids too. These are set out in its national 14th Five Year Plan. With a target of reaching peak emissions by 2030, the plan calls for reaching carbon neutrality by 2060 while promoting the use of biodiesel and bio-SAF in the country. Similarly, India is gradually reducing petroleum-based fuels with the introduction of its National Policy on Biofuels. The policy seeks to promote the use of biofuels in the transport sector by mandating 20% blending of ethanol in gasoline and 5% blending of biodiesel in diesel by 2030.

In addition to supporting policies, the continuous advancement of biofuels and synthetic fuel technology is aiding the projected growth. For instance, the conversion of non-economical conventional refineries into bio-refineries, and the utilisation of different types of feedstocks reflect on the supply potentials. Moreover, and with the difficulties in electrifying the aviation sector, proposed mandates in this sphere has brought more attention towards providing alternatives to oil-based jet aviation fuel. The total supplies of non-fossil aviation fuel (including both of biological origin and synthetic fuels), is projected to grow from around 120 tb/d in 2021 to more than 600 tb/d by 2045, or around a 7% share of global jet fuel demand.

#### Global NGLs, biofuels and other non-crude liquids supply

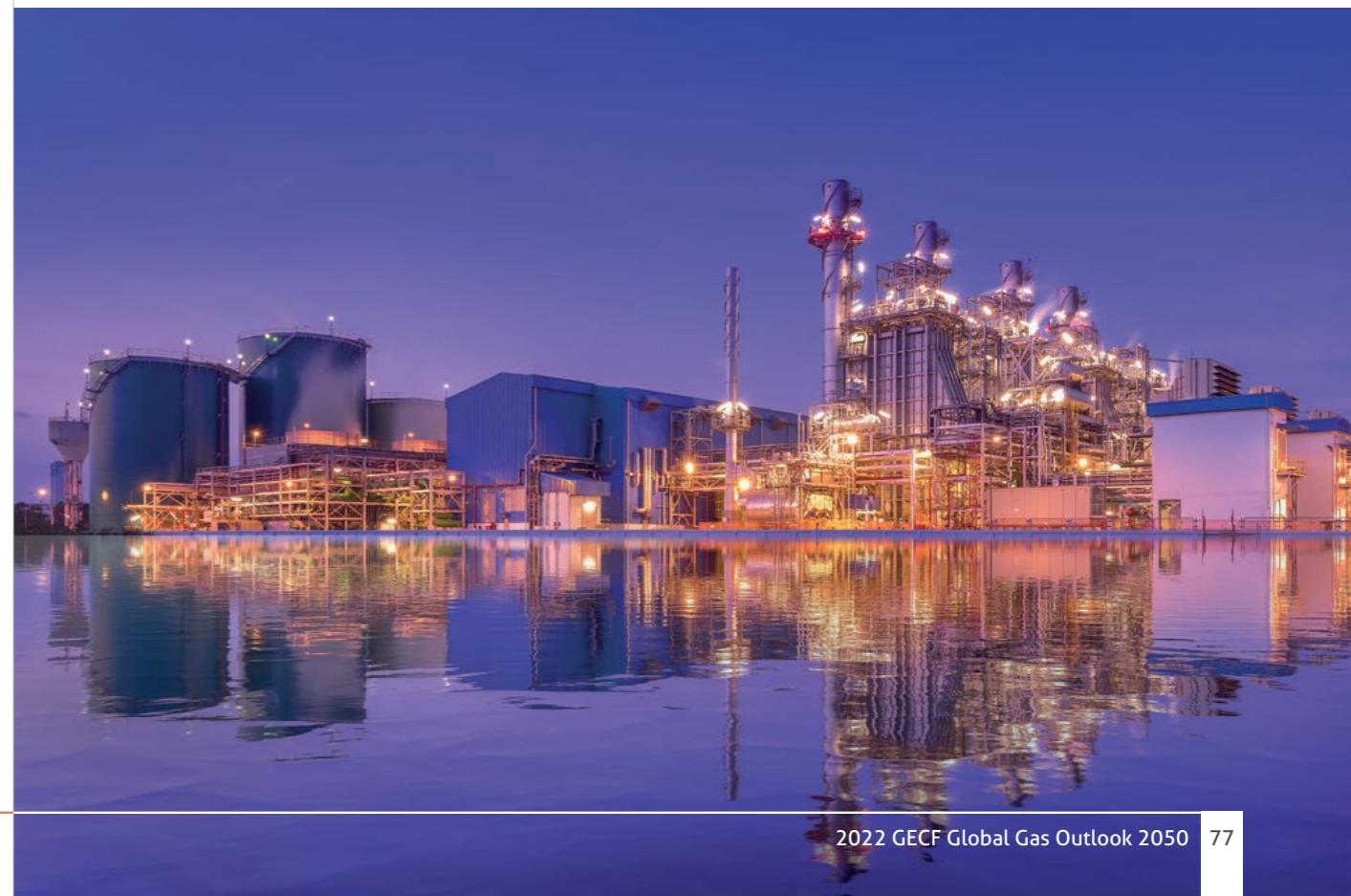
	2021	2025	2030	2035	2040	2045	Change 2021-2045
<b>Global NGLs</b>	<b>16.8</b>	<b>18.6</b>	<b>19.8</b>	<b>20.6</b>	<b>21.4</b>	<b>21.7</b>	<b>4.9</b>
Fuel ethanol	1.7	1.9	2.1	2.3	2.5	2.6	0.9
Biodiesel*	0.8	0.9	1.2	1.4	1.6	1.8	1.0
<b>Total biofuels</b>	<b>2.5</b>	<b>2.9</b>	<b>3.3</b>	<b>3.7</b>	<b>4.2</b>	<b>4.4</b>	<b>1.9</b>
Canadian oil sands	3.1	3.4	3.7	3.9	4.1	4.3	1.2
Gas-to-liquids (GTL)	0.2	0.3	0.3	0.3	0.3	0.3	0.0
Coal-to-liquids (CTL)	0.3	0.3	0.4	0.4	0.4	0.4	0.1
Synthetic aviation fuel ('SAF')	0.0	0.0	0.1	0.1	0.2	0.4	0.4
Other**	0.3	0.3	0.3	0.3	0.3	0.3	0.0
<b>Total 'Other liquids'</b>	<b>3.9</b>	<b>4.3</b>	<b>4.7</b>	<b>5.0</b>	<b>5.3</b>	<b>5.6</b>	<b>1.7</b>
<b>Global</b>	<b>23.2</b>	<b>25.7</b>	<b>27.7</b>	<b>29.3</b>	<b>30.9</b>	<b>31.8</b>	<b>8.6</b>

\* Biodiesel includes small volumes of biological origin jet kerosene

\*\* including kerogen, extra-heavy crude, MTBE and other refinery additives

Source: OPEC World Oil Outlook (WOO 2022)

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

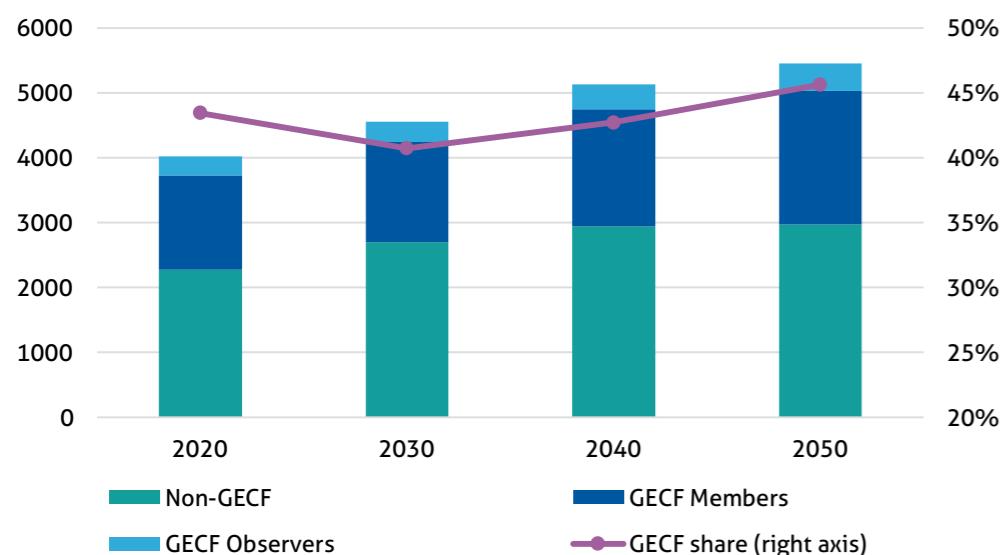


### 3.4 GECF Countries' gas production outlook

Almost all of the GECF countries will increase or maintain their annual production by 2050. Norway is the exception, where a 57% decline or almost 66 bcm is expected. Iran, Qatar and Mozambique will deliver the strongest gas production growth, adding almost 540 bcm. This will account for 30% of current GECF production and 72% of total GECF change through to 2050.

We expect that the GECF share of gas output will decline from 43% to 41% by 2030 due to expansion in non-GECF countries, as well Russia and Norway declines. However, this will rebound to 46% by 2050 due to growth among many GECF countries.

Figure 3.9. GECF countries' gas production outlook (bcm)



Source: GECF Secretariat based on data from the GECF GGM

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04  
Natural Gas Trade Outlook

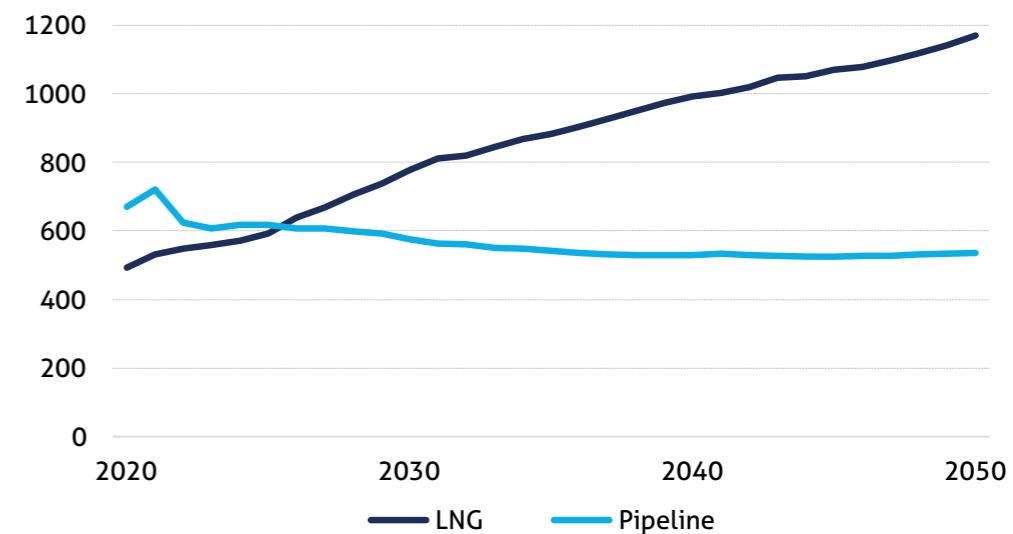
## Key findings:

- Global natural gas trade is to rise by 36% between 2021 and 2050, reaching 1,700 bcm, almost one-third of global gas demand.
- LNG trade will overtake long-distance pipeline trade by 2026, and is expected to more than double by 2050 to reach 850 mt.
- An overheated spot market has supported long-term supply contracting, with 65 mtpa in 2022. The Asia Pacific region accounted for two-thirds of all end-user contracts, while China accounted for about a half of all newly concluded volumes.
- The Asia Pacific region will remain the dominant long-term LNG market. China will be the largest growth market this decade, but India will assume that role after 2030.
- Europe is at the heart of the global energy crisis, and LNG is at the centre of European strategy for alleviating gas shortfalls.
- European gas imports will decline by 80 bcm/year by 2050 compared to 2021. Most of this shift will materialise by 2030 as countries work to reduce natural gas use and Russian imports. The bloc continues to expand and add regasification capacity to meet short- and medium-term LNG imports requirements.
- Liquefaction capacity will top 1 billion tonnes per year by 2050, with utilisation expected to reach 80%.
- Regasification capacity could reach 1.8 billion tonnes per year by the end of the outlook period, with utilisation just under 50% based on demand projections.
- The largest regasification capacity additions by 2050 are expected to be in the Asia Pacific region.
- Russia has dominated Eurasian region exports. Several pipeline plans remain under development to increase natural gas transport from the region to Asian markets.
- More than 130 mtpa of liquefaction capacity are planned for the Middle East by 2050, with Qatari expansion plans dominating growth.
- LNG will continue to dominate Latin American natural gas trade as consumption grows to displace oil and support renewables use. The US will remain the region's primary LNG source.
- LNG will account for 70% of Africa's natural gas exports by 2050, with Mozambique emerging as the largest player. The continent's liquefaction capacity will reach 200 mtpa.

## 04 Natural Gas Trade Outlook

Global natural gas will rise by 36% between 2021 and 2050, reaching over 1.7 tcm and accounting for almost one-third of global gas demand. Global LNG trade will accelerate, reaching 1.17 tcm by 2050, overtaking long-distance pipeline trade by 2026. This is earlier than our previous forecast.

**Figure 4.1. Global natural gas trade by flow type (bcm)**



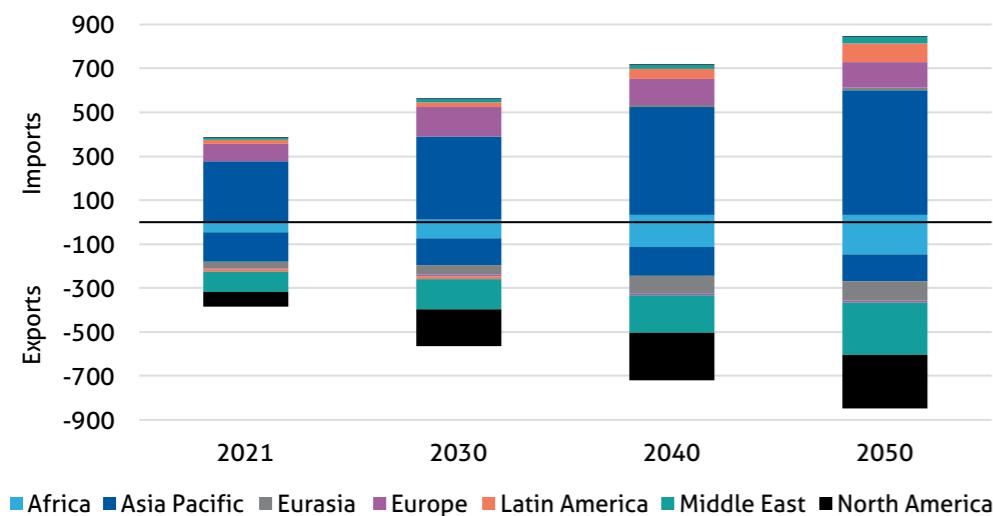
*Source: GECF Secretariat based on data from the GECF GGM*

LNG demand will increase over the forecast period, more than doubling in volume between 2021 and 2050. With domestic production declining in some Asia Pacific countries and Europe, LNG is gaining momentum and becoming the preferred natural gas supply source.

Asia Pacific natural gas demand has almost tripled in the past two decades, and the region has become the key global gas and LNG demand driver. Asia Pacific economies will account for 30% of global natural gas demand in 2050, retaining the region's role as the leading LNG importer. Emerging Asian countries, primarily South and Southeast Asian nations, will lead that growth. The large Asia Pacific share of the world's LNG trade will remain high, declining from 72% to 67% by 2050.

Historically, the global gas trade was led by key pipeline exporters such as Norway and Russia supplying gas to Europe. Since 2016, US shale-sourced LNG has joined Australian and Qatari LNG in gaining share in the global gas trade.

Figure 4.2. LNG imports and exports by region (mt)



## 4.1 Global pipeline and LNG market trends

### European energy crisis and security of supply

The global energy crisis, underpinned by post-pandemic recovery and the effects of the Russia-Ukraine conflict, revived energy security concerns. Europe is the epicentre of the global energy crisis, where navigating the “energy trilemma” of energy security, sustainability, and affordability is the key challenge.

The Russia-Ukraine conflict significantly impacted the Europe-Russia energy trade, specifically Russian pipeline gas exports to the EU. It has complicated the financing and logistics of existing deals and triggered further acceleration of the European energy policy from the climate perspective. The European Commission’s REPowerEU Plan aims to reduce the EU gas demand while aiming to phase out Russian gas by 2027. To date, though, there is no legally binding ban on Russian natural gas imports into the EU. LNG is at the heart of the EU’s strategy, ramping up imports and expanding regasification capacity while alleviating bottlenecks in existing gas infrastructure.

The European energy crisis is transforming the global LNG market. Global LNG producers are benefiting from tight gas markets and extremely high prices. Soaring LNG demand is providing a supportive environment for new LNG projects worldwide, including the US, Middle East, and Africa. For now, suppliers are increasing utilisation of their existing plants while importing countries are working to add Floating Storage Regasification Units (FSRUs).

Other countries dependent on their own gas production will encounter a more limited impact from international gas trade disruptions. However, macroeconomic ramifications, particularly inflationary pressures, are a real challenge.

### The continued surge in natural gas prices

Surging prices have broken records. The Dutch Title Transfer Facility (TTF) benchmark reached an all-time high on August 26th, 2022, soaring to US\$96/mmmbtu. This was 12 times higher compared to year-ago prices. Gas price volatility has been exacerbated by nuclear maintenance in France and low interconnector capacity, along with limited regas capacity and connection with Spain, among other factors. (Please, see Figure 1.8. Daily spot natural gas prices in 2020 – 2022.)

Some European and Asia Pacific countries were forced to switch to oil and back to coal as gas prices surpassed those fuels on an oil-equivalent basis. At its peak, the TTF price was equivalent to 5.5 times the price of oil. Gas-to-oil switching has been more common in the Asia Pacific region as countries have encountered LNG cargo diversions to Europe. Fuel oil cracks have declined considerably in Asia due to the larger availability of crude oil cargoes, including Russian supplies.

Europe is replacing lower priced Russian pipeline gas imports with LNG, extending its run as the world’s premium LNG market. As a result, Asia is becoming a swing market. Europe will enjoy a better position in 2026 when the next LNG wave helps balance the market, eroding prices. The US and Qatar will be key suppliers.

Over the long term, natural gas prices are expected to be structurally higher and volatile as Asian and European markets compete for LNG with less market flexibility space available for Europe.

### Long-term contracts LNG contracts are ramping up globally

Continued elevated spot prices have pushed buyers further to engage in long-term contracting to ensure energy security and usual economic activity. New long-term LNG contracts signed in 2022 topped 65 mtpa, with the majority to be supplied from US and Qatari LNG projects.

The **Asia Pacific** region led in the volumes committed, accounting for two-thirds of all end-user contracts. China accounted for about half of all newly concluded volumes. The trend was already evident in 2021, when end-user deals were the highest in five years. Rising spot prices were a key trigger, with China signing deals for supply from Qatar and the US. Other Asia Pacific consumers, particularly legacy markets Japan, South Korea, and Taiwan, source more of their LNG through long-term deals typically indexed to oil. On a weighted average basis, their exposure to market volatility has been somewhat muted relative to other buyers.

Europe's increasing LNG imports are unlikely to be accommodated by long-term contracts as shorter deals better suit their energy transition targets. Also, European needs are likely better fulfilled by portfolio players and trading houses well positioned to provide needed flexible volumes, including supply on a short-term basis. European buyers signed eight deals in 2022, both firm and preliminary, totalling nearly 10 mtpa. In March 2022, the EU and US signed an agreement setting a target for 50 bcm/year (35 mtpa) of LNG to be delivered into Europe by 2027. But Germany will be at the centre of both new terminal construction and growing European LNG deliveries. ConocoPhillips will supply 2 mtpa for 15 years from Qatar's North Field expansion project to the German LNG terminal in Brunsbuttel starting in 2026. EnBW, among the largest energy companies in Germany, also has executed long-term deals with Venture Global LNG for 2.0 mtpa from its Plaquemines and CP2 ventures. QatarEnergy also has a 1.1 mtpa agreement with RWE Supply & Trading (RWEST) to supply LNG to Northwest Europe from 2017-24.

#### Energy transition and natural gas trade

Global natural gas trade growth is underpinned by the important role it will play in the energy transition of key demand regions, including the Asia Pacific, North America, and Europe. Natural gas merits greater use over other hydrocarbons through emissions abatement, cost competitiveness, flexibility, and potential synergies of integration with existing energy infrastructure.

After 2030, diverging regional energy transition trajectories will be more challenging. LNG industry funding, both on the supply and demand sides, will decline by a factor of three in the 2030s and 2040s. Upstream and midstream investment will be sustained, but the manner in which natural gas resources will be developed and transported will be transformed considerably. Low-cost resources with both a strong environmental pedigree and lower carbon footprint will be prioritised for investment.

The gas value chain is set to be cleaner and "greener." The US IRA introduced methane regulation that could help lower emissions profiles across the entire gas value chain. The new tax credit for renewable natural gas (RNG) and higher subsidies for CCUS could help support the US gas pedigree by becoming greener. The gas industry has already engaged with third-party agencies to certify their operations, but regulatory advancement helps cement greener gas development.

#### Carbon-neutral LNG

Natural gas can be marketed as low- or no-carbon if producers reduce GHG emissions associated with getting it to market or purchase carbon offsets to cut net climate impact. Europe's energy crisis has deprioritised buyers' focus on LNG carbon intensity. As a result, announced carbon-neutral cargoes declined

from 30 in 2021 to less than 10 to date through mid-October 2022. The decline in demand for carbon-neutral LNG will likely be temporary until the global gas trade rebalances.

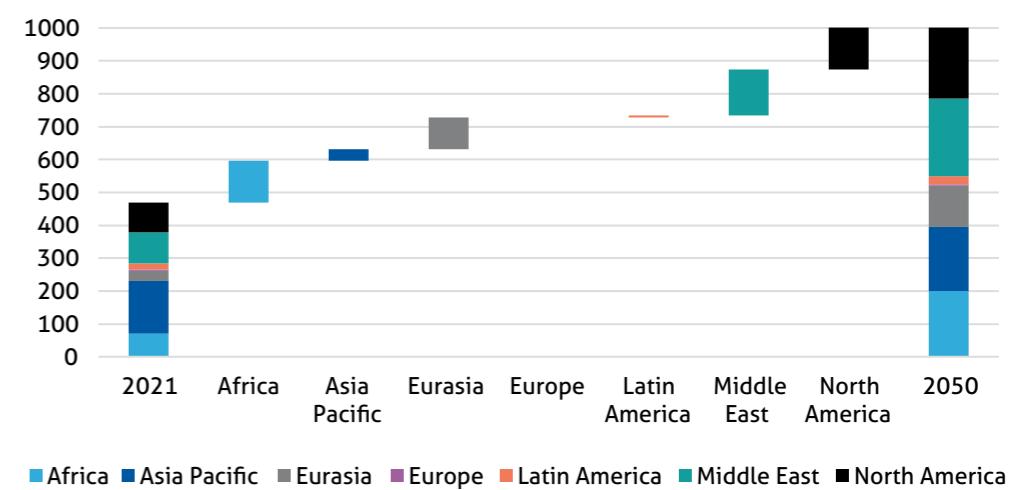
#### 4.2 Gas trade infrastructure prospects

Both pipeline and LNG infrastructure will grow by 2050. Liquefaction and regasification capacity will dominate spending through 2030, while expansion is set to slow after 2040. Export pipeline developments will endure through 2050, particularly in Eurasia and Europe.

##### LNG Supply

Global liquefaction capacity has grown from 270 mtpa in 2010 to 462 mtpa in 2021 and will more than double to about 1,032 mtpa by 2050. LNG demand expected to reach 850 mtpa by 2050 will utilise over 80% of liquefaction capacity, making markets well-supplied throughout the forecast period.

Figure 4.3. Global LNG liquefaction capacity outlook (mtpa)



Source: GECF Secretariat based on data from the GECF GGM

We see around 560 mtpa of additional liquefaction capacity poised to launch from 2021 through 2050. This includes projects under construction and in all FEED (front-end engineering and development) stages, along with proposed, potential, stalled, and speculative ventures.

North America will supply the largest liquefaction gains, adding nearly 160 mtpa supported by unconventional gas. The Middle East will add 140 mtpa, led by Qatar's North Field mega-expansion projects.

The US has the most liquefaction capacity in the world, becoming the top exporter in the first half of 2022. LNG expansion has been underpinned by around 60 mtpa of new facilities starting up since 2019. These included Corpus Christi Trains 2-3, Cameron Trains 1-3, Sabine Pass Trains 5-6, Freeport Trains 1-3, Elba Island and Calcasieu Pass. Golden Pass, Plaquemines Phase 1 and Corpus Christi Stage III, all under construction, will expand US liquefaction by 43 mtpa by 2025.

**Qatar** exported 77 million tonnes in 2021. QatarEnergy is working to increase its liquefaction capacity to 110 mtpa by 2026 and 126 mtpa by 2027. Another 55 mtpa of speculative LNG projects may be developed.

**Australia** was the world's top LNG exporter in 2021 but it will likely lose this position due to rapid expansion plans emerging in Qatar and the US. Australia is not expected to expand significantly beyond 88 mtpa. North West Shelf, the country's largest venture, in operation since 1989, is expected to encounter continued feed gas declines. The lack of new project developments will also cap Australian LNG exports. The Santos-operated Barossa development was sanctioned in 2021, but it is a backfill project intended to extend the life of the Darwin liquefaction facility at Wickham Point. Woodside's Scarborough field and Pluto Train 2 were sanctioned as well, which will provide some incremental volumes and backfill gas supply to the company's other operating liquefaction trains.

**Russia's** long-term plans to expand LNG export capacity to between 80 to 140 mtpa by 2035 from 30 mtpa now are enumerated in the country's 2035 energy strategy. A revised Russian Energy Strategy expected by mid-2023 will seek new destinations for LNG, especially developing Asian markets. It will also tackle the issue of much-needed technological development given the new sanctions environment limiting LNG industry technology and equipment imports. Novatek is aiming to launch the first train from its Arctic LNG 2 venture before the end of 2023. Arctic LNG 2 will be Novatek's second LNG venture in the polar region following launch of Yamal LNG in 2017.

Africa could emerge as a key LNG production region, ramping up its liquefaction capacity three-fold from 71 mtpa to 200 mtpa by 2050. If these projects materialise, new exporters sub-Saharan African countries such as **Mozambique, Mauritania, and Senegal**, will join as key African LNG exporters.

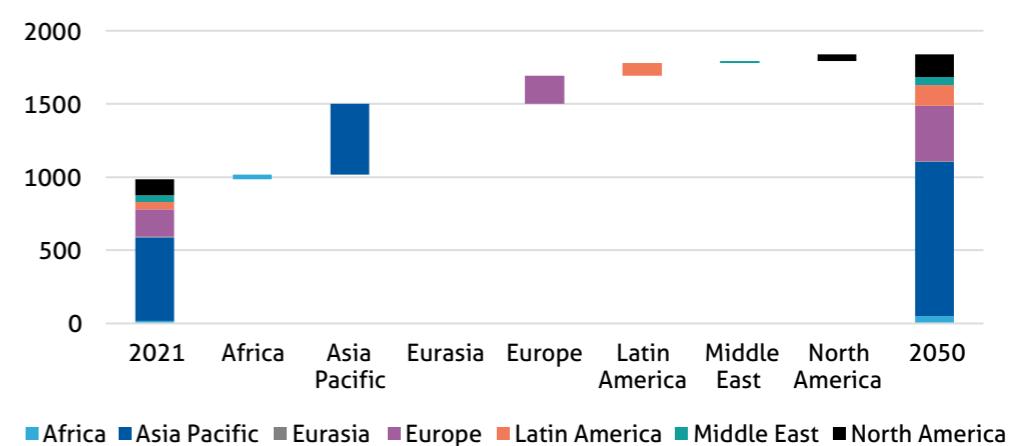
#### LNG Demand

Globally LNG demand will more than double from 372 million tonnes in 2021 to 850 million tonnes by 2050, fuelled by developing Asia's strong demand.

The largest regasification capacity additions are expected to be in the Asia Pacific region. Global regasification capacity grew from 630 mtpa in 2010 to 993 mtpa in 2021. By 2050, capacity could surge to almost 1,840 mtpa, when operating, under

construction proposed, mothballed and stalled projects are considered. This would be more than double expected LNG demand of around 850 million tonnes. Roughly 1,060 mtpa, or 60% of global capacity, will be located in the Asia Pacific region by 2050. Some 380 mtpa, or 20%, will be in Europe. We have revised the European capacity figure upward by 100%, with growth being implemented before 2030.

Figure 4.4. Global LNG regasification capacity outlook (mtpa)



Source: GECF Secretariat based on data from the GECF GGM

Asian LNG demand remains subdued in the short term, also supported by an increase in domestic coal use where possible. High LNG spot import prices and a weakening global economic outlook dampen overall Asian gas demand growth, especially in price-sensitive markets. China and South Asia are at the greatest risk of demand downgrades.

However, demand will rebound strongly when LNG supply availability increases and prices moderate around 2026. China, Southeast Asia, and South Asia account for all the medium to long-term growth upside, while Northeast Asian demand remains flat and declines after 2030. Southeast Asia and South Asia will be the fastest growing LNG markets.

Several companies in China are building out some 50 mtpa of regasification capacity over the next two years, with total capacity reaching about 225 mtpa by 2050 – even as price sensitivity remains a key demand headwind. Japan will be home to 210 mtpa, while South Korea and India will follow with around 140 mtpa and 145 mtpa, respectively.

European governments and utility companies have been quick to develop new regasification capacity but have yet to move meaningfully to long-term LNG contracts to secure supply. European LNG imports will increase from 81 mt (111 bcm) in 2021

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to 135 mt (186 bcm) by 2030, while Europe is set to develop 72 mtpa (100 bcma) of additional regas capacity by 2025.

LNG deliveries to Europe in 2022 are expected to grow by over 40 mt over 2021. However, location and availability of existing regas capacity, along with connectivity constraints within the European gas network, limit access options for many potential European buyers. As a result, multiple countries have announced plans to install additional regas capacity via new or operating proposals. There are 10 expansions planned at 7 terminals between 2022 and 2030 totalling more than 30 bcm/year.

### Floating Storage and Regasification Units and Floating Liquefaction

FSRU capacity build-up in Europe and FLNG across the globe, especially in Africa, are growing. Both are adding flexibility and feasibility to further LNG industry development by reducing costs, construction time, and transportation to markets. Demand for FSRUs is booming amid the global LNG trade expansion. For Europe in 2022, FSRUs became a 'geopolitical' solution as well. Floating LNG storage and distribution suggest the best and quickest option for Europe to create LNG import infrastructure.

FSRUs are gaining momentum and growing share of global regasification terminal capacity. The fleet consisted of 48 units in 2021, with a capacity of around 7.1 mtpa. Five vessels were under construction, one of which was set for 2022 delivery. LNG infrastructure will see a much faster build-up than pipelines as it circumvents intergovernmental negotiations and geopolitical tensions.



## 05

### Natural Gas Investment Outlook

**Key findings:**

- Chronic underinvestment since 2014 has been a major contributor to rising energy prices in 2021, further to the post-pandemic rapid economic recovery.
- Almost US\$10 trillion is expected to be required to satisfy growing natural gas demand and to supply 5.5 tcm of natural gas in 2050.
- Africa, the natural gas well endowed continent, needs to invest a hefty US\$1.7 trillion in the upstream sector to increase its natural gas production and reach 585 bcm in 2050.
- The strong rise in natural gas supply from the Middle East would require US\$1.11 trillion of upstream investment to increase production by 520 bcm and reach 1,190 bcm in 2050.
- Between 2021 to 2050, total forecasted midstream natural gas investment requirements reach US\$775 billion, driven mainly by higher global LNG demand growth.
- Global LNG liquefaction-related investment is expected to be of US\$475 billion over 2021-50, with over half - US\$250 billion - over 2021-30.
- 2022 has been a 'game-changing' year for the LNG industry. In the short to mid-term, the European and global energy crisis will define the trends for accelerated LNG infrastructure development, especially by 2030. The past and the upcoming decades, these two decades, can be considered a 'golden age' for LNG infrastructure investment.
- Between 2021 and 2050, the largest natural gas infrastructure spending will be in Asia Pacific region – almost US\$200 billion or 25% of total global midstream investment. The lion's share - 80% - will be attributed to LNG regasification infrastructure.
- Banking and financing institutions will be weighing on the natural gas industry, with tightened financial conditions.

## 05 Natural Gas Investment Outlook

### 5.1 Upstream gas investment

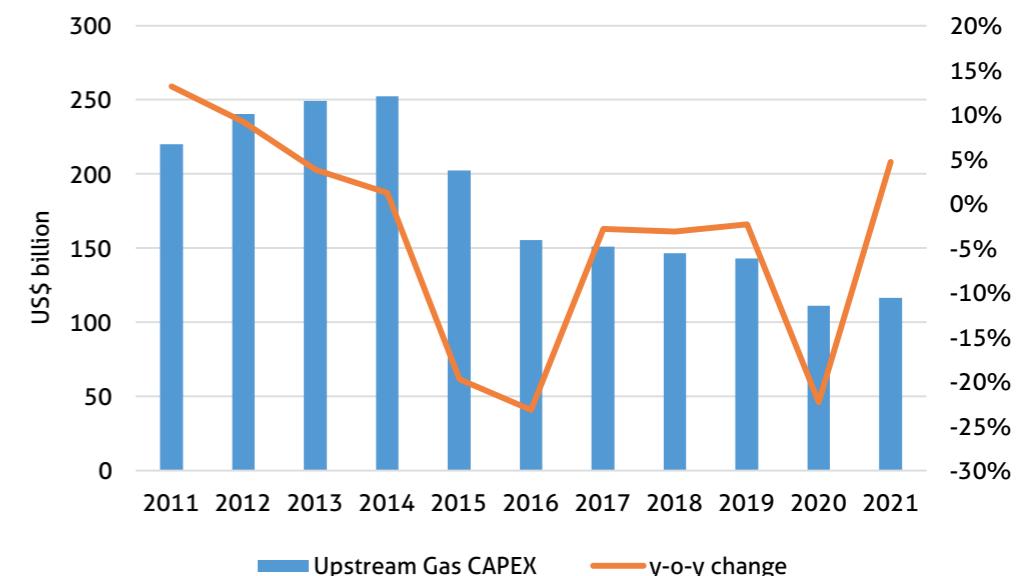
#### Overview of upstream oil and gas investment

Underinvestment since the 2014 oil price decline has been a major contributor to rising energy prices as global economic activity rebounds from the COVID-19 pandemic.

Global oil and gas upstream investment was trending upward at the beginning of the past decade, peaking at US\$840 billion in 2014. Since then, as companies were trying to protect their balance sheets in a low-price environment, upstream spending declined by 40% in only two years. The COVID-19 pandemic in 2020 led to a deep recession, lockdowns and drastically reduced travel, resulting in a huge decline in oil and gas demand. This situation compounded with low energy prices and supply disruptions forced companies to limit their upstream investment.

The oil and gas industry developed several learnings from the 2014 price drop. Companies managed to reduce well construction costs compared to pre-2014. Technology improvement in well drilling and completion helped increase operation efficiency and reduced the overall upstream costs. This operational improvement supported the resilience of the industry during the severe shock of COVID-19.

**Figure 5.1. Global upstream gas investment from 2011 to 2021**



Source: GECF Secretariat based on data from Rystad Energy

For upstream natural gas sector, the underinvestment has contributed to the current global natural gas shortage, which has supported higher gas and LNG prices. Global capital investment in the upstream natural gas sector rose from US\$195 billion in 2010 to US\$250 billion in 2014, followed by declining spending as companies were navigating the low-price environment from 2014 to 2020. Natural gas market tightness in the post-COVID-19 recovery in 2021 has been a major contributor to soaring natural gas prices and improving business profitability, which, as a result, led to increased investment.

#### Natural gas upstream investment to 2050

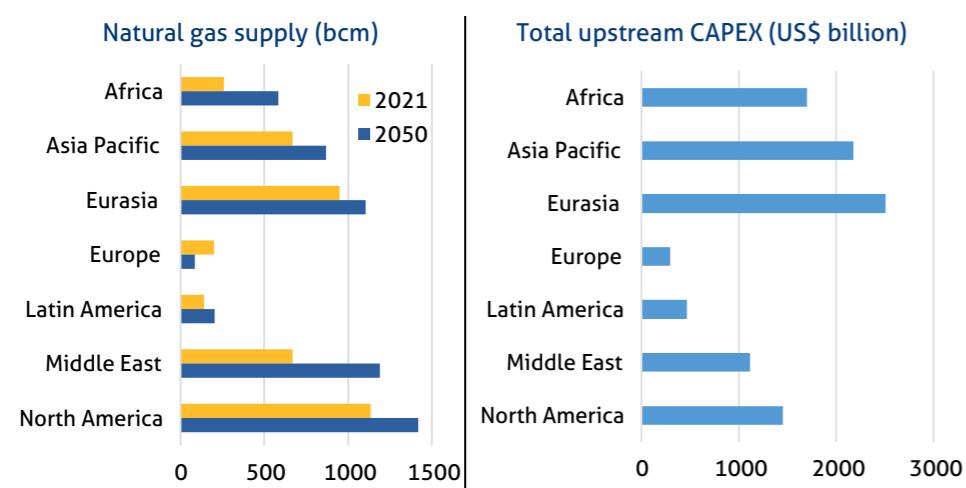
To reach the required natural gas supply level of 5.5 tcm by 2050, the GECF expects the industry to require US\$9.7 trillion of upstream capital investment in natural gas over the forecast period.

The majority of the capital investment is related to Yet-to-Find (YTF) resources, a risked estimate of the remaining hydrocarbons expected to be found. YTF resources are expected to account for 64% of the global upstream capital investment over the forecast period. Conventional and unconventional YTF resources will require US\$4.5 trillion and US\$1.7 trillion, respectively. This highlights the need to sustain exploration and production activities while ensuring that the industry has access to adequate financial resources.

#### Regional upstream investment

The GECF forecasts natural gas supply to increase in 2050 compared to 2021 in all regions except for Europe as shown in the left-side chart in figure 5.2 with respective upstream investments shown in the right-hand side.

**Figure 5.2. Natural gas supply in 2021 and 2050 in bcm (left) and total upstream investment up to 2050 (right)**



Source: GECF Secretariat based on data from the GECF GGM

Global investment in natural gas supply should be supported and facilitated to ensure natural gas markets are well supplied to ensure markets are protected from price fluctuations.

Africa and the Middle East will show the largest percentage increase in natural gas supply at a total upstream investment of US\$1.7 and US\$1.11 trillion respectively.

#### Africa

Investments in Africa will support the continent's long-term position as a natural gas exporter, increase access to a low-carbon fuel, generate foreign currency, and support African countries in building and modernising their energy systems. African upstream gas investments in 2022 are estimated at US\$34 billion compared to US\$25 billion in 2021. Greenfield investment in sub-Saharan Africa and brownfield developments in North and West Africa are key drivers.

Over the long term, the outlook expects Africa to produce 585 bcm of natural gas in 2050 at a total upstream investment of US\$1.7 trillion. Algeria, Egypt, Southern Africa and Nigeria will account for 84% of total upstream investment in Africa. For Sub-Saharan Africa, the majority of upstream gas investment in the region will be directed towards deep-water developments. According to Rystad Energy, 66% of greenfield investment in 2021 was spent on deep-water. Over the forecast period to 2050, deep-water investment will account for 70% of the total upstream investment in the region.

In Mauritania and Senegal, the attractiveness of the agreement with International Oil Companies facilitated securing investment for the deep-water Greater Tortue Ahmeyim project with a plan of drilling 12 offshore wells connected to an FPSO. Phase 1 of the project straddles the borders between the two countries. Both countries have a promising exploration record. By the end of 2019, the success rate was 100% from nine gas exploration wells (1).

#### Asia Pacific

Asia Pacific is the largest consumer of natural gas with natural gas demand is forecasted to reach 1,620 bcm in 2050 in the reference case scenario. Asia Pacific is estimated to require US\$2.1 trillion of upstream gas investment to boost its gas production to 870 bcm in 2050, 54% of its projected demand. Australia, China and Indonesia will lead natural gas investment in the region.

Upstream gas investment has been facing a downturn in Australia since the 2014 high. Last year upstream investment stood at US\$6.3 billion (2), only 12.5% of the 2014 peak. Exploration, production and appraisal well count is decreasing. For example, the appraisal well count dropped by 23% (3) in 2021 mainly in the Cooper Basin. Moving forward, it is expected for Australia to require US\$800

billion of upstream gas sector investment to maintain its current level of natural gas production over the forecast period to 2050.

**India** is targeting increasing natural gas in the energy mix by 15% by 2030 through the expansion of pipeline networks, building LNG terminals and supporting domestic production. As a result, the Indian Oil and Natural Gas Cooperation (ONGC) is planning to increase its natural gas production by 25% in 2025. To this end, the company is planning to invest US\$4 billion in oil and gas exploration in the coming three years.

India's upstream gas investment in 2021 is estimated at US\$2.7 billion, a 6% increase from the 2020 investment level. For a further push of investment, India launched a competitive bid round of 23 offshore exploration blocks, 15 in ultra-deep water and eight in shallow water. In this bid round and after the reforms, the country expects the participation of international companies. We expect India to reach 50 bcm of natural gas production by 2040 and can sustain production to 2050 at total upstream capital investment of US\$180 billion.

**Indonesia** is expanding its oil and gas production with a plan to reach 1 mb/d and 0.34 bcm/day of gas in 2030 to meet national energy demand. In 2021, the Indonesian government offered four oil and gas exploration blocks in a direct offer as part of the 2021 Oil and Gas Working Area Bid Round. The total investment of the four blocks is US\$14 billion. Indonesia announced two bid rounds in 2022. The first one offered five exploration blocks and one exploitation area. One example of the offered blocks is the Meulaboh deep-water with estimated resources of 135 bcm of natural gas. Another field is the OSWA working area (Singkil) which has an estimated recoverable gas reserve of 240 bcm. The second bid round included four oil and gas blocks.

**Papua New Guinea's** gas investment is on the rise after the 2020 low. Upstream investment increased to US\$250 million in 2021, a 31% increase compared to 2020, with gas production reaching 12 bcm. The country is working on attracting investment in its natural gas assets to support the county's development. Later this year, the country announced a commitment to change its oil and gas fiscal regime by 2025. The need for amendment aligns with the country's plans to develop the Papua LNG, P'nyang, and the Pasca gas condensate field projects. The development of these projects by 2032 will support the economic expansion goal of Papua New Guinea.

#### Eurasia

Approximately US\$2.5 trillion of upstream investment is required in the Eurasian region to boost its natural gas production by 12% in 2050. The high investment figure for the region is a result of high estimated investment requirements in challenging basins like the offshore Kara Sea and the Yenisey-Khatanga Basin in the Arctic.

#### Europe

Europe is projected to account for 3.1% of global upstream gas investment by 2050 with the majority of investment in Norway. However, with the recent development and response from some European countries to enhance energy security, natural gas in particular, the investment figure could be revised upward. The energy dialogue in the continent has shifted from focusing on one dimension to realising the need to diversify energy sources as well as supplies. As a result, a move towards increasing natural gas production, from Norway and the United Kingdom, has been observed. Norway is expanding natural gas production to support the EU energy security plan by maximizing natural gas production and increasing gas investment. Similarly, the United Kingdom is promoting natural gas investment and offering 900 locations for oil and gas exploration. Furthermore, recently, the UK government lifted the ban introduced in 2019 on hydraulic fracturing to boost oil and gas production.

#### Latin America

Latin America will require US\$370 billion of upstream investment over the outlook period to 2050 to increase its natural gas production from 140 bcm in 2021 to 205 bcm in 2050. Argentina, Venezuela, Trinidad and Tobago, Bolivia, and Brazil will account for 93% of the region's upstream investment.

Natural gas upstream activities are picking up in **Argentina**. In 2019, Argentina conducted its first offshore licensing round in which eighteen blocks were awarded. The majority of the blocks are in the Argentina and Malvinas basins (4). Over the long term, the outlook expects the production of Argentina to average around 70 bcm in the last decade of the outlook period. That would require an investment of US\$190 billion in the upstream gas sector.

**Brazil** is expected to see investment surge to US\$36.7 billion this decade (2). According to Rystad Energy, Brazil's sales gas production is expected to double by 2030 due to promising offshore developments. For example, Equinor plans to start oil and associated gas production from the pre-salt field by 2024. For non-associated gas, a group of International Oil Companies are developing Pao de Acucar, the giant offshore gas condensate field. The approved development plan includes the drilling of 11 offshore wells to deliver gas to a new FPSO.

#### Middle East

Conventional assets are expected to remain the primary source of natural gas supply in the Middle East. The region requires US\$1.11 trillion of investment to increase production to 1,190 bcm in 2050, a 520 bcm increase from the 2021 level. Qatar, Saudi Arabia and the UAE are projected to account for 79% of natural gas investment in the region.

**Saudi Arabia** is diversifying its energy exports and stimulating the expansion of domestic gas demand. The Kingdom is working on increasing its oil export potential to 13 mbbls/d by 2030 by expanding the use of natural gas and renewable energy. In addition, Saudi Aramco is planning to increase its natural gas output by 50% by 2030. As a result, the Kingdom has been boosting exploration and production activity and developing natural gas processing facilities.

In 2022, the company announced approval for the development of the Jafura field, an unconventional gas play resource estimated to be 5.7 tcm. The field, with an approved US\$110 billion investment, is expected to start production by 2024 at 31 mcm/d, with a 57 mcm/d target by 2030 and 62 mcm/d peak production by 2036. The Jafura investment plan is equivalent to 46% of the total upstream investment required by 2050. The Kingdom has the experience of fast-tracking natural gas fields. For example, Karan field, the first non-associated gas field in Saudi Arabia, took only 6 years from discovery to production.

#### North America

Taking advantage of the shortage of natural gas globally and the robust natural gas future, North America is expected to increase natural gas production to 1,420 bcm by 2050. That would require a total upstream investment of US\$1.45 trillion by 2050.

Even though the Biden administration in the **United States** is committed to net-zero emissions and supporting renewables and alternative energy sources, the facts indicate that natural gas plays a fundamental role in the US' energy and economy. In 2021, in his first year in office, the Bureau of Land Management approved around 333 (5) drilling permits monthly. In addition, in 2023 the US will launch the licence round Gulf of Mexico Lease Sale 259 to boost oil and gas production from the Gulf of Mexico Continental Shelf to counter the declining natural gas production since its peak in 2010 as well as boost oil production.

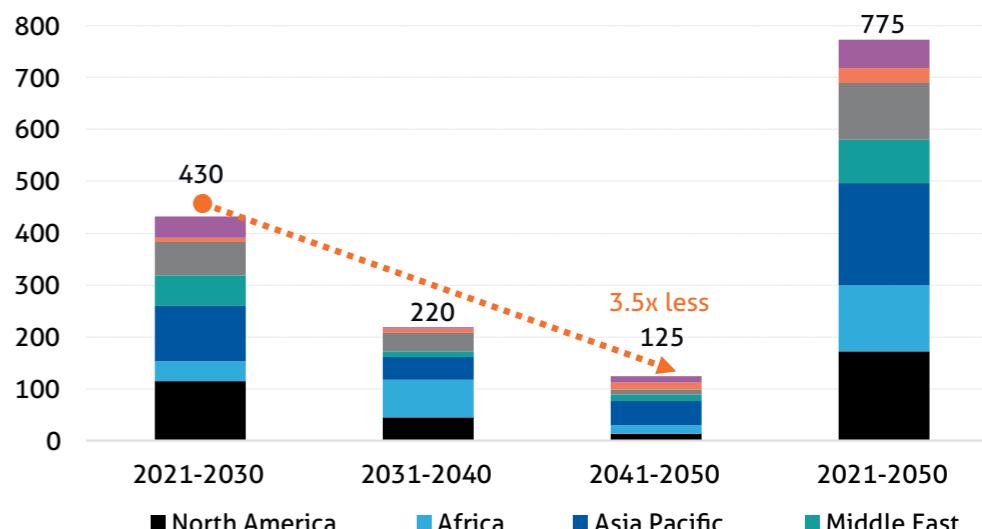
Accelerated drilling in shale basins has been evident. Haynesville rigs jumped from 30 in July 2020, during the heart of the pandemic, to 70 in May 2022 (6). More broadly, the Marcellus, Haynesville, Montney, and Utica plays attracted around US\$16.5 billion in 2021 and are expected to rise by 33% to US\$22 billion in 2022 (7). Higher spending us a response to both higher natural gas prices as well as cost inflation. The US will require US\$1 trillion to boost production by 19% by 2050.

#### 5.2 Midstream natural gas investment

Midstream natural gas investment will accelerate to US\$775 billion by 2050. Higher global LNG demand growth, particularly in Europe this decade, along with elevated Asia Pacific LNG appetite longer term, will be key drivers. The major share of investment will be dedicated to the capital-intensive natural gas upstream.

But spending in the midstream, which includes pipelines, liquefaction and regasification facilities, will be dominated by liquefaction capacity.

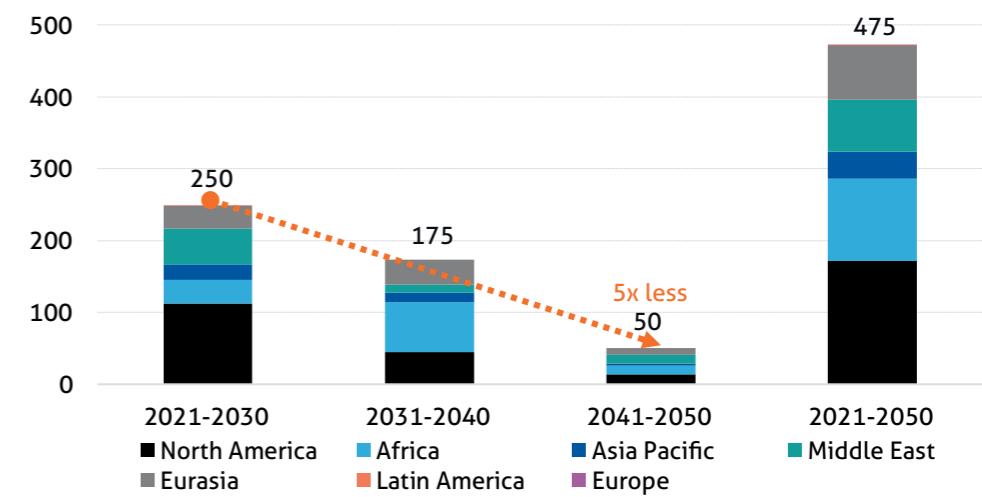
Figure 5.3. Global midstream capex by region (real US\$ billion)



Source: GECF Secretariat based on data from the GECF GGM

Investments in new LNG infrastructure are anticipated to surge following 2022, a game-changing year for the LNG industry. This decade will be critical given the increase in LNG demand in Europe and the Asia Pacific region. The European and global energy crisis drive more accelerated LNG infrastructure development in the short to medium term.

Figure 5.4. Global LNG liquefaction capex by region (real US\$ billion)



Source: GECF Secretariat based on data from the GECF GGM

Liquefaction investment will reach US\$475 billion by 2050, with around US\$250 billion allocated this decade. Timely execution will be critical for project developers as this decade will require five times more funding than the 2040s.

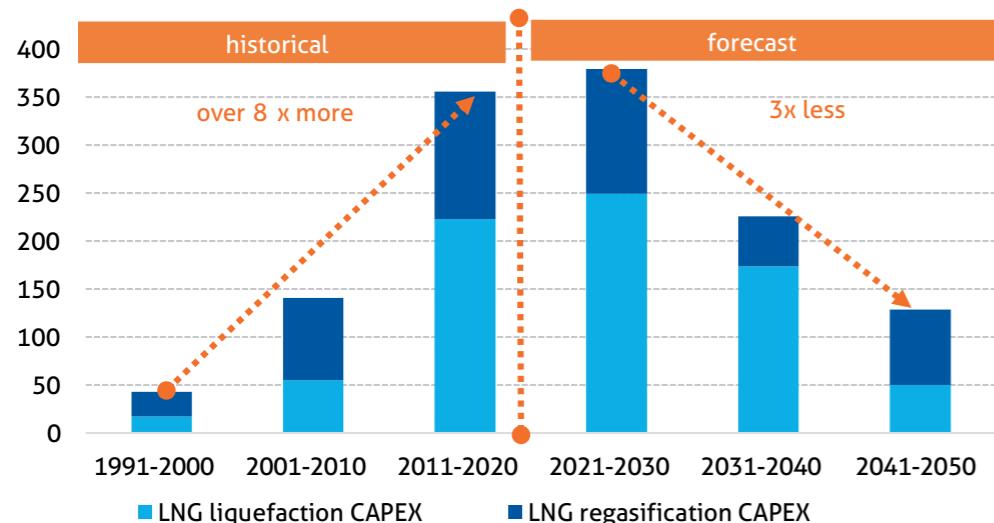
Amid the capacity boom, LNG supply will increase from around 372 mt in 2021 to about 565 mt in 2030. This figure will jump to 720 mt in 2040 and 850 mt in 2050, with major projects already under construction or working toward sanction.

Australia, Mozambique, Qatar, Russia and the US are expected to sustain their LNG spending, securing their place as key producers by 2050 - regardless of the green energy transition.

#### Historical background and current trends

Historical LNG infrastructure investments for the past three decades worldwide witnessed a staggering accumulative growth. Total LNG liquefaction and regasification capex for the period of 1991-2000 surged by more than 8 times from US\$45 billion to US\$355 billion in 2011-20.

Figure 5.5 Historical and future LNG investment trends (real billion US\$)



Source: GECF Secretariat based on data from the GECF GGM

The 2010s and 2020s will be considered the 'golden age' of LNG investment. But spending—both on the supply and demand sides - will decline considerably after 2030 (see Figure 5.5.). GECF countries, particularly Qatar and Russia, along with non-GECF Australia and the US have driven dramatic growth in liquefaction investment over the past three decades.

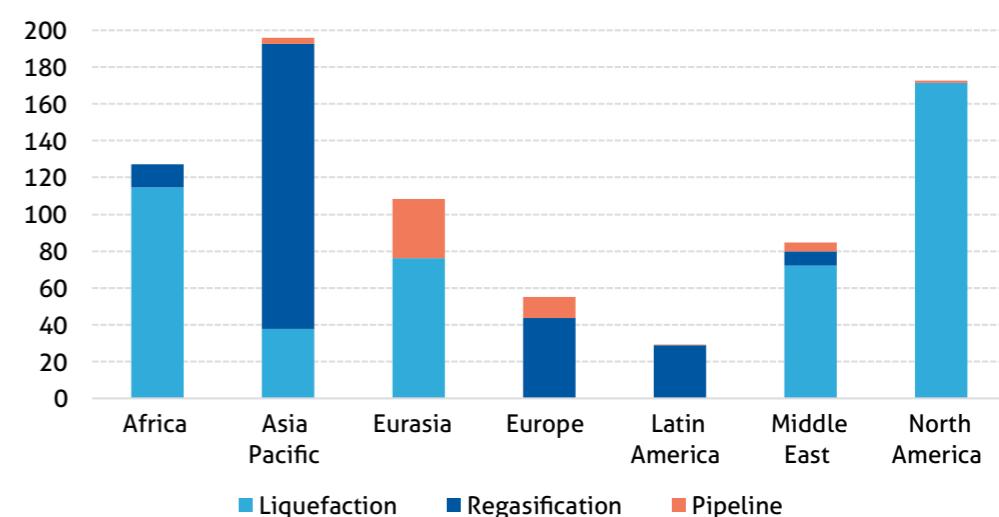
Dramatic growth in global gas LNG liquefaction investment during the past three decades was due to GECF member countries, particularly Qatar and Russia, as they saw a great expansion in their LNG facilities as well as non-GECF Australia. Another key factor that can explain that was the ambitious plans of the US to ramp up LNG exports on the back of massive shale gas output from unconventional resources. The first wave of the US LNG construction began in 2012, while the second wave of US LNG started in 2018 on the back of a China-led rise in natural gas demand. All that enabled the US to become a key LNG exporter with around 80 mtpa of liquefaction capacity as of 2021 end (8).

The 2010s and 2020s will be considered the 'golden age' of LNG investment. But spending—both on the supply and demand sides - will decline considerably after 2030 (see Figure 5.5.). GECF countries, particularly Qatar and Russia, along with non-GECF Australia and the US have driven dramatic growth in liquefaction investment over the past three decades.

#### Midstream gas investment by region

Asia will be home to US\$200 billion in natural gas infrastructure spending by 2050, around 25% of global midstream investment. Around 80% will be attributable to regasification infrastructure.

Figure 5.6. Midstream gas investment by region 2021-50 (real billion US\$)



Source: GECF Secretariat based on data from the GECF GGM

Liquefaction capacity investment will dominate spending in North America, Africa and the Middle East over the longer term. The Eurasia region will be split between liquefaction (70%) and regasification (30%), while European and Latin American infrastructure investment will be allocated primarily to regasification (see Figure 5.6.).

Africa and Middle East midstream CAPEX will be designated primarily towards liquefaction capacity build-ups with an estimated US\$115 billion and US\$70 in 2021-50 respectively. Meanwhile, European and Latin American gas infrastructure investment will be mainly allocated to LNG regasification capacity developments.

#### **Africa**

New projects in Mozambique, Tanzania and Mauritania, along with Nigeria, Egypt and Senegal, to a lesser extent, will drive African midstream investment. Spending will top US\$115 billion, with roughly 61% of the total expected in the 2030s. US\$33 billion will be allocated this decade, 2021-30; about US\$70 billion – the next decade, 2031-40; and US\$12 billion - in 2041-50.

#### **Asia Pacific**

China and India are leading in regional regasification investment following decades of South Korean, Japanese and Taiwanese import domination. Many other markets in – developing South and Southeast Asia are also aiming at developing regasification capacity. Countries like Malaysia and Indonesia, which are net LNG exporters, are increasingly importing LNG to meet rising, localised natural gas demand. Indonesia continues to add regasification capacity around the archipelago.

#### **Eurasia**

The Russian LNG industry started its transformation in 2013 when the government designated LNG expansion as a significant investment and commercial priority and opened the space to third parties (9). Novatek has led Russian LNG development, launching its Yamal LNG project both on time and on budget. The project attracted the largest ever project financing in Russia, totalling US\$19 billion, with more than 90% of funding sourced by Russian and Chinese entities. Novatek, along with Rosneft and Gazprom, have several new projects planned. Russia can remain one of the world's largest LNG exporters if technological and financing challenges can be navigated successfully. Current Russian liquefaction capacity development is focused on the successful completion of the Novatek-operated Arctic LNG 2 project.

#### **Europe**

Europe is expected to invest US\$45 billion in regasification infrastructure over the 2021-50 period, with US\$30 billion before 2030. LNG resides at the heart of the EU's near-term energy security strategy. It is aiming to expand regasification capacity and resolve existing gas infrastructure bottlenecks. Companies in the bloc have invested heavily in LNG infrastructure over the past few decades. More than 20 large-scale terminals are in operation and connected to the grid, and additional capacity is under construction. European governments have moved quickly to install new regas capacity with the swift deployment of FSRUs in the first stage. By 2025, Europe might add between 60 mtpa and 80 mtpa capacity. Growth will

come from new projects and expansions to existing terminals as well. Germany will reside at the centre of new regasification capacity, but new terminals are planned for Italy, Greece, and other countries as well.

#### **Latin America**

Regasification will be a priority in Latin America, with investment expected to reach US\$29 billion by 2050. Brazil, Chile and Argentina are the region's key importers. Brazil, which has the largest LNG regasification capacity of the region is followed by Argentina. The region has around 53 million tonnes per year of regasification capacity, of which around 30% are FSRUs. Another 20 million tonnes per year of projects are under construction. With two major LNG exporters, Trinidad and Tobago and Peru, the continent doesn't anticipate any further LNG liquefaction capacity expansion in the future. Uncertainty regarding indigenous production, geopolitical hurdles and proximity to abundant US LNG are expected to drive down the need for export pipelines, though domestic networks will still be expanded.

#### **Middle East**

Qatari plans for North Field expansion anchor the region's liquefaction capacity growth. Qatar's North Field East (NFE) and North Field South (NFS) phases, both of which are expected to be operational by 2027, will cost US\$50 billion (10). NFE is the larger and more expensive of the two, accounting for 58% of the total. Other regional projects expected to require significant investment include Adnoc's liquefaction project planned for Fujairah in the UAE and several Eastern Mediterranean pipeline plans intended to increase flows both within the region and to export markets.

#### **North America**

The European and global energy crisis is 'setting the scene' for US LNG exporters vying to be part of a 'third wave' of projects to reach an FID in the coming years. A wave of long-term foundation agreements concluded in 2022 is helping to underpin new US LNG project developments. Long-term contracting mainly refers to buyers in the Asian gas markets, while European buyers are more reluctant to commit to long-term contracts due to the EU's energy transition ambition and net-zero emissions goals. North America is the leading region with liquefaction projects expected to be sanctioned by 2025. A wave of long-term foundation agreements concluded in 2022 is helping to underpin 85 mtpa (11) of new US LNG project developments. Still, several ventures are already under construction. This includes the US\$10 billion Golden Pass project in Texas, a joint venture between QatarEnergy (70%) and ExxonMobil (30%), which is poised to start up in 2024. Venture Global's US\$13 billion Plaquemines project in Louisiana reached FID in 2022 and expected to launch in 2025.



## 06

### Focus on Africa

**Key findings:**

- Natural gas is expected to be Africa's greatest opportunity to help alleviate energy poverty.
- Africa's population is expected to increase from 1.4 billion people today to 2.5 billion by 2050. This accounts for more than 60% of the world's population growth in the period, and its share rises from 17% to 26%. Urbanisation will increase from 44% to 60%.
- The COVID-19 pandemic, Russia-Ukraine conflict and current economic headwinds are slowing progress towards reaching Sustainable Development Goals. Still, real GDP is forecast to grow almost three-fold, from US\$2.7 trillion in 2021 to US\$7.1 trillion in 2050.
- Oil and gas exports are a major source of revenues, accounting for 50% to 80% of export revenues in some countries.
- Dramatic demographic changes and rapid economic growth will drive African energy demand growth to exceed the average rate of 2% per annum through 2050. Sub-Saharan Africa will account for 84% of this increase.
- Access to clean energy is a key requirement for African sustainable development, with government policy focused on encouraging investment. Natural gas will benefit from this policy push, with renewables providing a growing contribution as well.
- Natural gas will be responsible for around 30% of the continent's primary energy demand increase. Rich gas reserves align with the region's push for socioeconomic development, along with LNG export revival, to generate economic growth.
- Natural gas demand will expand by 3.2% per annum, from 165 bcm in 2021 to 415 bcm in 2050. Around 70% of total demand growth will be attributable to power generation.
- The continent's natural gas production will increase from 260 bcm in 2021 to 585 bcm in 2050, representing an average annual growth of 2.8% over the period. Nigeria and Mozambique are expected to account for 63% of African output growth.
- African LNG export capacity will reach 199 mtpa by 2050. Mozambique, Nigeria and Mauritania/Senegal will drive this increase.

## 06 Focus on Africa

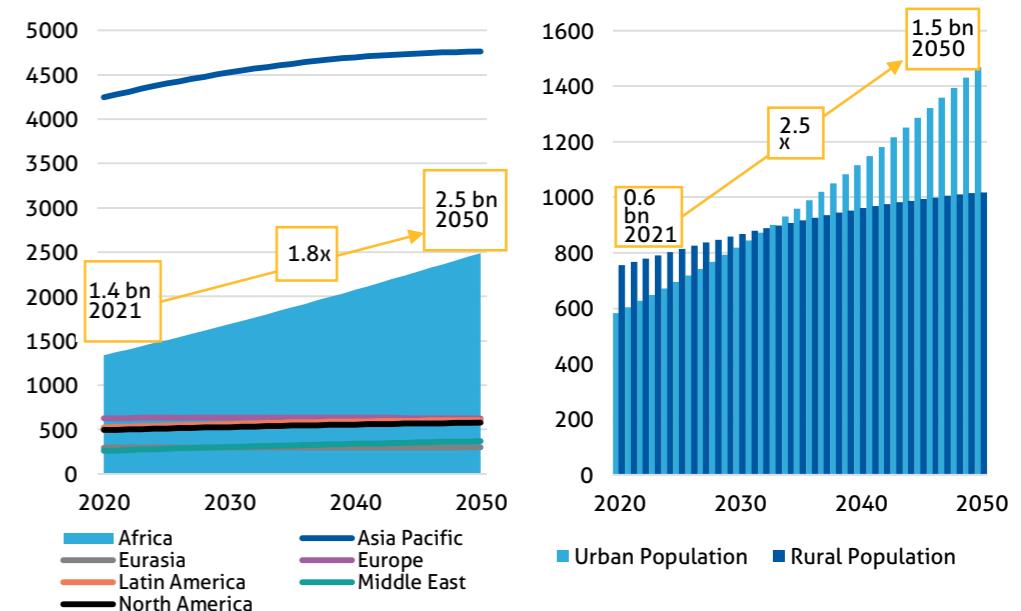
### 6.1 Key assumptions and energy challenges

The COVID-19 crisis and challenging post-pandemic recovery have erased years of economic and social progress (1), particularly in sub-Saharan Africa. However, the continent long-term economic outlook is positive, underpinned by a young and growing population, abundant natural resources, and pro-growth policies aiming at achieving the UN Sustainable Development Goals. Natural gas is expected to be Africa's greatest opportunity as a long-term supply solution to help alleviate energy poverty and enhance quality of life, especially in sub-Saharan Africa.

#### *Population and demographics*

Africa has the youngest and fastest-growing population in the world. It is set to grow at an average rate of 2.1% per annum between 2021 and 2050, more than three times the global average of 0.7%.

**Figure 6.1. African population (left) and African urban population (right) (million people)**



Source: GECF Secretariat based on data from the GECF GGM

The UN projects that the global population will increase from 7.9 billion in 2021 to 9.7 billion in 2050. Africa will account for more than 60% of this growth, with the continent's population almost doubling from around 1.4 billion in 2021 to close

to 2.5 billion in 2050. Its current population of 1.4 billion people is equivalent to that of China, or India. By 2050, it will represent more than 80% of the population of China and India combined. The continent's share of the world population is forecast to rise from 17% to 26% by 2050.

Africa's population is very young, as the median age is about 20 years. Nigeria, Ethiopia, Egypt and the Democratic Republic of the Congo (DRC) accounted for over 500 million people in 2021, almost 40% of Africa's population.

The share of Africa's urban population is also set to increase 2.5 times over the next three decades, from 44% in 2021 to almost 60% in 2050. The urban transition offers great opportunities, but it also poses significant challenges – particularly pressure on existing infrastructure. Weak coverage of basic services, access to reliable and affordable energy, clean water, and dependable electricity are among the key issues.

#### **Economic developments**

In the long run, Africa's real GDP is forecast to grow almost three-fold, from US\$2.7 trillion in 2021 to US\$7.1 trillion in 2050. This pace of growth is higher than that of the world's GDP, which is expected to double.

African GDP growth is expected to decline to 3.7% in 2022 from 4.2% in 2021. Global economic conditions driven by rising food and energy prices, as well as adverse weather conditions and rising risk of debt distress (2), hinder poverty reduction in the Sub-Saharan region. The COVID-19 pandemic has reversed the previous years' gains obtained in alleviating extreme poverty. Inequality within countries has also widened, exacerbated by higher energy and food prices. The Sub-Saharan economic performance is uneven across sub-regions: West and Central Africa have grown faster in 2022 than East and Southern Africa.

Food insecurity and soaring inflation exacerbate the social tensions, in addition to low agricultural productivity and lack of infrastructure in many countries. More than one in five people faces hunger in Africa. In 2022 about 140 million people are estimated to be acutely food insecure in Sub-Saharan Africa (3). Total factor productivity in agriculture grew at an average annual rate of only 0.2% in Sub-Saharan Africa from 2000 to 2019.

The COVID-19 pandemic and, to a lesser extent, the Russia-Ukraine conflict, led to a "freeze" in UN SDG progress in sub-Saharan Africa. Before the pandemic lockdown, all sub-Saharan African countries were expected to deliver SDG progress by 2030, while only 18 of 44 countries were anticipated to advance less than halfway to their targets by 2030. However, SDG progress, especially SDG 1 and SDG 2 (poverty and hunger elimination), is expected to continue at a slower rate – or even regress – due to the current economic situation and uncertainties (4).

Slowing growth may hasten pandemic-induced reductions in per capita income. In 2023, per capita incomes are expected to remain below pre-pandemic levels in 45% of the region's economies and half of its unstable and conflict-affected countries. In early 2022, approximately 40% of sub-Saharan African economies and 39% of the region's vulnerable and conflict-affected states were thought to be in this situation. Sub-Saharan Africa is currently expected to remain the only emerging market and developing economy (EMDE) region where per capita incomes will not reach 2019 levels even in 2023 (5).

Despite decades of rapid growth, regional inequalities persist in sub-Saharan Africa. Many of these economies grew at a record pace before the pandemic. Ethiopia and Rwanda enjoyed some of the fastest expansion in world – an average of more than 7.5% annually over the past two decades (6). African countries have delivered tremendous progress in reducing domestic income inequality. Improvements in basic infrastructure helped lagging regions converge faster to national levels. This is even more pronounced in the oil and gas exporting countries.

Macroeconomic stability, trade openness, strong institutions and political stability, along with well-targeted investments, were key drivers helping to reduce regional inequality in Africa. African countries, particularly in sub-Saharan Africa, need to pursue a broad-based policy framework. This is anchored around well-designed redistributive fiscal policy with a clear investment strategy to assist underserved regions, macroeconomic stability to foster inclusive growth, and building institutions to ensure political stability and equitable public service delivery (6).

Oil and gas exports are a major source of revenue for many African countries, accounting for 50% to 80% of total government revenue in some countries (7). Most of the gas produced in Africa is exported. On a broader scale, Africa is also set for producing large supplies of metal and mineral commodities such as bauxite, diamond, gold, iron ore, platinum group metals, lithium, rare earth metals and zinc. Higher commodity prices for energy as well as metal and mineral commodities are expected to support extractive sector recoveries and boost export and fiscal revenues. Algeria, Angola, Botswana, DRC, Egypt, Equatorial Guinea, Gabon, Mauritania, Mozambique, Nigeria, Sudan, and Zambia are poised to benefit.

#### ***Africa and the low carbon energy mix-climate-SDGs nexus***

The African continent is widely seen as the new frontier in the energy industry. However, it is also regularly qualified as the most vulnerable continent to the effects of climate change. Smartly managing the policies of energy transition across the continent can help create lasting synergies between energy and climate goals, and more sustainable development for all.

Strong demographic growth, increasing standards of living, and expanding manufacturing sectors have led to a sustained interest from African and international investors in the continent's markets, driving a resilient growth in energy demand. However, the challenges of energy access and low-carbon energy development across the continent can appear daunting. Until now, and despite important national differences, the continent suffers overall from limited civil infrastructure, and especially inadequate transportation infrastructure, and undersized industrial and supply chain ecosystems. The limited energy sectors are both contributing to this issue and a consequence of this situation. But a series of large gas discoveries and important gas projects hold the potential to challenge this status quo.

Several important projects have started in a number of African countries, such as Mauritania, Mozambique, Senegal, and among others, and populations and governments share the understanding that benefiting from natural gas could constitute a sharp modernisation of their national energy systems, boost the economy, and accelerate the sustainable development the continent urgently needs.

African nations were badly hit by the COVID-19 pandemic, the subsequent global recession, and the recent rise in energy and food commodity prices. Against this background, the shift from biomass, charcoal and coal for basic energy needs towards natural gas for power generation and butane for cooking purposes could be cleaner solutions, both in terms of local air pollution and greenhouse gas emissions, especially black carbon, and generate cheaper electricity than by diesel generators or crude oil burning power plants.

Also, gas exports are expected to eventually provide governments with the financial means to develop their broader energy sector, including renewables, which should undergo a rapid growth this decade, especially in rural areas via off-grid systems. Meanwhile, the greater use of natural gas should help contain the demographic pressure on forestry resources, by limiting the need for logging and charcoal production. In some contexts, natural gas should help the fertiliser industry, and enable the continent to witness substantial gains in agricultural productivity. This is important as the continent's population will almost double by 2050 and as agriculture is vulnerable to environmental degradation (especially loss in biodiversity) and climatic changes (especially more erratic rainfall patterns).

The energy infrastructure will also have to be modernized, and with technologies that adapt to the need of the twenty-first century. That includes robustness, smartness; to be part of smarter national and regional grids, and lower carbon emissions. As most countries on the continent cannot afford, due to various industrial constraints, to develop a reliable base load featuring nuclear energy, using the continent's conventional natural gas resources is a way to mitigate current issues of pollution and greenhouse gases emissions, while monetising and optimising the continents' resources, and giving greater support to the intermittent but direly needed renewable energies the African continent is naturally rich in. This could fuel a sustainable

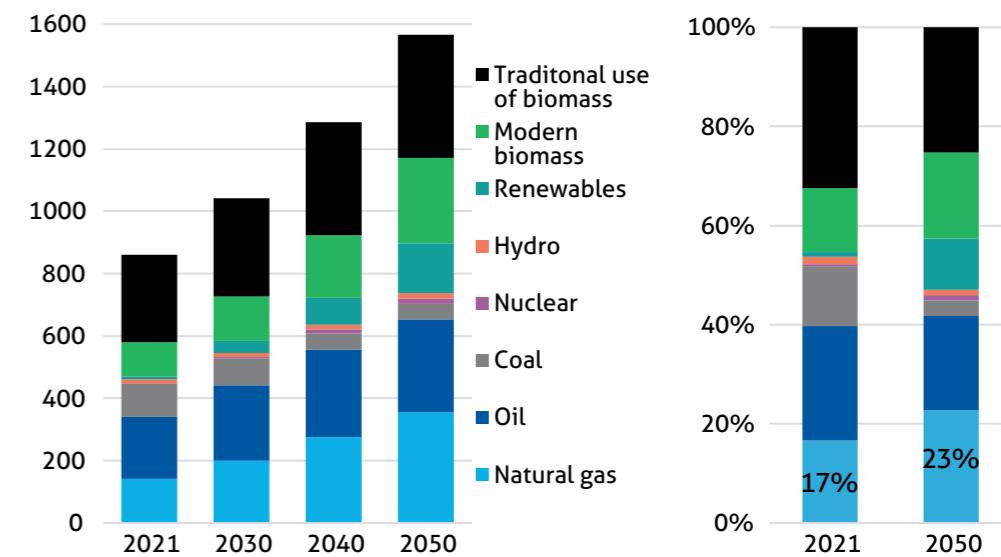
development of Africa in this decade and well beyond the current United Nations development agenda and the 2030 SDG targets.

## 6.2 Energy and natural gas demand trends

Primary energy demand in Africa is projected to increase by 82% from 860 Mtoe in 2021 to 1,565 Mtoe by 2050. Sub-Saharan Africa will account for 84% of this growth amid higher living standards and better access to energy.

Natural gas will be responsible for around 30% of Africa's total energy demand increase – the most significant gains of any fuel. Natural gas endowment confirmed by a series of major discoveries fits well with Africa's push for industrial and social development. Africa will enjoy an LNG export expansion, while resulting revenues will help to drive economic growth and structural transformation.

**Figure 6.2. Primary energy demand trends in Africa (Mtoe) and fuel shares (%)**



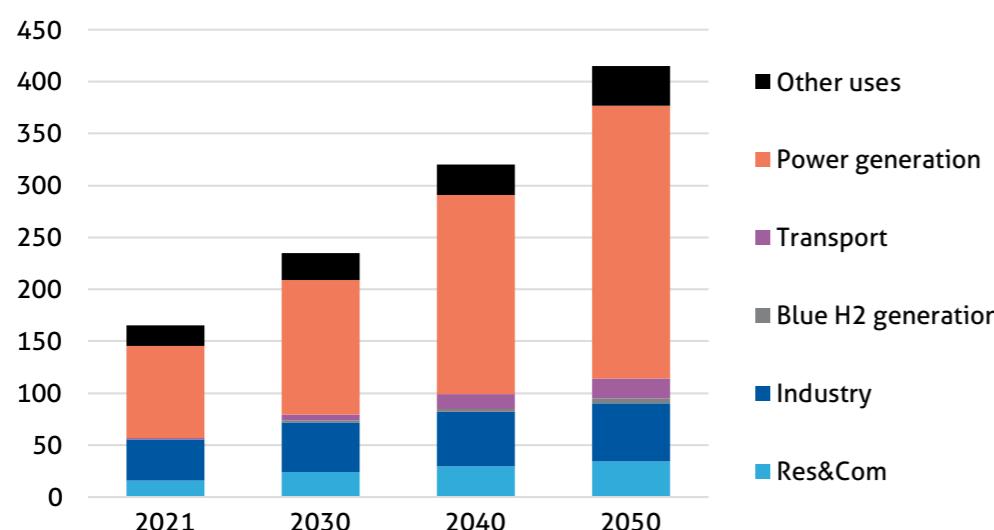
Source: GECF Secretariat based on data from the GECF GGM

There is scope for natural gas to meet a critical power deficit and enable accelerated electrification in partnership with renewables. Moreover, there is potential for gas to penetrate the residential segment while helping to move away from the use of traditional biomass, thereby alleviating air pollution and preventing deforestation. Simultaneously, natural gas as a key fertiliser input will contribute to agricultural sector productivity and play a role in ensuring food security.

We project that African natural gas demand will rise by 3.2% annually, from 165 bcm in 2021 to 415 bcm in 2050. Power generation represents 70% of the increase over the outlook period. Other sectoral contributions will be relatively balanced.

Most residential and commercial gas demand growth will emerge in North African countries amid increasing grid connections. Rising gas availability will also encourage demand in gas-based industries such as petrochemicals, methanol, and fertilisers. Many industrial projects proposed for several sub-Saharan countries provide strong commercial cases for domestic gas market development. The transport sector will emerge as a new area as well.

**Figure 6.3. Africa natural gas demand by sector (bcm)**



Source: GECF Secretariat based on data from the GECF GGM

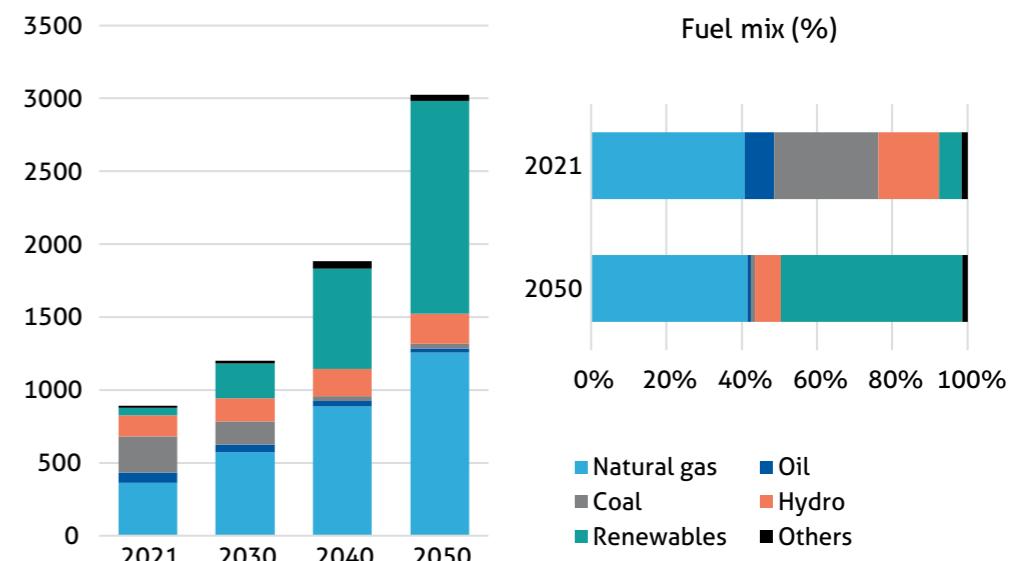
Natural gas demand will be met by the continent's own production, allowing African nations to intensify intra-regional integration. Recent announcements indicate that regional gas infrastructure will expand rapidly and become more diverse. Countries without direct access to large gas resources are exploring prospects for LNG deliveries. For example, Ghana plans to become West Africa's gas hub, developing the Tema LNG import project to supply the domestic market and sell fuel to nearby countries.

There is also strong impetus for long-distance pipeline development. Algeria, Niger, and Nigeria signed agreements to build the Trans-Saharan Gas Pipeline with a capacity of 30 bcm, linking Nigeria to Europe through the Algerian gas transport system, a pipeline that gained recently renewed importance. In September 2022, Central African countries signed an agreement to create a Central Africa Pipeline System, a new 6,500-km oil and gas network linking 11 countries with hubs, terminals, and storage facilities (8). In October 2022, Kenya and Tanzania agreed to accelerate the realisation of cross-border natural gas pipeline (9). There has also been movement on the Nigeria-Morocco Gas Pipeline.

The potential for gas demand in the African power generation sector is quite high (see Figure 6.4). With electricity generation rising from 890 TWh in 2021 to 3,025 TWh in 2050, natural gas is forecast to cover more than 40% of the total growth and account for 42% of the regional power generation mix by 2050. Renewables are expected to provide a larger 48% share by that date, given similarly rising electricity needs for green hydrogen production in some countries in view of export-oriented project advancement (particularly after 2035).

Additionally, options such as gas-by-wire within the same regional power pool and integration of LNG-to-power units will create additional sources for monetising locally produced gas. Natural gas, in tandem with renewables, will become essential in improving electricity access while displacing oil-fired generation and constraining coal-fired power – particularly in South Africa and neighbouring countries where coal is dominant. Natural gas will continue to play an important role in backing up hydropower during dry spells, particularly in sub-Saharan Africa.

**Figure 6.4. Africa power generation by fuel (TWh)**

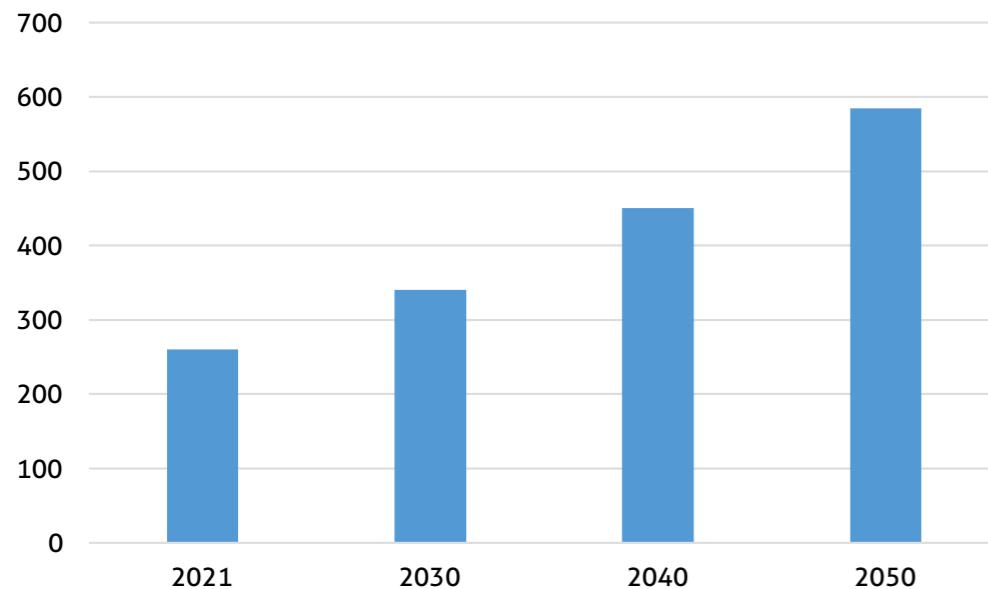


Source: GECF Secretariat based on data from the GECF GGM

Note: Others include bioenergy, nuclear and hydrogen

### 6.3 Natural gas supply outlook

Africa's natural gas production is expected to increase from 260 bcm in 2021 to 585 bcm in 2050. This is an upward revision from our previous outlook due to changes to the Mozambique, Senegal, Mauritania, and Tanzania supply profiles.

**Figure 6.5. Africa natural gas production outlook (bcm)**

Source: GECF Secretariat based on data from the GECF GGM

African natural gas output will be produced from conventional reservoirs. Unconventional YTF (prospective) resources will play a minor role during the last decade of the forecast period, amounting to only 3% of the total supply by 2050.

We also expect that African natural gas utilisation at the expense of carbon-intensive fuels, along with renewables, will drive down emissions. Furthermore, the continent's proximate geography positions it well to supply natural gas to European and Asia Pacific markets. A new natural gas global exporter, Mozambique, celebrated its first LNG cargo from Coral-Sul FLNG. Mozambique's gas production is expected to reach 123 bcm by 2050, driven by abundant gas discovered since 2010. New natural gas suppliers and future exporters, Senegal and Mauritania are expected to reach 45 bcm in 2050. Some 20 mtpa of LNG exports capacity are planned, along with domestic gas market development.

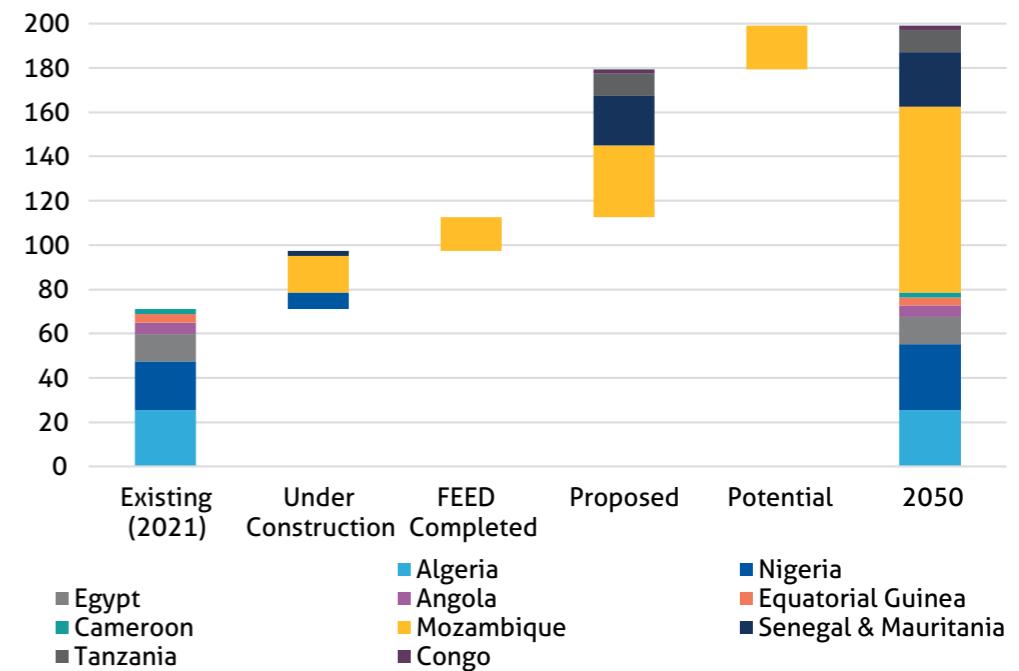
#### 6.4 Natural gas trade outlook

African countries exported around 82 bcm of natural gas to other regions in 2021. Some 41 million tonnes (57 bcm) were exported as LNG, mostly from GECF countries, including Algeria, Angola, Egypt and Nigeria. Algeria and Libya supply gas by pipeline to Europe. In addition, there is also some intra-regional trade by pipelines such as from Algeria to Tunisia, from Mozambique to South Africa, and West African Gas Pipeline from Nigeria to Benin, Togo and Ghana.

Global LNG producers are benefiting from the current tight gas markets and high gas prices. Soaring LNG demand - as Europe attempts to tackle the issue of energy security by reducing dependence on Russian gas - is triggering an upsurge in new LNG projects worldwide, including in Africa.

Africa is expected to raise its LNG export share to Europe from under 45% in 2021 to around 55% in 2022. In the short run, Africa can expand LNG exports by raising the utilisation of its existing plants and deploying more FSRUs, provided sufficient feed-in gas could be made available.

The long-term future for LNG exports in Africa is promising, with exports forecast to reach 166 bcm by 2050, of which 157 bcm (114 mt) will be net LNG.

**Figure 6.6. Africa LNG liquefaction capacity (mtpa)**

Source: GECF Secretariat based on data from the GECF GGM

Currently, Africa has about 71 mtpa of liquefaction capacity in Algeria, Nigeria, Egypt, Angola, Equatorial Guinea, and Cameroon. Utilisation reached only 58% in 2021, primarily due to upstream constraints.

African liquefaction capacity is projected to reach 199 mtpa by 2050. Mozambique, Nigeria, Mauritania and Senegal will drive liquefaction capacity growth, while Algeria, Egypt and several other African nations' capacity will grow incrementally.

as well. Timely execution and fast-track project development are crucial as the African LNG sector is competing with other countries such as the US.

The prospects for LNG from Sub-Saharan Africa vary significantly in terms of scale and timing. There are LNG liquefaction projects amounting to 23 mtpa that are under construction in Mozambique (13 mtpa), Mauritania/Senegal (2.5 mtpa), and Nigeria (7.6 mtpa). There are 15.2 mtpa of Rovuma LNG liquefaction capacity with the Front-End Engineering Design (FEED) stage completed in Mozambique. Furthermore, proposed projects amount to about 67 mtpa, while 20 mtpa of potential projects may exist.

Considerable gas reserves were discovered in the Grand Tortue Ahmeyim (GTA) gas field in 2014 spanning the border between Mauritania and Senegal.

Mauritania and Senegal will become LNG exporters in 2023 when the 2.5 mtpa Greater Tortue Phase 1 project starts up. The BP-operated venture, which counts Kosmos Energy, Petrosen, and Societe Mauritanienne des Hydrocarbures as partners, uses gas from GTA.

The partners reached FID on Phase 1 in 2018. Phase 2 would double capacity to 5 mtpa. Capacity could reach 10 mtpa. BP has a 20-year lease and operating Agreement with Golar LNG for a floating liquefaction vessel, while Kosmos Energy has a 20-year deal to supply the full capacity for the project's first phase. Phase 1 was 80% completed at the end of the second quarter of 2022.

Yakaar-Teranga (Senegal) and Bir Allah (Mauritania) are two additional fields under consideration for the area. While Yakaar-Teranga is expected to supply gas for domestic use initially, both areas are said to have 10 mtpa potential. Some 30 mtpa are expected for the Mauritania/Senegal complex.

Mozambique will emerge as the largest African LNG producer by the mid-2030s and retain its position through 2050. LNG can be a game-changer for Mozambique's economic transformation and development.

Mozambique joined the LNG exporters 'club' in November 2022 when the first cargo departed from the offshore Coral Sul FLNG facility. It is the first floating liquefaction facility to be deployed in African deep water.

The country has over 30 mtpa slated to come on stream before 2030 (see Table 6.1.).

**Table 6.1. Mozambique LNG liquefaction projects**

	Project/operator	Capacity/location	FID/stage	Offtakers	Source field/reserves
1	Coral Sul LNG <i>Eni-operated</i>	3.4 mtpa/ offshore Rovuma Basin	US\$7bn FID/ 2017; operational in 2022	BP for 20 years	Coral offshore gas field in Area 4/450 bcm
2	Mozambique LNG <i>TotalEnergies- operated</i>	12.88 mtpa (2 trains)/ Afungi peninsula, Cabo Delgado province	US\$20bn 2019 FID; under construction (suspended)	Long-term contracts with key LNG Asian and European buyers	Golfinho/Atum field, offshore in Area 1
3	Rovuma LNG <i>ExxonMobil- operated</i>	15.2 mtpa (2 trains)/ Rovuma Basin off the Cabo Delgado coast	US\$30bn/ FID planned in 2024	n/a	Rovuma Basin off the Cabo Delgado coast, 3 fields in Area 4 /2,400 bcm

Mozambique LNG construction is currently on hold because of the region's security situation, while the Rovuma project has yet to reach FID. Eni has proposed (10) construction of a second FLNG processing facility to circumvent political risks that have disrupted ExxonMobil from building an onshore mega plant. Such a facility could be delivered in less than four years, enabling both offshore and onshore concepts for gas resource development.

Long term by 2050, Mozambique is expected to reach 84 mtpa of LNG liquefaction capacity.



## 07 Alternative Scenarios

## Key findings:

- The Energy Sustainability Scenario (ESS) and Accelerated Energy Decarbonisation Scenario (AEDS) provide two alternative trajectories for the long-term global energy outlook.
- The ESS considers ending energy poverty and promoting economic growth in Africa in line with the United Nation's Sustainable Development Goals. It bridges the gaps between three interdependent pillars of energy economics, energy environment, and energy security.
- Africa's economy is set to rapidly expand under the ESS. Africa's GDP per capita assumed to be reached US\$5,000 by 2050, which is 75% higher than US\$2,850 under the Reference Case Scenario (RCS) in 2050. This indicates that Africa's GDP will reach US\$12.4 trillion by 2050.
- Primary energy demand in Africa will increase from 860 Mtoe to 2,180 Mtoe, or 154%, by 2050. More than 85% of this growth will originate in sub-Saharan Africa.
- Primary energy intensity will decline by 2.2% annually on average over the period, compared to 1.4% annually in the RCS. Improvements in energy efficiency, primarily through declining reliance on inefficient use of traditional biomass for cooking, is a key driver.
- Natural gas and renewables account for 51% of Africa's energy mix, with gas demand growing to about 600 bcm by 2050. More than 90% of the total growth will originate in sub-Saharan Africa.
- Natural gas in Accelerated Energy Decarbonisation Scenario (AEDS) remains resilient, with its share rising from 23% to 25% by 2050. However, absolute natural gas demand will be almost 730 bcm lower than indicated in the RCS.
- The AEDS, which explores a wide range of decarbonisation pathways, indicates a much more aggressive emissions reduction profile compared to the RCS. Almost 14 Gt of energy-related CO<sub>2</sub> will be emitted by 2050- half of the RCS projection and 60% lower than the current emissions level.
- Carbon capture and storage (CCS) is a key decarbonisation option as well as blue hydrogen. Indeed, the AEDS indicates that, with CCS, 8.7 Gt of CO<sub>2</sub> can be abated by 2050.

## 07 Alternative Scenarios

This edition of the Global Gas Outlook considers two alternative scenarios. The Energy Sustainability Scenario (ESS) explores the possibility of ending energy poverty and promoting economic growth in Africa. It also considers implementation of the United Nations Sustainable Development Goals (SDGs), specifically SDG 7, to ensure access to affordable, reliable, sustainable, and modern energy for all.

The Accelerated Energy Decarbonisation Scenario (AEDS) considers possible pathways for faster energy system decarbonisation. This scenario aims to assess the maximum decarbonisation potential through the natural gas supply chain. This involves current natural gas use, such as coal-to-gas switching primarily in the power sector, or in decarbonised form through pre- and post-combustion carbon capture.

### 7.1 Energy Sustainability Scenario (ESS)

#### Introduction

The energy transition debate is underpinned by the crucial role sustainable energy sources and decarbonisation should play in mitigating climate change. Many countries, businesses, and cities have pledged to reach net-zero by 2050 or thereafter. However, associated near- to medium-term low-carbon plans are missing or remain vague. Net-zero requires broad changes in production and consumption patterns. In addition, there is no one-size-fits-all model. Energy specialists' perspectives and expectations differ significantly regarding the future architecture of energy systems and technologies necessary to provide sustainable, efficient, and secure energy supply.

In this regard, different scenarios have emerged focusing merely on clean energy supply and pathways to the net-zero energy system. Specifically, a misguided narrative has the developed world calling for prohibition of funding for new gas pipelines, gas-fired power stations, or gas-consuming sectors in the developing world such as Sub-Saharan Africa (SSA).

Most energy transition scenarios are intensely focused on decarbonising the entire energy system. However, this ignores the fact that sustainable development is based on the three intertwined and mutually supportive pillars of economic development, social progress, and environmental protection.

The need for balancing the energy trilemma's three core dimensions of energy security, sustainability, and affordability is acute. The developed world can prioritise energy sustainability over energy affordability, as it is capable of bearing

substantial energy transition costs. However, low-income countries are struggling to meet their population's basic needs of food, water, shelter, and energy.

The use of Africa's abundant gas resources has become a contentious issue amid a worldwide push to reduce emissions and combat climate change. However, even if SSA boosts its energy consumption overnight using natural gas only, the extra CO<sub>2</sub> would be comparable to only 1%-2% of global emissions (1). Accordingly, it is less likely that gas prohibition in Africa will effectively combat current and future climate issues. Furthermore, a more developed and less vulnerable Africa will have the means to better protect the environment. Finally, socio-economic development will provide Africa with the means to adapt to climate change, as it already suffers from its impacts while being the least responsible for it. Africa's vulnerability is driven by its low adaptive capacity in education, health, infrastructures, and governance systems. Furthermore, urban infrastructures is poorly equipped to deal with the effects of climate change (2).

In Africa, natural gas trails biomass and oil in terms of energy supply. Yet, unlike biomass and oil, gas burns more cleanly and improves air quality. Using gas will reduce both the share of biomass in Africa's future energy supply and reliance on diesel power plants. A robust local gas market in oil-producing African countries will also minimise harmful gas flaring.

Furthermore, less expensive gas-burning turbines help governments avoid massive cost overruns common with coal-fired or nuclear power plants. This is a key benefit, particularly for SSA countries, given prevailing socio-economic conditions. Gas turbines are also less polluting than diesel generators, which are the most widely used modular energy source in several SSA industrial economies.

Africa is a diverse region with substantial human and natural resources that can potentially contribute to inclusive growth and alleviate poverty. Over 1 billion people reside in the region, half of whom will be under 25 by 2050. Africa, benefiting from the world's largest free trade zone and a massive population, could move toward sustainable economic development faster due to its natural resources endowment, notably natural gas.

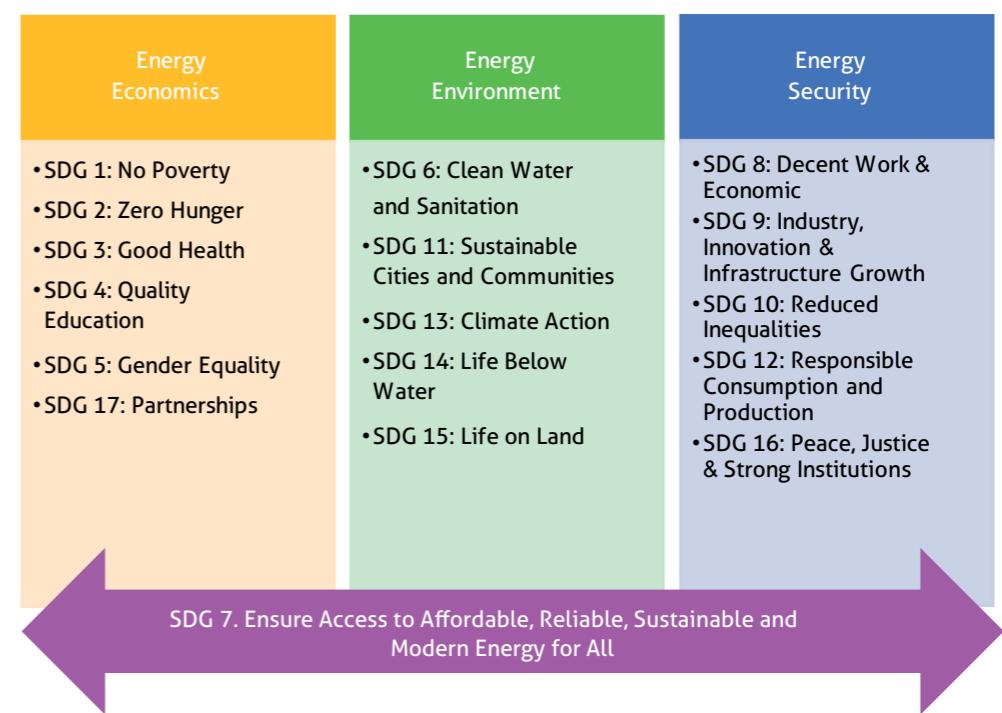
Despite promising economic and industrial trends, more than 600 million people lack access to reliable electricity. Over 900 million do not have access to clean cooking fuels. Traditional fuels, such as waste and biomass (i.e., fuelwood, charcoal, or dung) dominate their daily activities and dramatically threaten their living conditions and health. Smoke from such cooking fuels causes around 500,000 premature deaths in SSA annually — more than malaria, HIV, and tuberculosis combined. Sadly, women and children are the most vulnerable groups exposed to such toxic conditions (3). Furthermore, collecting wood for cooking consumes time,

particular for women and children, that otherwise could be used for education or income-generating activities.

Accordingly, its transition from traditional biomass to cleaner, affordable, widely accessible, and modern energy sources, such as natural gas, renewables and modern biomass shall benefit from massive unhindered support, particularly multilateral financial institutions such as the World Bank and the African Development Bank.

The ESS aims to align with SDG 7 – Affordable and Clean Energy, SDG 8 – Decent Work and Economic Growth, SDG 9 – Industry, Innovation and Infrastructure, and SDG 13 – Climate Action, and bridges the gaps between the three interdependent pillars of Energy Economics, Energy Environment, and Energy Security in Africa.

**Figure 7.1. Energy Sustainability Scenario outlook**



### 1. Energy Economics

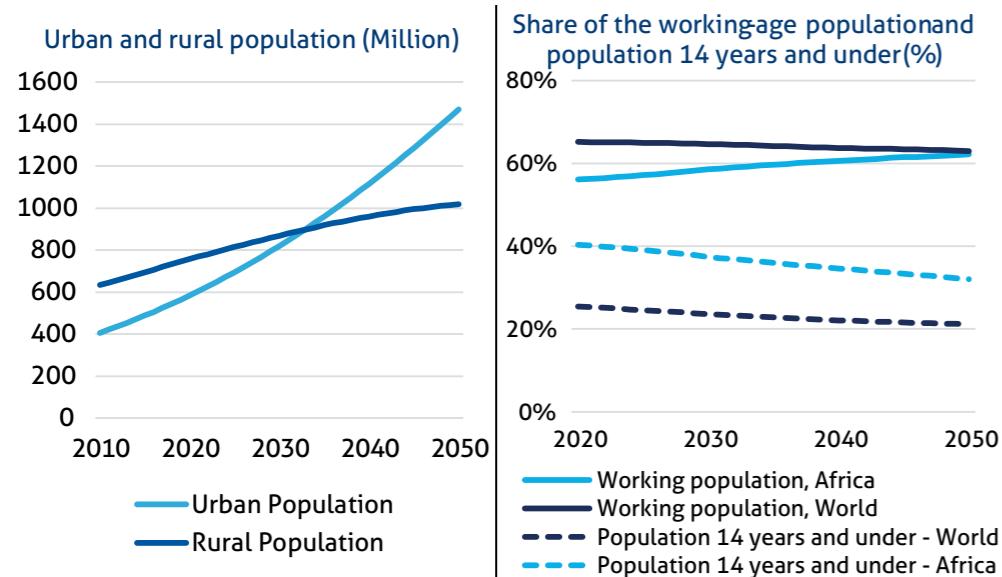
The Reference Case Scenario (RCS) and ESS base their demographic assumptions on the United Nations Department of Economic and Social Affairs Population Division's medium variant projections. The average annual population growth rate is 0.7% from 2021 through 2050, with 2.1%, the highest rate, expected in Africa. Africa's population reached 1.3 billion people in 2021. This translates into a share of 20%. This share was only 13% in 2000, illustrating Africa's significantly higher

population growth relative to the rest of the world. The continent will account for over one-quarter of the global population by 2050. In addition, urbanisation in Africa continues to accelerate, growing from 44% in 2020 to 59% in 2050. This urbanisation rapid trend occurs in Africa and non-OECD Asia. Other crucial demographic factors impacting energy economic growth include age and global migration patterns.

The under-14 share of the African population will remain elevated, though declining from 40% to 32% from 2021 through 2050. Still, even in 2050 this share will be higher than the current global average of 25%.

Conversely, the working population share will grow from 56% to 62% in the long term, reflecting increasing youth entry into the working-age population.

**Figure 7.2. Demographic trends in Africa**



Source: GECF Secretariat based on data from the GECF GGM

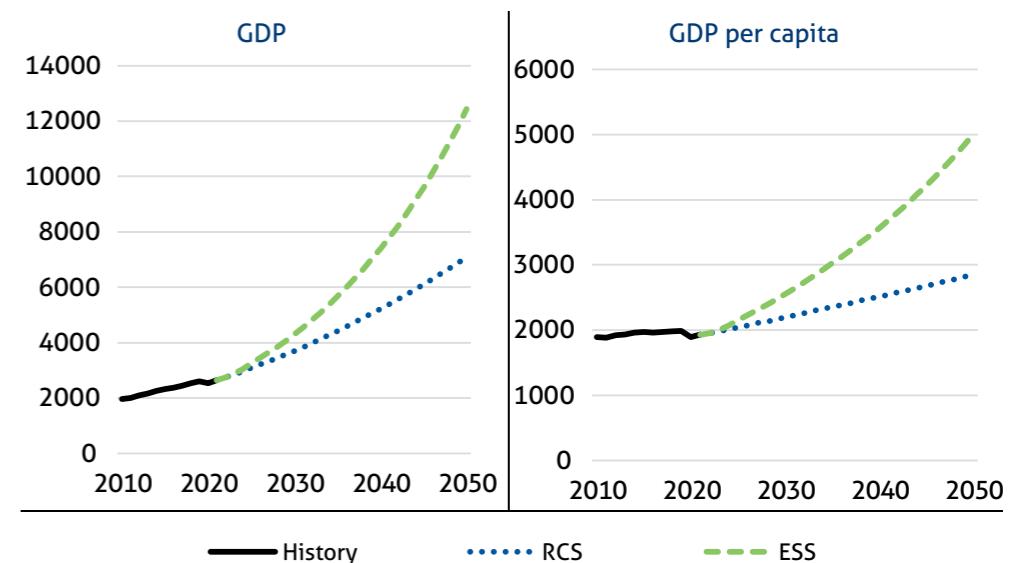
Short- and medium-term RCS economic forecasts are based on the IMF World Economic Outlook (April 2022) projections and in-house estimates. Long-term projections are based on key factors determining long-term economic growth rates, such as working population and productivity improvements.

African GDP was about US\$2.7 trillion in 2021, while GDP per capita was US\$1,928. In the ESS, it is assumed that the continent's GDP per capita will reach US\$5,000 by 2050, 75% higher than US\$2,850 in the RCS in 2050. This corresponds to Africa's

GDP reaching US\$12.4 trillion by 2050, which is roughly equivalent to China's GDP in 2015. Therefore, in the ESS, Africa's economy is set to expand rapidly, with GDP approaching US\$4.3 trillion in 2030 and US\$7.4 trillion in 2040.

Many African economies, particularly SSA countries, grew at record rates before the pandemic. Ethiopia and Rwanda (4) were among the fastest expanding economies in the world, averaging more than 7.5% annually over the past two decades. In the 'golden' 15 years between 1996 and 2010, African real GDP growth averaged 4.7% annually, while SSA grew by 5.1% during the later 'golden' 15 years of 2000–14. The ESS suggests real GDP growth will average 5.4% between 2021 and 2050, which is slightly higher than in the most prosperous periods of past African economic growth.

**Figure 7.3. Africa GDP outlook (real billion US\$)**



Source: GECF Secretariat based on data from the GECF GGM

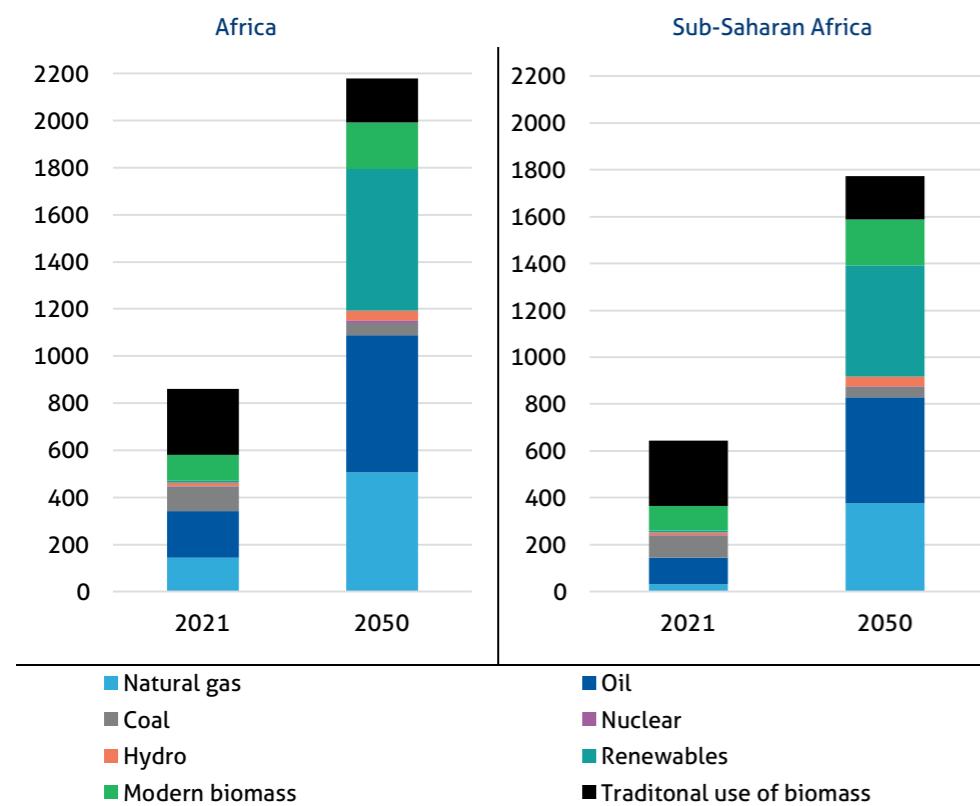
By reaching US\$5,000 average GDP per capita by 2050, the African continent will surpass the threshold of middle-income countries, according to World Bank classification (5). SSA GDP per capita will average around US\$4,000 by 2050.

Given the young, burgeoning, and rapidly urbanising African population and strong projected economic growth, the energy sector has a vital role to play in Africa's future.

In this scenario, the continent's primary energy demand is expected to increase by 154%, from 860 Mtoe to about 2,180 Mtoe by 2050. This is 615 Mtoe higher than the RCS. More than 85% of this growth will originate in the SSA region.

Primary energy intensity in the ESS is also set to decline by 2.2% annually over the 2021-50 period compared to 1.4% in the RCS. This is driven primarily by improvements in energy efficiency amid declining reliance on inefficient use of traditional biomass for cooking. Moreover, energy intensity benefits from smaller heat losses during power generation given the rising share of renewables.

Figure 7.4. Primary energy demand by fuel type (Mtoe)

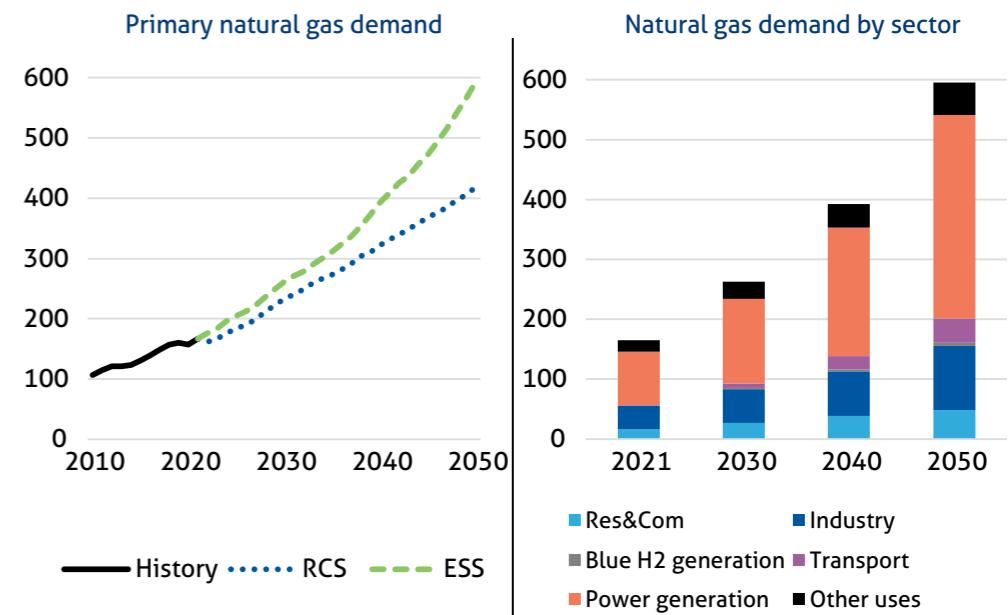


Source: GECF Secretariat based on data from the GECF GGM

Supplying reliable and affordable energy to a growing population should be aligned with relevant, sustainable goals that are addressed in the ESS. This includes no poverty (SDG 1), zero hunger (SDG 2), and good health (SDG 3).

Promoting access to electricity and clean cooking energy is widely recognised as a vital economic development driver and critical to encouraging equitable growth to lift people out of poverty. To this end, natural gas can play a key enabling role in access to clean, affordable energy.

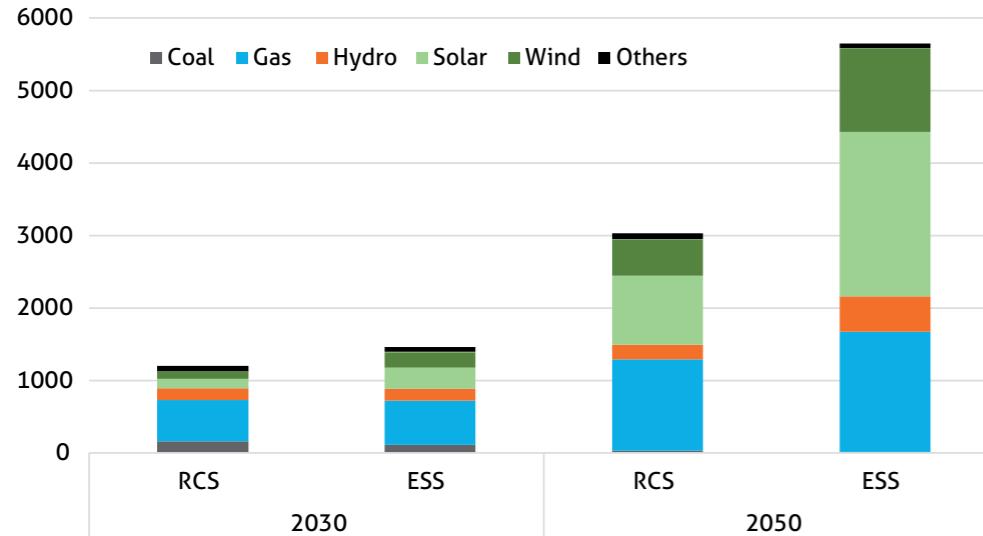
Figure 7.5. Natural gas demand in Africa (bcm)



Source: GECF Secretariat based on data from the GECF GGM

In the ESS, natural gas demand is expected to grow by an average rate of 4.5% per annum, from 165 bcm in 2021 to 595 bcm by 2050. This is around 180 bcm higher than the RCS. The SSA region, led by Western African countries, will account for 92% of the growth.

Africa's rapid electricity demand growth and increased demand for gas-fired generation will be the primary driver. Power generation will account for 57% of total additional gas use. A sizable increase will be evident in the industrial sector as well, as expanding production is essential for diversifying economies. As a result, electrification becomes a priority in Africa, with natural gas playing a pivotal role in bridging the region's abundant energy resources and limited access to energy – particularly electricity, which stifles economic and social progress. Power outages constrain the creation of new businesses through their negative effect on entrepreneurship and reduce the output and productivity of existing firms. This forces them to reduce labor demand or reduce the trade and exports. They also diminish an individual's chances of employment by 35%-41% (6, 7). In contrast, increasing access to power is correlated with increased labour-force participation.

**Figure 7.6. Power generation in Africa by energy source (TWh)**

Source: GECF Secretariat based on data from the GECF GGM

## 2. Energy Environment

In the ESS, electrification through natural gas use is a key enabler in climate change mitigation (SDG 13). The positive impact of natural gas use for electricity generation and cooking in the SSA region is equally as important as battling environmental issues, such as deforestation, air and water pollution, and loss of biodiversity. With only about 4% of global energy-related CO<sub>2</sub> emissions, any obstacle to gas-burning power plants and pipeline developments creates strong negative impact on people's health and economic conditions.

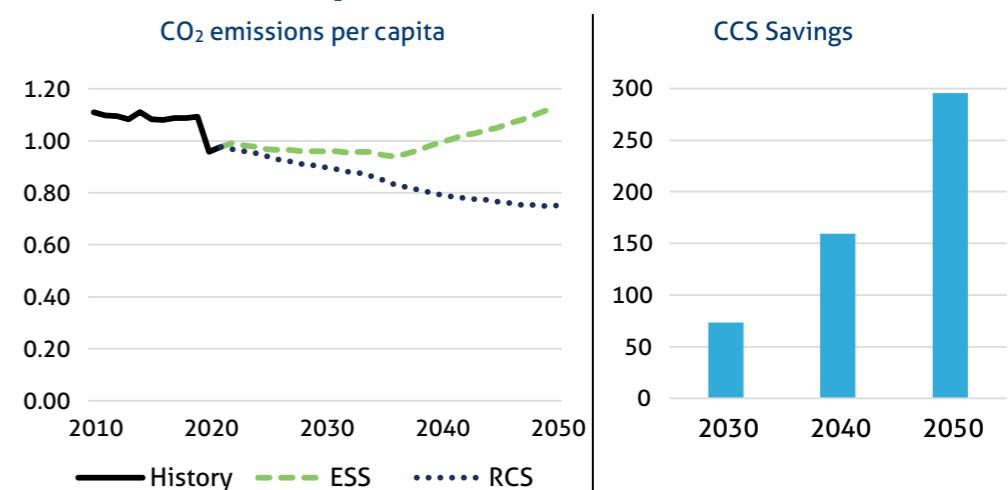
The benefits of gas use in electricity generation are well established. A gas-fired power station emits 50% less CO<sub>2</sub> during combustion than a coal power plant. Natural gas is reliable, abundant and as easy to store and distribute.

Gas is especially well suited to energy-intensive adaptation technologies such as steel and concrete for strong infrastructure, along with desalination for enhanced freshwater supply. This is also consistent with SDG 13.

In the ESS, we believe that natural gas can play an important complementary role along with the development of renewables to fuel green industries and climate change resilience infrastructure in both the short- and long term. Supplying green industries in Africa with natural gas can contribute significantly to green vehicle and battery developments. Increased demand for EVs, essential minerals, and renewable energy systems presents Africa with a greater share of supply chains

in the new green economy. For instance, the Democratic Republic of the Congo accounts for 70% of the world's cobalt production, a mineral critical to battery manufacturing. Cobalt demand is expected to more than triple by 2030 (8).

Greater natural gas use also aids in indoor air pollution reduction. Cooking with traditional biomass, causes millions of premature deaths. The conversion to gas cooking — either piped natural gas in cities or, more often, LPG in cylinders — has significantly reduced indoor air pollution in China, India, and Indonesia. The same can be accomplished in Africa.

**Figure 7.7. CO<sub>2</sub> emissions per capita (tonne CO<sub>2</sub>/person), and Carbon Capture and Storage Savings (Mt of CO<sub>2</sub> eq.)**

Source: GECF Secretariat based on data from the GECF GGM

In the ESS, the absolute CO<sub>2</sub> emissions in Africa will increase from 1.3 Gt of CO<sub>2</sub> in 2021 to 2.8 Gt of CO<sub>2</sub> in 2050. CO<sub>2</sub> emissions per capita will reach from 0.98 tCO<sub>2</sub> per person in 2021, to 1.13 tCO<sub>2</sub> per person in 2050, compared to 0.75 tCO<sub>2</sub> in the RCS. In this scenario, CCS is added to power generation in Algeria, Egypt, Nigeria, and South Africa. As a result, CCS will save 8% of Africa's CO<sub>2</sub> emissions in 2050, equivalent to 295 MtCO<sub>2</sub>.

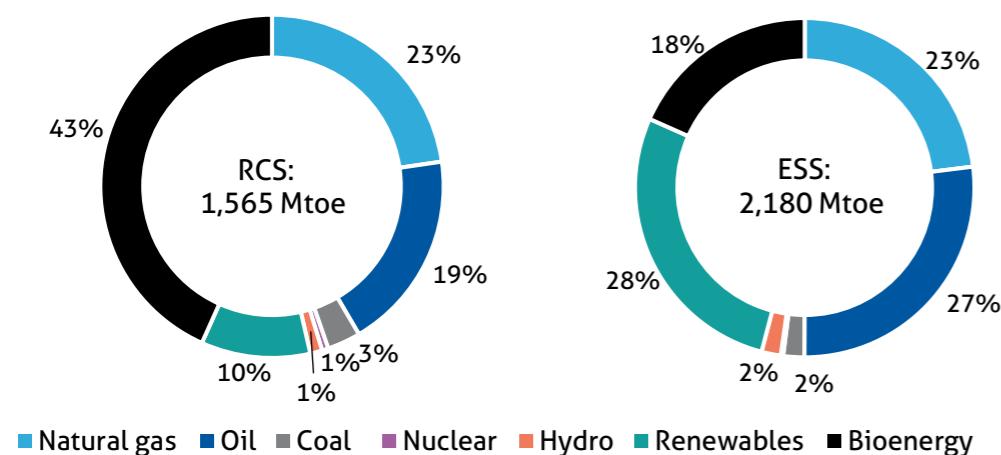
## 3. Energy Security

Considering that SDG 7 and SDG 9 envision access to affordable, reliable and clean energy for all, the ESS defines energy security for SSA in a manner that satisfies both climate target and socio-economic factors. Together, renewables and natural gas, combined with established decarbonisation technologies, both boost energy security and reduce CO<sub>2</sub> emissions.

Solar and wind energy have become much more competitive, but African countries are struggling to manage intermittency. For instance, Kenya is already experiencing significant voltage instability with only around 15% of installed wind and solar power capacity (9). Given current storage technology, African countries cannot meaningfully boost power supply without additional investments in gas backup systems. Africa receives just 4% of global investment in electricity supply despite being home to 17% of the world's population. Only 58% of Africa's population is assumed to have access to electricity, and two-thirds of the continent's networks are considered insecure. Forty-eight Sub-Saharan African nations (excluding South Africa) have roughly the same generating capacity as Germany, which serves 83 million people (10, 11).

Accordingly, we believe that SSA transition toward more sustainable and accessible energy requires gas as both the primary driver and a bridge fuel to renewable energy.

**Figure 7.8. Africa's energy mix in the RCS and ESS in 2050**



Source: GECF Secretariat based on data from the GECF GGM

### Conclusion

For Africa to increase its average income to US\$5,000 per capita, natural gas and renewables use will be required to increase. Their combined share is expected to reach 51% of the energy mix. The ESS demonstrates that a balanced energy mix will help the continent to greatly reduce biomass share to 18% from 43% by 2050 in the RCS, while expanding economic activity and energy demand. At the same time, the energy intensity of GDP drops 20% with corresponding per capita emissions of only 1.3 tCO<sub>2</sub>.

Natural gas and renewables are driving major energy sector transformation in Africa. The continent's ambitious economic and social objectives need quick progress in boosting energy capacity. This can be accomplished by investments in clean energy sources and the rapid adoption of natural gas as a clean transition fuel. Accordingly, in line with relevant SDGs, such as SDG 7, SDG 8, SDG 9, and SDG 13, our proposed ESS aims to demonstrate that sustainable growth would necessitate an increase in gas supply and consumption in Africa's energy mix.

Transitioning to low-carbon energy sources is critical for reducing global GHG emissions, but it must be consistent with attaining the continent's development goals and satisfying 600 million Africans' unmet energy requirements.

In order to address the daunting possibility of nearly doubling electricity consumption over the next few decades, natural gas provides a leading source of electricity to bridge the transition to renewable energy in SSA. Nonetheless, a number of barriers limit Africa's gas revolution. These range from lack of sufficient gas infrastructure and minimisation of flaring, to the mobilisation of public and private sector investment and gas-focused policy development.

Given the enormity of the required electrification in Sub-Saharan Africa, gas and renewables have a large role to play in the future of the SSA's energy mix. Therefore, to reap the potential benefits, policy and regulatory reforms must be implemented to launch, support, and incentivise the required energy mix with a larger share of natural gas.

### 7.2 Accelerated Energy Decarbonisation Scenario (AEDS) Introduction

Recent assessments of nationally defined contributions (NDCs) set to achieve low-emissions and climate-resilient development suggest that they lack ambition, and that the world is not on track to meet the long-term temperature goal set forth in the Paris Agreement.

Several reasons may explain this shortage. There is neither a single solution for energy decarbonisation, nor a one-size-fits-all model to balance energy security, affordability, and sustainability. Renewable energy is one pathway. However, overestimation of its potential without consideration of limitations, such as market penetration and intermittency, will drive a significant gap between targets and achievements.

It is widely acknowledged that renewables cannot fully decarbonise some sectors in which high temperatures are needed or where energy needs to be stored such as in some industries and heavy transportation. Furthermore, electrification is

also constrained by lithium and cobalt production, and reserve levels may be inadequate for extensive EV development.

Energy market volatility is another consideration. Upheaval in 2021 and 2022 shifted the focus from climate change to energy security and affordability. Achievement of Paris Agreement targets requires the energy transition to be realistic, cost-effective and just, while incorporating all viable decarbonisation alternatives.

### Main assumptions

The AEDS considers various pathways, along with penetration level and implementation pace. Coal-to-gas switching in the power sector is considered to be the lowest-hanging fruit. Accordingly, this change is modelled to take place early in the forecast period and continues throughout the outlook period to account for markets where coal phase-out is slow.

The AEDS uses backcasting to formulate an accelerated trajectory relative to the RCS. There are questions about the timing and relative contributions of decarbonisation measures, and the AEDS, above all, considers how natural gas can contribute to this shift. It also assumes development and large deployment of clean technologies, such as pre- and post-combustion CCS.

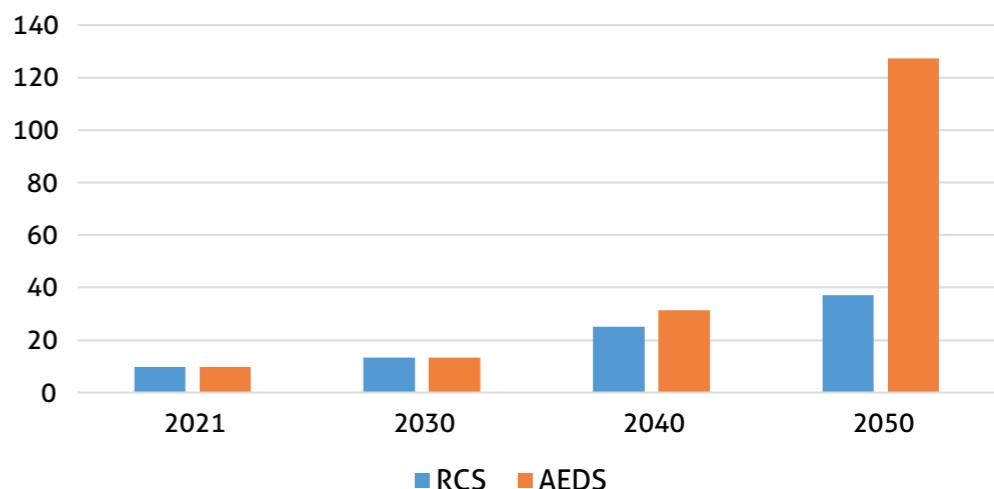
### Final sectors

The AEDS and RCS use the same assumptions for macroeconomic drivers such as GDP, population, and urbanisation rate. However, measures such as energy conservation and efficiency enhancement in the final sectors in buildings and appliances impact final energy demand and are considered to be a crucial pathway for decarbonisation.

The AEDS considers almost 10% of energy efficiency enhancement in residential and commercial buildings. Conservation is achieved through efficient building isolation, such as use of double-glazed windows. This scenario also considers 10% pipeline network expansion for greater access and blended fuel transport in this sector. This will be particularly important in regions with large gas reserves but still developing networks.

Hydrogen penetration will be critical for those industry sectors where processes require very high temperatures. However, supply chain development requires significant investment in infrastructure development and enhancement. This scenario considers that most hydrogen development will materialise in the second half of the outlook period. Electrification, particularly in easy-to-electrify sectors such as mining, is an important scenario driver, as is coal-to-gas switching and CCS.

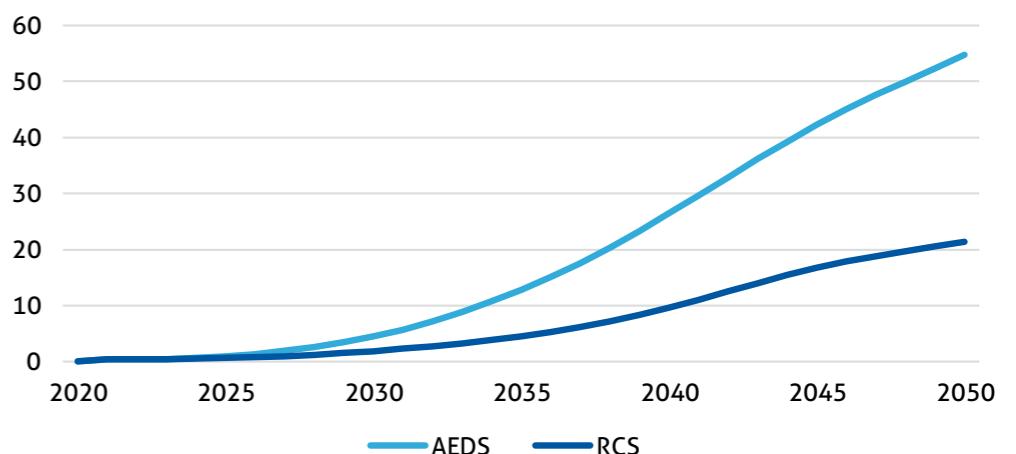
Figure 7.9. Hydrogen consumption in the industry sector (Mt of H<sub>2</sub>)



Source: GECF Secretariat based on data from the GECF GGM

Hydrocarbon demand in all areas of transport is expected to decline. Electrification and to a lesser extent hydrogen are among the central decarbonisation means. The AEDS considers a combined 40% increase in Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) in the passenger and light commercial vehicle sector compared to the RCS. It is expected that the BEVs and PHEVs fleet will reach 1250 million by 2050 in the AEDS, more than 80 times higher than today's level. Still, electric vehicles are promising in the RCS as well. The RCS expects almost 890 million PHEVs and BEVs by 2050, nearly 58 times higher than the current level.

Figure 7.10. Hydrogen car fleet in passenger and LCVs (Million cars)



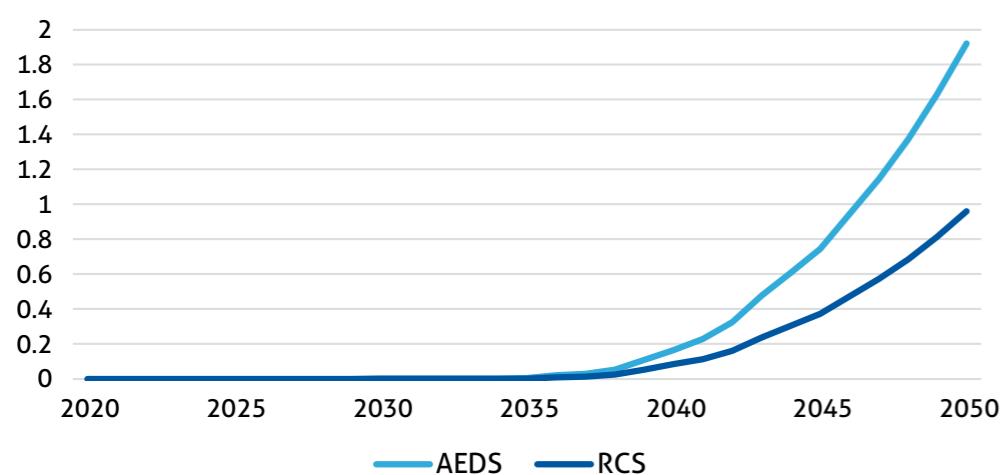
Source: GECF Secretariat based on data from the GECF GGM

Hydrogen vehicles will also gain share in passenger and light commercial vehicle sectors. However, hydrogen supremacy in road transport is limited to heavy and long-haul transportation. Thus, the number of hydrogen vehicles in passenger and light commercial transport will be much lower than BEVs and PHEVs. The AEDS assumes almost 54 million hydrogen cars in light commercial use and passenger transportation will be on the road by 2050, more than 150% higher than 21 million in the RCS.

Hydrogen will be the primary solution for decarbonising the heavy goods vehicle (HGV) sector. In the AEDS, almost 67 million tonnes of hydrogen will be consumed by 2050, compared to 13 million tonnes in the RCS.

In rail transportation, 17 million tonnes of hydrogen will be consumed in the AEDS. This is most pertinent to regions such as Europe, where rail transportation is significant. Aviation is more difficult to decarbonise, particularly long-haul flights. Despite some efforts, technology and infrastructure development is slow. The AEDS expects hydrogen use in aviation in the mid-2030s. Consumption will reach 2 million tonnes by 2050, almost double the RCS assumption.

**Figure 7.11. Hydrogen consumption in the aviation sector (Mt of H<sub>2</sub>)**



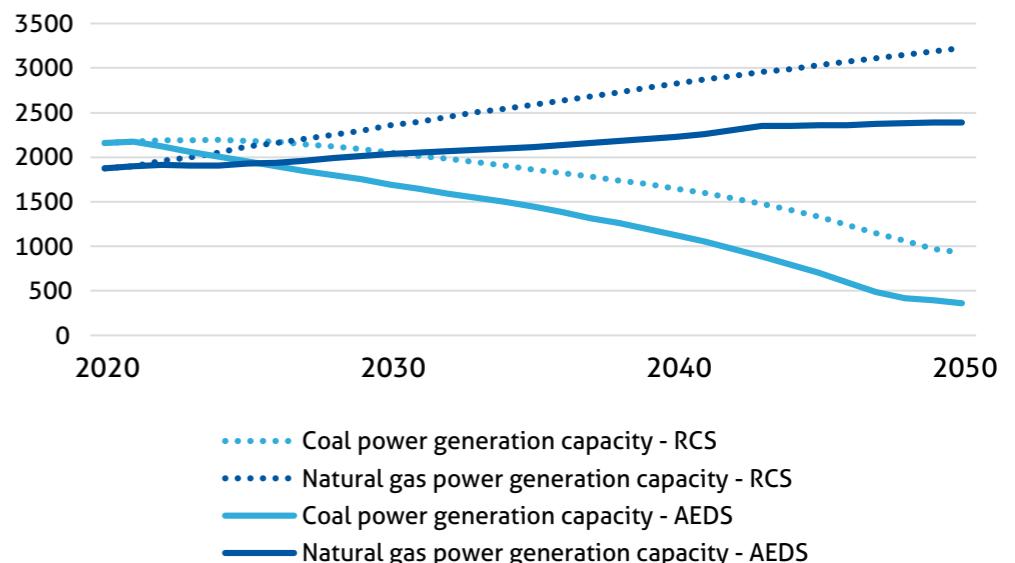
Source: GECF Secretariat based on data from the GECF GGM

Onboard carbon capture in marine transport supports natural gas use, but hydrogen is still seen as the primary decarbonisation option. The AEDS assumes around 73 million tonnes of hydrogen will be consumed in bunkering, compared to 32 million tonnes in the RCS.

#### Transformation sectors

In the energy system's transformation sectors, power generation is the most significant energy transition area. As high as 12.5 Gt, or almost 36% of total energy-related CO<sub>2</sub> is emitted by power plants alone.

**Figure 7.12. Natural gas and coal power generation capacity (GW)**

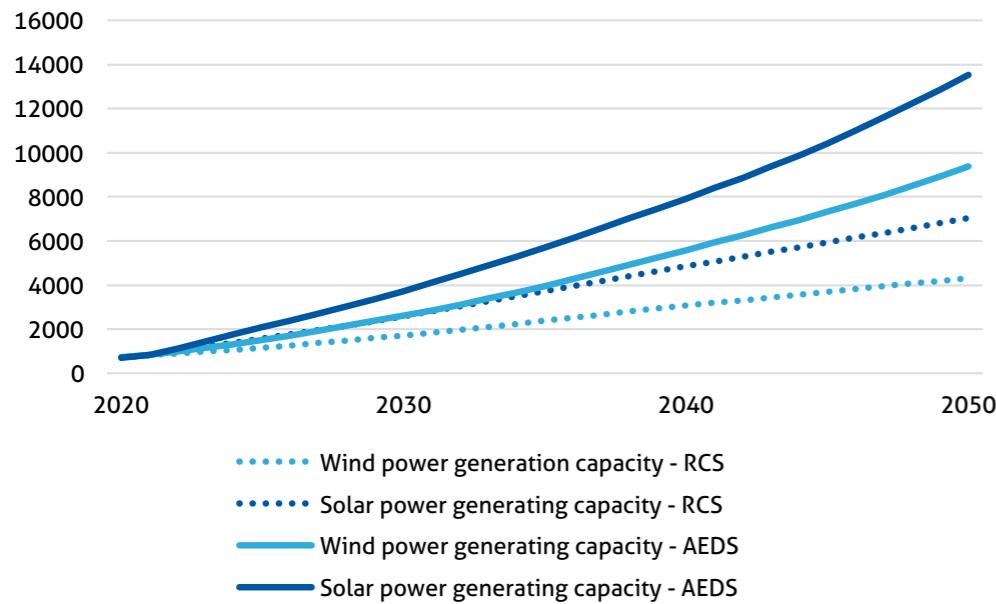


Source: GECF Secretariat based on data from the GECF GGM

In 2021, coal power plants emitted almost 9 Gt of CO<sub>2</sub>, representing 73% of total power sector emissions. Renewable power is critical, but dispatchable electricity sources, including gas power plants, are necessary to offset intermittency and variability. In 2050, solar and wind capacity in the AEDS is double that the RCS.



Figure 7.13. Wind and solar power generation capacity (GW)



Source: GECF Secretariat based on data from the GECF GGM

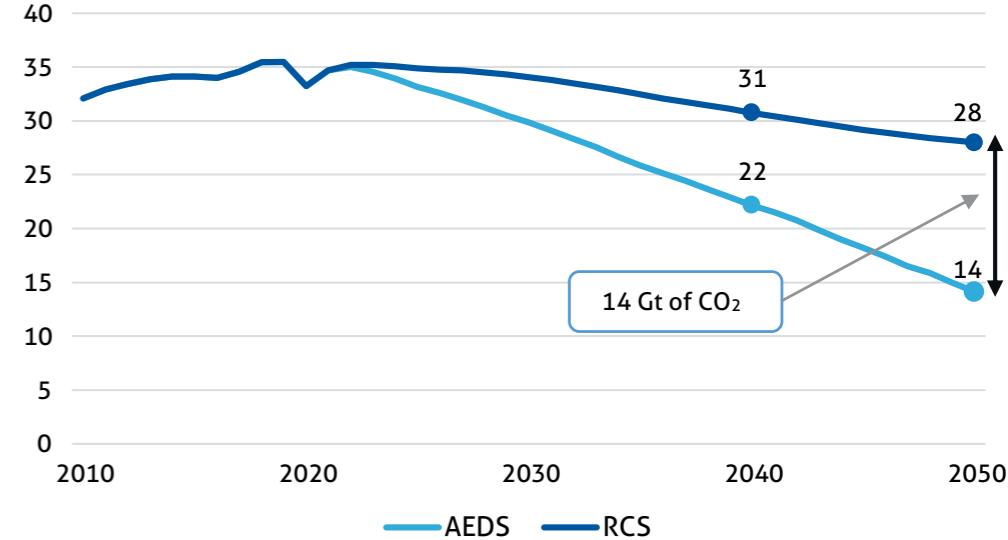
There is also ample room for hydrogen sector decarbonisation. Clean hydrogen can displace oil products in transportation and assist in hard-to-decarbonise sectors. But current hydrogen production processes are relatively high CO<sub>2</sub> emitters. Current hydrogen production methods, which utilise coal gasification and natural gas steam reforming without CCS, are the source of 1 Gt of CO<sub>2</sub>. The AEDS assumes almost all of the current hydrogen production will be coupled with CCS, and by 2050, only 48 million tonnes of CO<sub>2</sub> emissions will result from hydrogen production.

## Results

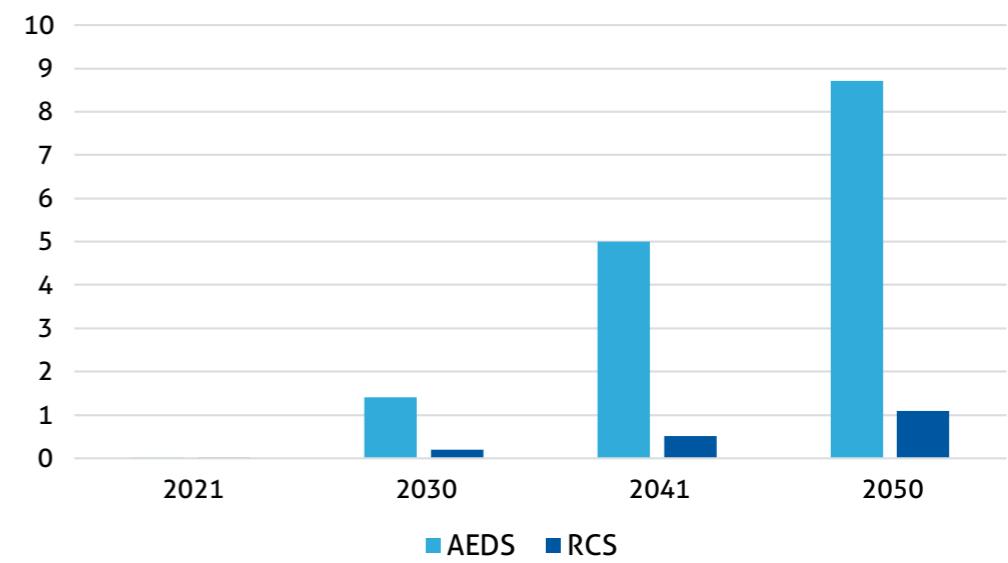
### Carbon emissions

The AEDS results suggest a robust potential carbon mitigation pathway for energy-related activities, with a much more aggressive emission reduction profile compared to RCS. In AEDS, CO<sub>2</sub> emissions will reach 14 Gt by 2050, only half of the level in the RCS.

The AEDS trajectory could be consistent with the goal to limit global temperature rise to less than 1.5°C by the end of the century, should other sectors, such as agriculture, undertake aggressive emission reduction targets. It is all the more so with regard to the 2°C goal. The AEDS scenario's 2050 emissions will be only 60% of the estimated 2021 level. The importance of both pre- and post-combustion CCS is evident, with the AEDS scenario indicating abatement of almost 8.7 Gt of CO<sub>2</sub>.

Figure 7.14. Global energy-related CO<sub>2</sub> emissions (Gt of CO<sub>2</sub>)

Source: GECF Secretariat based on data from the GECF GGM

Figure 7.15. CO<sub>2</sub> saving by CCS (Gt of CO<sub>2</sub>)

Source: GECF Secretariat based on data from the GECF GGM

### BOX 7.1. Current situation in hydrogen supply and demand and its role in energy decarbonisation

Growing climate ambitions and plans to reduce GHG emissions have elevated hydrogen as a major decarbonisation pillar for governments and companies to achieve their commitments. For governments, hydrogen supports global efforts to reduce GHG from hard-to-abate sectors, diversify energy sources, and back up renewables.

Hydrogen has been gaining interest since 2002 based on maturing technology and climate concerns. Recently, hydrogen has been seen as an optimum solution for sustainable and low-carbon energy systems.

#### Demand

In 2021, hydrogen demand was estimated at 94 Mt with 99% produced from fossil fuels (12). Even though hydrogen is seen as a means to decarbonise transport, hard-to-abate industries, heating, and other uses, conventional demand sectors for hydrogen constituted almost all of its demand.

The total hydrogen demand in new applications accounted for 40 kilotonnes (kt), mainly in heavy-duty trucks in China, while hydrogen demand in buildings and power generation is negligible. Demand for hydrogen in new applications is facing several challenges. For heating buildings, hydrogen use is limited due to safety concerns as well as low efficiency. In the UK, for example, the government is planning to decide on the safety and feasibility of hydrogen for heating by 2026 after completing a first-of-its-kind heating trial (13). In addition, the safety of using 100% hydrogen to an equivalent safety level like natural gas in multi-occupancy buildings has not been assessed yet (14).

A combination of energy sources and decarbonisation tools is more necessary than ever before considering hydrogen in sectors where decarbonisation options are limited. The selectivity in targeting hydrogen demand sectors is attributed to the complexity of the hydrogen supply chain (15).

#### Hydrogen production

In 2021, 62% of global hydrogen production was produced from natural gas. Green hydrogen produced by electrolysis made up only 0.04% of the total output. The environmental case for green hydrogen is attractive, but the high production cost is a challenge (16). This makes low-carbon hydrogen produced from natural gas with CCS/CCUS (blue hydrogen) more competitive. In 2022, the Global CCS Institute reported that 40 hydrogen facilities equipped with CCS are at various stages of development (17).

Green hydrogen is three times more expensive than blue hydrogen if large-scale CCS/CCUS is applied. The average cost of blue hydrogen ranges from US\$1/kg to US\$2/kg (18). In Portugal, the cost of blue hydrogen production is estimated at €1.68/kg, compared to green hydrogen at €3.54/kg from solar power (19). The EU strategy on hydrogen in 2021 recognised the competitiveness of blue hydrogen over green hydrogen and consequently its fundamental role in scaling the hydrogen economy (20). In addition to the cost benefits, blue hydrogen offers a development pathway to the existing conventional hydrogen production process by integrating CCS/CCUS technology.

Over the long term, scaling up electrolyser production could drive green hydrogen costs down. Similarly, advanced blue hydrogen technologies could provide cost reduction estimated at 12% with high carbon capture ratios (21).

#### Hydrogen and its role in energy decarbonisation

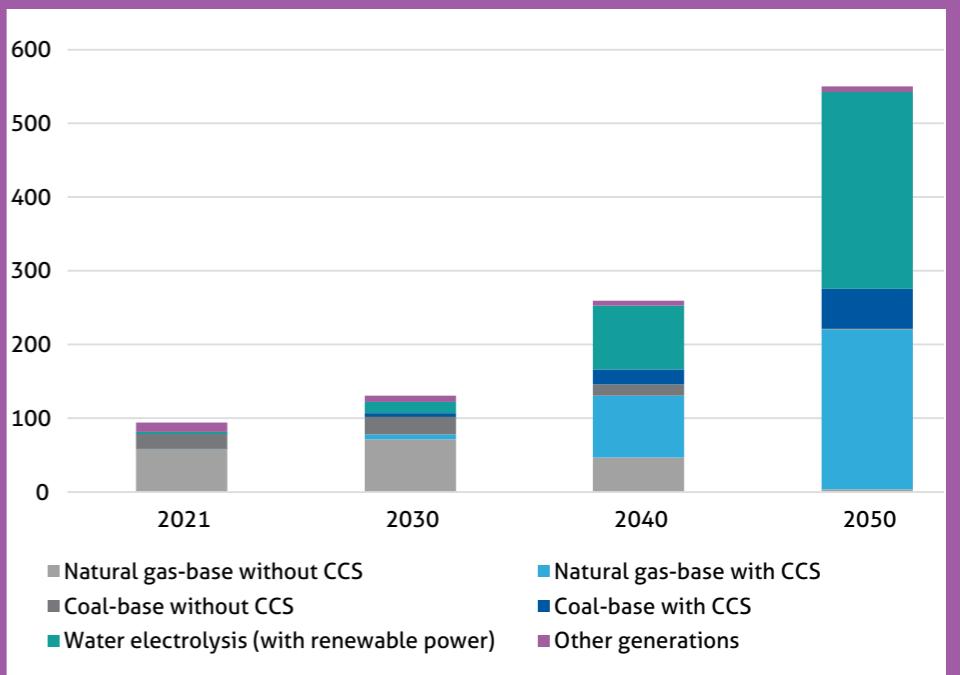
Hydrogen is presumed to be a well-suited and compatible energy vector to meet future energy needs. Therefore, it is expected that hydrogen will gain more share in the AEDS.

Total demand for hydrogen in the AEDS is expected to reach 550 Mt by 2050, which is more than double of the RCS. This level of hydrogen demand is almost 10% of total energy mix by 2050 compared with 4.3% in the RCS and current share of 1.8%.

Most of this demand in the AEDS will be driven by transport and industry. Almost 300 Mt will be consumed in these two sectors, mostly in sub-sectors with high-grade temperature needs such as iron and steel, as well as heavy long-haul, marine, aviation and rail transport.

Hydrogen use as a feedstock is the other primary demand driver, reaching almost 190 Mt by 2050 in the AEDS. Residential, commercial, and power sectors are also among the other sectors expected to consume hydrogen. But volume will be much lower due to alternative decarbonisation pathways such as electrification and natural gas coupled with CCS/CCUS.

Figure 7.16. Outlook for hydrogen output by method of production in AEDS (Mt of H<sub>2</sub>)



Source: GECF Secretariat based on data from the GECF GGM

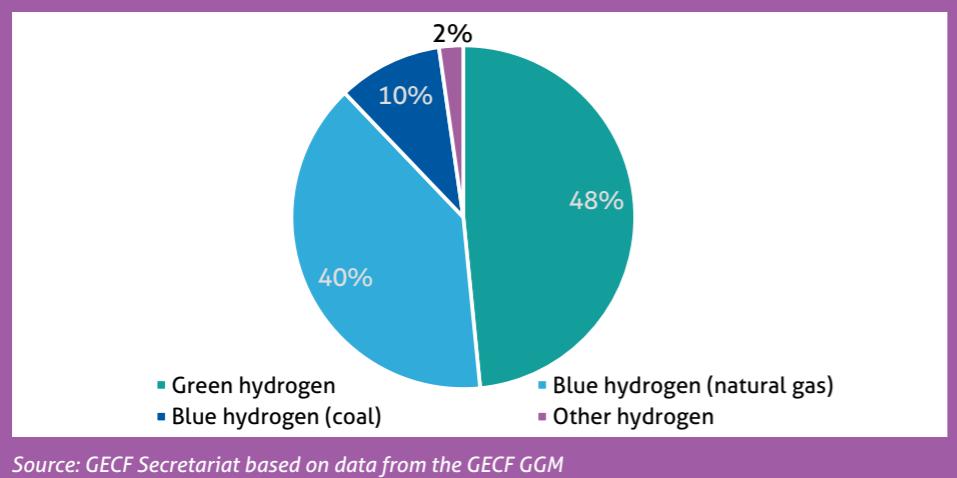
There is less uncertainty around the demand drivers in the decarbonisation trajectory modelled in the AEDS. However, there is a higher level of supply-side uncertainty. There is a variety of technologies to produce hydrogen with different expected market penetration and rate cost curves, as well as uncertainties associated with the level of infrastructure development for the hydrogen supply chain.

Undoubtedly, the hydrogen production technologies in the future shall be clean or low emission, such as the electrolysis of renewable power (green hydrogen), natural gas steam reforming with CCS (blue hydrogen) and coal gasification with CCS (blue hydrogen).

According to the AEDS results, the current hydrogen production technologies must turn into clean technology. The AEDS expects that slightly less than 220 million tonnes of hydrogen will be produced using natural gas with CCS, accounting for 40% of total output by 2050. This production level would require more than 930 bcm of natural gas by 2050.

Coal gasification with CCS will contribute to 10%, or 54 Mt of hydrogen production by 2050 in the AEDS. Green hydrogen production will gain almost 48% of the output, or around nearly 270 Mt. This level of green hydrogen production will require a huge amount of electricity estimated at 12,000 TWh in 2050. This is equivalent to 43% of current world annual electricity production.

Figure 7.17. Technology share in hydrogen production in 2050 in AEDS (%)

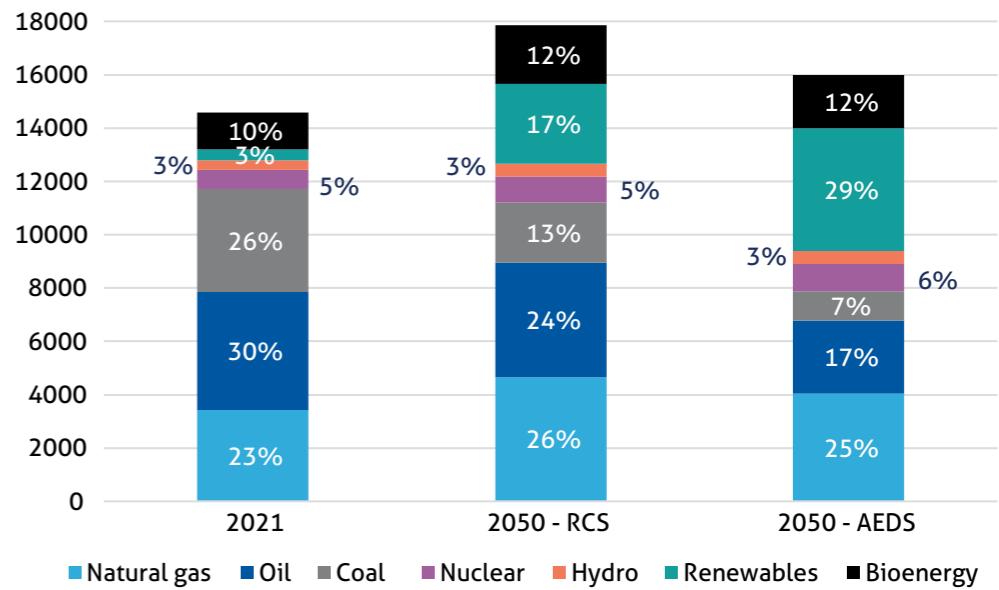


#### Global energy demand trends

Increasing energy demand will be offset by substantial energy efficiency gains across consuming sectors, along with accelerated electrification — particularly from renewables.

Energy intensity will decline by 2.8% annually over the 2021-50 period in the AEDS, compared to 2.4% in the RCS. As a result, global primary energy demand will increase by just 10% to almost 16,000 Mtoe in the AEDS by 2050, nearly 1,890 Mtoe lower than the RCS.

Figure 7.18. Global primary energy demand in 2021 and in 2050 by scenario (Mtoe)

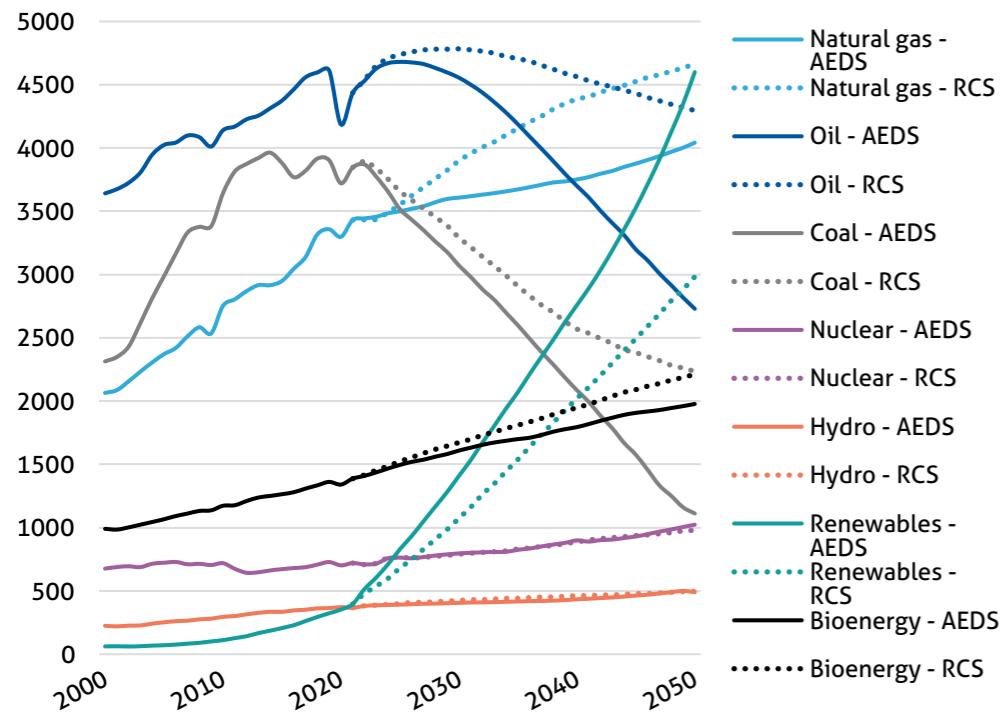


Fossil fuels' share in the primary energy mix will decline from 79% in 2021 to 49% in 2050. Coal will encounter the most significant drop, driven by coal-to-gas switching and structural changes in both the power sector and industry. Its share will be squeezed to 7% by 2050. Oil demand will end up 38% lower in 2050 compared to 2021 amid overall fuel efficiency improvement increased EVs and hydrogen fuel cell vehicle penetration. Hydrogen fuel cell trucks will also emerge, offsetting oil use in the HGV segment. Oil will account for 17% of the energy mix in 2050, driven in large part by petrochemicals.

Natural gas share will rise to 25% by 2050 as large-scale implementation of deep gas decarbonisation options through blue hydrogen and CCS improve the fuel's environmental and climate credentials. Still, natural gas demand in volumetric terms will be almost 730 bcm lower in the AEDS compared to the RCS.

Nuclear and hydro will retain 6% and 3% shares, respectively, in the AEDS, with nuclear offering a particularly effective carbon-free pathway for baseload power generation. Renewable energy demand will jump to 4,600 Mtoe by 2050, 54% higher than the RCS, and account for 29% of the global energy mix. The need for flexibility in the power system will mount in tandem with growing renewables penetration. Gas-fired power is set to play a key role — even with advancements in storage technologies.

Figure 7.19. Global primary energy demand trends by fuel type by scenario (Mtoe)



Source: GECF Secretariat based on data from the GECF GGM

**Annex**

## 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:

Algeria, Angola, Egypt, Equatorial Guinea, Libya, Morocco, Nigeria, South Africa, Tunisia, as well as aggregated of;

Central Africa: Central African Rep., Congo, Democratic Republic of the Congo, Gabon

Eastern Africa: Eritrea, Ethiopia, Kenya, South Sudan, Sudan, Tanzania, Uganda

Southern Africa: Mozambique, Namibia, Zambia, Zimbabwe

Western Africa: Benin, Ghana, Ivory Coast, Mali, Mauritania, Niger, Senegal, Togo

**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 Vietnam

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

**Developed Asia:** Australia, Hong Kong, Japan, South Korea, and New Zealand

**Developing Asia:** Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Chinese Taipei, Cook Islands, Democratic People's Republic of Korea, Fiji, French Polynesia, 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 Vietnam

**Developing economies:** All other countries not included in "advanced economies"

**Eurasia:** Caspian region and Belarus, Moldova, Russia, and Ukraine

**Europe:** European Union and Albania, Bosnia and Herzegovina, Gibraltar, Iceland, Montenegro, Norway, Serbia, Switzerland, Macedonia, Moldova, and Türkiye

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

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

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

**Latin America:** Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba,

Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands (Malvinas), French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Pierre et Miquelon, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay and Venezuela

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

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

**North America:** Canada, Mexico, and United States

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

**Southeast Asia:** Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam

## Annex II: Conversion factors and definitions<sup>1</sup>

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

NATURAL GAS									
MJ/Nm <sup>3</sup> (GCV)	kCal/Nm <sup>3</sup> (GCV)	kWh/Nm <sup>3</sup>	(N)bcm/mtoe	(S)bcm/mtoe	MJ/Sm <sup>3</sup> (GCV)	kCal/Sm <sup>3</sup> (GCV)	kWh/Sm <sup>3</sup>	Btu/Scf GCV	
41.959	10,022	11.66	1.1087	1.1696	39.775	9500	11.04	1068	

### Definitions

Agriculture	Includes all energy used on farms, in forestry and for fishing (ISIC Divisions 01-03).
Associated gas	Natural gas found in contact with or dissolved in crude oil in the reservoir.
Barrel of Oil Equivalent (BOE)	The term allows for a single value to represent the sum of all the hydrocarbon products that are forecast as resources. Typically, condensate, oil, bitumen, and synthetic crude barrels are taken to be equal (1 bbl = 1 BOE). Gas and NGL quantities are converted to an oil equivalent based on a conversion factor that is recommended to be based on a nominal heating content or calorific value equivalent to a barrel of oil.

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

Biofuels	Liquid fuels derived from biomass or waste feedstocks, including ethanol and biodiesel.
Biomass and waste	Renewable organic materials such as wood, agricultural crops, or wastes, and municipal wastes, especially when used as a source of fuel or energy. Biomass can be burned directly or processed into biofuels such as ethanol and methane.
Bunkers	Includes both international marine bunkers and international aviation bunkers.
Coal	Includes primary coal (hard coal, lignite, coking, and steam coal) and derived fuels (including patent fuel, brown coal briquettes, coke oven coke, gas coke, gas-works gas, coke-oven gas, blast-furnace gas, and oxygen steel furnace gas). Peat is also included.
Coalbed methane	Natural gas contained in coal deposits. Coalbed gas, although usually mostly methane, may be produced with variable amounts of inert or even non-inert gases. (Also called coal-seam gas or natural gas from coal.)
Condensate	A mixture of hydrocarbons (mainly pentanes and heavier) that exist in the gaseous phase at original temperature and pressure of the reservoir, but when produced, are in the liquid phase at surface pressure and temperature conditions. Condensate differs from NGLs in two respects: (1) NGL is extracted and recovered in gas plants rather than lease separators or other lease facilities, and (2) NGL includes very light hydrocarbons (ethane, propane, or butanes) as well as the pentanes-plus that are the main constituents of condensate.
Contracts for Difference	A mechanism of hedging the price of electricity for renewables between renewable generators and counterparties (e.g., Low Carbon Contracts Company in the UK). It allows the generators to receive a pre-agreed level for the duration of contracts (strike price). Under this mechanism, when the market price for electricity generated (reference price) is below the strike price agreed in the contract, compensation is paid by the counterparty. On the other side, when the reference price is above the strike price, the renewable generator pays the counterparty.
Conventional resources	Resources that exist in porous and permeable rock with buoyancy pressure equilibrium. The petroleum initially in place is trapped in discrete accumulations related to a localised geological structural feature and/or stratigraphic condition, typically with each accumulation bounded by a down dip contact with an aquifer, and is significantly affected by hydrodynamic influences such as buoyancy of petroleum in water.
Cost tranche	A set of production entities grouped according to a defined cost range.

<b>Curtailment</b>	According to National Renewable Energy Laboratory, curtailment is a reduction in the output of a generator of variable renewable energy from what it could otherwise produce given available resources like wind or sunlight. Variable renewable energy curtailment is usually used as a way to reduce the production of energy that cannot be delivered due to lack of power system flexibility.	<b>Feed-in premium</b>	A renewable policy support mechanism that offers compensation based on market conditions. In this mechanism, electricity from renewable energy sources is sold on the electricity spot market, and renewable producers receive a premium on top of the market price of their electricity production. No premium is paid if market prices are higher than the reference tariff level.
<b>Decommissioned LNG project</b>	Project is officially announced by owner as decommissioned (mothballed) or has been inactive for a significant period of time.	<b>FEED completed LNG project</b>	Project that has finished front-end engineering and design (FEED) for both the upstream and liquefaction segment.
<b>Distributed energy system</b>	Includes systems which generate and deliver energy services (Power, cooking or heating services) independent of centralised systems. For renewable power, they include particularly off grid renewable generators such as home solar panels.	<b>Feed-in tariff</b>	A renewable policy support mechanism which offers a fixed compensation to renewable energy producers, providing price certainty and long-term contracts that help finance renewable energy investments. The level of compensation is based on the cost of generation of each technology.
<b>Domestic</b>	The domestic sector includes energy used in the residential, commercial, and agricultural sectors. Domestic energy use includes space heating and cooling, water heating, lighting, appliances, and cooking equipment.	<b>Feedstock</b>	Includes refinery feedstocks and petrochemical feedstocks.
<b>Dry gas</b>	Natural gas remaining after hydrocarbon liquids have been removed before the reference point. This is a resources assessment definition, not a phase behaviour definition. (Also called lean gas.)	<b>Final Investment Decision (FID)</b>	Project approval stage when the participating companies have firmly agreed to the project and the required capital funding.
<b>Electricity generation</b>	Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation.	<b>Flare gas</b>	The total quantity of gas vented and/or burned as part of production and processing operations (but not as fuel).
<b>Energy sector</b>	Covers the use of energy by non-energy sector and the energy losses in converting primary energy into a form that can be used in the final consumption sectors. It includes losses by gas works, petroleum refineries, blast furnaces, coke ovens, coal and gas transformation, and liquefaction. It also includes energy used in the distribution network. Transfers and statistical differences are also included in this category.	<b>Gas exports (upstream volumes)</b>	Gas volumes shipped by a gas-exporting country to an importing country including all the losses (pipelines, liquefaction, shipping and regasification).
<b>Enhanced oil recovery (EOR)</b>	The extraction of additional petroleum, beyond primary recovery, from naturally occurring reservoirs by supplementing the natural forces in the reservoir. It includes water flooding and gas injection for pressure maintenance, secondary processes, tertiary processes, and any other means of supplementing natural reservoir recovery processes. Improved recovery also includes thermal and chemical processes to improve the in-situ mobility of viscous forms of petroleum. (Also called improved recovery.)	<b>Gas hydrates</b>	Naturally occurring crystalline substances composed of water and gas, in which a solid water lattice accommodates gas molecules in a cage-like structure or clathrate. At conditions of standard temperature and pressure, one volume of saturated methane hydrate will contain as much as 164 volumes of methane gas. Gas hydrates are included in unconventional resources, but the technology to support commercial maturity has yet to be developed.
<b>Existing gas production facilities</b>	Facilities producing as of 2020.	<b>Gas imports (end use volumes)</b>	Net gas volumes delivered by an exporting country to an importing country, not including the losses during the shipment.
<b>Existing LNG project</b>	Existing capacity that has reached commercial start-up. Includes projects in temporary shutdown. For FSRUs, vessels are chartered at the port on a regular basis.	<b>Heat energy</b>	Obtained from the combustion of fuels, nuclear reactors, geothermal reservoirs, the capture of sunlight, exothermic chemical processes and heat pumps which can extract it from ambient air and liquids. It may be used for heating or cooling, or converted into mechanical energy for transport vehicles or electricity generation. Commercial heat sold is reported under total final consumption with the fuel inputs allocated under power generation.
		<b>Heat generation</b>	Refers to fuel use in heat plants and combined heat and power (CHP) plants.
		<b>Heat Plants</b>	Refers to plants (including heat pumps and electric boilers) designed to produce heat.

<b>Hydropower</b>	The energy content of the electricity produced in hydropower plants.	<b>New project gas production</b>	Fields that have been discovered but have yet to be developed or are in development.
<b>Industry</b>	Includes fuel used within the manufacturing and construction industries. Key industry sectors include iron and steel, chemical and petrochemical, nonferrous metals, non-metallic minerals and other manufacturing.	<b>Non-energy use</b>	Fuels used for non-energy products excluding use as feedstock in petrochemical plants. Examples of non-energy products include gas works, cooking ovens, lubricants, paraffin waxes, asphalt, bitumen, coal tars, and oils as timber preservatives.
<b>In FEED LNG project</b>	Project has started FEED (for either upstream or liquefaction segment).	<b>Nuclear</b>	Refers to the primary energy equivalent of the electricity produced by a nuclear plant, assuming an average conversion efficiency of 33%.
<b>International aviation bunkers</b>	Includes the deliveries of aviation fuels to aircraft for international aviation. The domestic/international split is determined based on departure and landing locations and not by the nationality of the airline.	<b>Oil</b>	Includes demand for crude oil both conventional and unconventional and petroleum products including refinery gas, ethane, LPG, aviation gasoline, motor gasoline, jet fuels, kerosene, gas/diesel oil, heavy fuel oil, naphtha and other oil products (white spirit, lubricants, bitumen, paraffin, waxes, and petroleum coke), and natural gas liquids but excludes biofuels and synthetic oil-based products.
<b>International marine bunkers</b>	Covers those quantities delivered to ships of all flags that are engaged in international navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. Consumption by ships engaged in domestic navigation is excluded. The domestic/international split is determined by the port of departure and port of arrival, and not by the flag or nationality of the ship.	<b>Oil sands</b>	Sand deposits highly saturated with natural bitumen. Also called "tar sands". Note that in deposits such as the western Canada oil sands, significant quantities of natural bitumen may be hosted in a range of lithologies, including siltstones and carbonates.
<b>Nationally Determined Contributions (NDCs)</b>	Intended Nationally Determined Contributions (INDCs) after their ratification by individual governments. They include the countries' GHG mitigation and adaptation pledges submitted to the UNFCCC in the framework of the Paris Agreement.	<b>Petrochemical Feedstocks</b>	The petrochemical industry includes cracking and reforming processes for the purpose of producing ethylene, propylene, butylene, synthesis gas, aromatics, butadiene and other hydrocarbon-based raw materials in processes such as steam cracking, aromatics plants and steam reforming.
<b>Natural gas liquids (NGLs)</b>	A mixture of light hydrocarbons that exist in the gaseous phase in the reservoir and are recovered as liquids in gas processing plants. NGLs differ from condensate in two principal respects: (1) NGLs are extracted and recovered in gas plants rather than lease separators or other lease facilities, and (2) NGLs include very light hydrocarbons (ethane, propane, or butanes) as well as the pentanes-plus that are the main constituents of condensates.	<b>Power generation</b>	Refers to fuel use in electricity plants and combined heat and power (CHP) plants.
<b>Natural gas production capacity</b>	The potential volumes of natural gas ready to be produced by developed wells and processing units associated with a production entity.	<b>Pre-FEED LNG project</b>	Project has officially announced that it has started pre-FEED (for either upstream or liquefaction segment).
<b>Natural gas production</b>	Marketed production including domestic sales and exports.	<b>Probable reserves</b>	An incremental category of estimated recoverable quantities associated with a defined degree of uncertainty. Probable Reserves are those additional reserves that are less likely to be recovered than Proved Reserves but more certain to be recovered than Possible Reserves. It is equally likely that actual remaining quantities recovered will be greater than or less than the sum of the estimated Proved plus Probable Reserves (2P). In this context, when probabilistic methods are used, there should be at least a 50% probability that the actual quantities recovered will equal or exceed the 2P estimate.
<b>Natural Gas Proven Reserves</b>	Refers to existing reserves, new projects and unconventional (existing) gas resources.	<b>Production entity</b>	A gas field, or group of gas fields located in the same zone, or gas geological prospects from which marketed natural gas production is expected to be available and economically viable.
<b>Natural gas</b>	Portion of petroleum that exists either in the gaseous phase or is in solution in crude oil in a reservoir, and which is gaseous at atmospheric conditions of pressure and temperature. Natural gas may include some amount of non-hydrocarbons.		

<b>Production signature</b>	A curve that models the rate at which the remaining recoverable gas reserves will be produced without damaging the corresponding reservoir.	<b>Total final consumption</b>	The sum of consumption by the different end-use sectors. TFC is broken down into energy demand in the following sectors: industry, transport, domestic (including residential, commercial and agriculture), and feedstock uses.
<b>Proposed LNG project</b>	Proposed and planned capacity that has not yet started FEED. Includes projects that have completed pre-FEED but not yet begun FEED.	<b>Total primary energy demand</b>	Represents domestic demand only and is broken down into power generation, heat generation, refinery, energy sector, non-energy sector, and total final consumption.
<b>Proved reserves</b>	Those quantities that, by analysis of geoscience and engineering data, can be estimated with reasonable certainty to be commercially recoverable from a given date forward from known reservoirs and under defined economic conditions, operating methods and government regulations.	<b>Transport</b>	Fuels and electricity used in the transport of goods or persons within the national territory irrespective of the economic sector within which the activity occurs. This includes fuel and electricity delivered to vehicles using public roads or for use in rail vehicles; fuel delivered to vessels for domestic navigation; fuel delivered to aircraft for domestic aviation; and energy consumed in the delivery of fuels through pipelines. Fuel delivered to international marine and aviation bunkers is presented only at the global level and is excluded from the transport sector at a domestic level.
<b>Refinery Feedstocks</b>	Processed oil destined for further processing (e.g., straight run fuel oil or vacuum gas oil) other than blending in the refining industry. It is transformed into one or more components and/or finished products. This definition covers those finished products imported for refinery intake and those returned from the petrochemical industry to the refining industry.	<b>Unconventional gas production</b>	Fields that are associated with gas resources that are from either coal bed methane, tight shale or other resources that require special development techniques.
<b>Renewables</b>	Geothermal, hydropower, solar photovoltaics (PV), concentrating solar power (CSP), wind, and marine (tide and wave) energy for electricity and heat generation.	<b>Unconventional resources</b>	Unconventional resources exist in petroleum accumulations that are pervasive throughout a large area and lack well-defined oil/water contact (OWC) or gas/water contact (GWC) (also called "continuous-type deposits"). Such resources cannot be recovered using traditional recovery projects owing to fluid viscosity (e.g. oil sands) and/or reservoir permeability (e.g. tight gas/oil/CBM) that impede natural mobility. Moreover, the extracted petroleum may require significant processing before sale (e.g. bitumen upgraders).
<b>Reserves</b>	Those quantities of petroleum anticipated to be commercially recoverable by application of development projects to known accumulations from a given date forward under defined conditions. Reserves must satisfy four criteria: they must be discovered, recoverable, commercial and remaining (as of a given date) based on the development project(s) applied.	<b>Under construction LNG project</b>	Capacity that is currently under construction or going through commissioning.
<b>Residential</b>	Energy used by households including space heating and cooling, water heating, lighting, appliances, electronic devices, and cooking equipment.	<b>Yet-to-Find (YTF)</b>	Refers to the theoretical volume of undiscovered gas reserves, calculated based on the probability of finding reserves in certain geological areas. YTF also assumes that technological advancements will make it economically feasible to extract the gas in the future.
<b>Shale gas</b>	Although the terms shale gas and tight gas are often used interchangeably in public discourse, shale formations are only a subset of all low-permeability tight formations, which include sandstones and carbonates, as well as shales, as sources of tight gas production.		
<b>Speculative LNG project</b>	Capacity that the GECF believes is a long-term possibility for future liquefaction supply based on available reserves, but which has not been officially proposed by a company.		
<b>Stalled LNG project</b>	Project not officially cancelled but which has not made progress in recent years.		
<b>Tight gas</b>	Gas that is trapped in pore space and fractures in very low-permeability rocks and/or by adsorption on kerogen, and possibly on clay particles, and is released when a pressure differential develops. It usually requires extensive hydraulic fracturing to facilitate commercial production. Shale gas is a sub-type of tight gas.		

## Annex III: References

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