Global Gas Report 2019

With special contribution from

Hellenic Gas Transmission System Operator SA

Foreword

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The 2019 edition of the Global Gas Report carries on with an analytical tradition of reviewing key global gas trends and major developments, helping to distil them into lessons for the industry, governments, and the broader community of stakeholders.

Like last year, this is a report that was created by Snam in partnership with the IGU and BCG. This year's report special feature is on the Future of Gas in Europe that has been co-produced with key European gas infrastructure operators: DESFA, Interconnector UK, Terēga and TAG.

Last year was yet another year of astonishing growth for the global gas market, with a nearly 5 percent expansion. Prices at key regional natural gas hubs have reached multi-year lows, making it affordable for more consumers. Both natural gas production and consumption grew at record rates, and international trade infrastructure – in the form of LNG and pipeline capacity – is growing at the fastest rate in a decade.

Natural gas is an energy source that offers a diverse set of benefits to the world that is in the process of an unprecedented energy transition. It is a unique and abundant fuel that is able to reliably supply the world's rapidly changing energy systems with more energy, while helping to immediately cut emissions and improve air quality. Yet, there are a number of obstacles that the industry and its partners will have to overcome, in order to enable gas to deliver its full value.

Namely, investments in infrastructure, policy measures and sustained industry innovation will be critical for expanding access to low cost gas reserves globally while also reducing costs at all steps through natural gas supply chains. Also we stress that continued action to reduce methane emissions and improve data availability and transparency will be critical for gas to maintain its environmental credentials. That will be essential to allow gas playing a prominent role in the energy transition. Another critical point is a need for a truly collaborative strong push for development of low carbon gases and carbon-reducing technologies as they will be necessary for nations to attain their climate goals.

We invite you to have a look at the special section dedicated to the Future of Gas in Europe and see how the role of gas may be evolving across sectors in the coming decades, and what that means for the infrastructure and consumers. This section demonstrates the continued importance of the natural gas infrastructure in the region, required to support the role of gas in Europe going forward, particularly to improve network interconnectivity, support renewables integration, and to scale the development of low carbon gas technologies. In this section we also offer a number of interesting case studies, exploring renewable gases, reliability, and security angles of the future of gas in Europe.

Overall, in this report, we reaffirm a major theme for the global gas sector -- the potential future for natural gas is strong, but realizing it at full will require consistent support and coordinated action by industry, national governments, and the international community. This report demonstrates that it is entirely possible to achieve a sustained rapid growth for natural gas, in a sustainable energy future scenario, but it will take deliberate effort, commitment, and leadership from the industry and working alongside its partners and stakeholders.

We hope you find this a useful source.

Contents

Executive summary

The past year has been exceptional for natural gas. Prices at key regional natural gas hubs have reached multi-year lows. Both natural gas production and consumption have grown at record rates. And international trade infrastructure – in the form of LNG and pipeline capacity – is growing at the fastest rate in a decade.

This report assesses the comprehensive drivers of these recent trends, focusing on the key factors that explain recent developments and that will drive future outcomes in the global gas sector. As in the second edition the Global Gas Report released last year, this report assesses the forces shaping global gas now and in the future across the three components of the energy trilemma, finding that:

- **Cost competitiveness of natural gas continues to improve**. While low spot prices at key hubs driven by an LNG supply surplus has attracted significant attention in recent months, this development masks deeper structural changes. In the upstream segment, new technology and innovation continues to bring down breakeven costs; nearly 70% of proven gas reserves globally are now estimated to be in fields with average breakeven prices of less than $3 per MMBtu.In the midstream, the cost of LNG shipping has declined by 20% on average in the past two decades. And in downstream, the growth of carbon pricing is helping to close the gap between the cost of natural gas and coal.

- **Security of supply of natural gas is also improving**, due in large part to the rapid growth in the availability of LNG. In the past decade 21 countries have begun importing LNG for the first time. Over that period supply has also become much more diversified given the addition of Australia and now the US as major exporters, countries that are set to become the second and third largest suppliers of LNG respectively. Meanwhile, the LNG market has become much more liquid as the share of spot and short term sales has reached a record high, now more than 30% of the global market.

- **Sustainability is a key driver of natural gas consumption growth**, now and likely in the future. In the past three years China has been the fastest growing market for natural gas due in large part to clean air policies prompting coal to gas fuel switching. The role of natural gas as a mitigation lever for climate change is growing given the expansion of carbon pricing policies as well as measures to support the development of low carbon gas technologies (including biomethane, hydrogen, and CCUS). And in the past year the long term role of natural gas under any climate change scenario has been affirmed, including by the IPCC which demonstrated a clear and sustained role for gas under a 1.5° Celsius scenario (i.e. natural gas averaging 19% of global energy supply in 2040 vs. 22% today).

Despite these positive recent trends, some potential challenges remain to the future of natural gas. Most significantly, the current rapid growth of global gas is being driven by a limited number of markets, namely the US and Russia for production (68% of prior year global production growth) and the US and China for consumption (60% of prior year global consumption growth). To diversity the growth of natural gas and achieve future projections, further key developments are required, including:

- **Cost innovation**. Despite an abundance of low cost gas reserves globally, there are multiple barriers to the supply of gas at competitive costs in key markets. In the upstream segment, regulatory barriers often continue to prevent the development of low cost reserves. In the midstream segment, the cost of supplying gas to markets remains high; in LNG for example, 60% of the delivered cost is driven by transmission, liquefaction, and re-gas costs. Moreover, regulated market structures still often inhibit competitive access to gas, particularly in non-OECD markets.

- **Infrastructure investment**. As rapidly as natural infrastructure is growing, it is not necessarily fast enough. Global investment in natural gas infrastructure totaled roughly $360 billion in 2018, but annual investment needs to amount to $440-500 billion per year to enable growth in line with most market forecasts. One key investment gap is in transmission and distribution infrastructure, particularly in non-OECD markets. Asia in particular presents the greatest growth potential for natural gas, but that growth is currently constrained by a lack of access to gas.

- **Enabling policies**. Where clear and consistent climate or air quality policy measures have been adopted, fuel switching to natural gas has played a role in reducing emissions. However, climate and clean air policies in most markets remain insufficient. As a result, coal consumption still contributes 44% of global energy sector emissions. To maximize the contribution of natural gas to GHG emissions reductions in the near term, a sufficient market value must be placed on CO_2, particulates, and other pollutants. For the longer term consistent policies are also critical to enable the development of technologies to reduce the emissions intensity of gas itself, including biomethane, hydrogen, and CCUS.

To assess these global opportunities and challenges for gas in a more focused way, this report takes a detailed look at the future of natural gas in Europe. While the role of natural gas is well established in Europe, it is reaching a critical juncture for the future. Coal phase outs and broader GHG emissions reduction measures are demonstrating potential for significant market growth for gas in some areas, while challenging the role of gas in others. As a result, natural gas is poised to play a more diverse set of roles in the European energy mix, including managing intermittency and seasonality of energy supply and demand, reducing emissions intensity of the transport sector, and enabling the introduction of low carbon gas technologies.

Natural gas shows the potential for sustained and rapid global growth. However, it should not be taken for granted. Sustained and coordinated efforts by industry participants and governments are needed to continue improving the cost competitiveness of gas, develop the required infrastructure, and implement enabling policy measures.

Introduction

If natural gas has often been described as the "fuel of the future," recent trends indicate that the future is here. Building on consistent growth over the past decade, the global market for natural gas experienced the second fastest rate of annual growth on record[1]. Through the first half of 2019, these strong growth rates have also been sustained, driven in part by gas prices at key hubs reaching multi-year lows. Rapid growth in gas infrastructure is also continuing, with significant LNG liquefaction and regasification capacity continuing to come online.

In the past year, major energy forecasts have also reaffirmed the future role of natural gas in the global energy mix. Projected long-term growth rates for gas have largely remained unchanged—averaging around 1.7% per year in the major reference case forecasts—with most projections predicting gas to overtake coal in the global energy mix by the 2030s. At the same time, future energy scenario modelling has provided greater clarity over the role of gas in rapid energy transition scenarios aligned with a less than 2° Celsius pathway. More extensive modelling by the IEA, IPCC, and others has indicated a continued leading role for gas in global energy supply as well as its potential as a pathway for further GHG emissions reductions through the application of low carbon gas technologies such as renewable gas, hydrogen, and Carbon Capture Utilization and Storage (CCUS).

Despite these positive trends, natural gas faces some specific near-term challenges while several long-term risks to future growth have started to come into greater focus. In the near term, more diversified market growth is required as a small number of countries are driving recent gas production growth (notably the US and Russia) as well as consumption growth (US and China). In the longer term, potential gaps in policy and infrastructure investment will need to be closed to achieve the positive projections for gas.

This report looks beyond the headline numbers in the headlines to assess the deeper drivers of the recent trends in global gas (Chapter 1) as well as what will be required to sustain market growth going forward (Chapter 2). Three core drivers stand out throughout the analysis as critical for assessing the role of gas:

- **Cost competitiveness**. While recent record low gas prices are due in part to over-supply in the global LNG market, low cost gas reserves are abundant, and the structural cost competitiveness

[1] Cedigaz.

of gas is improving. Nearly 70% of proven gas reserves globally are now estimated to be in fields with average breakeven prices of less than $3 per MMBtu[2]. More widespread adoption of carbon pricing is also improving the cost competitiveness of gas relative to coal. However, more consistent development of low-cost gas reserves as well as lower cost means of delivering gas to end markets will be critical to sustaining greater and more consistent gas market growth around the world.

- **Security of supply**. Growth in LNG infrastructure is improving gas supply security and flexibility today while also helping to extend access to gas in new markets around the world. Looking forward though, infrastructure investment will need to grow even faster across gas value chains to meet further growth expectations. Global investment in natural gas infrastructure totaled roughly $360 billion in 2018, but annual investment needs to amount to $440-500 billion per year to enable anticipated future growth[3]. The challenge of sustaining investment in infrastructure is particularly stark in Asia, where access to gas remains limited in many countries.

- **Sustainability**. The role that natural gas can play in improving both outdoor and indoor air quality has become clearer as governments such as China succeeded in using gas switching to achieve environmental goals. In the near term, fuel switching from coal to gas can make significant progress in reducing GHG emissions as coal consumption still contributes 44% of global energy sector emissions[4]. While in the longer-run, low carbon gas technologies are available to reduce emissions from natural gas (21% of global energy sector emissions[5]). Yet, government policies are largely not mature enough in most non-OECD markets to promote widespread fuel switching in the near term, nor can they enable the development and deployment of low carbon gas technologies for the long term.

To understand how the future of global gas may play out, this report takes a focused look at how the future of gas is first likely to develop in Europe (Chapter 3). European energy markets are already going through extensive transitions, which will only intensify as more aggressive emissions reduction targets are adopted. First and foremost, this is affecting the power sector, where coal phase outs are likely to result in gas requiring a greater share of power generation. Beyond the power sector, however, attention is increasingly turning to reducing emissions in the buildings and industry sectors, specifically the role low carbon gas technologies can play relative to electrification. Given these trends, gas is starting to play a more dynamic and diverse role in the energy sector across Europe and between local communities. In many ways, that is likely to be increasingly the case for gas around the world.

2 BCG analysis based on Rystad upstream asset analysis.
3 IEA, “World Energy Investment 2019”, 2019; Oxford Institute for Energy Studies, “The Energy Transition and Oil Companies’ Hard Choices”, 2019; WoodMackenzie; 2018 Global Gas Report.
4 IEA.
5 Ibid.

1 /
Recent global gas trends

Highlights

- The global gas market is experiencing rapid growth across production, consumption, and trade.
- In the short run, this growth is supported by low gas prices and rapid growth of supply infrastructure.
- Meanwhile, other structural changes are emerging supporting the competitiveness and accessibility of gas going forward, particularly the role of LNG providing more diverse and lower cost means of natural gas supply.
- Adoption of supportive policies in key markets is also driving growth, including policy measures to promote fuel switching and develop new gas infrastructure.
- But international pipeline developments are lagging and the development of low carbon gas capacities remains small globally.

The global natural gas market is in the midst of a sustained and substantial growth phase. Over the past five years the market has grown at an average of 2% per year, double the rate of global primary energy demand. Enabling this are a series of structural developments across the global gas industry.

Delivered LNG costs are continuing to decline given greater efficiencies in shipping and lower cost projects coming online in the US and Russia[6]. The development of gas infrastructure – LNG in particular – is enabling cost-competitive access to gas in new markets. And the environmental benefits of gas as a tool for urban air quality improvement and greenhouse gas (GHG) emissions reductions is increasingly recognized by government policymakers.

Nevertheless, recent trends have exposed some ongoing challenges for gas. Both production and consumption growth have been highly concentrated in a small number of countries, particularly the US, which remains unique in its development of unconventional gas resources and the existence of extensive gas pipeline infrastructure. The slow progress of gas market liberalization and infrastructure development in high growth potential markets contributes to this trend, particularly in non-OECD Asian countries. Looking forward, there are also concerns about the sustainability of gas given the current understanding of methane emissions and key gaps in emissions data.

Global gas: headline trends in the past year

+4.9%	-$2.1 /MMbtu	+4.1%	+143 bcma
Global production & consumption growth	Change in average gas price at key global hubs*	International pipeline & LNG trade growth	Gas import & export capacity growth

Note:
All data points except gas price reflect 2018 annual change. | * Calculated as Q1 2019 average less Q1 2018 average – average of Henry Hub, NBP, and NE Asia spot.
Source: IGU, Cedigaz, Bloomberg, Argus, EIA, GIIGNL, BCG analysis.

[6] These projects include Yamal, Sabine Pass, and Cove Point; Cedigaz.

Developments in global gas fundamentals

Global gas production and consumption growth

+4.9%

US AND CHINA ACCOUNTED FOR MORE THAN 60% OF TOTAL MARKET GROWTH

The global natural gas market experienced dramatic growth in 2018. Consumption and production grew by 4.9% (179 BCM) year-on-year, the fastest annual rate since 2010 when demand was rebounding after the global financial crisis. In total, gas accounted for nearly half the growth in global primary energy demand in 2018[7]. Preliminary data from 2019 indicates that robust global gas consumption and production growth trends are continuing this year[8].

Both consumption and production growth were highly concentrated in 2018. The US and China led the way in consumption, accounting for more than 60% of total market growth. So far in 2019, global gas consumption is growing at a similar rate, though the rate of growth has slowed in the US and China while it has accelerated in Europe[9]. Meanwhile on the supply side, surging US and Russian production growth of 89 BCM and 34 BCM respectively enabled global gas supply to match the consumption growth rate of 4.9% year-on-year in 2018. Together the US and Russia accounted for more than 68% of global gas production growth in 2018, a trend that has continued through the first half of 2019[10].

Additional LNG liquefaction capacity has also been a critical enabler of the rapid growth of the global gas market in the past year, supporting global LNG market growth of 10% year-on-year[11]. New projects in Australia, the US, and Russia added nearly 40 BCM of LNG liquefaction capacity in 2018. On the demand side, China led all markets in LNG consumption growth, accounting for more than 60% of global LNG market growth in the 2018[12].

To assess what drove the rapid growth in the global gas market over the past year and the ongoing sustainability of that growth, the energy trilemma framework is a useful tool[13]. The 2018 Global Gas Report analysis of historic gas demand demonstrated that three factors are critical for explaining growth in global gas markets in the past and projecting the future: 1) cost competitiveness of gas relative to other energy sources; 2) security of supply in the form of infrastructure and supply flexibility; and 3) perceptions of the sustainability of gas and the role it can play in addressing environmental concerns focused on climate change and localized pollution.

7 IEA.
8 JODI – based on submission of 46 countries to date.
9 JODI, US EIA, China National Energy Association, European Commission.
10 Cedigaz.
11 IGU, "2019 World LNG Report", 2019.
12 Cedigaz, US EIA.
13 While inspired by the World Energy Council's energy trilemma framework, the 2018 Global Gas Report outlined a distinct interpretation for gas based on an assessment of historic drivers of gas market growth.

Key recent developments in global gas

Region	Consumption	Gas price[1]	Production	Trade – Region average Imports	Trade – Region average Exports	Infrastructure
Africa	5.3%	-	4.5%	-31.8%	-2.3%	Mozambique and Tortue LNG FIDs
Asia	7.3%	-$4.9/MMBtu (NEA spot)	3.5%	12.9%	5.4%	Regional LNG liquefaction & regas expansion; power of Siberia pipeline
CIS	2.0%	-	4.7%	-5.8%	9.3%	Russian LNG & pipeline capacity expansions
Europe	1.0%	-$1.9/MMBtu (NBP)	-5.3%	1.2%	-9.9%	Trans-Anatolian pipeline completed
Latin America	-2.9%	-	-1.7%	-0.2%	5.3%	No key developments
Middle East	3.6%	-	4.7%	-6.4%	3.1%	Growing LNG export capacity
North America	8.8%	-$0.2/MMBtu (Henry Hub)	9.8%	-1.9%	12.8%	Pipeline and LNG export capacity growing

Note: All data points except gas price reflect 2018 annual change.
1 Calculated as Q1 2019 average less Q1 2018 average.
Source: IGU, Cedigaz, Bloomberg, Argus, EIA, GIIGNL, BCG analysis.

Increasingly competitive gas pricing, growing security of supply and environmental benefits of natural gas vs other fossil fuels contributed to strong growth in gas markets

Through 2018 and in the first half of 2019, developments in each of these three dimensions contributed to strong growth in gas markets. Yet, obstacles remain within each that will be critical to overcome in order to sustain the rapid growth of gas markets in the future. They include:

- **Cost competitiveness**: Global gas market growth has demonstrated that gas is an abundant resource with increasingly competitive pricing. But local market regulations and infrastructure constraints in some countries still limit the competitiveness of gas.
- **Security of supply**: Supply continued to grow and become more diverse, supported by greater and more flexible gas liquefaction capacity. Yet the limited scale of investment in cross-border pipelines continues to limit access to gas and growth in some markets.
- **Sustainability**: Government policies continued to recognize the role of gas in reducing GHG intensity and improving local air quality, spurring further gas market development. But methane emissions present a strong challenge to the industry with gaps remaining in the available data on emissions, and a large disparity between different assessment methods.

Cost competitiveness

Natural gas prices at two year lows in key hubs

Market developments through 2018 and into 2019 have confirmed gas as an abundant global resource with increasingly competitive pricing. Global gas prices declined markedly in late 2018 and through the first half of 2019, due to a milder winter in the northern hemisphere increased supply, and market flexibility, which enhanced the competitiveness of gas for different end uses. US Henry Hub prices reached two-year lows in early 2019, even falling below $2.50 per MMBtu[14]. Within the US, natural gas spot prices in the Permian Basin even reached negative levels given the prevalence of associated gas from oil production and a lack of pipeline takeaway capacity. In Europe[15] and Asia, LNG spot prices also reached two-year lows in 2019;the NBP spot price declined more than 23% year-on-year, while in Asia the NEA spot price was down more than 47% year-on-year[16].

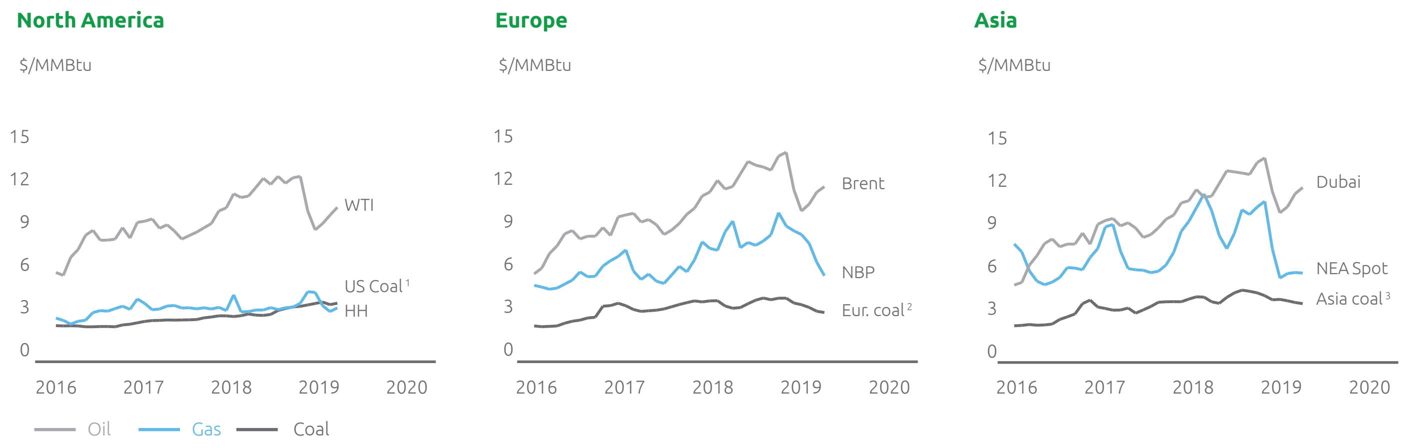
Rapidly growing gas production and LNG supply were the greatest driver of declining natural gas prices. The US shale boom has continued, with dry gas production up by more than 11% over the course of 2018 and through the first half of 2019[17]. This enabled more than 70 BCM of domestic consumption growth while also contributing 17 BCM to net exports via pipelines and LNG in 2018.

Change in average price at key global hubs

-$2.1/MMbtu*

[14] US EIA.
[15] For the purposes of this report, Europe includes the EU28 countries plus Albania, Bosnia & Herzegovina, Macedonia, Norway, Serbia, and Switzerland.
[16] Bloomberg; Argus; Calculated as the percentage change in average Q1 prices in 2018 and 2019.
[17] US EIA.

Oil, gas and coal prices in major reference markets (2016 - Q1 2019)



1. US coal price is Central Appalachia price; 2. Rotterdam index; 3. Australia coal.
Source: World Bank, Bloomberg, EIA, Argus, BCG analysis.

* Calculated as Q1 2019 average less Q1 2018 average – average of Henry Hub, NBP, and NE Asia spot.

Rapidly growing gas production and LNG supply were the greatest drivers of declining natural gas prices

Significant new LNG export capacity additions in Australia (18 BCM), Russia (15 BCM), and the US (7 BCM) over the course of 2018 added roughly 8% to global liquefaction capacity. Despite the addition of substantial new capacity, global liquefaction utilization remained unchanged at 77%[18]. As a result, spare liquefaction capacity provided for greater LNG market liquidity and flexibility. New flexible contracting of LNG sales is another key contributor to lower natural gas import prices in Europe and Asia. LNG short-term[19] and spot sales reached an all-time high as a share of market transactions in 2018, growing to more than 30% of total LNG trade from 25% in 2016[20]. For long term LNG contracts, the use of more liquid indices is also growing – particularly Henry Hub contracting for US LNG supply and sales to Asian customers on a JKM (Japan Korea Marker) basis. More liquid pricing instruments allow LNG customers to rapidly respond to market developments, as evidenced by the decline in LNG spot prices in late 2018 and early 2019. Additionally, the growing liquidity of key LNG hubs allows LNG to more readily compete with pipeline and domestic supply, helping to bring down costs for all gas customers.

The downward trajectory of gas prices is making gas more competitive with other fuels on a levelized basis. This is critical for gas consumption in Asia, which traditionally has among the highest natural gas prices, but lowest coal prices across regions. In Q1 2019, the Levelized Cost of Electricity (LCOE) for natural gas in power generation fell below that of coal in Japan and South Korea. In China, the gap was narrowed from a 66% premium for gas vs. coal to a 35% premium[21].

In Europe, low gas prices combined with a high Emissions Trading Scheme (ETS) price of carbon has enabled gas to increasingly displace coal in power generation through the first half of 2019[22]. ETS prices rose from €8 per ton in early 2018 to a sustained price of more than €20 per ton in late 2018 and into 2019[23]. As an example of the impact of carbon pricing on market conditions due to the implementation of a carbon price floor, the United Kingdom power sector went two weeks in May 2019 without burning coal for power the longest period since 1882[24]. This demonstrates that when environmental externality costs are integrated into markets, gas is highly cost competitive with coal. With a current social cost of carbon around $40 per ton, incorporating a carbon price into power generation will typically reduce the cost of gas below coal on a levelized basis in most markets[25].

Despite the significant gains in the cost competitiveness of gas through 2018 and into 2019, gas faces some headwinds. Most immediately, ongoing trade conflicts risk limiting the competitiveness of LNG. So far, the impact has been limited to China's imposition of tariffs on US LNG exports, initially at 10% and recently raised to 25% in response to US-imposed tariffs on Chinese exports. In the short run, the market has adapted to the US-China trade dispute by diverting trade flows as more liquid global supply was able to offset US supply (around 3 BCM before the tariffs)[26]. However, this is a risk to the future supply of global LNG as it may limit the ability of US projects to contract future capacity. As an example, LNG Limited cited US-China trade tensions in October 2018 as a reason it delayed its Final Investment Decision (FID) for its Magnolia LNG export project in Louisiana[27].

The slow progress of gas market liberalization and infrastructure development in some parts of Asia is also an ongoing risk to gas competitiveness in key growth markets. Governments in China and India are both taking steps to open access to gas markets. In the past year, Chinese regulators continued to launch domestic reforms including boosting third-party access to LNG terminals and

[18] Cedigaz.
[19] Cargoes delivered under contracts of a duration of 4 years or less..
[20] IGU, "2019 World LNG Report".
[21] BNEF, BCG analysis.
[22] IEA, "Gas Report", 2019.
[23] Eurostat.
[24] Press reports.
[25] The estimated value of those costs, or social cost of carbon, are estimated to be around $40 per ton; EPA, "Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866", 2016.
[26] US EIA.
[27] Press reports.

Slow progress of gas market liberalization and infrastructure development in some countries

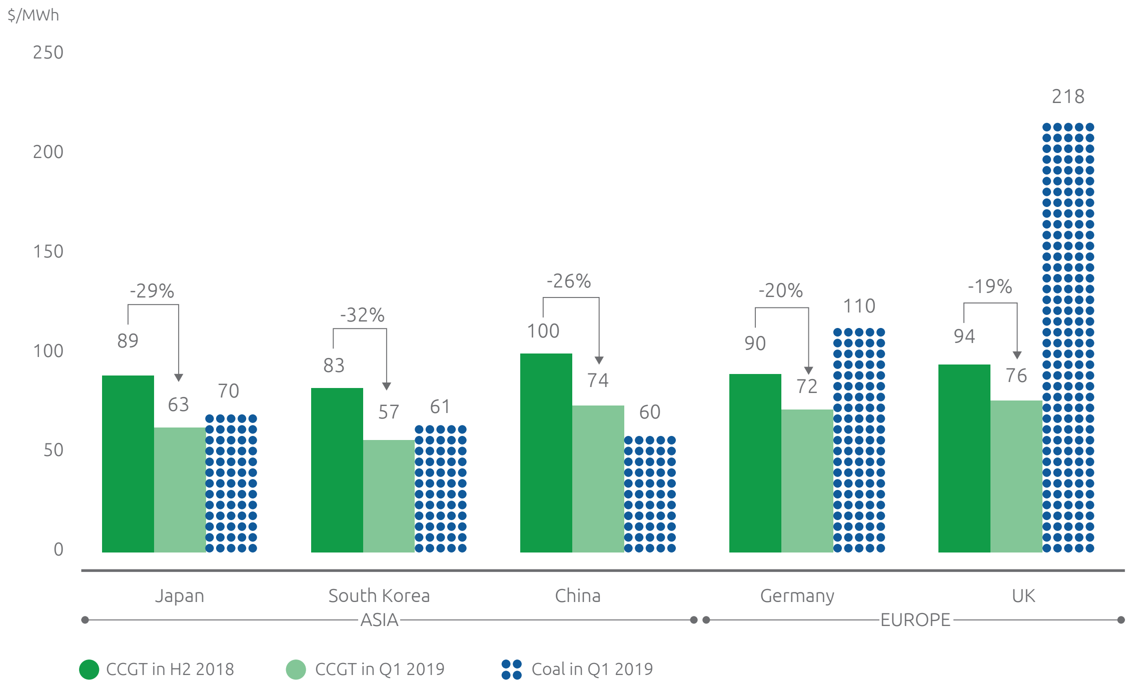
liberalizing domestic gas pricing[28], while in India the gas regulator is in the midst of issuing new concessions to expand city gas distribution infrastructure[29]. However, both of these gas markets remain highly regulated and the development of key infrastructure has progressed slowly.

In China, transmission pipeline access is still held by the national oil companies (NOCs) without access of third party line rights[30]. In India, the development of transmission infrastructure under a state-owned operator is lagging behind planned city distribution capacity.

Across countries with high market growth potential, the regulated structure of gas markets also continues to be a barrier to the development of new local gas production. Such regulatory barriers typically take the form of regulated price structures and/or access by non-state-owned entities. In India, for example, the regulated price for domestically produced gas is widely recognized to be insufficient to spur investment in upstream production[31]. In other countries such as Argentina, state control of, or intervention in, the oil sector has limited foreign participation and innovation to reduce costs. Only recently has the development of more open and competitive markets attracted sufficient investment and cost competition to spur significant growth in production from the Vaca Muerta basin[32].

Low gas prices have improved gas competitiveness with coal for power generation

Average Levelized Cost of Energy of gas vs. coal (2018-2019)



Source: BNEF, Lazard, UT Austin, BCG analysis.

[28] S&P Platts, "Opportunities and challenges of China's LNG expansion", 2018.
[29] India PNGBR.
[30] Oxford Institute for Energy Studies, "China's Long March to Gas Price Freedom: Price Reform in the People's Republic", 2018.
[31] See for example assessment of India in 2018 Global Gas Report.
[32] BCG analysis, press articles.

Security of supply

The global supply of LNG is rapidly growing and becoming more diverse and flexible, improving overall security of supply of natural gas

Global LNG market growth continues to improve overall security of supply for natural gas as a whole. The global supply of LNG is rapidly becoming more diverse and flexible. Meanwhile, for countries that are adding LNG import capability, it is providing greater flexibility to complement pipeline imports and domestic gas supply. These developments are facilitating LNG import growth in Europe and Asia, as LNG helps to offset declining domestic production in Europe while enabling gas consumption to grow faster than production in Asia. Market growth can be further improved by continuing to improve the flexibility in commercial contracting mechanisms, and removing bottlenecks that arise from slow investments in gas pipelines.

In 2018, LNG supply continued to become more diverse and secure globally. The large addition of Australian LNG export capacity has already helped to diversify global supply, given exports have tripled from 30 BCM in 2013 to 90 BCM in 2018[33]. Looking ahead, current liquefaction projects under development will further diversify supply sources. US projects in particular are adding more than 80 BCMA of capacity, so that by 2022, the US will rival Qatar and Australia as the top source of LNG exports[34].

New investment decisions on LNG liquefaction capacity development will add further geographic diversity to LNG supply. Recent FIDs will add three new countries to the ranks of LNG exporters by 2025: Mozambique (both Coral and Mozambique LNG projects); Mauritania/Senegal (Tortue FLNG); and Canada (LNG Canada). Notably, nearly all of these projects, plus Golden Pass LNG in the US and the Arctic II project in Russia, were able to proceed to FID with portfolio buyer backing, ensuring that the projects were not dependent on securing individual customer contracts.

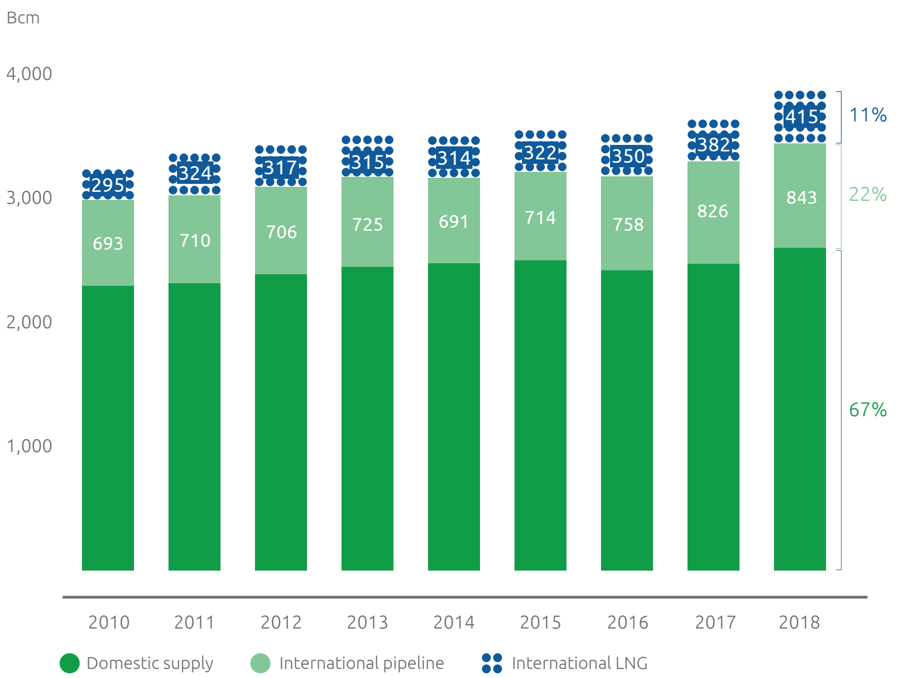
Investment in LNG regasification capacity is also growing rapidly, expanding access to gas in existing and new LNG import markets. In 2018, LNG importers added nearly 70 BCMA of regasification capacity. China is developing LNG import capacity most aggressively, with 24 BCMA of capacity additions in 2018, representing more than 20% of the country's capacity[35]. At the same time China has also rapidly expanded natural gas storage capacity to better manage seasonality, more than doubling storage capacity in past three years[36]. This rapid growth has been essential to facilitating China's coal-to-gas fuel switching that has been ramping up since 2017.

The ranks of LNG importing countries is also becoming more diverse as two countries added regasification capacity for the first time over the past year and a half. Panama received its first LNG cargo at its new 2 BCMA import facility in June 2018, and Bangladesh opened a 5 BCMA Floating Storage Regasification Unit (FSRU) in August 2018. This makes 21 countries[37] in total that have begun importing LNG in the past decade[38]. Looking forward, projects are now under development to introduce LNG to several new markets including the

[33] Cedigaz.
[34] Sanctioned US LNG export projects under development include Sabine Pass expansion, Cameron LNG, Freeport LNG, Elba Island LNG, and Golden Pass LNG; Cedigaz.
[35] Cedigaz.
[36] China Daily.
[37] In addition to Panama and Bangladesh, these countries include Chile, Colombia, Egypt, Finland, Indonesia, Israel, Jamaica, Jordan, Kuwait, Lithuania, Malaysia, Malta, Netherlands, Pakistan, Poland, Singapore, Sweden, Thailand, and UAE.

2/3 of international gas trade growth was driven by LNG

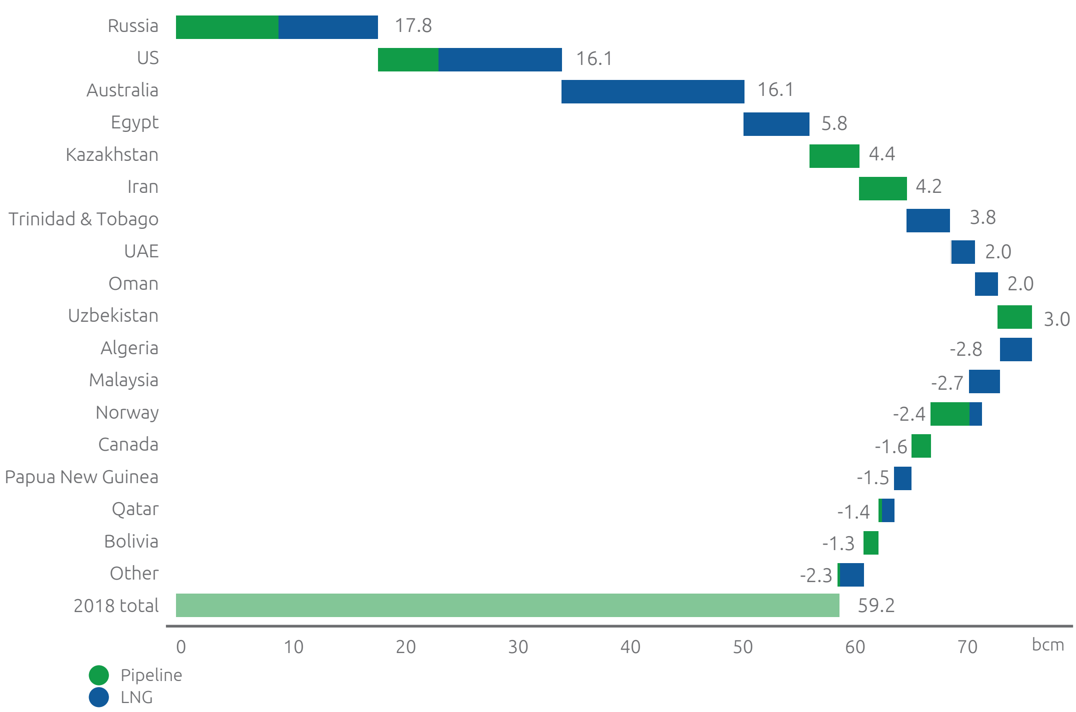
Global gas trade by year



Source: Cedigaz, BCG analysis.

Strong global gas trade growth in 2018 led by the US, Russia, and Australia exports

2018 annual change in net exports



Philippines, Ghana, Croatia, Bahrain, and El Salvador[39]. While these developments help to diversify LNG demand, the largest global volume of LNG import capacity still remains concentrated in a handful of countries – Japan, South Korea, and China – which hold roughly 45% of the world's LNG regasification capacity[40].

LNG is also now providing flexibility for countries to shift between imports and exports as their domestic gas supply/demand balances change. Egypt has become an LNG exporter again as production from the Zohr gas field came online starting in late 2017. This followed a temporary switch of Egypt to a net import position, due to the decline in traditional domestic production. Existing LNG liquefaction capacity allowed Egypt to rapidly increase production and also enabled their 2018 agreement to export gas from new developments in Israel. Similarly, in Argentina, the growth of unconventional gas production is poised to turn the country into a net exporter of gas. Meanwhile, in Indonesia and Thailand, LNG imports provide sustained supply of gas as domestic production has peaked and is now declining.

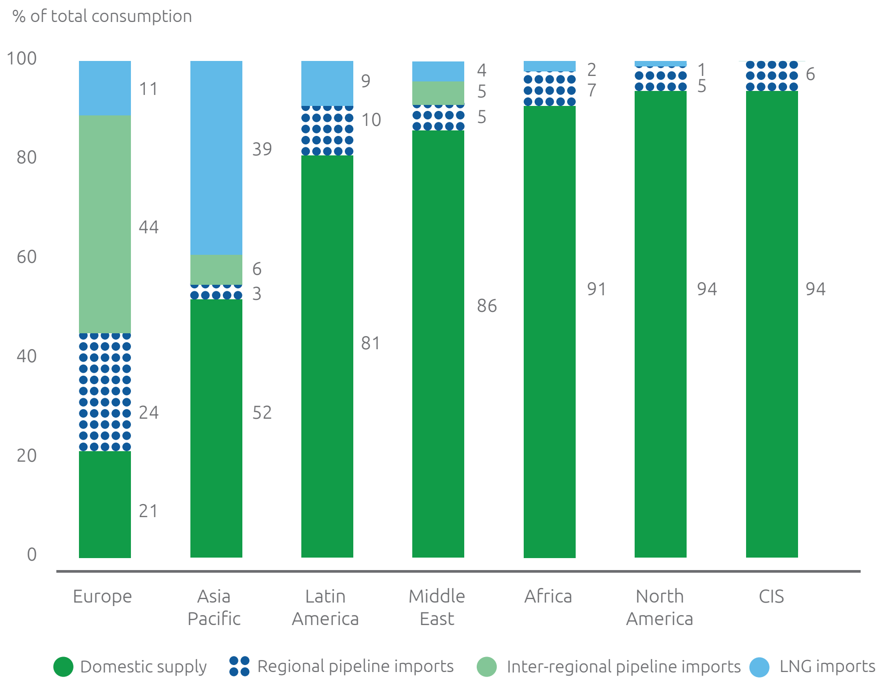
In Europe, access to both pipeline gas and LNG supply has provided flexibility to adapt to declining local production. Total European production fell 5% from 250 to 236 BCM in 2018, led by a decline of 7 BCM in the Netherlands due to the phase out of production from the Groningen field. Increased pipeline supply from Russia offset the bulk of the decline in local supply, while growth inLNG imports made up much of the remainder[41].

Although the global LNG market has grown and become more dynamic, some specific challenges remain to ensure that LNG provides maximum stability and flexibility for global gas markets. One of those challenges is the legacy of existing gas contracting structures. Long-term contracts and oil index pricing have historically provided certainty about natural gas prices. However, given recent price volatility for both crude oil and natural gas, these contracts can now risk locking customers into high price differentials between spot and term prices (there is potential for either spot or term to be considerably higher).

[38] Cedigaz; Press reports.
[39] IGU, "2019 World LNG Report", 2019.
[40] Cedigaz.
[41] Cedigaz.

Europe and Asia Pacific are most dependent on gas imports

2018 regional gas supply by source



Source: Cedigaz, GIIGNL, BCG analysis.

Government policy should internalize the environmental costs of CO_2 and reflect the environmental benefits of natural gas

Top LNG & inter-regional pipeline supply source

	EUROPE		ASIA PACIFIC	
	EXPORTER	**BCM**	**EXPORTER**	**BCM**
LNG SUPPLY	Qatar	19	Australia	90
	Algeria	8	Qatar	77
	Nigeria	10	Malaysia	34
	Russia	6	Indonesia	25
	Norway	5	Russia	17
	Other	11	Other	79
	Total	**59**	**Total**	**322**
INTER-REGIONAL PIPELINE SUPPLY	Russia	174	Turkmenistan	41
	Algeria	35	Uzbekistan	4
	Libya	5	Kazakhstan	1
	Total	**214**	**Total**	**46**

In Asia, the difference between spot and typical term LNG contracts reached $6 per MMBtu in early 2019, with term sales more than double the price of spot[42]. While the share of long-term[43] and oil indexed contracts is decreasing, they still account for nearly 70% of the global LNG trade[44].

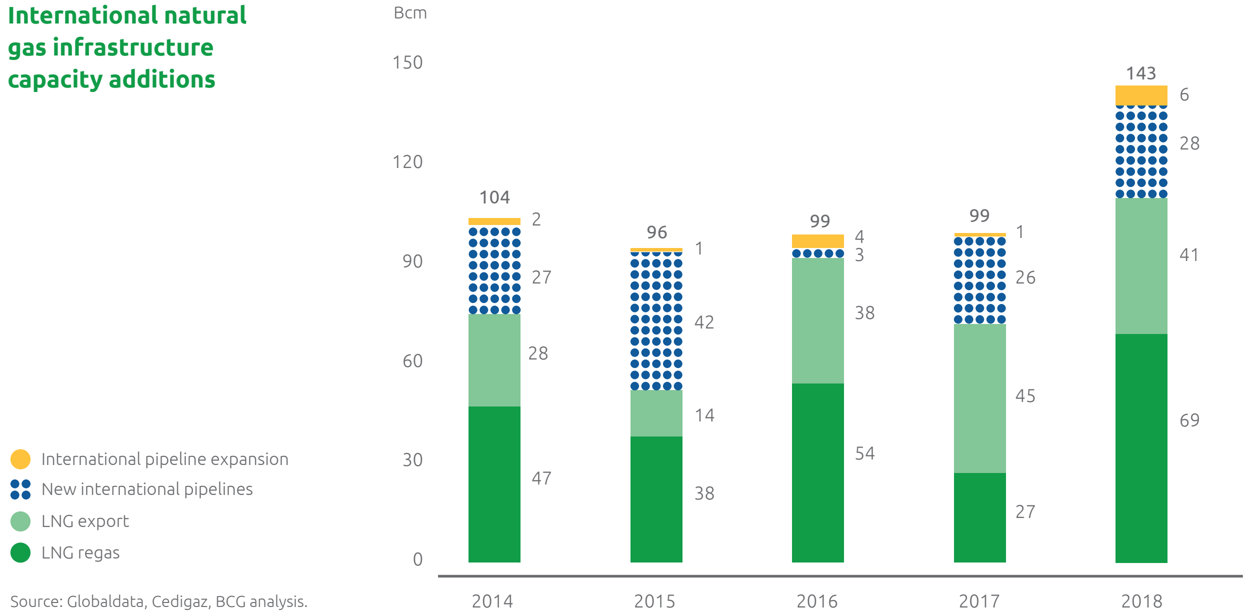
Global pipeline development is also lagging behind LNG infrastructure investment, limiting access to gas in some high potential growth markets. Key regional trends in international pipeline development include:

- **North America** leads in the development of cross-border pipeline capacity, with expansions from the US to Mexico and Canada facilitating exports of surging US gas production. Since 2017, more than 40 BCMA of cross-border capacity has been completed, amounting to one-fifth of existing capacity[45].
- In **Asia**, the only major cross-border pipeline development project underway is the Power of Siberia project connecting Russia to China. The pipeline is set to be completed by the end of 2019, providing 38 BCMA capacity.
- In **Europe**, the Trans-Anatolian Natural Gas Pipeline (TANAP) was completed in 2018, providing additional 16 BCMA capacity from Azerbaijan to Turkey. Complementing that, the Trans-Adriatic Pipeline (TAP) is under development to connect TANAP to Greece, Albania and Italy, providing 10 BCMA of initial capacity.
- Additionally, **Russia** is expanding pipeline capacity to Europe. The Turkstream pipeline is currently under development, which will add more than 30 BCMA capacity to Turkey, South and Southeast Europe. The Nord Stream 2 pipeline continues to be built which will add capacity from Russia to Germany, but still faces political challenges from opposition by the US and some EU member states.

[42] S&P Platts.
[43] Cargoes delivered under contracts of a duration of more than 4 years.
[44] IGU, "2019 World LNG Report".
[45] US EIA.

LNG infrastructure growing more rapidly than international pipeline capacity

International natural gas infrastructure capacity additions



Source: Globaldata, Cedigaz, BCG analysis.

Major 2018 natural gas infrastructure completions

	GEOGRAPHY	PROJECT	CAPACITY (BCM)
INTERNATIONAL PIPELINE EXPANSIONS	US - Mexico	Rio Bravo Hidalgo	4
	US - Mexico	KM Border	2
	US - Canada	Portland Xpress	<1
NEW INTERNATIONAL PIPELINES	CIS - Turkey	Trans-Anatolian	16
	US - Mexico	Impulsora Xing	11
	US - Canada	SSA	<1
LNG EXPORT	Russia	Yamal	15
	Australia	Icthys	12
	US	Cove Point	7
	Australia	Wheatstone T2	6
	Cameroon	Cameroon FLNG	2
LNG REGAS	China	6 onshore, 1 FSRU	24
	Japan	Soma	12
	Turkey	Dortyol	8
	India	Mundra	7
	Thailand	Mab Ta Phut	7
	Bangladesh	Moheshkhali FSRU	5
	Greece	Revithoussa	2
	Panama	Costa Norte	2
	Sweden	Gothenburg	<1
	Finland	Tornio Manga	<1

Sustainability

Environmental benefits of natural gas and low carbon gas technologies are increasingly being recognized in government policy, but methane emissions must be addressed

The role of gas in both reducing GHG emissions intensity and improving air pollution is increasingly being recognized in government policy, providing a boon to gas market growth. Meanwhile, low carbon gas technologies such as biomethane, hydrogen, and CCUS are starting to receive greater government policy support. Capacity of all three technologies is growing globally, although it remains small. Nonetheless, the issue of methane emissions presents a critical potential challenge to the sustainability credentials of gas. As the science on the identification and estimation of methane emissions is relatively new and continues to develop, there are large gaps in data availability. As a result, there are some highly divergent claims stemming from different research studies and methodologies, and some recent studies suggest emissions levels are higher than previously reported, while others assert the opposite. Gaining greater clarity on the scale of methane emissions and measures taken to reduce them will be critical for the sustainability of gas.

The role of gas in reducing GHG emissions in the short run has become clearer in recent years. As coal-fired power generation is reduced in some markets, a combination of gas and renewables are clearly filling the gap. In 2018 alone the IEA estimated that 95 MT of CO_2 emissions were avoided due to coal to gas switching[46].

In the US, market forces are predominately driving continued coal-to-gas switching given the sustained low price of gas. In 2018, planned US coal capacity retirements totaled nearly 14 GW, while 2018 planned net increase in US natural gas power capacity totaled 16 GW[47]. Moreover, since 2008, gas has grown from 21% of the US power generation mix to 35%, while the share of coal has declined from 48% to 27%[48]. As a result of both gas and renewables growth offsetting declining coal use, the carbon intensity of the US power sector declined by more than 25% in that period[49].

In parts of Europe, policy is more directly driving the switch from coal to gas. Eight countries, including the United Kingdom, Netherlands, Italy and Portugal have announced coal phase outs while another six countries are considering them, including Germany and Spain[50]. While a switch to gas specifically is not mandated, it is highly likely as gas generation capacity already exists in these markets and gas has previously demonstrated the ability to gain share as a lower carbon, dispatchable source of power. Nevertheless, governments in Eastern Europe have been slower to adopt such measures, and in total about 40% of European coal capacity is operated in countries with no proposed policies to phase out coal.

To provide a long-term pathway for a deep reduction in global GHG emissions, new low carbon technologies for gas will need to be adopted including renewable gas (biomethane), low carbon hydrogen, and CCUS. These technologies provide a viable pathway to reduce the carbon intensity of gas supplied to end consumers by 90% or more. As a result of targeted policy support and ongoing technological development, global installed capacity of all three

46 IEA, "Global Energy and CO_2 Status Report", 2019.
47 US EIA.
48 US EIA.
49 Carnegie Mellon University Power Sector Carbon Index.
50 Beyond Coal EU.

technologies is growing between 7-13% per year, though from a small base[51]. This is only a small fraction of the capacities that will be required to achieve the Paris Agreement goal of limiting warming to below 2° Celsius. For example, capacity for CCUS would need to grow at a rate of 25% per year through 2040 to meeting the Paris objective[52].

Among low carbon gas technologies, CCUS is now receiving significant new policy support in some regions and is poised to experience more rapid capacity growth in the coming years. For example, a new CO_2 capture tax credit in the US ("45Q") is expected to spur growth in CCUS capacity by providing a sufficient economic incentive[53]. Globally, CCUS capacity is poised to grow at a faster pace as current capacity under development is roughly equal to all operating capacity, or about 40 metric tons of CO_2 captured per year. More than two-thirds of this capacity comes from large scale, commercial projects, whereas past projects have largely been pilot or demonstration scale[54]. Nevertheless, even faster growth is required to meet the Paris targets as the IEA estimates CCUS will need to make up around 15% of global CO_2 emissions reductions by 2040[55].

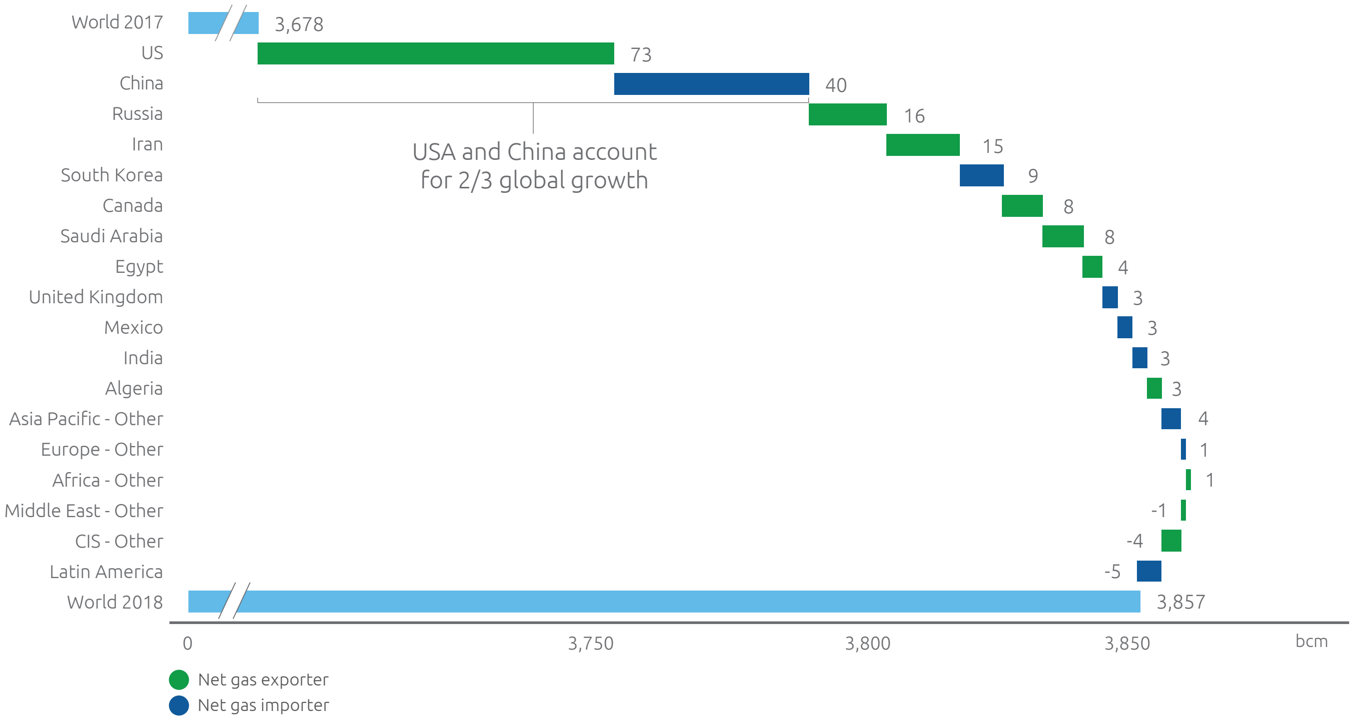
Policies focused on reducing GHG emissions and improving air quality are key drivers of natural gas consumption growth

Sustainability-focused policies in select markets

China	Mandated coal to gas switching to improve local air quality
South Korea	Reduction in coal and nuclear power generation
Saudi Arabia	Phase out of oil products used in power generation
United Kingdom	Carbon price floor driving coal out of power generation
India	Expansion of city gas distribution to improve air quality

51 Cedigaz; IEA; Global CCS Institute, "2018 Global Status Report".
52 Global CCS Institute, "2018 Global Status Report".
53 BCG, "The business case for carbon capture", 2019.
54 Global CCS Institute, "2018 Global Status Report".
55 IEA Sustainable Development Scenario.

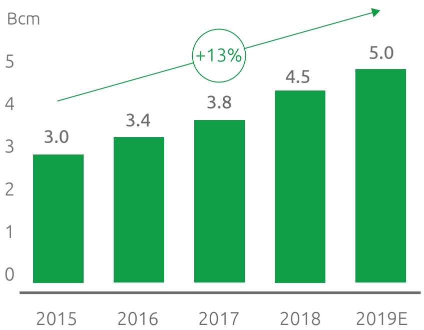
Change in natural gas consumption by country (2017-2018)



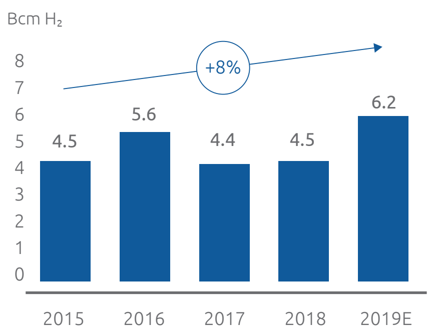
Source: Cedigaz, BCG analysis.

Global low carbon gas capacities are growing

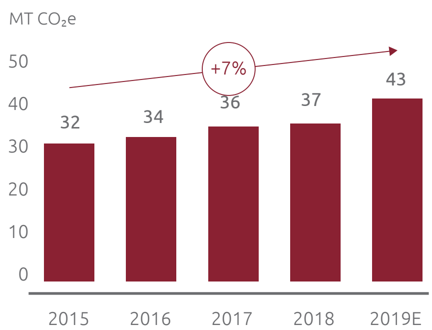
Global biomethane capacity (2015-2019E)



Global low carbon hydrogen capacity [1] (2015-2019E)



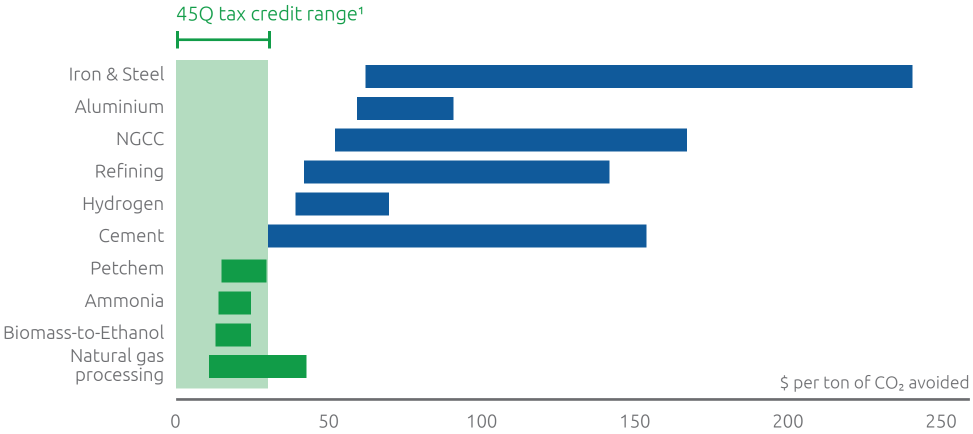
Global CCUS capacity (2015-2019E)



1 Defined as projects using electrolysis or fossil fuel based hydrogen paired with carbon capture.
Source: Cedigaz, IEA, Global CCS Institute, BCG analysis.

CCUS: 45Q tax credit in the US will make some projects economically competitive

Estimated CCUS cost ranges per sector



1. 45Q tax range based on value of CO_2 avoided assuming 90% plant efficiency; assumes average of $15/t transport and storage costs for sequestration.
Source: BCG - estimates sourced from published academic and research papers, excluding industry sources, all costs normalised to USD 2019. Cost/tonne avoided includes the emissions from power used from the grid.

The impact of methane emissions from the oil and gas industry has emerged as a significant challenge to the perceptions about the sustainability of gas. There are continued uncertainties and large gaps in data when it comes to an accurate understanding of the global scale of methane emissions, particularly outside of North America and Europe. Improving clarity about current emissions estimates and measures taken to reduce emissions will be critical for the assurance of natural gas' sustainability credentials.

To this effect, there has been notable action from both industry participants and governments. In the US, several states have continued to develop methane regulations despite a rollback at the federal level. In the EU, the European Commission is examining approaches to develop methane emissions policies. On the industry side, several prominent voluntary initiatives have been gaining steam, including the Methane Guiding Principles (MGP), a group that started with eight companies in late 2017 and today stands at over 30 signatories and supporting organizations[56]. Its goal is to verifiably reduce global methane emissions from natural gas value chains. Several major industry players also announced specific methane reduction targets in 2018.

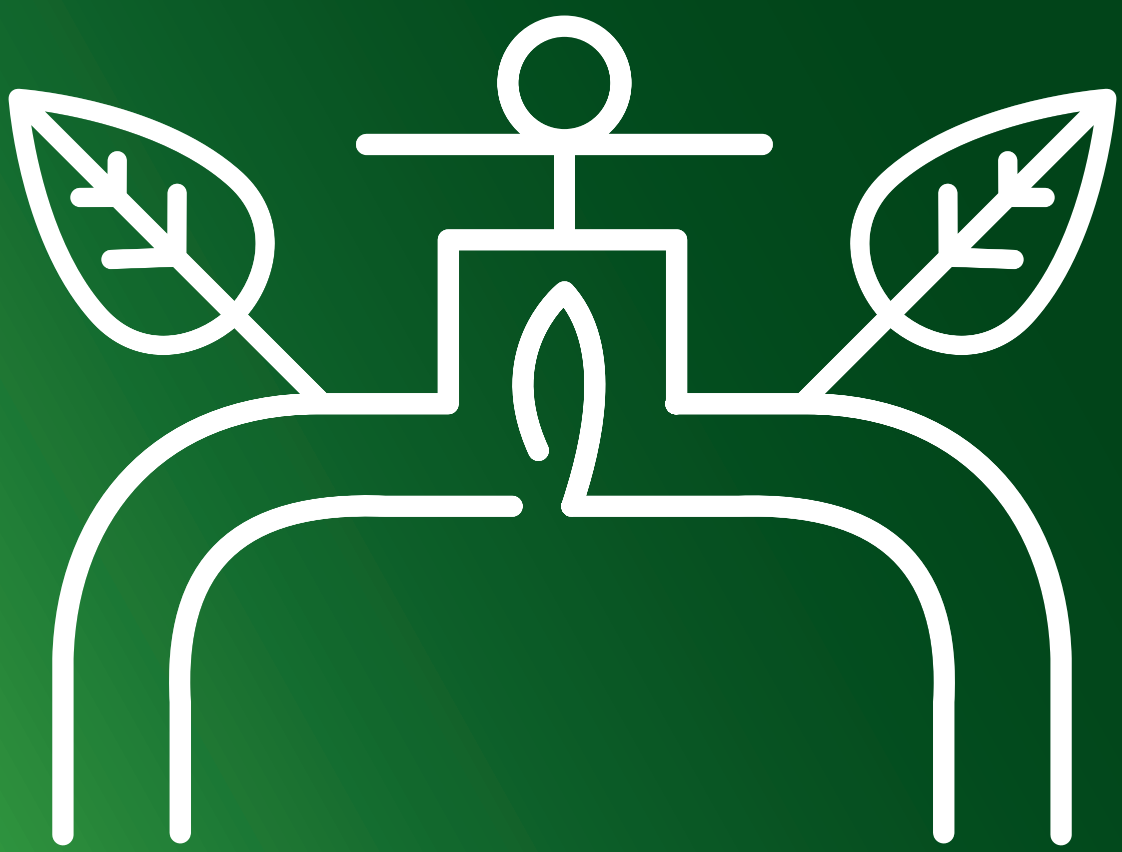
In addition to climate change impacts, the other significant sustainability benefit of gas is the reduction of localized pollutants such as particulates (PM2.5 & PM10), sulphur oxides (SO_x), and nitrogen oxide (NO_x). Energy policy promoting gas consumption in Asia is largely motivated by the local pollution benefits of gas use.

[56] Press reports.

China in particular continues to demonstrate the impact that coal to gas switching has on improving air quality. In 2018 the average level of PM2.5 fell by more than 9% across the largest Chinese cities, surpassing the decline of 6.5% in 2017[57]. This was due in large part to the increasing share of natural gas in urban energy and industry consumption.

In India, natural gas is poised to play a more prominent role for improving air quality going forward. The Indian government launched its first national goal for air quality improvement in 2018, targeting a 20-30% reduction in particulate pollution by 2024. Aligned with this goal, the India Petroleum and Natural Gas Regulatory Board conducted two rounds of bidding for new city gas distribution licenses over the course of 2018-19. In total, 136 new licenses were granted, more than all current existing licenses. The objective is to spur investment of more than $14 billion to expand access to natural gas across Indian cities, enabling its use in home cooking, small scale industrial applications, and natural gas vehicles for transport[58].

[57] China Ministry of Ecology and Environment.
[58] India PNGRB.



2 /
The future of global gas

Highlights

- Recent energy scenarios have reaffirmed the strong growth potential for gas as well its likely continued prominent role in the global energy mix under more rapid energy transitions (i.e. 1.5° Celsius warming scenarios).
- The industry sector has overtaken power generation as the greatest driver of future gas demand.
- Going forward, multiple challenges will need to be addressed for gas to achieve growth projections:
  - » **Cost competitiveness**: sufficient low-cost gas reserves are available to enable projected growth, but the biggest challenge remains connecting these resources with end use markets for gas at low cost;
  - » **Security of supply**: an estimated $500 billion of infrastructure investment is also required to enable gas growth, but recent investment has fallen short particularly in the development of mid- and downstream infrastructure;
  - » **Sustainability**: sustained policy support is also required to ensure the environmental value of gas is reflected in market incentives, but to date such policy adoption has been limited.

The latest long-term energy outlooks released in the past year have again confirmed the potential for the sustained strong growth of natural gas. Across reference case scenarios, there is strong alignment around an average annual growth rate for natural gas of about 1.7% per year through 2040[59]. On this basis, gas is expected to overtake coal as the second largest source of global energy supply at some point in the late 2020s or early 2030s.

However, a closer look at these scenarios reveals some critical areas of uncertainty. While average growth rates in the key reference scenarios have remained unchanged, the projected growth across different sectors is changing. Also, scenarios modeling more rapid energy transitions are increasingly divergent on the role that gas can play when the world moves closer to a 2° Celsius pathway.

Diverging outcomes and assumptions in key scenarios demonstrate that the future role of gas in global energy will significantly depend on the near term actions of governments and industry participants. Assessing what is required for strong, sustained gas growth relative to recent trends reveals several key themes that will shape the future of global gas:

- More widespread development of low-cost gas resources and unconventional gas will be critical for ensuring the ongoing cost competitiveness of gas vs. other fuels.
- Infrastructure for accessing gas supply is a key gap in multiple markets with the greatest growth potential. Infrastructure investment to date appears to be insufficient to achieve long term growth expectations; and
- Government policy mechanisms will be critical for internalizing the cost of environmental impacts, supporting the development of low carbon gas technologies, and developing viable pathways for using gas to achieve deep GHG emissions reductions.

[59] For the purpose of this analysis reference scenarios from IEA, US EIA, BP, and Shell were used as they are the most commonly cited.

Developments in future gas projections

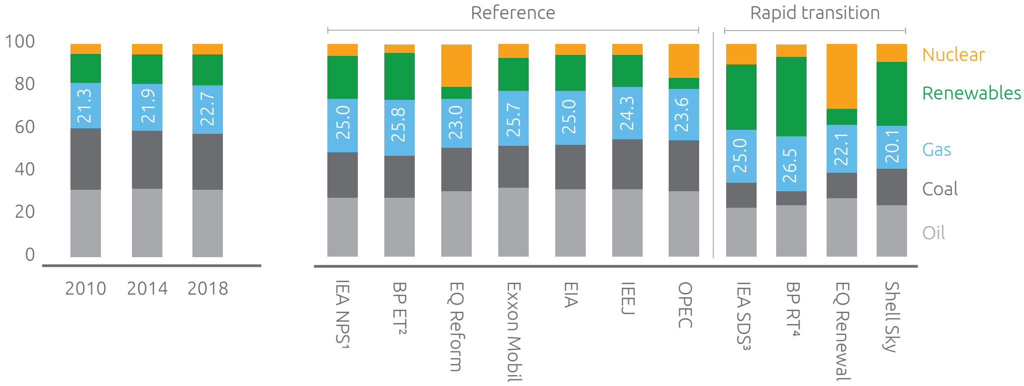
Across leading industry reference case scenarios from the IEA, US EIA, BP, Shell and others, a strong consensus has emerged that global gas demand is expected to grow by around 1.7% per year on average to 2040[60]. On the basis of that growth, most of these scenarios also project gas to gain a share in the global energy mix from around 22% today to 24-25% by 2040. As such, gas is projected to overtake coal as the second largest source of energy supply after oil. These growth projections for gas have been largely unchanged for the past five years.

While a consensus has been established that gas will be the fastest growing fossil fuel through the 2030s, the understanding of the relative drivers of gas market growth has started to shift. Specifically, the role of gas in the industrial sector is playing a more prominent role in projections, while the outlook for gas in power generation is weakening. For example, in the IEA New Policies Scenario, the long-term projected growth rate for gas in the power sector has declined from 1.8% per year to 1.2% since the 2011 outlook, while in the industry sector, projected annual growth rates have increased from 2% to 2.3% in the same period[61].

Recent developments along the three dimensions of the energy trilemma framework help to explain how these forecasts have evolved as well as key requirements for the projected growth to be achieved in the future.

Natural gas forecasted to take a larger share of global energy demand by 2040 in most scenarios

Historic global primary energy demand mix **Forecasts of 2040 primary energy demand mix**



1. New Policy Scenario, 2. Evolving Transition; 3. Sustainable Development Scenario; 4. Rapid Transition.
Source: IEA, BP, EIA, Shell, Resources for the Future Global Energy Outlook, BCG analysis.

[60] The IEA's most recent NPS forecast shows gas demand with a 1.6% CAGR, the latest BP Energy Outlook Evolving Transitions scenario shows gas demand with a 1.7% CAGR, the latest Shell LNG Outlook also shows gas demand with a 1.7% CAGR, the latest OPEC World Oil Outlook shows gas demand with a 1.7% CAGR, the latest IEEJ shows gas demand with a 1.8% CAGR. Two reference scenarios show gas growing at a slower rate: the latest ExxonMobil Outlook for Energy shows gas demand with a 1.3% CAGR, and the latest Equinor Reform scenario shows gas demand with a 1.1% CAGR.

[61] IEA, "World Energy Outlook", 2011; IEA, "World Energy Outlook", 2018.

In the industry sector, two factors are driving the assessment of gas demand growing faster than previously expected: sustainability and cost competitiveness. First, as governments adopt policies to improve air quality – particularly in Asia – gas is increasingly likely to displace coal. Second, the relative costs of electrifying industrial heat are coming into greater focus, indicating that industrial sector gas demand is likely to be resilient even under rapid energy transition policies. Per analysis by BCG, options for electrifying industrial heat consumption are two to three times or more expensive than natural gas on a levelized basis in most markets[62].

In power generation, declining costs of renewables and battery storage are shifting forecast growth away from gas in the long run. On average, solar PV costs have fallen 80% and wind costs are down 30-40% since 2009, while battery storage costs are down 60% since 2014[63]. As a result multiple studies indicate solar and wind are now lower cost than combined cycle gas turbines (CCGTs) on a levelized basis in some geographies[64], though this depends on project specific grid connection costs. Similarly, lithium ion battery storage is starting to become competitive with gas peaking plants in some applications for managing short duration intermittency, though they are not yet a general replacement for gas in providing peaking capacity. As a result, the share of renewables and battery storage is increasing in multiple long-term forecasts, though gas is still likely to play a prominent role for power generation given it typically provides the lowest cost means of balancing renewable intermittency on a grid-wide basis.

Long term forecasts for gas demand growth are particularly prone to swings based on changing assumptions about the role of gas in the energy trilemma for two inter-connected reasons. First, because projected growth is highly concentrated in Asia and China specifically. Nearly half of all global projected natural gas demand growth is forecast to come from the Asia Pacific region through 2040, with China specifically driving one quarter of all global growth[65]. As a result, seemingly small changes in relative cost, access to gas, or government policies can produce significant changes in the modeled outcome for demand.

Second, gas demand growth across sectors can be highly uncertain because gas is often not the incumbent fuel source, so it must displace other energy sources. This is particularly true in the Asia Pacific region where gas provides 11% of all energy supply. While the share of gas has been modestly growing across sectors in Asia, coal still dominates in power generation (68% of primary energy demand) and industry applications (44% of primary energy demand), while in the buildings sector, traditional biomass is the incumbent fuel (32% of primary energy demand)[66]. Therefore, for gas to displace incumbent energy sources, it must overcome higher barriers across the components of the energy trilemma to prompt new or different policies and investment, not just achieve marginal changes in consumption patterns.

The role of gas challenging incumbent fuel sources is also an important driver of uncertainty in the case of more rapid energy transition scenarios. Among mainstream scenarios for future energy demand, when constraints are applied that move the energy mix toward a 2° Celsius pathway, the result for gas demand is highly variable. In the case of BP's Rapid Transition scenario, the share of gas in the global energy mix by 2040 would rise relative to their reference case[67]. Meanwhile, in Shell's Sky Scenario the share of gas falls from 23% today to only 20% of the global energy mix in 2040[68].

Regardless of how conditions evolve according to different future energy scenarios, there are a common set of factors which will maximize the potential for gas demand to grow and take a greater share of the global energy mix.

[62] BCG analysis.
[63] IRENA, "Renewable Power Generation Costs in 2017", 2018.
[64] For example, Lazard and Bloomberg estimates.
[65] According to IEA's 2018 New Policy Scenario, though regional drivers are similar across other scenarios.
[66] IEA.
[67] BP, "Energy Outlook", 2018.
[68] Shell, "Sky Scenario", 2018.

Industry now the leading sector for projected gas demand growth, concentrated in Asia

Net additional gas consumption (2017-2040, bcm per year)[1]

REGIONS	INDUSTRY[2]	POWER	BUILDINGS	OTHER[3]	TOTAL
China	187	147	73	20	427 (26%)
Asia Pacific[4]	137	92	32	93	354 (21%)
Middle East	68	92	86	58	304 (18%)
North America	35	43	5	124	206 (13%)
Africa	27	70	38	32	167 (10%)
Latin America	40	24	9	28	101 (6%)
Eurasia	17	5	7	32	62 (4%)
Europe[5]	-6	5	-32	10	-23 (-1%)
Global Bunkers	-	-	-	49	49 (3%)
Total	**505 (31%)**	**479 (29%)**	**218 (13%)**	**446 (27%)** TRANSPORTATION INCLUDED	**1,647**

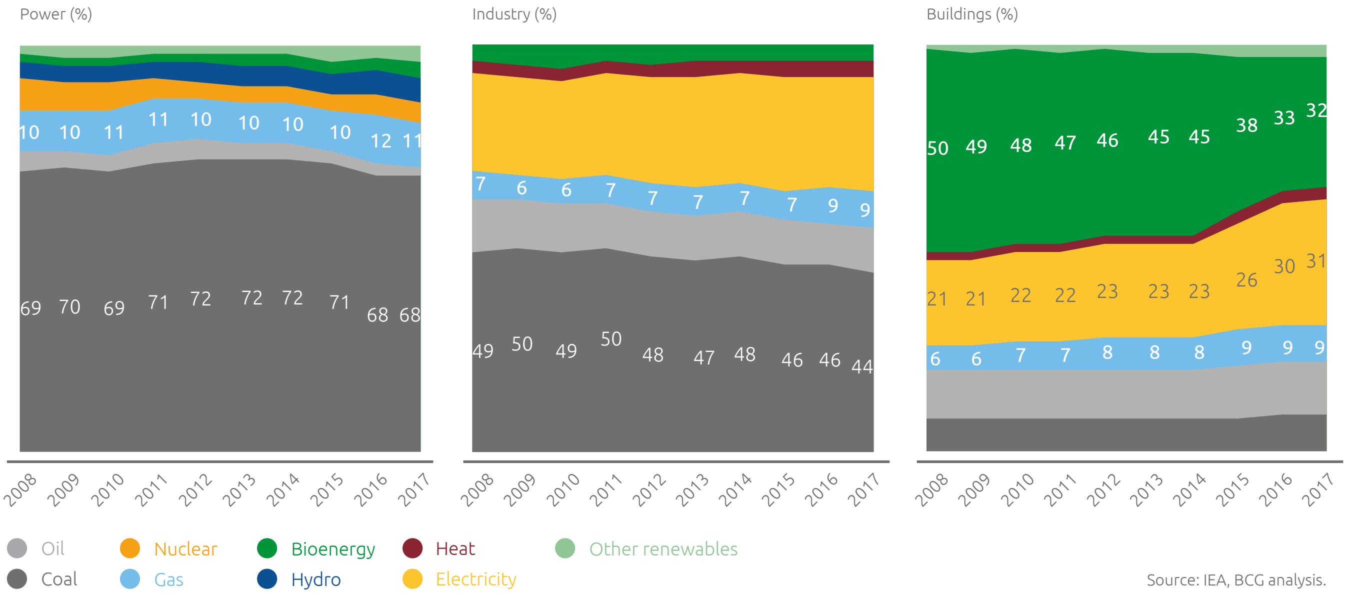
<0 | 0-25 | 25-50 | 50-75 | 75-100 | >100

1 Chart represents net change in annual gas consumption between 2017 and 2040.
2 Industry sector: includes fuel used within the manufacturing and construction industries
3 Other Energy Sector: covers the use of energy by transformation industries and the energy losses in converting primary energy into a form that can be used in the final consuming sectors.
4 Asia Pacific does not include China.
5 Europe includes Turkey. It includes losses by gas works, petroleum refineries, coal and gas transformation and liquefaction. It also includes energy used in coal mines, in oil and gas extraction and in electricity and heat.

Source: IEA, BCG analysis.

Share of gas in the Asia Pacific energy mix remains small

Asia Pacific regional energy mix by sector (2008-2017)



Source: IEA, BCG analysis.

Cost competitiveness

While natural gas prices at key global hubs have recently been declining, the biggest question about the future is how competitive gas will be with other fuel sources, particularly given new developments in technology and policy. To fulfill growth expectations, gas must continue to become more cost competitive given that it will continue to be challenged by declining costs and policy support for other fuel technologies. Multiple trends suggest that further cost declines in the supply of natural gas are possible though.

Ample gas reserves are available to enable gas supply at current or lower prices, but the central uncertainty revolves around what and when low cost resources will be developed. Nearly 100 TCM of proven gas reserves are located in gas field with an average estimated commercial breakeven cost of less than $3 per MMBtu. Of that, only about 2.7 TCM per year is being produced, providing roughly 35 years of low-cost reserves under $3 per MMBtu breakeven prices[69]. The development of these low-cost gas reserves is not evenly distributed around the world, though, particularly where producing countries lack access to consumption markets. For example, Turkmenistan stands out as producing a very low share of its low-cost gas reserves, with a rate of production to reserves of less than half of other countries[70].

While the development of low-cost gas reserves in general has been uneven, the story is more acute in the case of the development of unconventional gas resources. Producing unconventional resources remains challenging outside of North America given challenges with geology in addition to above-ground operating obstacles in the form of resource access, infrastructure, and water rights. Meanwhile, in some countries, particularly in Europe, governments have significantly curtailed or banned access for developing unconventional reserves due to environmental concerns. As a result, the US and Canada account for nearly 90% of global unconventional gas production.

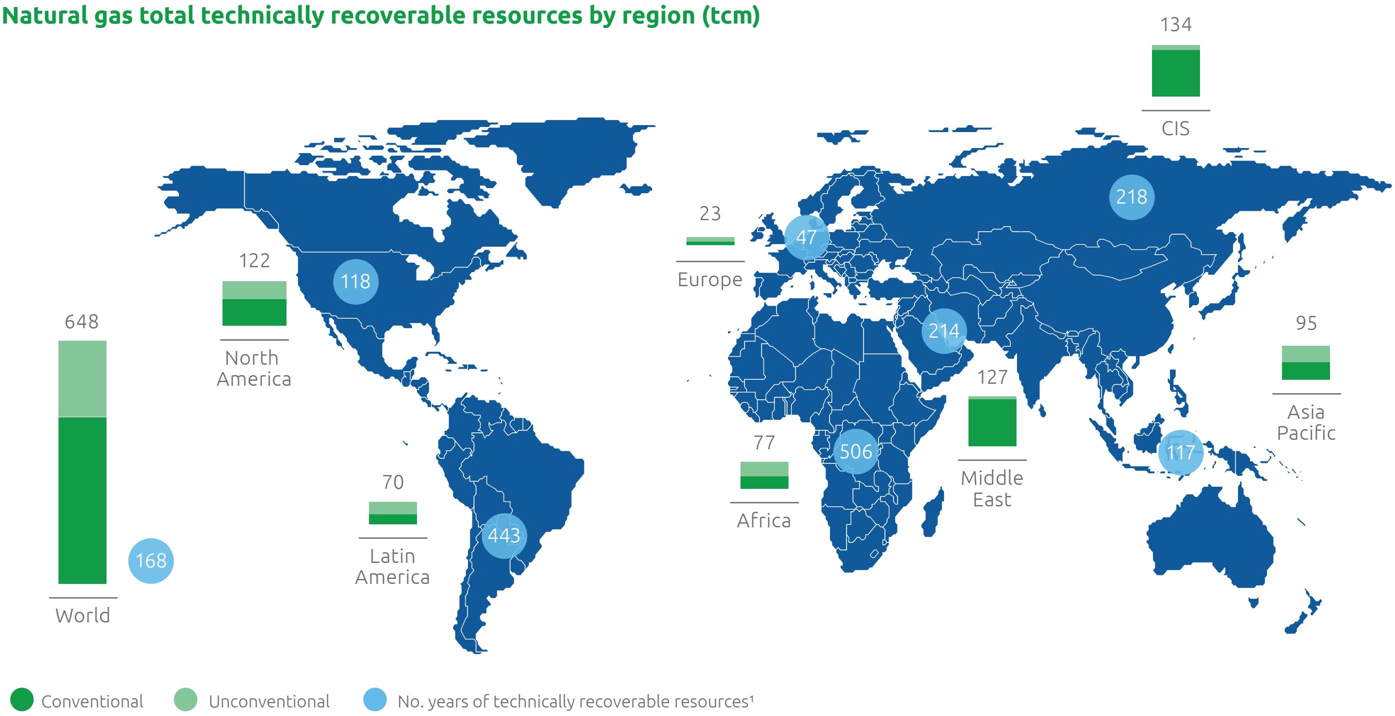
Outside of North America, unconventional gas production is starting to grow in China, Australia, and Argentina, but all at a relatively slow rate of less than 5 BCM per year[71]. However, looking ahead, Saudi Arabia and Algeria also now have ambitious plans to jumpstart shale gas production. Saudi Arabia in particular has announced its intent to increase unconventional production 2 BCM per year to over 100 BCM per year over the next decade[72].

LNG is one avenue through which low cost or stranded gas can be connected to potential markets. Supporting this potential, the delivered cost of LNG has declined due to technological developments in LNG regasification and shipping. LNG shipping costs have been reduced by more than 20% on average over the past two decades as ships have become larger, cheaper cost to build, and more efficient to operate[73]. In LNG regasification the development of Floating Storage and Regasification Units (FSRUs) has reduced the upfront capital

69 BCG analysis on Rystad data.
70 Ibid.
71 Rystad.
72 Press reports.
73 Since 2000 average LNG tanker size has increased by 13%, cost per capacity has declined by 15%, and fuel efficiency has doubled Flex LNG,
"The next generation of LNG carriers", 2017.

Gas resources are widely distributed, though greatest share are in the Middle East and CIS regions

Natural gas total technically recoverable resources by region (tcm)

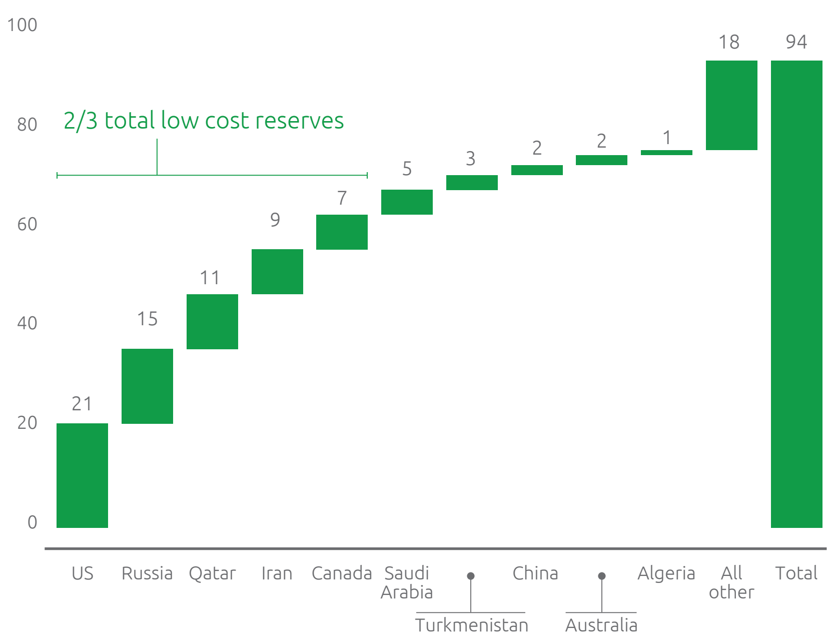


1. Calculated as total technical recoverable resources divided by 2018 region consumption.
Source: EIA, BCG analysis.

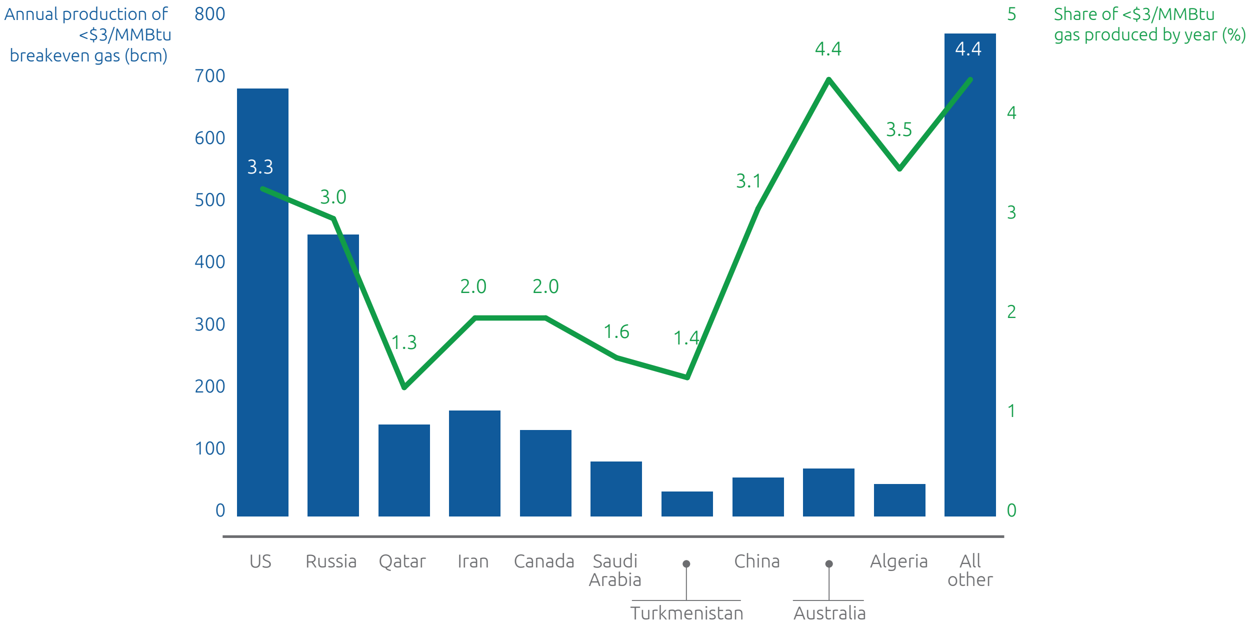
Low cost* gas reserves concentrated in a few countries, but are not evenly developed

* Low cost defined as gas fields with an estimated break even of less than $3 per MMBtu Note: Gas fields with less than 1 MMBoe reserves excluded from analysis.

Distribution of gas reserves <$3/MMBtu production cost



Commercialization of <$3/MMBtu reserves by region



requirements to access LNG from more than $1bn for a conventional terminal to around $200mn[74]. This makes LNG more accessible to new markets, particularly in countries where local utilities or other LNG buyers may be capital constrained.

Despite some progress in bringing down LNG costs, the cost of liquefying and delivering LNG remains high as a share of total cost, contributing more than 60% of the end-delivered cost of LNG on average[75]. Capital costs of liquefaction do not appear to be declining, with some new projects more than double the cost of prior generation projects on the unit basis[76]. Developing solutions to reduce capital costs will be a key level for ensuring LNG is cost competitive in the future.

For the consumption of gas, the biggest uncertainty in the future is how competitive gas will be relative to other energy sources. In power generation, a key area of uncertainty for is how gas will compete with renewables plus battery storage. Wind and solar costs have shown consistent learning curve improvements, but it is unknown where the limits of these effects might be, particularly in the development of future generations of technology. The future role of battery storage for managing intermittency is particularly uncertain. Lithium ion batteries are cost-effective when the time requirement is less than 4 hours, but the levelized costs increase exponentially for longer durations[77]. Meanwhile, other storage technologies are being developed, but their cost competitiveness with gas is unclear. Therefore, the competition between natural gas and batteries for providing peaking capacity provides significant divergence in future forecasts.

In the industry and buildings sectors, the competitiveness of gas relative to electricity is the key uncertainty driving different forecasts for gas demand. New electric heat pump technologies have reduced the cost of electrifying heat applications and improved the efficiency of their operations in buildings. However, given that electricity is more expensive than gas on an energy delivered basis in nearly all markets and that new gas boilers are highly efficient (i.e. above 95%), gas still typically remains lower cost on a levelized cost of service basis[78]. This is particularly true in colder climates and industrial applications where heating requirements are greater and fuel costs make up a significant portion of operating costs. This cost advantage is likely to sustain gas demand in buildings and industry uses, especially in markets with existing gas distribution infrastructure.

74 BCG analysis.
75 Ibid.
76 Oxford Institute for Energy Studies, "LNG Plant Cost Escalation", 2014; Oxford Institute for Energy Studies, "LNG Plant Cost Reduction 2014-2018", 2018.
77 NREL.
78 BCG analysis.

Security of supply

Natural gas infrastructure investment falling short of requirements to achieve growth

To enable natural gas market growth, substantial investment is required in infrastructure across natural gas supply chains. Given that gas is not always the incumbent fuel source and is infrastructure-intensive to transport, investment requirements in gas are even greater than other sources of energy. Historic evidence from established gas markets demonstrates that once infrastructure is developed gas demand tends to be resilient, so the challenge is to establish infrastructure in the first instance[79].

In recent years, it is unclear whether sufficient infrastructure investments are being made to achieve the projected natural gas market growth. Investment in upstream production, LNG capacity, and downstream infrastructure appears to be falling behind future requirements in some dimensions:

- **Upstream**: in order to ensure sufficient natural gas supply going forward, the IEA estimates that new investments in conventional natural gas production equivalent to more than 15 billion barrels of oil equivalent must be made per year. Annually that will require investment of at least $240 billion per year. Since 2013 actual investment has not reached that level in any single year[80].

- **LNG liquefaction capacity**: additional LNG export capacity will require investment to sustain rapid LNG market growth. Without additional investment, demand would outstrip supply by 2025.

  To achieve enough liquefaction capacity growth, more than 100 MTPA of liquefaction capacity growth is necessary by the mid-2020s, requiring up to $200 billion additional investment according to one estimate[81]; and

- **Downstream**: investment in mid- and downstream gas markets is required to extend access to gas across consuming sectors. In total, achieving natural gas demand growth projections will require $130-150 billion of annual investment to maintain existing gas networks while also developing new LNG regasification capacity, transmission, and distribution infrastructure within gas consuming markets[82]. In the past year, total downstream gas investment was estimated to be $125 billion. While close to the required range, much of that investment was concentrated in the US build-out of transmission infrastructure. Critically, investment in potential high-growth Asian markets does not appear to be keeping pace with what is required.

Asia represents the greatest opportunity for gas market growth but requires the greatest investment in midstream and downstream assets. For example, only 4.8 million of India's 250 million households have access to city gas[83]. In new or small-scale gas markets, it is necessary to develop entirely new gas value chains, including LNG regasification, transmission networks, and distribution networks. This is particularly challenging in the context of emerging markets where utilities and industrial customers face a more diverse range of capital requirements and where the cost of debt tends to be higher.

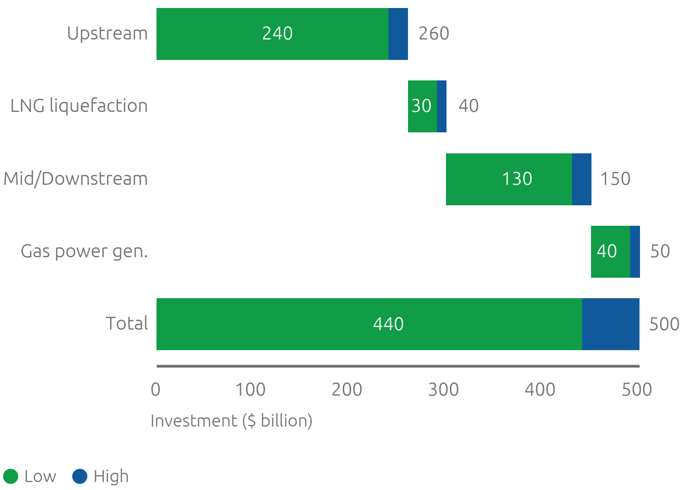
Future international pipeline development

[79] 2018 Global Gas Report assessed long term trends in demand.
[80] IEA, "World Energy Investment", 2019.
[81] WoodMackenzie.
[82] 2018 Global Gas Report, INGAA, and BCG analysis.
[83] Press reports; India Ministry of Home Affairs.

will also be critical for connecting gas resources with growth markets, particularly connecting low cost gas reserves in central Asia to South and East Asia. However, geopolitics is limiting access to gas in the region. For example, progress on the Turkmenistan-Afghanistan-Pakistan-India (TAPI) pipeline continues to be stalled as the respective governments cannot reach agreement. Considering the development of further capacity from Russia to China, the failures of state-owned parties to reach agreement on commercial terms is constraining access to gas[84].

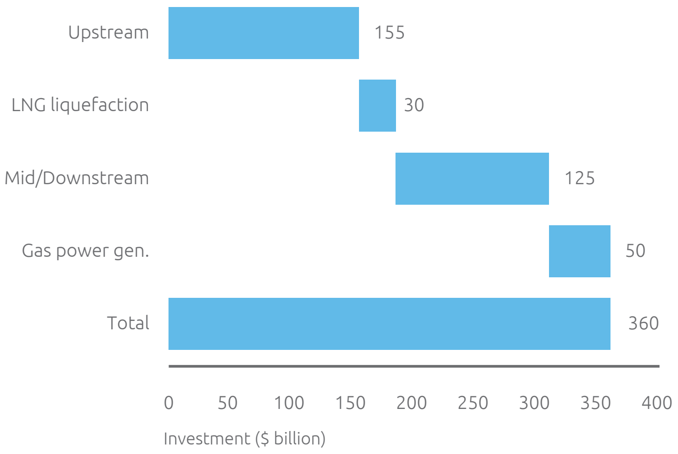
Small scale LNG (SSLNG) technologies[85] offer the potential to fill this gap, enabling greater access to gas in emerging markets that lack traditional gas infrastructure. SSLNG technology can take many forms, but the concept is relatively simple: it is defined as any distribution of LNG in parcels smaller than an LNG tanker. The clearest demonstration of SSLNG technology to date has been in China. Rapid gas demand growth and attractive price arbitrage opportunities have spurred the rapid deployment of LNG distribution by truck. In the midst of the major coal-to-gas switching initiative, LNG trucks in China roughly tripled from 100,000 in 2017 to 300,000 in late 2018[86]. LNG trucks require much less capital than new pipelines, so the growing fleet provided an attractive option to alleviate pipeline constraints in China. SSLNG also enables gas to be used flexibly for different applications such as transport, off-grid applications, and small-scale power generation.

Required investment to achieve natural gas market potential projections



Source: IEA, WoodMac; Oxford Institute for Energy Studies; BCG analysis.

2018 estimated natural gas infrastructure investment



Source: IEA, WoodMac; Oxford Institute for Energy Studies; BCG analysis.

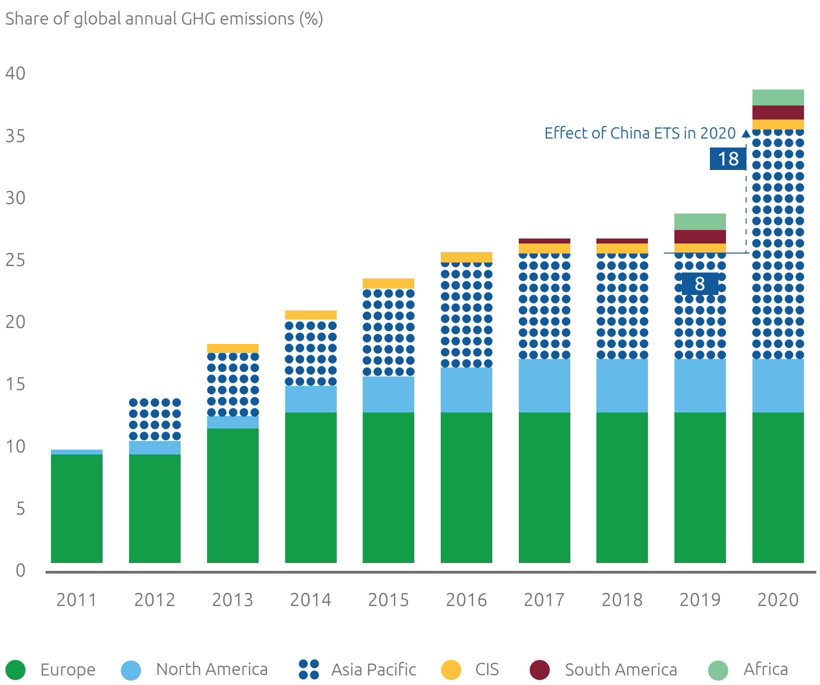
[84] Press reports.
[85] Generally defined as an LNG application with less than 1 MTPA of capacity; Cedigaz, "Catching Cold or Catching Fire? Current state and growth prospects for small-scale LNG", 2018.
[86] Cedigaz, "Catching Cold or Catching Fire? Current state and growth prospects for small-scale LNG", 2018; S&P Platts.

Sustainability

Natural gas provides many sustainability benefits in the form of low localized pollution and lower GHG intensity than other fossil fuels. However, government policy is required to internalize these environmental costs and reflect the value of the environmental benefits natural gas provides. Policy is also critical for facilitating the development of low carbon gas technologies including CCUS, biomethane, and hydrogen. In many ways, the future of gas depends on future policy developments related to sustainability.

Carbon pricing is one of the most effective policy tools for incorporating the environmental externality cost of CO_2 emissions. It is also effective at closing the gap between the cost of natural gas and coal, but only at sufficient levels. For example, in the UK, the carbon price floor of £18 ($23) per tonne was sufficient to drive most coal power generation out of the market. Beyond Europe and North America, governments are increasingly adopting new carbon pricing measures. China's national emissions trading scheme, covering for nearly 40% of global emissions, will include by some form of carbon price in 2020[87]. However, in many cases the price of carbon is often not yet sufficient to prompt significant fuel switching.

Carbon pricing initiatives as a share of global emissions covered

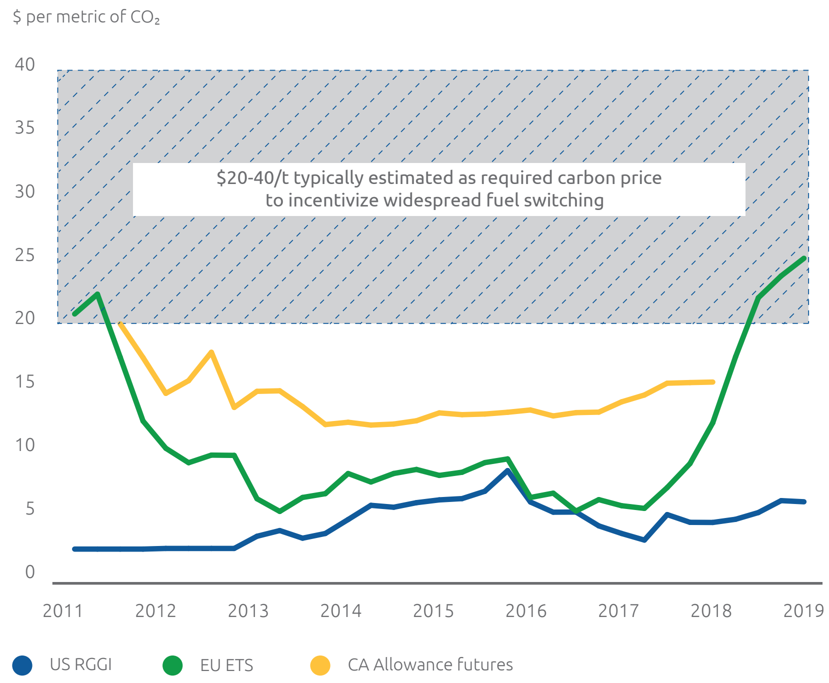


Source: World Bank, Eurostat, Climate Policy Initiative, RGGI, BCG analysis.

[87] World Bank, "State and Trends of Carbon Pricing", 2018.

Adoption of carbon pricing is growing, though prices often remain too low to prompt significant fuel switching

Average carbon prices on major indices



Clean air policies in Asia is another critical driver for determining the future role of gas. While governments such as those in India, Indonesia, and Vietnam have set goals to improve air quality, few aside from China have implemented material policies to prompt fuel switching as a means of achieving those goals. To grow the use of gas as a means of improving air quality, governments have a range of policy measures at their disposal, including:

- Specific air pollution measures not limited only to CO_2 emissions, including technology of fuel use mandates, pollution limits, and market-based measures that put a cost on pollutants (including taxes or tradeable permit schemes);
- Policy measures governing the competitiveness of gas versus other fuels, which can include regulated prices, taxes, or forms of subsidy; and
- Direct development or enablement of gas infrastructure investment to provide access to gas as a means of facilitating fuel switching from other sources or enabling access to clean energy. This includes measures such as providing gas connections and stoves for home cooking.

The future development and deployment of low carbon gas technologies also depends on government action. On the supply side, support for R&D, project financing, and incentives to accelerate project development can be effective enablers in the early stage of technology development and deployment. To generate demand and markets for low or zero carbon gas, policies such as fuel standards and market-based incentives have demonstrated their effectiveness in the development of renewable power generation.

Developing and deploying low carbon gas technologies will be critical to move the world to a less than 2° Celsius climate pathway. In recent IPCC analysis on pathways to limit global warming to 1.5° Celsius, natural gas combined with low carbon technologies (e.g. CCUS) plays a prominent role in three of the four pathways presented. Only in the most dramatic pathway does gas not feature prominently, which would entail global emissions peaking in 2025 and declining to net zero by 2070. Furthermore, across 85 different 1.5° Celsius consistent models and scenarios reviewed in the IPCC study, the average share of gas in total primary energy supply is projected to remain as 19% by 2040 (versus 23% today)[88]. Achieving a stable transition to a low carbon world therefore requires gas along with support for low carbon gas technologies.

Multiple examples of policies supporting gas exist in specific national or sub-national governments, but few governments have combined all the tools that can be applied to accelerate a transition to gas in the near term while also developing low carbon gas technologies for the medium to long term. Doing so will be increasingly critical to combatting the dual global environmental challenges of climate change and air pollution.

[88] IPCC, "Global Warming of 1.5º C", 2018.

3 / The future of gas in Europe

Highlights

- Gas is reaching a critical juncture in Europe given coal phase outs in power generation, GHG emissions reduction measures in other sectors, and shifting supply dynamics.
- In the power sector, a rapid transition from coal to gas is likely due to phase outs of coal power generation, followed by a subsequent shift to renewables.
- In industry and buildings sectors, greater competition is likely to occur between the existing uses of gas, electrification, and new low carbon gas technologies.
- The transport sector provides the greatest long-term growth opportunity, but depends on policy support to promote consumption and infrastructure development.
- As a result of these trends, the role of gas in Europe is becoming more diverse across markets.
- Additional infrastructure will be required to support the role of gas in Europe going forward, particularly to improve network interconnectivity, support renewables integration, and to scale the development of low carbon gas technologies.

Gas has played a central role in the European energy mix for decades, supplying around a quarter of all energy demand in Europe. Gas access is also extensive across the continent, with widespread availability for residential, commercial, and industrial users. The resilient role of gas in the European energy mix is due to its positioning across the dimensions of the energy trilemma -- it is relatively cost competitive to alternative fuels, ample infrastructure ensures secure supply, and gas has contributed to reduction in localized pollution and GHG emissions.

While the role of gas in Europe[89] has been stable for some time, the European gas market is now reaching a critical juncture. In the power sector, the adoption of policies to phase out coal from power generation is poised to boost gas-fired generation in the near term, but a second transition of gas to renewables and battery storage may follow quickly. In the industry and buildings sectors, the speed and means of reducing GHG emissions intensity is highly uncertain, with a range of electrification and low carbon gas technologies poised to compete. Meanwhile, the structure of gas supply in Europe is shifting as domestic production is declining and Russian supply continues to take a greater share.

At a local level in Europe, gas is playing a more diverse role across different sectors. Governments are adopting policies promoting more widespread use of gas while also enabling the adoption of low carbon gas technologies. For example: In the UK, gas has now largely displaced coal in the power generation mix, due to the implementation of a carbon price floor. In Greece, investment is being made to enable the development of an LNG bunkering hub. While in France, the biomethane sector is poised for rapid growth.

[89] For this Europe includes the EU28 countries plus Albania, Bosnia & Herzegovina, Macedonia, Norway, Serbia, and Switzerland

The role of gas in Europe

Share of gas in the European energy mix over the past two decades

23-26%

Gas is the second largest source of energy supply in Europe after oil and provides stable supply, averaging between 23% and 26% of European energy mix over the past two decades[90]. While consumption fluctuates year to year, the greatest drivers of these changes are typically economic growth and weather rather than structural changes. This central, stable role of gas is driven by its positioning along the dimensions of the energy trilemma:

- **Cost competitiveness**: Natural gas prices in Europe typically range from $5-8 per MMBtu at key trading hubs, which incorporates both pipeline supply sources and LNG imports[91]. This is nearly double the cost of coal based on heat output, but gas is competitive on the basis of delivered energy when accounting for energy intensity and the cost of carbon. In power generation, on a levelized cost of energy basis, gas has been cheaper than coal across EU28 markets since mid-2018 when the Emissions Trading Scheme (ETS) price began to steadily increase[92]. In the industry and buildings sectors, gas is substantially lower cost than electricity on the basis of delivered energy. In 2018, EU28 gas prices for households averaged €0.06 per KWh while power prices for households averaged €0.21 per KWh. Similarly, gas prices for commercial customers averaged €0.04 per KWh and power prices for commercial customers averaged €0.14 per KWh[93]. On average, gas is priced at about one third to 50% less than electricity on a levelized cost of service basis in Europe[94].

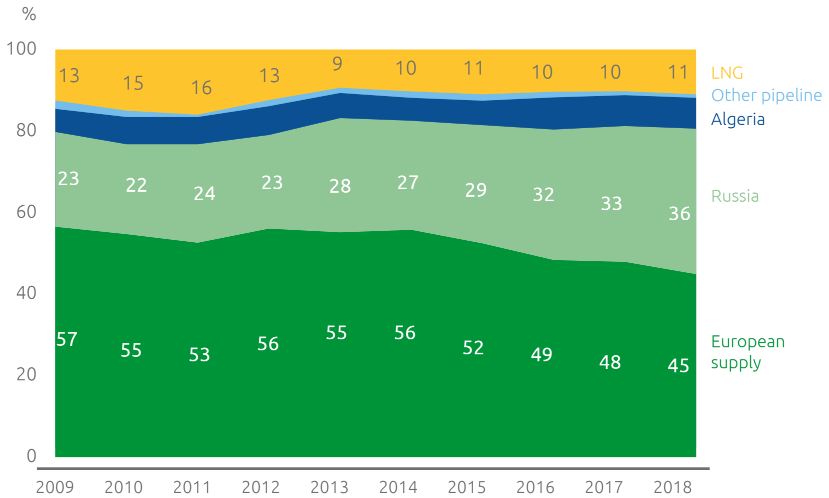
- **Security of supply**: Europe is highly dependent on imports with around half of all gas supply coming from outside the region. Given declining local gas production within Europe, the share of Russian supply has grown from 23% of European supply in 2009 to 36% in 2018[95]. Nevertheless, supply of gas in Europe is relatively flexible. Multiple pipeline supply sources are available from outside the region in addition to Russia, including Algeria, Azerbaijan, and Libya. LNG regasification capacity is also providing flexibility to European gas supply. Notably, six new European countries started importing LNG since 2010. Regasification capacity utilization has remained low, though, averaging less than 30% over the past five years[96]. The excess regasification capacity combined with availability of natural gas storage capacity provides Europe with a means to rapidly increase and diversify gas supply should it be necessary.

- **Sustainability**: Gas has contributed to lower GHG emissions in Europe while also reducing particulates and other localized emissions. However, air pollution remains a key challenge in Europe, especially within cities. The latest European Environment Agency estimates show that concentrations of PM2.5 were responsible for about 422,000 premature deaths in 41 European countries in 2015. NO_2 emissions are also estimated to have caused 79,000 premature deaths in the same countries in 2015[97]. Fuel switching to gas from coal in the power sector and diesel in the transport sector is widely acknowledged as a potential solution for this[98].

90 IEA.
91 World Bank, Bloomberg.
92 Bloomberg.
93 Eurostat.
94 Cedigaz.
95 Cedigaz.
96 Cedigaz.
97 European Environment Agency, "Air quality in Europe", 2018.
98 Scientific American, "Switch to Natural Gas Slashes Power Plant Pollution", 2014; US Department of Energy Alternative Fuels Data Center.

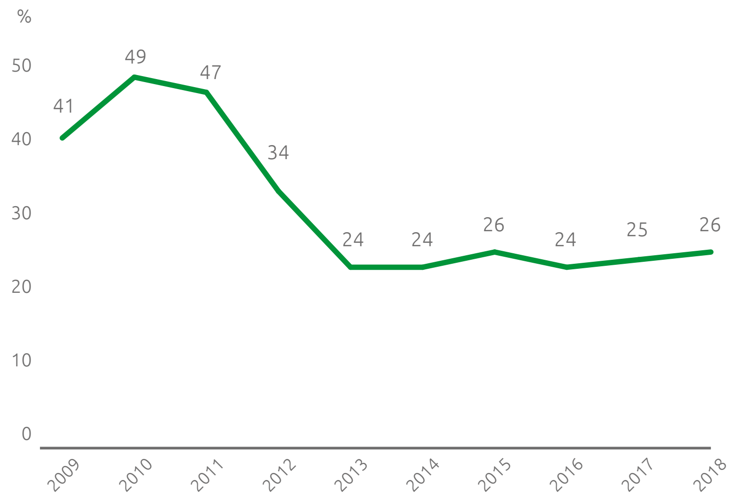
Russian pipeline gas is the fastest growing source of European gas supply, but capacity exists for greater LNG imports

European gas supply mix (2009-2018)



Source: Cedigaz, BCG analysis.

European LNG regasification utilization



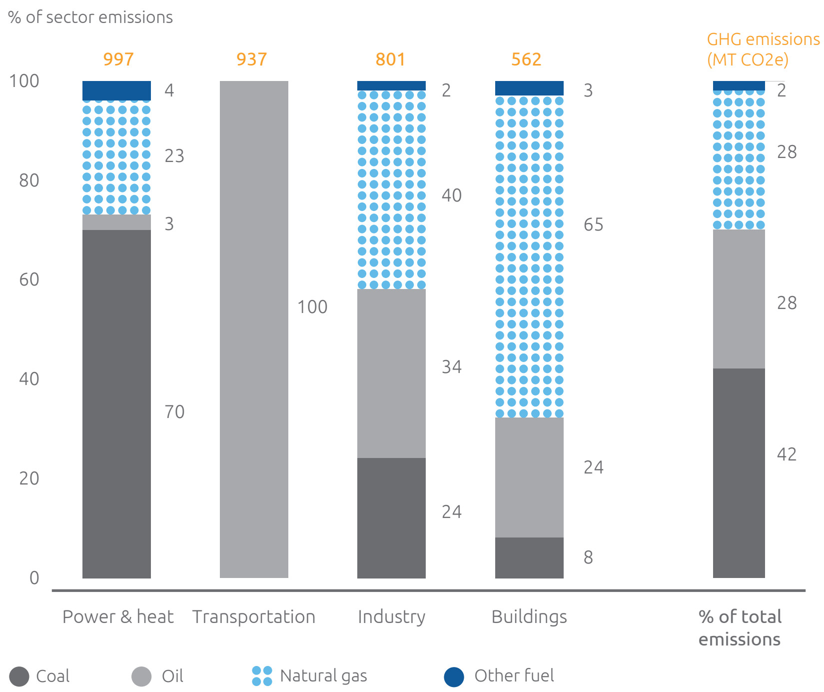
The outlook for gas in Europe

Looking ahead, the role of gas is reaching a critical juncture in Europe. In the power sector, the potential phase out of coal power generation across multiple markets represents significant growth potential for gas, but just how quickly that transition occurs and the share of demand that flows to gas relative to renewables and battery storage is highly uncertain. Meanwhile, in the buildings and industry sectors, a move toward electrification could increasingly displace gas. The use of gas for transport (both road and marine bunkering) represents true growth potential, but it is a small market to date and growth is uncertain.

While overall gas demand in Europe is unlikely to grow substantially given low growth of primary energy demand and improvements in energy efficiency, the composition of gas demand and the role it will play in Europe's energy mix is likely to significantly evolve. To understand this evolution, it is critical to both assess the role of gas on a holistic basis in Europe along with specific national and local drivers. The following analysis does that by drawing on both a regional perspective and localized case studies.

Oil and coal make up the majority of EU energy GHG emissions

EU28+Iceland energy GHG emissions by sector (2017)



Source: European Environment Agency, BCG analysis.

Power sector

The potential impacts of coal phase outs present the greatest opportunity for gas market growth in the near term. Countries with 96 GW of coal power generation capacity have adopted or are considering some form of a coal phase out, including Germany, Italy, France, and Spain[99]. These policies could result in the growth of gas demand in the power sector by as much as 22 BCM in countries that have adopted coal phase outs and 60 BCM in countries that are considering coal phase outs[100].

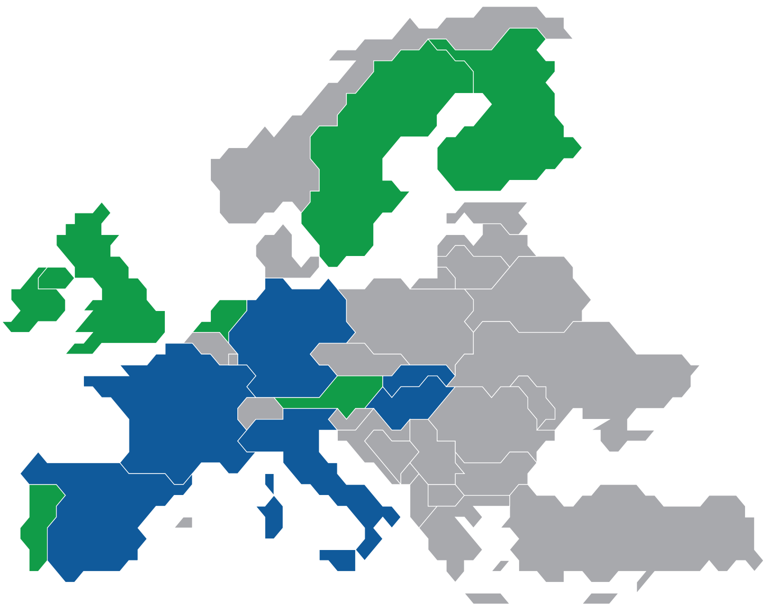
Coal-to-gas fuel switching represents the near-term energy transition impacting gas in Europe, but in the longer term, the role that gas plays will be increasingly shaped by how it complements renewables generation. So, while gas is likely to gain share in the near term, that share may quickly shift to renewable generation if the role of gas moves from baseload to peaking[101]. This is why multiple forecasts show flat demand for gas in power generation over the longer term. As an example, the IEA New Policies Scenario estimates European power sector gas demand will grow by only 5 BCM between 2017 and 2040[102].

Beyond implications for the level of gas demand, the role that gas plays in the European power sector will likely evolve. Given that gas is a dispatchable source of power, it is likely to play a greater role balancing the intermittency of renewable power generation. While this may result in lower aggregate demand for gas, the value that the dispatchability of gas provides to the grid is likely to grow as renewable capacity continues to expand.

[99] Beyond Coal EU; BCG analysis.
[100] Assumes current operational coal power capacity operates at 60% utilization and gas power is used to replace all coal fired generation.
[101] IEA, "Gas Report", 2019.
[102] IEA.

Europe coal phase outs could drive greater gas demand, but timing is uncertain

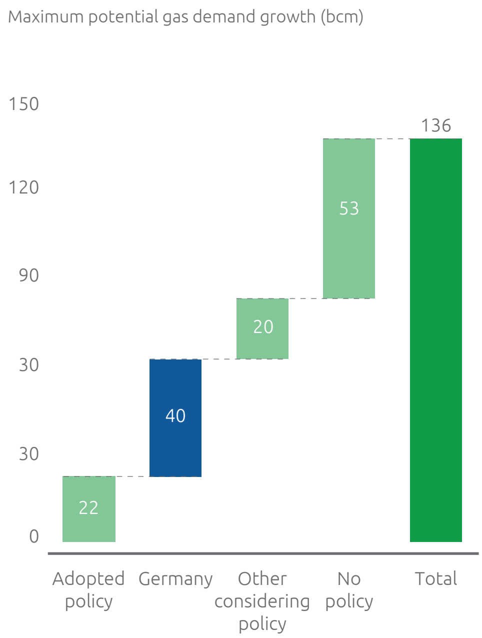
European countries by coal policy



Adopted coal phase out policy
Considering coal phase out policy
No coal phase out policy or negligible coal consumption

1. Assumes current operational coal power capacity operates at 60% utilization.
Source: Beyond Coal EU; BCG analysis.

Maximum potential coal to gas power switching[1]



1. Assumes current operational coal power capacity operates at 60% utilization.
Source: Beyond Coal EU; BCG analysis.

The role of natural gas in managing seasonality for the United Kingdom

The UK is a leading natural gas market in Europe, second in size only to Germany. In 2017, gas consumption totaled 72 BCM[103], representing almost 30% of the country's total energy demand[104]. Natural gas plays a key role helping the UK to manage variability in seasonal energy demand. Seasonal weather changes drive large swings in residential and commercial demand for space heating, resulting in swings in natural gas demand in the range of 8-9 BCM from peak to trough. This is only about 10-12% of total natural gas demand in the UK but represents two-thirds of peak natural gas demand in buildings[105].

At the same time, gas also serves as the primary source of flexible electricity generation required to manage intermittency from renewable sources. As the UK continues to reduce coal fired power generation, the seasonal variability in natural gas demand for power generation is expected to result in an additional 2 BCM to seasonal variability[106].

Natural gas as has traditionally played a central role managing seasonal energy variability for two main reasons. First, natural gas production, transportation and storage infrastructure is already in place, and natural gas is an economically efficient and reliable way to meet large swings in energy demand both in the short-term (e.g. hours across the day) and medium term (e.g. seasons across the year). Second, natural gas provides a much lower cost means of managing seasonality than electrification. For example, the UK's Interconnector natural gas pipeline provides roughly 30 times the energy capacity of a 1GWh electricity interconnector despite similar capital costs[107].

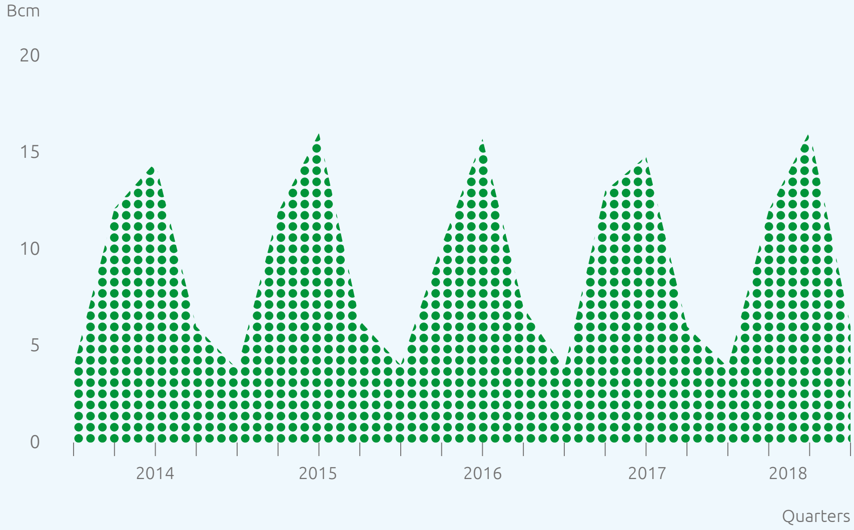
This is important context given the UK government's recent commitment to achieve net zero GHG emissions by 2050. Broadly there will the two options for eliminating GHG emissions while managing the seasonal variability in energy demand for buildings. The first option is to focus on electrification of end consumption by developing incremental renewable power generation capacity and converting gas appliances to electric, while also implementing energy efficiency and demand response measures to reduce total power consumption. This would require significant capital investment. Just developing the renewable power generation capacity to supply enough electricity to manage the seasonal variability in buildings (i.e. not the baseload) would require more than 100 GW of wind capacity, which is nearly 2.5 times the current wind and solar capacity in the UK today[108]. The capital costs to achieve that scale of wind and solar capacity development would likely be $115-150 billion, which does not include additional investment in storage, the power grid, or conversion of appliances to electric.

A second option would be to scale up and deploy the use of low carbon gas technologies such as biomethane or renewable hydrogen. Using biomethane as an example, this would entail investing in biogas digesters, biomethane upgrading plants, and grid injection and connection infrastructure. This option would require rapid growth of the UK biomethane industry, growing biomethane production capacity by approximately 35 times the current capacity operating in the UK today[109]. Achieving enough scale to manage the seasonal gas demand variability requirements in the UK would require total capital investment of between $25-30 billion, which is significant but only one-quarter to one-third that of electrification[110]. While this option is less capital intensive, there are also more unknowns; full levelized costs for low carbon gas are uncertain and such a large scale of capacity has yet to be developed in any market.

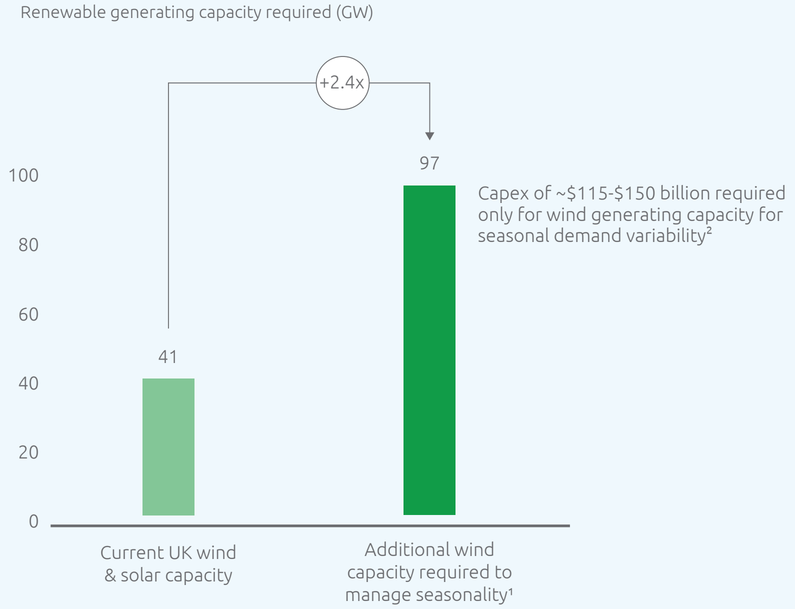
[103] Cedigaz.
[104] UK Department for Business, Energy & Industrial Strategy, "UK Energy Brief in 2018", 2018.
[105] UK OFGEM.
[106] Interconnector.
[107] Ibid; the Interconnector pipeline has a capacity of 800 GWh per day.
[108] UK Department for Business, Energy & Industrial Strategy, "UK Energy Brief in 2018", 2018; Lazard; BCG anlaysis.
[109] Cedigaz.
[110] Analysis assumes biogas and biomethane plants operate at 85% utilization and a methane yield of 65%; Navigant, "Gas for Climate", 2019.

Gas plays a key role in balancing seasonal buildings heating demand in the UK

UK residential & commercial gas demand seasonal variability (2014-2018)



Significant renewable capacity growth would be required to manage seasonal demand variability[1]



1. Assumes demand response and efficient electric heat pumps would reduce seasonal demand by 30% and include a reserve margin of 10%.
2. Investment amounts to 4-6% of UK GDP – estimate excludes buildings and transmission investment.

Source: National Grid, UK BEIS, Ofgem, DUKES, Lazard, BCG analysis.

Industry and buildings sectors

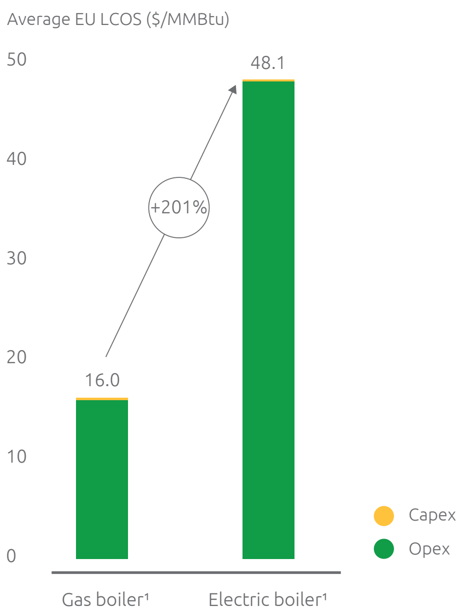
The future role of gas in the industry and buildings sectors will in large part be defined by how aggressively policy measures are adopted to promote electrification of end energy consumption. Electrification is often seen as a key pathway for reducing GHG emissions when combining the development of renewable generation capacity with the conversion of gas boilers to electric while also implementing energy efficiency and demand response measures.

As the incumbent fuel source in these sectors, and given the relatively low cost per energy delivered, gas will likely be very costly to displace with broad electrification measures. Doing so imposes significant capital requirements across the value chain, including in renewable power generation, new power transmission and distribution infrastructure, and for converting appliances from gas to electric. Electrifying energy consumption in industry and buildings contexts also imposes higher costs on end consumers given that power prices in Europe are 3 to 4 times more expensive than gas on the basis of energy delivered[111].

Given the high costs of electrifying heat and the existing gas infrastructure in Europe, low carbon gas technologies such as biomethane, low carbon hydrogen, and CCUS are the lower cost options for deep industrial and buildings emissions reductions. Even with only small-scale use today, these technologies are typically lower cost on a levelized cost of service basis than converting existing industry and buildings gas systems to electric[112].

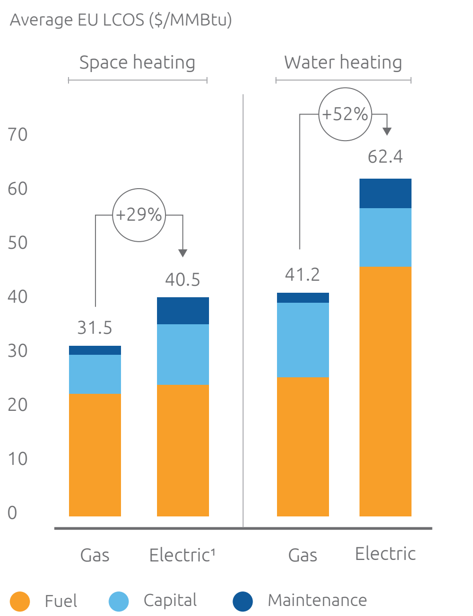
Gas provides a lower cost source of heat than electricity in Europe, on average

Industrial boilers – Levelized Cost of Service



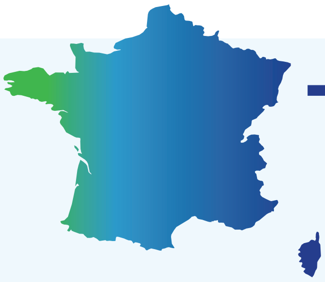
Note: Assumed prices are average 2018 prices across EU28 countries.
1. Analysis assumes industrial gas and electric boilers are 100 HP boilers and run 6,000 hours a year.
Source: NREL, Eurostat, BCG analysis.

Buildings water and space heating – Levelized Cost of Service



Note: Assumed prices are average 2018 prices across EU28 countries.
1. Air source heat pumps assumed – mix of cold and warm climates.
Source: NREL, Eurostat, BCG analysis.

[111] Eurostat.
[112] BCG analysis.



Biomethane market development in France

The biomethane sector in France is rapidly developing, significantly scaling up supply, and implementing measures to reduce costs. The French government has launched a series of enabling policies framed by an over-arching target set in the Energy Transition for Green Growth Law of renewable gas reaching 10% of total gas consumption by 2030. At the same time, in the draft multiannual energy program (PPE), the French government has committed €7-9 billion of subsidies through 2030, which is contingent on biomethane production costs declining 30% (to €67/MWh by 2023). These figures are currently under discussion with industry participants and are intended to be finalized in the final version of the PPE by the end of 2019.

To stimulate biomethane production, the French government has set a feed in tariff ranging from €65-135/MWh depending on plant size and feedstock source. It also provides an exemption on the domestic consumption tax for natural gas, amounting to €6/MWh[113]. This provides a premium for biomethane over conventional natural gas prices, which on a pre-tax basis have ranged from €50-60/MWh in the past five years[114]. Beyond production costs, some studies have indicated significant value from positive externalities associated with biomethane production (i.e. 40-70€/MWh), including the value of GHG emissions reductions, job creation, impacts on agricultural practices, and local air and water quality[115].

Additional government support is available to facilitate grid integration of biomethane plants. Biomethane producers are required to pay only up to 60% of required capex while the rest is included in the gas tariffs. Furthermore, a law was adopted in 2018 to facilitate the injection of biomethane on transmission or distribution gas networks.

On the demand side, the French government has established a guarantees of origin (GO) system which traces biomethane injections. While biomethane is distributed throughout a gas grid, the GO system allows consumers to purchase or otherwise exchange renewable credits. In turn this can enable producers to receive a price premium while consumers can use the credits to document compliance with renewable energy or emissions targets.

To date, these policies combined with rapid mobilization from industry have resulted in rapid biomethane production growth. The number of plants producing biomethane in France has growth from 3 in 2013 to 76 in 2018, now producing around 70 MCM. Looking ahead, a further 661 projects have registered in the plant connection queue, which could provide up to 1,400 MCM production per year[116].

[113] GRDF, GRTgaz, SER, SPEGNN, Terega, "Overview of Renewable Gas in 2018", 2018.
[114] IEA Energy Prices Report – price specific to residential sector.
[115] Enea, "Renforcer la compétitivité de la filière biométhane française: De nombreux leviers activables à court et moyen termes", 2018.
[116] Ibid.

French energy policy enabling biomethane market growth

Three key component of French biomethane policy

Targets

Goal of 10% renewable gas as a share of total gas consumption by 2030.

Continued subsidy support dependent on production costs declining.

Financial support

Feed in tariff system guarantees purchase price to biomethane producers for 15 years.

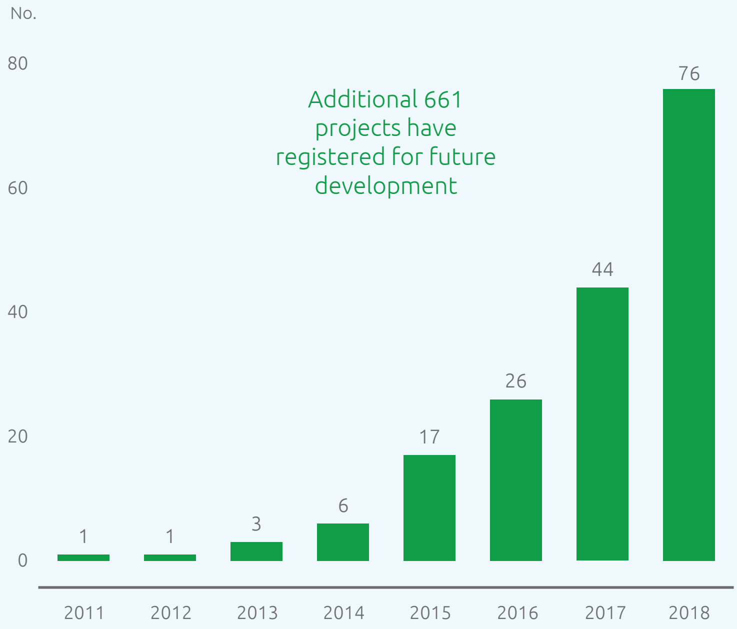
Commitment of €7-9 billion of subsidies through 2030.

Grid integration cost recovery measures.

Demand support

Guarantees of Origin system established to enable tracking of and exchange of renewable credits.

Number of injecting biomethane plants in France



Source: Terega, BCG analysis

Transport

Gas plays a very small role in the European transport sector today. However, it offers multiple benefits such as lower emissions for internal combustion vehicles and, compared to electric alternatives, it is cheaper and more flexible[117]. Natural gas vehicles (NGVs) also provide a pathway for a significant reduction in the GHG emissions intensity of the transport sector via the introduction of biomethane.

The share of natural gas consumption in ground transport continues to be low in Europe and is likely to remain low without policies favorable to NGV adoption. As a share of the vehicle fleet, NGVs are approximately 0.5% of all vehicles in Europe. NGV penetration only exceeds 1% in Italy (2.6%)[118]. While adoption of NGVs is growing – up by 65k in the EU last year – growth is still slower than for electric or even LPG vehicles[119].

Given the low penetration of NGVs in Europe, there is a continued untapped opportunity for gas to take a greater share. Policy measures will be necessary if NGVs are to take a more prominent role in transport, particularly for incentivizing vehicle adoption and enabling refueling infrastructure development. The Blue Corridors program is an example of how a successful public-private partnership can do that. Starting with €8m of European Commission funding, the program enabled a tripling of LNG refueling stations in Europe and an increase in the LNG trucking fleet by more than 45% over a five-year period[120]. Policies designed to reduce heavy duty vehicle emissions could also spur LNG truck adoption as technical limitations have slowed the development of other low emission heavy duty vehicles such as electric trucks[121].

LNG use for bunkering represents another potential growth market for gas. Given the current policy focus on MARPOL sulphur regulations, an increasing focus on reducing NOx emissions from shipping, and the need to reduce GHG emissions of the marine sector, LNG is emerging as a potential solution. The IEA has projected that the global LNG bunkering market will grow to be among a top 20 gas market on a standalone basis by 2040, contributing 49 BCM of demand[122]. Europe will be central to the development of this market given the combination of being a major global shipping market, imposing stronger environmental regulations, and the availably of LNG supply. In particular, large global ports such as Rotterdam could become key global hubs for LNG bunkering[123].

[117] IHS Markit, "Reinventing the Truck", 2018.
[118] NGV Journal; ACEA; BCG analysis.
[119] ACEA, "EU Automotive Industry Report: Full-year 2018", 2019.
[120] BCG analysis on press reports and EU data.
[121] Oxford Institute for Energy Studies, "A review of prospects for natural gas as a fuel in road transport", 2019.
[122] IEA 2018 New Policies Scenario.
[123] Press reports.

The role of natural gas for transport in Italy

Italy is the leading market in Europe for the use of natural gas in transport. With a fleet of more than 1 million vehicles, Italy is also among the top ten global markets for NGVs[124]. The Italian NGV market has also been fast growing, with the total number of vehicles increasing from 650 thousand in 2009 to more than 1 million in 2018. In total NGVs now account for 2% of all road vehicles and 4% of all busses in Italy[125].

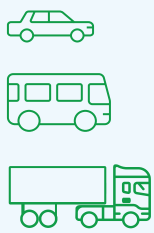
The development of natural gas use for transport in Italy has been due in large part to policy measures that have resolved the "chicken or the egg problem" of either insufficient vehicles or insufficient refueling infrastructure. To stimulate demand, the Italian government has provided vehicle purchase and conversion incentives. Combined with lower taxes on natural gas than petrol, the total cost of CNG vehicle ownership is now less than that of similar petrol, diesel, and electric vehicle options[126]. This in turn has prompted to development of a wide range of CNG vehicle models: in 2018 more than 30 models of NGVs were available in Italy across different segments, including SUVs[127].

Ensuring sufficient demand has in turn facilitated the development of CNG & LNG refueling infrastructure. More than 1,300 CNG and 50 LNG refueling stations are already available across nearly all regions in Italy[128].

A new focus of government policy is to incentivize further development of CNG and LNG refueling stations and to integrate the use of biomethane in road transport as a means of reducing GHG intensity of the transport sector. In 2018 the Italian government announced a decree that will provide an incentive for up to 1.1 BCMA of biomethane production for the use in cars until 2022. Recent estimates show that the potential pf biomethane use for the transportation could reach more than 2 bcm/year covering least one-third of the potential NGVs demand.

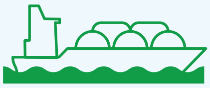
> 1 mln

Natural Gas Vehicles in Italy



[124] NGVA Europe.
[125] ACI.
[126] Snam analysis; Calculation assumes vehicles travel 16,000 kilometers per year and operate for 14 years, petrol costs €1.53 per liter and natural gas cost €0.97 per kilogram.
[127] Snam.
[128] NGVA Europe.

The potential for Greece as an LNG bunkering hub



Greece is emerging as a prominent location for LNG bunkering in the Eastern Mediterranean for three reasons. First, Greece is a material bunkering market today, supplying 1.7 MTOE of marine fuel or roughly 1% of global bunkering demand[129]. Second, Greece receives LNG cargoes from multiple sources and diversified routes; this enhances security of both large- and small-scale LNG supply. Third, the use of LNG as marine fuel will provide both regional and local environmental benefits from lower air pollution.

Given the increased interest in LNG bunkering and the country's strategic fit as an LNG marine fuel supplier, Greece is investing in all the necessary aspects of the supply chain. The Greek transmission system operator (DESFA) is actively promoting LNG bunkering as the owner and operator of the only LNG terminal in Greece, which is proximate to the core port of Piraeus and the first crucial link of the bunkering supply chain[130].

DESFA is planning to install small scale LNG facilities at the Revithoussa LNG terminal. A truck loading station will be constructed for delivering LNG to off-grid consumers for bunkering and other uses. The Greek transmission system operator also plans to build a small-scale LNG jetty for the supply of Greek ports and other satellite storage installations. The jetty will provide flexible scale with two berths and the ability to accommodate vessels from 1,000 m^3 to 20,000 m^3 [131].

For a flexible LNG bunkering supply chain in Greece, subsequent small-scale LNG infrastructure projects are planned at the major Greek ports of Patras, Igoumenitsa, and Heraklion. These include port infrastructure, storage tanks, and truck loading slots[132]. The design phase of all small-scale LNG facilities of the three major Greek ports and Revithoussa LNG terminal, is being executed within the framework of the EU co-financed project Poseidon Med II, where DESFA plays the role of Technical Coordinator[133].

The potential demand for LNG bunkering is material. To start, adoption is most likely by ferries and cruise ships which could provide an LNG bunkering market of 415 MCM of gas by 2030[134]. Over time, the development of an LNG bunkering hub in Greece can enable LNG vessels to operate in the Eastern Mediterranean more broadly. The new infrastructure will also provide Greece with a pathway to scale its LNG bunkering operations if demand increases.

[129] IEA.
[130] Gas Infrastructure Europe (GIE), "Small scale LNG data base", press release Feb 2018.
[131] DESFA.
[132] DESFA.
[133] www.poseidonmedii.eu
[134] DESFA.

Required infrastructure

Gas is reducing emissions intensity of the transport sector and is cost-competitive versus electric alternatives

Given the long track record of natural gas in Europe, the region is starting from a base of ample infrastructure availability. In particular, there is a demonstrated ability to use existing infrastructure in the region to adapt to shifting trade flows.

For the role of gas to evolve in Europe, and for gas to provide a viable pathway for deep GHG emissions reductions, the following targeted incremental investments will be required in specific supply chain segments and for the deployment of new technologies.

- **Imports**: Gas pipeline and LNG infrastructure will play a growing role in Europe given declining local production, but there is generally sufficient import capacity today to enable the evolving role of gas. Import pipelines only periodically operate at peaks above 80%[135]. Meanwhile, LNG regasification capacity utilization was only 28% in 2018[136]. The need for additional import infrastructure is likely to be limited to de-bottlenecking specific routes within Europe and adding resilience to further support supply security.
- **Cross-border connectivity within Europe**: A more pressing challenge is the need to establish greater cross-border transmission interconnectivity within Europe to adapt to shifting supply and demand patterns. The internal market functions effectively – around 75% of gas in the EU is consumed within a liquid market, meaning that gas can be redirected across borders to areas experiencing spikes in demand or shortages in supply. But physical interconnections need further development. More than 40% of EU's LNG regasification capacity cannot be accessed by neighboring countries, limiting the security benefits of importing LNG[137]. If cross-border gas infrastructure were frozen at current levels while remaining contractual and regulatory congestion persists, capacity utilization would reach a maximum constraint in the next 10-20 years[138].
- **Gas power generation capacity**: As intermittent renewables take a greater share of Europe's generation mix, the need for peaking capacity to manage the grid will increase. Global gas peaking capacity is expected to rise by 86% from 345 GW in 2017 to 640 GW in 2040as it plays a greater role managing intermittent renewables[139]. Europe's current gas peaking fleet only consists of around 15 GW. Assuming European gas peaking grows at the IEA's predicted global average, Europe would need to almost double of net gas peaking capacity by 2040.

[135] IEA, "A long-term view of natural gas security in the European Union", 2019.
[136] Cedigaz.
[137] IEA, "A long-term view of natural gas security in the European Union", 2019.
[138] BCG analysis.
[139] IEA.

Austria’s role providing natural gas supply for Europe

Over the past two decades Austria has emerged as a key hub for the flow of natural gas to and within Europe. Through the development of bi-directional pipeline capacity, Austria now has the ability to flexibly supply gas from Russia and Norway and distribute it to Germany, Italy, Slovenia and downstream toward Croatia, and Hungary[140]. Investment in 8 BCM of natural gas storage capacity also helps the system manage supply disruptions and fluctuations in demand[141]. Potential future supply from Black sea basin are also envisaged.

Most of the natural gas transmission in Austria passes through the Baumgarten hub in eastern Austria close to the Slovakian border. Baumgarten is a crucial gas node into the European energy system given that around 40 BCM per year moves through the hub, roughly five times Austria’s annual consumption[142]. It has also emerged as a key trading hub for European gas, providing both physical and financial liquidity to enable efficient market operations.

When designed, the Austrian transmission system was engineered to provide supply flexibility resilience. For example, the current infrastructure can supply more than the amount of peak Austrian gas demand even in the case of an outage at the largest point of gas supply (the Baumgarten metering and compressor station)[143].

The flexibility and resilience of Austrian natural gas infrastructure was tested in December 2017 when a shut-down of the transmission capacity occurred in Baumgarten. While the transmission hub was shut down, Austria’s storage capacity allowed uninterrupted gas supply. The Baumgarten hub was operational again within 24 hours, restoring the normal flow of gas across Austria[144]. While spot gas prices did limited spike around the time of the shutdown, no physical supply was interrupted.

TAG GmbH, in close coordination with Gas Connect Austria, both Austrian TSOs, plans the enhancement of the current physical reverse flow to a full firm commercial flow from Italian market toward Austrian Virtual Trading Point. This initiative, currently planned to be completed for 2020, will enable a flow capacity up to approx. 18 BCM, which will reinforce the Austrian national resilience to unplanned event and be able to be distributed toward the neighboring countries (Slovenia, Hungary, Slovakia, Germany)[145].

The case study of Austria demonstrates that the resilience of natural gas supply can be improved through concerted investments in flexible flow and storage infrastructure. As natural gas imports to Europe continue to increase and trade patterns shift, ensuring gas network resilience will require sustained investment in cross-border transmission capacity as well as natural gas storage capacity.

[140] These pipelines include the West-Austria pipeline and the Penta-West pipeline. The West-Austria pipeline stretches from the Baumgarten hub in the east across Austria into Germany, and the Penta-West pipeline branches off the West-Austria pipeline into southwest German.
[141] Gas Connect Austria.
[142] Gas Connect Austria; Cedigaz.
[143] The Austrian Infrastructure standard calculated according to regulation (EU) No 2017/1938 and currently in the amount of 132%, shows an positive balance (>100%) between the Austrian Peak demand and the import capability in case of outage of the biggest Austrian gas transportation infrastructure, the Baumgarten metering and compressor station.
[144] Press reports; TAG.
[145] The above Austrian Infrastructure standard should reach approx. 220 % after completion of the Italian-Austrian reverse Flow project. This project is part of the TYNDP 2018 (TYNDP: Ten-Year Network Development Plan, the European network development plan for gas infrastructures. See the project TRA-F-954: “TAG Reverse Flow”).

Baumgarten gas hub is a crucial node in the European energy system

- Developed Austrian routes
- Austrian routes under development

- **Infrastructure to enable gas use in the transport sector**: A lack of refueling infrastructure is a key limit on natural gas taking a greater role in the transport sector. Thus, investment in refueling infrastructure can be a key means of unlocking greater market adoption of NGVs. According to the NGVA Europe and the European Biogas Association, Europe will need to increase its number of CNG stations from 3,300 to 10,000 by 2030 to facilitate an increase of the number of NGVs from a little over 1.3 million to over 13 million[146]; and
- **Low carbon gas**: To enable future low carbon pathways using low biomethane, hydrogen, and CCUS, substantial investment will be required in the near to medium term. In one scenario for achieving net-zero EU energy emissions, low carbon gas consumption of around 270 BCM natural gas equivalent would be required by 2050. Of that, the analysis projects 110 BCM would consist of renewable methane and 160 BCM of natural gas equivalent would consist of low carbon hydrogen. The cost of biomethane capacity is estimated to be €5.7 billion, while the costs for new hydrogen infrastructure are estimated to be €9.5 billion annually[147]. Despite high investment in production capacity, these technologies use existing gas pipelines for distribution, thereby avoiding further investments in energy infrastructure and minimizing the risk of stranded assets.

[146] NGVA Europe, European Biogas Association, "Natural gas infrastructure and outlook towards 2030", 2018.
[147] Navigant, "Gas for Climate", 2019.

Conclusion

Implications for the global gas industry

The potential future for natural gas is strong, but it is not certain. Relative to other fuels, gas remains well-positioned as cost competitive, secure, and environmentally sustainable. Those attributes have helped to sustain strong market growth in recent years and enabled investment in infrastructure for the supply and consumption of natural gas.

To sustain growth over the long run, it will be necessary for the global gas industry to build on recent successes by enabling greater diversification of market growth in the near term while laying the groundwork to ensure the long term viability of gas under any circumstances.

Doing this requires three steps:

- Governments and industry need to make gas more cost competitive with other fuels on a sustained basis. This includes expanding access to low cost gas reserves globally while also reducing costs at all steps through natural gas supply chains. Sustained industry innovation will be critical in this regard;
- Investment in gas infrastructure will be critical to sustaining growth in access to gas while also preparing for future energy transitions. In Asia, expanding access to gas through LNG regasification and transmission and distribution infrastructure investment is most critical, while in Europe, the development of infrastructure to supply low carbon gas will be key; and
- To maximize the sustainability benefits of gas, the industry must continue to act to verifiably reduce methane emissions while governments implement new policies that enable greater use of gas. In the short term, this includes more stringent air quality policy measures as well as steps to enable more rapid coal-to-gas switching. For the development of low carbon gas technologies over the longer term, policy can play a key role in promoting technological innovation, developing supply sources, and ensuring market demand.

Realizing the potential of natural gas will require consistent support and coordinated action by industry and national governments. This report demonstrates that it is entirely possible to achieve sustained rapid growth for natural gas, but it should not be taken for granted.

www.snam.it

Snam is Europe's leading gas utility. It operates in Italy and, through its associated companies, in Austria (TAG, GCA), Greece (DESFA), France (Terēga) and United Kingdom (Interconnector UK). It is one of the main shareholders of TAP (Trans Adriatic Pipeline). Snam manages the Europe's largest, most accessible pipeline network (more than 41,000 km), the largest storage infrastructure (20 bcm capacity) and one of the first LNG terminals built in Europe. Its investments aim to facilitate the European Energy Union network integration and to promote natural gas as a key pillar of a sustainable energy mix.

www.igu.org

The International Gas Union (IGU) is a worldwide non-profit organisation that advocates gas as an integral part of a sustainable global energy system, and promotes the political, technical and economic progress of the gas industry. The more than 160 members of IGU are associations and corporations of the gas industry representing over 95% of the global gas market. IGU encourages international trade in gas by supporting non-discriminatory policies and sound contracting principles and practices, promoting development of technologies which add to the environmental benefits of gas and further enhance safe production, transmission, distribution and utilisation of gas.

www.bcg.com

The Boston Consulting Group (BCG) is a global management consulting firm and the world's leading advisor on business strategy. We partner with clients from the private, public, and not-forprofit sectors in all regions to identify their highest-value opportunities, address their most critical challenges, and transform their enterprises. Our customized approach combines deep insight into the dynamics of companies and markets with close collaboration at all levels of the client organization. Founded in 1963, BCG is a private company with offices in more than 90 cities in 50 countries.

www.desfa.gr

DESFA is the National Natural Gas System Operator in Greece responsible for the operation, management, exploitation and development of the National Natural Gas System and its interconnections. It transports gas from the Greek-Bulgarian border and the Greek-Turkish border to consumers in continental Greece through a main transmission pipeline with total length of 512 km and transmission branches with total length of 952 km. DESFA also owns and operates the Revithoussa LNG terminal that provides security of energy supply and operational flexibility in the transmission system.

www.interconnector.com

The Interconnector pipeline (IUK) provides a strategic energy link between the UK and continental Europe. IUK transportation service is a key factor in the liberalisation of energy markets across Europe. IUK commercial operation is based in central London with terminals at Bacton in Britain and Zeebrugge in Belgium, joined by a 235 km pipeline running under the southern North Sea. The pipeline forward capacity is 20 bcm/y and reverse capacity is 25.5 bcm/y.

www.terega.fr

Established in the greater South-West region of France, at the crossroads of major European gas flows, Terēga operates and develops gas transport and storage infrastructures for over 70 years. Today, it continues to develop innovative solutions to overcome the major energy challenges facing France and Europe. A true accelerator of energy transition, Terēga operates over 5,000 km of pipelines and two underground storage reservoirs, representing 16% of the French gas transport network and 25% of national storage capacities.

www.taggmbh.at

Trans Austria Gasleitung GmbH is a Transmission System Operator in Austria and the main artery of the natural gas network in central Europe. The TAG pipeline network consists of about 1,140 km high-pressure natural gas pipes for the transport of natural gas from the Slovakian/Austrian border to the Austrian/Italian border. More than 30 bcm of natural gas are transported through the pipeline system of TAG GmbH every year.