IHS Markit®

A Sustainable Flame:
The role of gas in net zero

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Special Report

Contents

A Sustainable Flame: The role of gas in net zero

Executive summary

Gas plays a pivotal role in today's global economy, providing almost one quarter of the world's energy supply. The IHS Markit study "A Sustainable Flame" argues that gas will continue to be critical to the future of energy, joining renewable electricity as a second pillar for decarbonization.

Natural gas and early action

Early action on emission reductions is vital to meeting the more ambitious decarbonization goals laid out by governments. And here natural gas can play a critical and unique role, particularly in developing economies. Natural gas can not only meet growing demand for clean, affordable energy but can also replace coal and oil and their associated higher emissions. This substitution toward natural gas can be done relatively quickly, requires limited deployment of capital, and has a significant impact on emissions. IHS Markit estimates that 420–550 Bcm per year of additional natural gas—10–15% of current global consumption—would be required to meet a cost-optimal pathway for emission reductions in the Asian power sector alone, generating between 0.9 and 1.2 gigatons (Gt) of annual carbon dioxide (CO_2) reductions.

Greenhouse gas (GHG) emissions are not just about CO_2; minimizing the methane emissions associated with natural gas will be essential in order to confirm and strengthen its status as a low-carbon fossil fuel. The focus here must be on the "three M's": measurement, monitoring, and mitigation. New technologies offer the prospect of credibly tracking, stopping, and verifying methane emissions in the short term. Suitable regulation and certification, which does not impede innovation, will be needed to underpin these evolving technologies and practices.

Renewable natural gas—otherwise known as biomethane—can also play a useful upfront role in existing gas infrastructure by greenifying the gas stream. More importantly, it can have a positive impact by capturing fugitive methane emissions from waste and agriculture and putting them to good use as a net-zero energy source.

The rich global resource base of conventional gas, shale gas, and renewable natural gas can meet these shorter-term needs in an affordable and reliable manner if policy frameworks allow sustainable and responsibly sourced developments to move forward.

Beyond natural gas and deep decarbonization

It is important to emphasize that gas can be a zero-carbon renewable option as well as a fossil fuel. Kick-starting low-carbon technologies in the short term is critical to enable expansion globally after 2030. Both carbon capture, utilization, and storage (CCUS) and hydrogen have the potential to make a huge contribution to emission reductions and can support in areas where direct electrification is difficult or impossible. Low-carbon hydrogen use is projected in some net-zero outlooks and roadmaps to reach anywhere between 10% and 25% of the global energy mix by 2050 from almost nothing today. CCUS capacity is projected to capture up to 1.5–8 Gt of annual emissions in 2050, compared with 37 Gt of energy-related emissions today.

Low-carbon gas technologies are at a critical juncture. Both hydrogen and CCUS have reached the point where they can be developed commercially where strong carbon pricing incentives exist such as in Europe and California or with the support of policy incentives such as the 45Q tax credit in the United States. IHS Markit finds that many applications for these technologies work with carbon price support of $40–60 per metric ton, close to levels in some markets today. Early deployment of these technologies will bring costs down as the industry scales up and will start to build up the supply chains required for what are essentially new industries.

Leveraging gas infrastructure—The key enabler

Today's gas infrastructure is an indispensable asset to support the transition from unabated natural gas to low-carbon gases to drive deeper decarbonization. Gas pipelines for transmission and distribution, storage facilities, liquefaction plants, and LNG vessels can all be repurposed over time to deliver low-carbon gases. The ability to convert gas infrastructure should ease concerns about "lock-in" of fossil fuels. Investments in new gas infrastructure should not be discouraged; instead they should be considered a prebuild of energy carriers for a lower-carbon future, enabling the shift to deeper decarbonization. Regulations and performance standards can be developed to incentivize this transition.

Thus far, decarbonization has focused primarily on power generation, where efforts are well underway. Renewable capacity will continue to grow, electrification will broaden its reach, and improvements in battery storage will make a decarbonized grid more reliable. Timing, scale, and supply chains will all be important variables. Alongside this trend, a second element of the energy transition must be encouraged urgently, a low-carbon gas supply, infrastructure, and pipeline business that can serve sectors beyond the reach of direct electrification and wires. Large-scale investment across the gas value chain and the harnessing of significant capital will be required.

Acknowledgements

A Sustainable Flame was a six-month research effort undertaken by the Climate and Sustainability group within IHS Markit between February and July 2021.

The aim was to explore the role, contribution, and limitations of gas in driving forward decarbonization both globally and in the United States. Six expert thematic workshops took place covering the topics:

- Global GHG Emissions: Setting the context
- Hydrogen and Renewable Gas
- Carbon Offsets and Methane Emissions
- Carbon Capture, Utilization, and Storage (CCUS)
- Substitution and Growth Areas
- The United States and Net Zero

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All views in this report are those of IHS Markit and do not necessarily represent the views of any of the participating companies.

A Sustainable Flame

When we think of gas, we often think of the familiar blue flame. This blue flame plays a central and critical role in today's global economy, providing almost one quarter of the world's primary energy. The IHS Markit study "A Sustainable Flame" proposes that gas will continue to be critical to future energy, joining renewable electricity as a second pillar for decarbonization. It is important to note that gas can be a zero-carbon renewable option and not necessarily a source of GHG emissions. **Today's gas infrastructure will be tomorrow's carriers of low- or zero-carbon gases:** This infrastructure is a key enabler, not simply a "fossil fuel asset."

As a starting point, today, gas meets almost one quarter of the world's energy needs, and one quarter of all the world's electricity is produced from gas. These shares have been rising throughout the 21st century, bringing efficient and safe energy to customers and improving air quality in developed and developing economies.

A Sustainable Flame report structure

The report is arranged in three parts

- "Redefining gas" outlines why gas is needed to help drive faster and deeper decarbonization and how gas can contribute to a full transition to net zero without "lock-in" of emissions.
- "'Early action and unabated natural gas" examines how unabated natural gas can achieve quick wins in emissions reduction, particularly in emerging economies over the next couple of decades.
- "Beyond natural gas" examines how emerging technologies and low-carbon gas can scale up to make a meaningful contribution to emission reductions.

The report has a prescribed focus: it is an investigation of the areas where gas—in its many forms—can support and accelerate decarbonization. The report is not intended as a full decarbonization study. Other tools—such as renewable and nuclear power, batteries, and demand-side management—will have critical roles to play but are addressed here only indirectly. The report does not replicate the multiple quantified simulations or scenarios about how the global energy system may evolve to be consistent with the Paris Agreement or with net-zero targets. These have been done elsewhere by IHS Markit and other organizations.* Instead the report highlights areas where gas has specific advantages, whether in terms of large impacts on emission reductions, competitive costs, or addressing sectors where few viable alternatives exist to facilitate decarbonization.

* For example, see the IHS Markit Scheduled Updates *Accelerated Carbon Capture and Storage Low Emissions Case Energy Data Set, September 2020* and *Multitech Mitigation Low Emissions Case Energy Data Set, September 2020*.

There are significant geographical differences. The developed world has benefited most. In the United States, gas accounts for 35% of primary energy, the European Union 25%, and Japan 22%.[1] The emerging and developing world lags behind. In mainland China, natural gas has scarcely reached 8% of primary energy, and in India the figure is closer to just 6%. Coal and oil remain the foundation of these economies. Both markets and others in Asia, Africa, and Latin America still have scope and aspirations to increase the role of this convenient and clean burning fuel.

Can the flame be sustained into the future? A change of thinking and an acceleration are needed. If gas is to maintain and build on its legacy success, it must be within a sustainable framework that works—urgently—toward a low-carbon or a net-zero future. Corporates must be mindful of the role gas plays within their environmental, social, and governance commitments and, in particular, their GHG emission reduction goals.

An increasing number of jurisdictions worldwide are making commitments to a net-zero future. Approximately three quarters of global GHG emissions are currently produced in countries that have made some political commitment to net zero—and these countries account for more than 80% of global GDP. Corporates too have accelerated net-zero commitments and strategies in the past year. Policy measures and frameworks are being developed in support of linked targets. For energy producers, research, development, and technology innovation all focus on finding more efficient ways of delivering the energy that consumers need with a low- or zero-carbon footprint. At the same time, many of the engines of future growth in energy and the economy are in countries that continue to seek the midterm benefits of affordable fossil fuels that can alleviate poverty and drive economic growth.

Gas: The second pillar of decarbonization

Why is gas needed?

For power, there is an ongoing critical role for gas to provide reliable "on call" power supply when variable renewables are not generating—"when the sun is not shining, and the wind is not blowing." Batteries and demand-side responses will cover part of that role, providing short-term storage, but they are unlikely to be able to offer long duration and seasonal storage. The primary choice for long-duration power storage remains gas generating capacity since it has lower capital costs than other forms of on-call power such as coal or nuclear. The use of gas plants still allows a number of competing alternatives with different trade-offs between emissions and costs. These plants can continue to operate with unabated natural gas, or with carbon capture, or they can be converted to run on hydrogen.

Beyond power generation, governments are recognizing the limitations to full electrification as decarbonization progresses beyond power into heat and mobility. Power represents only 21% of final energy. Electricity delivered by wire is less well-suited than gas for meeting the need to produce heat, either for industrial processes or for space heating of buildings. The electricity system—generation, transmission, and distribution—is usually not designed nor can be readily modified to meet peak heating needs. Take as an example of the scale of such modification an IHS Markit case study of New York state. While the current power system is sized at 31 GW, full electrification of heat would require a system sized to more than 150 GW. Even with full deployment of air-sourced heat pumps, the power system would need to be sized at 133 GW. Most electricity systems are simply not built to handle heat loads.

Gas may also be a solution for part of transport. Electricity is potentially better-suited to power light-duty vehicles like cars, but cars consume less than half of the energy consumed in mobility. For the rest—trucks, ships, trains, and airplanes—other solutions may be needed, either ways to transform electricity into gases and liquids or alternatives to electricity.

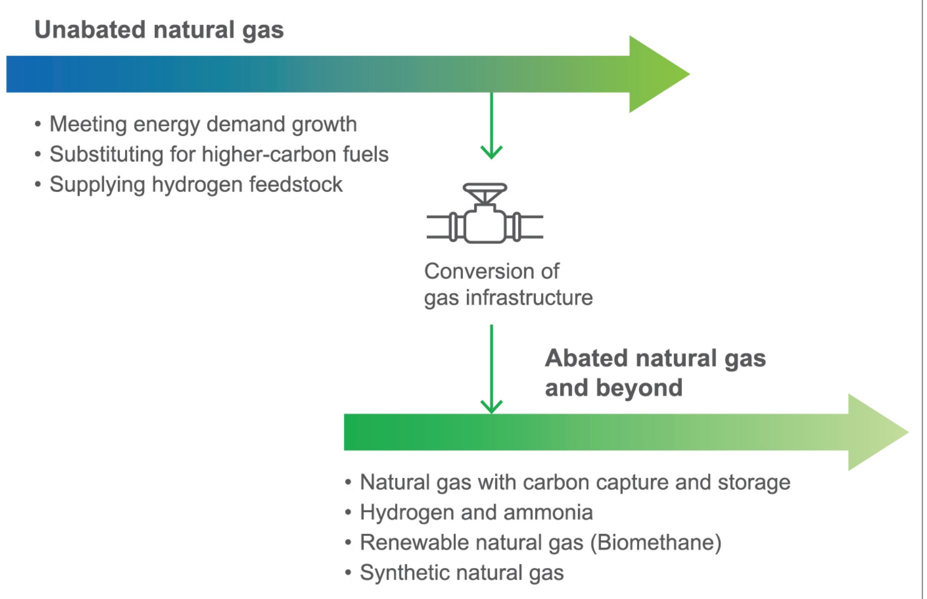
1. The European Union comprises EU27 and United Kingdom for 2020.

Redefining gas

Gas has a role to play in the short- to midterm, using unabated natural gas, and in the longer term as abated gas and other low-carbon gases and technologies scale up. The distinction between "natural gas" and "gas" is essential: gas embraces a wide set of supply solutions (see Figure 1).

Figure 1

Redefining gas



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- **Early action and unabated natural gas.** Natural gas can not only meet growing demand for clean, affordable energy but can also replace coal and oil and their associated higher emissions. In the short and midterm, natural gas remains one of the most impactful, practical, and affordable means to reduce emissions quickly and at scale this decade, especially in the United States and emerging economies.
- **Deep decarbonization, abated natural gas, and beyond.** In the longer term, gas can continue to play an important role as unabated natural gas use declines and is displaced by a range of low-carbon gas-based options, including ammonia, hydrogen, synthetic methane, and renewable natural gas.[2] CCUS application to natural gas will also play a large role. Just as the development of renewable energy sources is enabling a reduction of the carbon intensity of electricity generation over time, so too there will be a reduction in the carbon intensity of the gas blend.

It is important to stay within a fixed carbon budget. The budget is the total cumulative amount of emissions that can be accommodated to limit temperature rises to a specific threshold. When the focus is solely on arbitrary target dates like 2050 rather than carbon budgets, the risk is that unnecessary concentrations of GHG emissions will build up in the atmosphere before the zero-carbon technologies have had time to scale up. In contrast, a focus on using unabated natural gas early can lead to lower emissions, lower GHG concentrations, and ultimately lower temperature outcomes (see Figure 2).

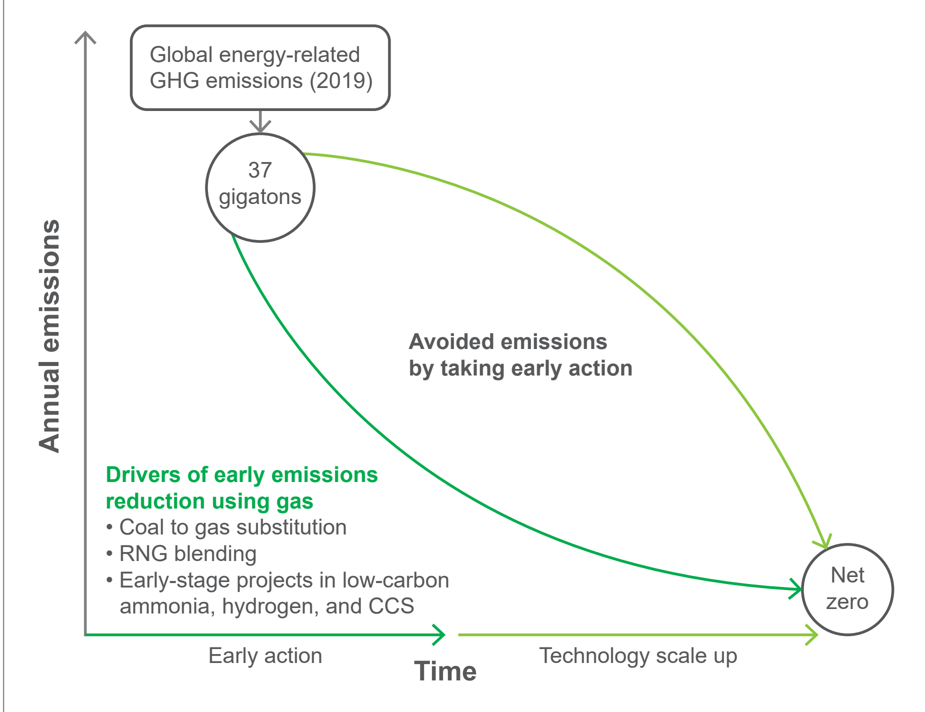
This transition from unabated natural gas to gas will play out differently across countries depending on their state of development, their energy endowment, and their own emissions budgets. In Europe, for example, natural gas demand peaked in 2010, and the focus has begun to turn to the promotion of low-carbon gases. In China, natural gas demand may not reach its peak until the 2040s.

2. Renewable natural gas is also referred to as "biomethane" in some parts of the world.

Lock-in, asset lives, and repurposing

Figure 2

Acting early reduces emissions



Source: IHS Markit

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As gas demand in these sectors grows, is there a risk that investment made to deliver the fuel today will lead to the "lock-in" of higher carbon emissions in the future? Investments today in unabated natural gas can, by substituting for higher emitting fuels, have an immediate and discernible impact on GHG emissions, preventing the trapping in the atmosphere of CO_2 that may last for hundreds of years. But these investments tend to be long life assets. Therefore, the concern is that these investments may embed or lock in future emissions for several decades. The level of emissions associated with these investments may be lower in the early period than what came before, winning valuable time, but may make it more difficult to achieve future lower emission targets. This is an objection that can and must be addressed.

It is critical to recognize that much midstream and downstream investment is a prebuild of the backbone of the future decarbonized world. Such investment need not lock in unabated natural gas use; on the contrary it lays the groundwork for a zero-carbon future because the infrastructure can be repurposed.

- Pipelines—both transmission and distribution—can ship renewable natural gas. In an early stage, they can blend in "green" gases to lower the carbon footprint, while in the longer term, they can be repurposed for shipping of 100% hydrogen. So too with gas storage infrastructure. Early examples of large-scale repurposing of natural gas pipelines to hydrogen carriers are being studied in the United Kingdom (H21), the Netherlands (Hydrogen Backbone), and in Germany (H2 Startnezt).
- Gas-fired power plants can convert to run on hydrogen or sustainable ammonia, or in some circumstances to incorporate retrofit CCUS. The EU turbines association, for example, has committed that all turbines commissioned from 2020 onward can operate with a 20% hydrogen blend and that all turbines from 2030 should be able to handle 100% hydrogen.
- Liquefaction plants can be converted to liquefy hydrogen, probably at a lower cost than building a liquefied hydrogen plant from scratch.[3]

3. See the IHS Markit Strategic Report *Getting Colder: From LNG to liquefied hydrogen*.

- Industrial and domestic gas boilers can be manufactured to be readily adaptable from natural gas to hydrogen, as they have been for many years in some countries designed to operate using natural gas with varying calorific values and "flame speed."

These facilities or investments are not "fossil fuel assets"—they are energy carriers or energy converters. **By prebuilding gas assets with the option of repurposing, the energy industry can accelerate the transition and reduce its overall cost.**

Repurposing infrastructure has technical challenges and requires investment. In each case, the costs of conversion may be significant but still at a lower cost than new investments. Investors can decide whether this route is a viable or non-viable option. Policymakers and lenders do not need to ban these investments, ruling out, point blank, the option of repurposing. A more constructive approach would be that authorizations and loans come with defined performance standards relating to emissions with the possibility of limits on the life the asset can operate with unabated natural gas. Funders and regulators might also specify that any newbuild infrastructure be predesigned to be conversion-ready. That way investors can decide whether to risk the investment on the basis of later conversion or to run the economics on shorter asset life assumptions.[4]

Early action—Unabated natural gas

Increases in global population and economic growth are continuing to drive an ongoing need for raw materials, heating, and mobility. This will require natural gas—the cleanest of fossil fuels—to support key manufacturing sectors, including steel, cement, fertilizer, and paper and pulp. Especially in developing countries, natural gas will serve as a key bridge fuel for 10–15 years at a minimum.

From the emissions perspective, natural gas currently accounts for approximately 8 Gt of the 37 Gt of CO_2e produced by the energy sector. Whether there is scope to increase unabated burning of natural gas in particular markets depends upon specific decarbonization emission targets and their timing. All fossil fuels face pressures under deep decarbonization pathways. In the case of oil and coal use, it appears a one-way risk: it is difficult to see how increased consumption of these fuels can be consistent with reducing overall emissions.[5]

The same is not true for natural gas. This is because natural gas includes a number of counter-balances in any decarbonization. That is, **the decline of natural gas use in certain areas is compensated for by upside needs in another.** The four main drivers of natural gas use under decarbonization are as follows:

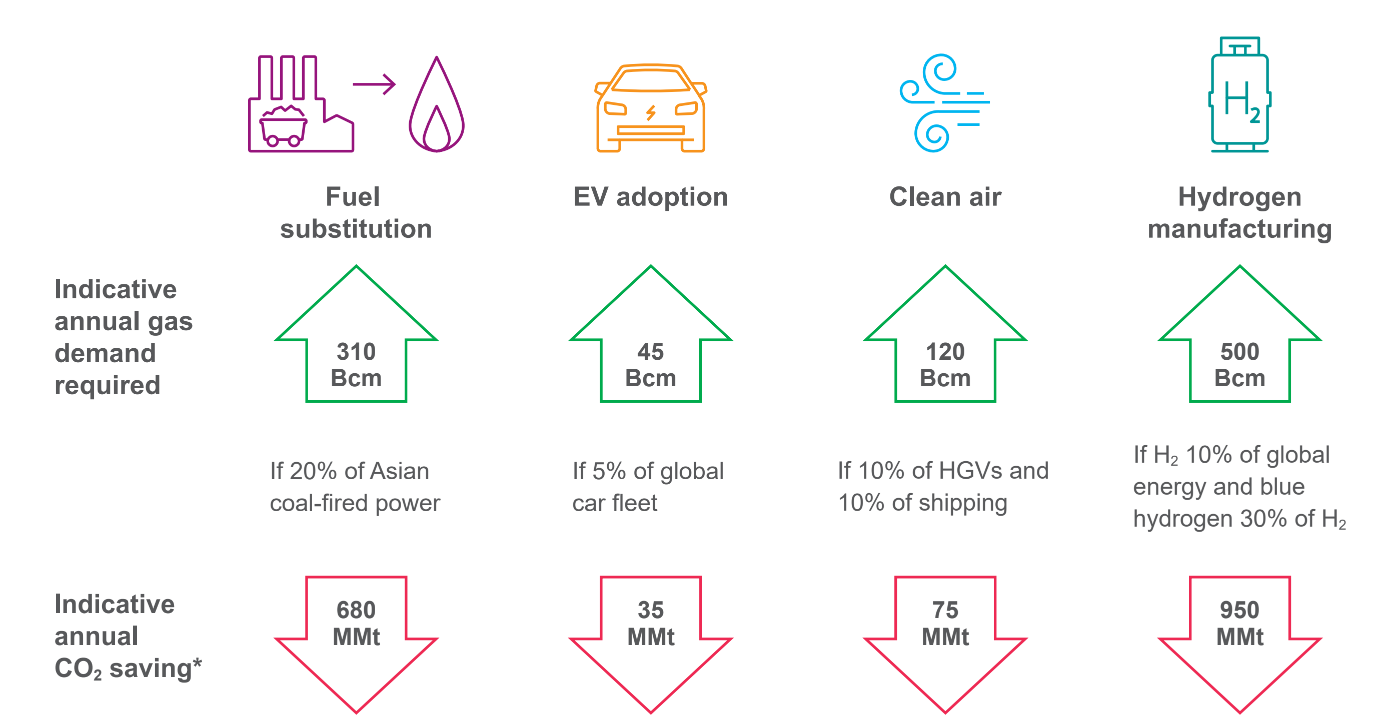
- **Substitution toward natural gas**—the opportunity to make immediate deep emission reductions by replacing the higher emitting fuels of coal and oil with natural gas
- **Electric vehicle (EV) adoption**—natural gas may be required to help supply part of the additional demand for electricity
- **Hydrogen manufacturing**—the development of a major potential new market for natural gas as a feedstock for producing hydrogen through steam methane reforming in conjunction with carbon capture, i.e., "blue hydrogen"
- **Clean air**—use of natural gas in transportation, notably trucks and ships, to help improve air quality

4. One parallel here is the German government's approach to the phaseout of nuclear plants, where the ongoing operation was authorized based on a fixed number of operating hours.

5. However, much can be done by producing and using these fuels more efficiently so that less energy is wasted and more useful energy is provided within an existing emission footprint.

Figure 3

Four ways natural gas can support decarbonization



*Total annual energy-related GHG emissions in 2019 were 37 gigatons. Global gas demand in 2019 was 3,900 Bcm.

Source: IHS Markit

Based on illustrative levels of use in different sectors, the implied requirement for natural gas supply is shown and the level of emission reductions achieved. The emissions savings are greater when natural gas is replacing coal and less in transport, where natural gas is replacing oil. Each area is discussed in more detail below (see Figure 3).

There exists globally a rich resource base of conventional, shale, and renewable natural gas that can meet these shorter-term needs in an affordable and reliable manner. Advances over the last 10 years or so, notably in deepwater technology and onshore shale gas extraction, have greatly expanded the known resource base both in the United States and internationally.[6] The focus of the upstream industry has turned to developing these resources as sustainably as possible with a minimum GHG footprint. The challenge will be to match supply-side investments with the timing of demand needs to ensure that companies have the confidence to make the necessary investments. Well-crafted policy frameworks are needed to allow sustainable developments to move forward.

Substitution toward natural gas

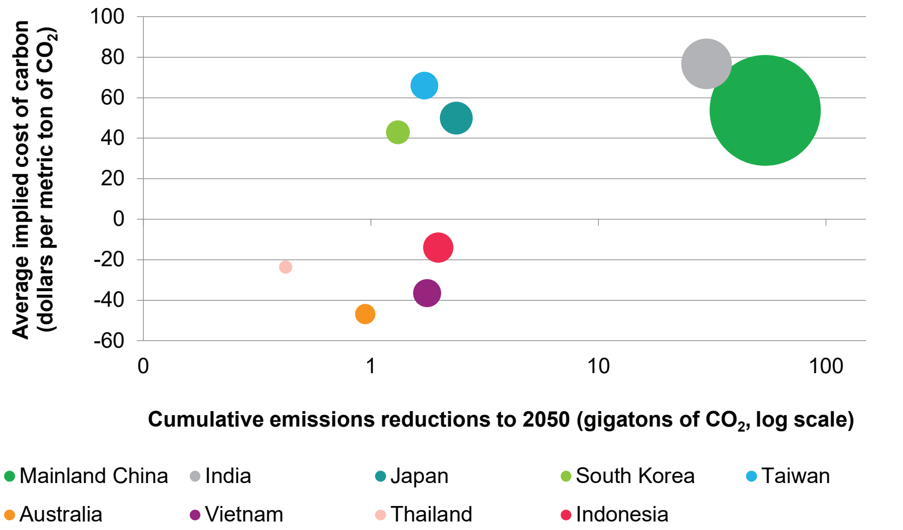
As the lowest-carbon fossil fuel, and the one that is used in what are normally the most energy-efficient technologies, there are advantages in substituting natural gas for other fossil fuels. It would be better still from an emissions perspective to substitute natural gas with zero-carbon sources but scaling up quickly to the extent required is often not possible. Since early action is essential from a climate perspective, substitution to natural gas should be considered. The case for substitution is all the stronger if measures are put in place to enable the asset repurposing described above, and to plan for a transition to zero-carbon solutions.

6. See Daniel Yergin & Sam Andrus IHS Markit Strategic Report *The Shale Gale turns 10: A powerful wind at America's back* (2018).

Coal-to-gas

Figure 4

Impact of coal to gas substitution in power generation in Asia



Note: High renewables case.
Source: IHS Markit

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The biggest substitution opportunity by far is still coal-to-gas substitution. Coal is responsible for 43% of global energy-related GHG emissions, most of it from coal-fired power. China alone accounts for 48% of global steam coal used to generate power and 61% of the coal used in industrial processes worldwide. India and the United States are the other big markets for coal generation, with further significant opportunities for substitution across Asia. And many countries continue to add coal-fired capacity. Although not well-recognized even in Europe, coal still accounts for 13% of power generation, more than solar. It would be possible to substitute natural gas for coal in many markets at a cost of less $60 per metric ton of carbon. Indeed, in some markets the cost of switching from coal to natural gas is negative because of the lower capital costs of gas plants, which is increasingly important in a system where thermal generation is backing up renewable power supply (see Figure 4).

Replacing older and less efficient plants with best-in-class natural gas generation will reduce emissions by more than 50% per unit of electricity.[7] IHS Markit estimates that 420–550 Bcm per year of additional natural gas would be required to meet a cost-optimal pathway for emission reductions in the Asian power sector alone. This is equivalent to about 10–15% of today's global natural gas consumption and would generate 0.9–1.2 Gt of annual CO_2 reductions. In addition, this substitution can bring more immediate and tangible benefits by reducing local air pollution.

The production of ammonia and methanol provide another opportunity to replace coal with natural gas. Ammonia is a key input in the production of many fertilizers; as populations grow, demand for fertilizers is expected to increase substantially. Today more than 70% of ammonia and almost 60% of methanol is produced from natural gas, with coal (the second-largest feedstock) used primarily in mainland China. Ammonia and methanol production together consume 113 Bcm of natural gas and emit 0.5 Gt of CO_2, representing almost 1% of global GHG emissions. Replacing existing and expected coal-based production with natural gas would save 224 million metric tons of CO_2 per year by 2050 and require an increase of gas consumption by 80 Bcm annually.

Further potential to reduce emissions with natural gas is based on technical innovations that could widen the scope for industrial gas use, notably in the steel sector. About one billion metric tons of metallurgical coal are used in steel production every year. Part of this can be substituted by natural gas using direct reduced iron (DRI) technology.

7. The advantage of using natural gas over coal in power generation is threefold. First, natural gas has a lower carbon content to start with; second, a modern CCGT converts natural gas to electricity with a 50–60% efficiency, compared with 35–45% for a supercritical coal plant; third, gas-fired power can follow load, filling in for fluctuations to solar and wind patterns, more closely, quicker, and cleaner than coal.

Besides coal, there is also the possibility to substitute natural gas for oil in certain stationary facilities. The main opportunity is the 1.5 MMb/d of oil used to generate power in the Middle East.

Takeaway: coal-to-gas substitution has huge potential to cut emissions quickly. From a GHG emissions perspective, the arguments are extremely compelling, but phasing out coal often runs up against socioeconomic objections given the implications for coal mining communities.

Heavy transportation

Very little natural gas is used in the transportation sector. In recent years, environmental concerns have raised interest in switching from diesel to LNG-fueled trucks, led by China, where about 1 in every 20 trucks is now running on LNG. Similar efforts in the United States and Europe have had a much smaller impact thus far. The primary driver for switching to natural gas is not GHG emission reductions, where the gains are relatively small, but to reduce tailpipe pollutants, where the difference is much greater and readily noticeable. The window of opportunity for LNG in this market may be closing, and the focus is beginning to turn to a direct jump to hydrogen, bio-LNG, or synthetic fuels. Blending of biogas with LNG may be an option to bolster the emission credentials of LNG as a road transport fuel.

Of greater potential is the marine shipping sector, where gas in the form of LNG can displace bunker fuel directly. This option is available today for newbuild vessels, and adoption of LNG bunkering by container ships in particular could have a major impact in terms of fuel use and associated emission savings. Blending ammonia with existing fuels could be another pathway to reduce emissions. For new vessels, shipbuilders are increasingly considering these lower-carbon options, as well as biofuels. But ships have long lives, and retrofitting is not usually attractive from an economic point of view.

Takeaway: LNG in shipping presents the main opportunity. Attention in both shipping and trucks is shifting to low-carbon gas solutions.

Light-duty vehicle fleet

Compressed natural gas (CNG) has attractive advantages in terms of producing less pollution and reduced noise than diesel and gasoline vehicles, with particular benefits among dense urban populations in megacities of the developing world. It also has the big practical advantage of fitting easily into the existing retail station networks. However, CNG is not an optimal choice if measured purely on the basis of GHG emissions. The internal combustion engine is an inefficient technology for converting gas to end-use energy, and tail pipe emissions of unburnt methane increase the overall GHG impact of CNG vehicles. To minimize overall emissions, it would be better to generate power from a gas-fired CCGT to power an EV. But this requires a reliable power supply and charging network.[8]

The key takeaway is if there is growing demand for electricity to power EVs, and if zero-carbon electricity growth cannot keep up fully with demand growth, then natural gas is best deployed indirectly via the electric or hydrogen route, not directly as CNG. The EV route—if powered by natural gas in the early years—also offers a clear route to lower-carbon options as the power generating slate evolves to incorporate more renewable resources.

The deployment of alternative vehicles will require more natural gas supply. The objective in markets such as Europe would be to use zero-carbon power to run EVs, but insofar as growth in renewable power failed to match fully growth in power demand for transport use, natural gas would be the next best option to meet the new power demand. If 5% of today's global car fleet were EVs running on gas-fired power, it would reduce emissions by 35 million metric tons and add 45 Bcm of new gas demand.

Takeaway: as the energy transition develops, the major upside for gas demand needs comes indirectly from increased power demand.

8. Alternatively, CNG could achieve greater emission savings if based partly on biomethane.

Hydrogen feedstock

The prospects for hydrogen are considered below. Suffice it here to say that hydrogen is now widely recognized to have a key role in decarbonization efforts beyond direct electrification. More than 20 countries now have declared hydrogen strategies, and there is a clear overlap between those who have made net zero pledges and those with high ambitions for the role of hydrogen in their energy balances. Some net zero simulations show hydrogen accounting for as much as 25% of energy end use by 2050. Natural gas (plus CCUS) faces competition as a source for this potential growth in hydrogen, primarily from electrolysis using renewable power, so-called green hydrogen. However, assuming some limitations in developing sufficient renewable capacity to meet both direct power demand as well as new demand for hydrogen, a large role for blue hydrogen is expected to develop, with the share of blue hydrogen in the overall mix varying based on policies in particular jurisdictions.

Takeaway: over the next decade at least, a big new market for natural gas demand is needed to produce blue hydrogen. In the longer term, this may be superseded by green hydrogen as it scales up and its costs come down.

Deep decarbonization, abated natural gas, and beyond—CCUS, hydrogen, ammonia, and renewable natural gas

Net-zero carbon targets mean also looking beyond unabated natural gas to low-carbon gas alternatives. **It is important to emphasize that gas can be a zero-carbon renewable option** as well as a fossil fuel. Kick-starting nascent low-carbon technologies in the short term is critical to enable the expansion globally after 2030. Both CCUS and hydrogen have the potential to make a huge contribution to emission reductions and can support in areas where direct electrification is difficult or impossible. Low-carbon hydrogen use is projected to reach anywhere between 10% and 25% of the global energy mix by 2050 from almost nothing today in some net-zero outlooks and roadmaps. CCUS capacity is projected to capture up to 1.5–8 Gt of annual emissions in 2050, compared with 37 Gt of energy-related emissions today.

Low-carbon gas technologies are at a critical juncture. **Both hydrogen and CCUS have reached the point where they can be developed commercially where strong carbon pricing incentives exist** such as in Europe and California or with the support of incentives such as the 45Q tax credit in the United States. IHS Markit finds that many applications for these technologies work with carbon price support at $40–60 per metric ton, close to levels in some markets today. Early deployment of these technologies will bring costs down as the industry scales up and will start to build up the supply chains required for essentially new industries.

Carbon capture, utilization, and storage (CCUS)

CCUS is a long-standing proven technology. Its application is currently limited, and the focus has been primarily at the oil and gas upstream production side linked to enhanced oil recovery. Gas processing associated with LNG facilities in Australia, Qatar, and Norway is currently the largest single application of CCUS. CCUS has also been applied to power stations. In the future, CCUS will be deployed in much greater scale downstream in industrial clusters or hubs applied to factories and possibly power plants. Large-scale deployment can be done in modular steps. About half of today's global emissions come from stationary sources that might lend themselves to carbon capture. Currently, CCUS technologies capture 42 million metric tons of CO_2 emissions from fossil fuels globally. Projections from IHS Markit and other analysts are for capture to increase to 1.5–8 Gt per year by 2050.[9] These levels represent a 50–200 times increase from today's use. CCUS capacity would need to double every 4–6 years for the next 30 years. CCUS does not sequester all emissions, but it can aim to remove 90–95%.

9. See, for example, BP Net Zero, IEA Sustainable Development Scenario, IEA Net Zero by 2050, IPCC 1.5, IRENA 1.5, Shell Sky Scenario. Also see the IHS Markit "Accelerated CCS" Low Emission Case.

CCUS has a potentially powerful role to play in the energy transition as a cost-effective means to achieving the policy goal of GHG abatement. The primary applications for CCUS will be in “hard-to-decarbonize” industries such as steel, cement, glass, and fertilizer, and these sectors typically use natural gas. The new industry of blue hydrogen will also be based primarily on natural gas and use CCUS. Longer term, CCUS will be required to produce negative emissions through either bioenergy with CCS and/or direct air capture.

Within energy, the biggest source of GHG emissions is power. The role for dispatchable thermal generation will be squeezed as renewables grow in the mix, often backed up by short-term battery storage. Nevertheless, there will be a continuing need for dispatchable generation, and carbon capture applied to power stations may be a good option if unabated thermal generation is inconsistent with policy objectives. In locations where this proves economically feasible and politically acceptable, natural gas stands to gain considerably. With the big exceptions of China and India, IHS Markit calculations suggest that the per-MWh cost of electricity from gas-fired power with CCS will often beat out coal-fired power with CCS.[10] The costs of transport and storage of CO_2 are less for natural gas than coal CCS, simply because there is less CO_2 to move and to store. Also, the lower capital costs of gas-fired power become more advantageous versus coal-fired generation as renewables penetration grows. This is because as renewable output increases, the utilization rates for dispatchable thermal generation decline and minimizing capital costs becomes the imperative.[11] An indicative range for the cost of CCS from gas-fired power is $39–57/MWh for electricity produced, with a corresponding cost range of $65–79 for CCS from coal-fired power.

If CCUS adoption takes off, much of the 1.5–8 Gt of future CCUS will be associated with natural gas because of its widespread use in industry. For power, coal with CCUS is generally less economic than natural gas, and mobile sources in transport associated today with oil use do not lend themselves to CCUS applications.

Takeaway: Many core industries will opt to use natural gas in combination with CCUS as the optimal means to reduce emissions. Within the power sector, CCUS on gas-fired power often has cost advantages over coal CCUS.

Hydrogen

Most hydrogen today is produced from natural gas or coal without carbon abatement. It is known as gray hydrogen. The conversion process involves significant emissions. If hydrogen is to play a key role in decarbonization, there are two options.

- It continues to be produced from fossil fuels, but the emissions are captured when it is known as blue hydrogen.
- It is produced from zero-carbon power sources, via electrolysis. When the power source is renewable power, it is known as green hydrogen.

Hydrogen is highly adaptable in its potential uses and can reach parts of the energy sector that other sources struggle to serve. A big advantage over direct electricity is the ability to store it long term. It has specific attractions for use in heat applications whether as industrial process heat or as a decarbonized option for residential and commercial buildings. Via fuel cells it is an option for road transportation. And even in power, it can be a good option for providing complementary dispatchable power in conjunction with variable renewable power.

10. Note that we choose to show the costs in dollars per MWh of produced power and not as dollars per metric ton of carbon stored. Dollars per MWh is the appropriate metric if the objective is to produce low-carbon electricity at the lowest cost.

11. See the IHS Markit *Global Gas Strategic Report: Exploring the efficient frontier – A global perspective on the gas-renewables partnership*.

Outside of its role in chemicals and refining, the hydrogen industry is in its infancy. However, many governments are proposing roadmaps in which it features strongly. In 2020, seven European countries and the European Commission released Hydrogen Strategies that envisage the development of a global traded market in hydrogen by the end of the decade. Potential exporters also released details of their ambitions. Canada and Chile joined Australia in seeking to become one of the world's top three hydrogen exporters. But it is important to remember that very little blue or green hydrogen exists in the world today.

Today blue hydrogen is estimated to be lower cost than green hydrogen. Cost differentials vary by region, but in most markets, green hydrogen is at least twice as expensive as hydrogen produced from natural gas. In the United States today, gray hydrogen can be produced for $1/kg ($7.5/MMBtu), blue hydrogen for about $1.7/kg ($12.5/MMBtu), and green hydrogen from $3/kg ($22/MMBtu) to more than $7/kg ($52/MMBtu) depending on the renewable power source. It is widely expected that green hydrogen costs will come down, but the degree and speed of any cost reduction is uncertain.

The drivers of cost reduction are benefits of scale from larger electrolysis projects, increased production driving down the cost of electrolysis cells, and lower costs for renewable power generation. The recent growth in the electrolysis pipeline—up from 24 GW at the end of 2019 to more than 100 GW in mid-2021—shows the belief the market has in the potential for costs to fall. Assuming the current pipeline is fully built, a learning rate of 10–13% would suggest that by 2030, green hydrogen costs would be approaching those of blue hydrogen. In 2030, we estimate that the cost of green hydrogen in the United States will fall below $2/kg ($15/MMBtu) in the best locations and in currently high-cost locations reduce from more than $7/kg ($52/MMBtu) to about $3/kg ($22.MMBtu). To achieve these cost reductions, a huge ramp-up in electrolysis factories is required.

The balance of blue and green hydrogen is important. Blue hydrogen will at first be favored over green if the cost of emission abatement is the driver. Green hydrogen offers the ultimate prospect of fossil-free zero emissions. Meanwhile it supports the balancing of the power system by absorbing excess renewable generation. However, creating the supply chains at scale will require time and complexity. Green hydrogen needs to be developed in tandem with the growth of renewable power. Otherwise if it is using grid power, it may boost at least temporarily the role of unabated fossil generation. The hydrogen and power business could find themselves competing over a limited resource.[12]

Green hydrogen offers the ability to transport renewable energy from areas with abundant renewable resources to areas where resources are more limited due to space constraints or other locational factors. All visions of a future large-scale use of hydrogen as an energy carrier include the development of an internationally traded market somewhat similar to that seen in LNG today. Today, hydrogen is mostly transported over short distances in trucks as a compressed gas or in liquid form. In the future, the vision is that hydrogen will be transported in large-scale pipelines (in many cases converted from carrying natural gas to hydrogen) or in ships. Ship-based transport could be in the form of liquid hydrogen, ammonia, methanol, or in a liquid organic hydrogen carrier. The optimal form of transport will depend on distance and on end use.

As with LNG, international transportation of hydrogen involves high costs. However, the cost differences of producing green hydrogen in different regions can justify the transportation costs and the development of an internationally traded market. For example, in 2030 we anticipate that it would cost $3.5/kg ($25/MMBtu) to produce firm hydrogen from offshore wind in Northwest Europe, or about $5/kg ($35/MMBtu) for firm hydrogen from onshore wind or solar in Japan. However, in many markets, including Australia, Chile, a number of Middle Eastern/North African states, and South Africa, it is expected that in 2030, it will be possible to produce large volumes of firm hydrogen for less than $2.5/kg. ($20/MMBtu). Development of a hydrogen transport infrastructure could allow this hydrogen to be transported to Northwest Europe or Japan for about $1–2/kg ($7.50–15/MMBtu).

12. This is analogous to the concern of biofuels competing with the food chain for its feedstock.

A side benefit of blue hydrogen is that it is a catalyst for supporting CCS developments. Applying carbon capture to a hydrogen plant is relatively easy, and the plant can then become the host to build up the scale to make CCS work across other industries.

Takeaway: Hydrogen presents an opportunity for the gas industry both as a new demand sector for natural gas as well as a way to extend the life of infrastructure that is critical for a net-zero carbon future.

Ammonia

Like hydrogen, ammonia is an established industry with potential to grow dramatically as a result of the energy transition. Today ammonia is mostly used in the production of fertilizers for agriculture. Although the technology is slightly less advanced than for hydrogen, ammonia has the potential to be used as a source of high-temperature heat in industry, as a fuel for power generation (cofired with coal or in a fuel cell) and as maritime fuel (blended into the existing fuel or in a fuel cell).

Ammonia production requires a source of hydrogen and nitrogen and the development of low-carbon hydrogen will allow for the development of low-carbon ammonia.

Direct use of ammonia is harder to manage than hydrogen because it is more toxic and less easy to combust, but it is being discussed as it is significantly lower cost to transport ammonia over long distances than hydrogen. It is expected that with scale it will cost $0.8/kg ($6/MMBtu) to transport liquid hydrogen 12,500 km but only $0.2/kg ($1.50/MMBtu) for ammonia. If ammonia can be used directly, it could reduce the cost of the delivered fuel by as much as 40%.

Owing to the long distances, much of the discussion of low-carbon ammonia has centered on Japan, while in Europe, discussion has generally been around hydrogen imports owing to the wider range of exporters within relatively close proximity to Europe and the need for onward transport through Europe most likely thought part of the existing, very dense gas network. However, as interest has grown in direct use of ammonia, discussion has turned to imports of ammonia in Europe in addition to hydrogen.

Takeaway: ammonia is easier to transport than hydrogen, presenting an additional avenue for natural gas to decarbonize.

Renewable natural gas (RNG)

RNG is methane-derived from biological sources (biomethane) or electrochemical processes (power-to-gas). Most production comes from anaerobic digestion of biomass from landfills, manure, municipal waste, sewage, and wastewater. Future commercialization of technology allowing conversion of energy crops, agricultural residues, seaweeds, and woody biomass to methane (gasification plus methanation) can unlock additional quantities of low-carbon RNG.

RNG's contribution to emission reduction is much greater than its volume contribution to gas supply. Small quantities of RNG can be mingled with fossil gas to produce a net-zero blend. For example, blending 10–25% of RNG from dairy manure into the natural gas stream results in a zero-emission blend. As a result, policy-makers at the state, provincial, and national level are targeting RNG production in their decarbonization strategies. Currently in the United States, credits for capturing emissions are based upon published emission factors. With the improvement of technology to track and measure emissions, credits can follow more closely the actual emission reductions efforts that are registered and reported.

RNG may have an important role to play in the decarbonization of domestic heating. Heat pumps are considered the leading technology to replace conventional gas furnaces. While heat pumps are a likely solution, they may often be part of a dual-fueled system in association with gas—especially in colder climates. In this case, RNG blending can support that transition to net zero.

The two limitations of RNG are cost and supply. RNG production, when brought up to pipeline quality specs, is normally significantly more expensive than natural gas production. A more dispersed and varied gas stream must be collected and treated. For comparison, current RNG production costs range from $15–23/MMBtu versus an all-in well price of $3–5/MMBtu for dry gas production. While this cost premium is substantial on a unit cost basis, the cost of diluting the natural gas stream will be far less since only a fraction of the overall stream needs to be RNG to make the overall blend net zero.

Supplies are also limited. In the United States, IHS Markit estimates that sustained investment above $10/MMBtu could bring online 100 Bcm per year, or more than one tenth of current US consumption. Not only do the economics become challenging as more marginal supplies come online, but the carbon intensity also increases as the effort of collecting the biomass becomes more onerous. With competition between sectors for clean fuels, supply will be stretched to meet demand.

Takeaway: RNG is an important but limited contributor to reducing CO_2 emissions of natural gas. RNG has the double benefit of being zero-carbon fuel but also reducing methane emissions from agriculture and waste, resulting in potential net-zero or net negative natural gas. RNG can play an early role as no additional investment is required in infrastructure.

Carbon offsets

One well-established alternative to eliminating or capturing emissions is for a company to balance its own emissions through the purchase of verified carbon offsets generated elsewhere. Offsets generated for sale to emitters—which are traded in what is called the Voluntary Carbon Market (VCM)—offer two alternatives: first, removal of CO_2 from the atmosphere, generally through nature-based solutions; or second, by compensating economic actors to reduce their emissions by taking steps that they would not otherwise have taken. Both alternatives rely heavily on nature-based solutions, but generation of avoidance-based offsets has also focused on waste disposal and energy efficiency. Renewable energy has also been a popular source of carbon offsets but is being phased out as avoiding emissions with renewable investments is now viewed as happening organically and not only because of compensation from offset sales. New emerging offset solutions include the capture of methane emissions from landfill sites, wastewater, or agriculture, and may in the future include direct air capture.

While carbon offsets can be used for all fossil fuels, its take-up thus far has been focused on the natural gas sector, where the past two years have brought the emergence of carbon-neutral LNG, which is marketed with all or part of the associated emissions offset by the purchase of credits on the VCM. The concept of carbon-neutral gas is expected to be extended to natural gas delivered by pipeline in the future.

Prices to offset emissions vary widely depending on perceived offset quality and are not comprehensively tracked. Recent data suggest most verified carbon offsets are trading at $8–10 per metric ton, but some offsets are still available at prices as low as $3 per metric ton, a level at which offsets represent an extremely cost-effective solution.[13] It should be noted that offsets in these VCMs are substantially lower than the carbon prices that prevail in leading compulsory markets like the European Emissions Trading System or the California cap-and-trade mechanism.

13. See the IHS Markit Insight *Why are carbon offsets and voluntary carbon markets important?*.

Offsets face two critical issues:

- First, it is questionable whether the offset prices can be maintained at their current low levels as the business scales up and demand for credits grows. If it becomes more cost effective for businesses to reduce their own emissions directly, they will no longer have any incentive to buy offsets. A theoretical ceiling price for carbon offsets would be set by direct air capture technology—since unlike nature-based solutions, it has no limit to its potential—but these costs remain extremely high today, at levels often above $100 per metric ton and possibly multiple times more.

- Second, unless very carefully managed, offsets may be liable to abuse. Four accepted verification standards play a key role in the VCM, but it is essentially self-regulated. It will always be difficult—but critical for the long-term legitimacy of the VCM—to assure that avoidance-based offsets meet the criterion of additionality. Would avoided deforestation actually have occurred without offset compensation? Do specific projects simply involve displacement—i.e., does saving one forest mean that a different forest will be cut down? And, crucially, how focused is forest management on emissions reduction? Over time, it seems inevitable that some form of tight governance system will need to be overlaid on top of the current voluntary system based on verification standards and certification.

Offsets may offer a particular attraction to natural gas. The number of offsets required depends on the carbon intensity of the fossil fuel used. Natural gas as the lowest-carbon fossil fuel, will therefore normally require the fewest offsets and pay the least. The offset market internalizes the carbon advantage that natural gas has in the same way as carbon markets and taxes tilt economic choices in favor of natural gas against alternative, more carbon-intensive fossil fuels. However, given in the wholesale markets that natural gas typically trades at a discount to oil prices, the extra burden of offset costs may be felt keenly.

Ultimately, regardless of any flaws or criticisms, carbon offsets will be needed to reach net-zero, given the difficulty of managing the most difficult-to-avoid GHG emissions—such as the residual 5–10% of emissions that typically remain even after the application of carbon capture.

Takeaway: offsets will be required where elimination of all emissions is impossible or economically prohibitive. Natural gas, as the lowest-carbon fossil fuel, will normally require fewest offsets and therefore pay the least relative to other fuels. But the extra envelope of emissions that offsets can provide at reasonable cost is not clear.

Methane emissions

GHG emissions are not just about CO_2; minimizing the methane emissions associated with natural gas will be essential in order to confirm and strengthen its status as a low-carbon fossil fuel. Methane is a more potent greenhouse gas than CO_2—estimates vary, but current conversion factors from methane to CO_2 equivalent range from 28 to 32.

Progress is being made to reduce methane emissions. In the United States, for example, reported methane emissions from the natural gas sector have fallen since 1990 by 22% even as overall natural gas production rose by about 75% as a result of the shale gas revolution. The main savings have been made in downstream pipeline management, with more focus turning now to upstream production.[14] Over the last 12 months, attention in the United States has turned to upstream emissions associated with the production and delivery of natural gas. A wider drive toward "responsibly sourced gas" aims at reducing methane emissions, flaring and reducing impacts more generally on land, water, and people. The European Commission has developed its own strategy for reducing emissions throughout the value chain.

14. US Environmental Protection Agency, "EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2018 (Table 3-57 data), IHS Markit.

The solution to the methane issue must be the three “M’s” of measuring, monitoring, and mitigating. **Technology is progressing rapidly both to measure emissions at a granular level and to minimize leaks.** Satellite technology—with ever increasing resolution—has grabbed the media headlines. But other technologies including drones and more careful and systematic use and reporting of already established measuring technologies are important. The industry will need to take a strict approach and be able to demonstrate its track record to the highest level of inspection and scrutiny.

When evaluating the relative emission advantages between fuels, it is important to take account of methane emissions associated with all fuels. The emissions of methane from coal mining and distribution—at about 40 million metric tons per year of methane—are about equal to the emissions from the supply and delivery of natural gas.[15] Methane emissions from oil production are also of the same order of magnitude as those from coal. These occur largely from oil production facilities where no market can be found for the gas, which is then flared or, worse, vented. Linking or finding markets for such associated gas therefore represents a route to reducing, not increasing, methane emissions.

Takeaway: the progress in North America in reducing methane emissions is a bellwether for the industry globally. The increased focus on emissions reduction should accelerate progress and the rapid deployment of technological solutions.

Conclusion—The second pillar of decarbonization

Thus far, decarbonization has focused primarily on power generation—renewable capacity will continue to grow, electrification will broaden its reach, and improvements in battery storage will make a decarbonized grid more reliable. Timing, scale, and supply chains will all be important variables. Alongside this trend, a second element of decarbonization must be encouraged urgently, the transition to a low-carbon gas supply that can serve sectors beyond the reach of direct electrification and wires.

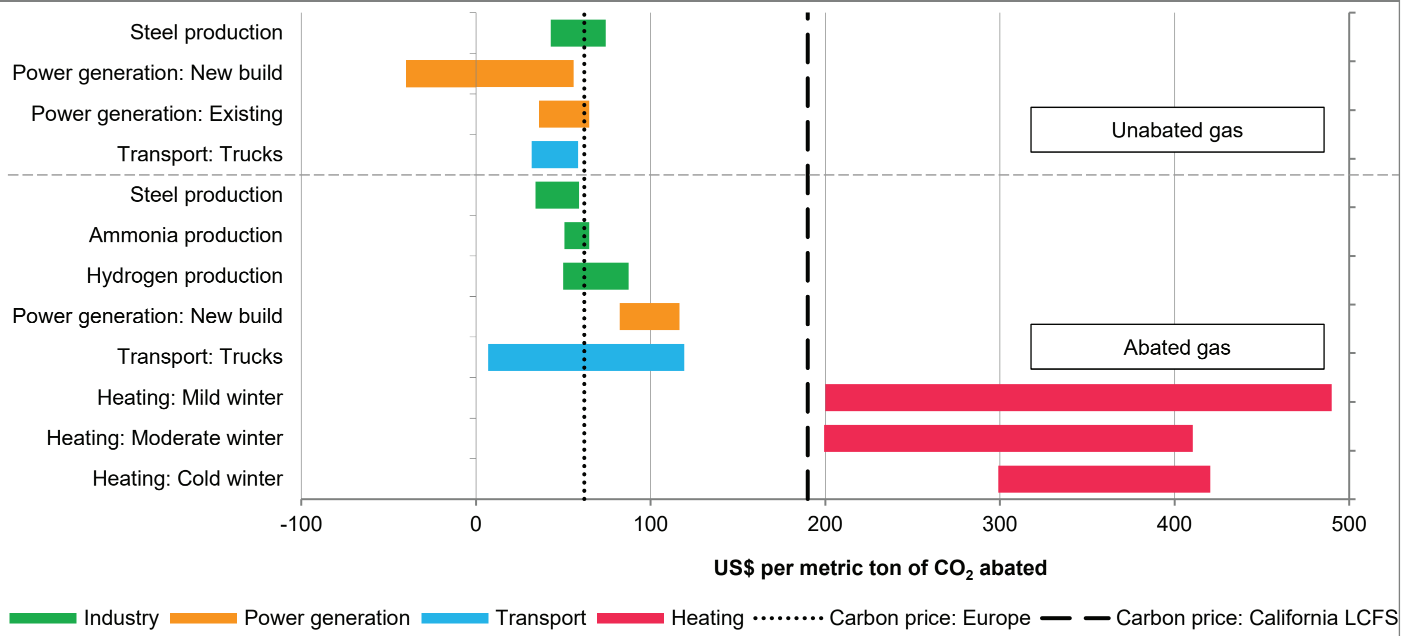
Large-scale investment across the gas value chain and the harnessing of significant capital will be required. However, the emission abatement costs of many of the alternatives discussed within this report fall within a range of $40–60, a range similar to current levels in Europe’s carbon market (see Figure 5).

Today’s gas infrastructure is an indispensable asset to support the transition from unabated natural gas to low-carbon gases to drive deeper decarbonization. Gas pipelines for transmission and distribution, storage facilities, liquefaction plants, and LNG vessels can all be repurposed over time to deliver low-carbon gases. The ability to convert gas infrastructure should ease concerns about “lock-in” of fossil fuels. Investments in new gas infrastructure should not be discouraged; instead they should be considered a prebuild of energy carriers for a lower-carbon future.

15. There is much uncertainty about these figures—for coal, for natural gas, and for oil.

Figure 5

Range of CO_2 abatement costs using gas to reduce carbon emissions compared with incumbent technology



Note: For unabated gas, steel production compares natural gas DRI with coal blast furnace, power generation compares gas-fired power to coal-fired power, and trucks compares LNG with diesel. For abated gas, steel production compares hydrogen DRI with coal, ammonia and hydrogen compare natural gas and CCS with unabated coal, power generation gas to coal, and heating renewable gas systems to unabated gas. LCFS = low-carbon fuel standard.

Source: IHS Markit

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