The Role of Gas in Today's Energy Transitions

Foreword

Natural gas is one of the mainstays of global energy: worldwide consumption is rising rapidly and in 2018 gas accounted for almost half of the growth in total global energy demand. Gas plays many different roles in the energy sector and, where it replaces more polluting fuels, it also reduces air pollution and limits emissions of carbon dioxide. But how widespread and durable is this role in clean energy transitions?

This report from the IEA's World Energy Outlook team provides an evidence base for this important discussion. It finds that switching to natural gas has already helped to limit the rise in global emissions since 2010, alongside the deployment of renewables and nuclear energy and improvements in energy efficiency.

More significantly, it finds that existing infrastructure in the power sector offers an immediate opportunity for major additional emissions reductions, if the economic and policy conditions are right. This would be enough to turn the rising emissions trend around and get global emissions back down to where they were six years ago. Air quality is another important consideration, especially in many emerging economies.

Overall, the case studies in this report show that the contribution of gas to energy transitions varies widely across regions, between sectors and over time. They also highlight the limits of this contribution: gas cannot, of course, do it all. It can bring environmental benefits, but it remains a source of emissions in its own right and new gas infrastructure can lock in these emissions for the future.

So there is homework to do for the gas industry. The near-term priority is to minimise emissions all along the chain from gas production to consumption, with a particular focus on methane emissions. For the longer term, the industry needs to explore seriously the possibilities to reduce further the emissions intensity of gas supply via biomethane or low-emissions hydrogen.

Our analysis also highlights another crucial variable for the future, both for coal and gas: the extent to which emissions are mitigated by large-scale deployment of carbon capture, utilisation and storage technologies.

This report reflects the IEA's "all fuels and technologies" approach to energy policy, as we seek to shape a more secure and sustainable energy future. I take this opportunity to extend my sincere appreciation to all those who provided input and advice in its preparation.

Dr Fatih Birol,
IEA Executive Director

Executive summary

This World Energy Outlook special report examines the role of fuel switching, primarily from coal to natural gas, to reduce emissions of carbon dioxide (CO_2) and air pollutants. Four case studies, covering the United States, the European Union, the People's Republic of China ("China"), and India, reveal the various opportunities, hurdles and limits of fuel switching as a way to address environmental challenges.

It is clear that switching between unabated consumption of fossil fuels, on its own, does not provide a long-term answer to climate change, but there can nonetheless be significant CO_2 and air quality benefits, in specific countries, sectors and timeframes, from using less emissions-intensive fuels. Deployment of carbon capture, utilization and storage technologies, for both coal and gas, is another crucial variable for the future.

The clearest example is the 'quick win' for emissions from running existing gas-fired plants instead of coal-fired plants to generate electricity. We estimate that up to 1.2 gigatonnes of CO_2 could be abated in the short term by switching from coal to existing gas-fired plants, if relative prices and regulation are supportive. The vast majority of this potential lies in the United States and in Europe. Doing so would bring down global power sector emissions by 10% and total energy-related CO_2 emissions by 4%.

The environmental case for new gas infrastructure is more complex, but we find that in more carbon-intensive energy systems like China and potentially India, it can play a significant role alongside the rise of renewable energy. Unlike in the US and Europe, the power sector is not likely to be the main arena for switching. In China, the focus has been on the residential and industrial sectors, as part of a strong policy push to improve air quality. In India, much will depend on the pace at which new city gas distribution infrastructure is built out; switching in the Indian context may affect demand for liquids more than coal.

Our analysis takes into account both CO_2 and methane emissions. On average, coal-to-gas switching reduces emissions by 50% when producing electricity and by 33% when providing heat. Best practices all along the gas supply chain, especially to reduce methane leaks, are essential to maximise the climate benefits of switching to gas.

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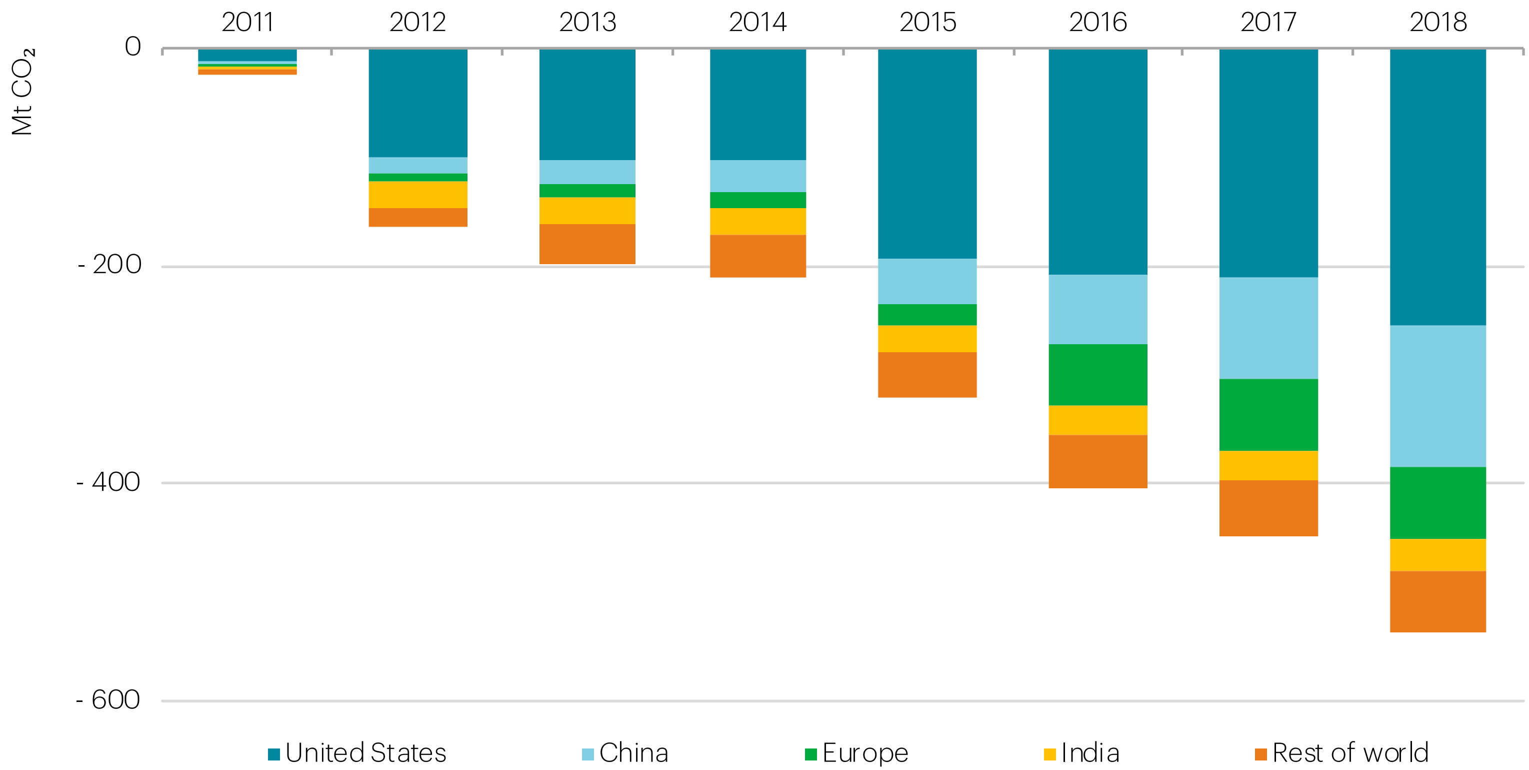
Key findings

Coal-to-gas switching has helped prevent faster growth in emissions since 2010…

CO_2 savings from coal-to-gas switching by region compared with 2010



Note: Mt CO_2 = million tonnes carbon dioxide. Coal-to-gas switching includes emissions reductions in sectors where the market share of coal decreased, and the market share of gas increased within each region. The baseline increase in emissions assumes no improvement in the carbon intensity of energy or the energy intensity of gross domestic product (GDP) since 2010. Savings are calculated as those which occur compared to 2010.

... mainly in the United States and China

After three flat years, global energy-related CO_2 emissions resumed growth in 2017 and 2018; annual emissions of more than 33 Gt represents a dangerous disconnect with global climate goals.

These emissions would have been closer to 40 Gt without changes in the global economic and energy system since 2010 : these include reductions in the energy intensity of the world economy, in part due to greater efficiency, as well as reductions in the carbon intensity of the energy sector related to the rise of renewables and switching to less carbon-intensive fuels. Coal-to-gas switching avoided more than 500 million tonnes of CO_2 emissions over this period.

The role and potential for emissions savings from coal-to-gas switching vary significantly between different regions. In this analysis, we provide four case studies to illustrate these contrasts.

The largest emissions savings from coal-to-gas switching occurred in the United States. The remarkable rise of shale gas has pushed down natural gas prices and underpinned large-scale switching from coal to gas in the power sector, where emissions dropped by a fifth since 2010.

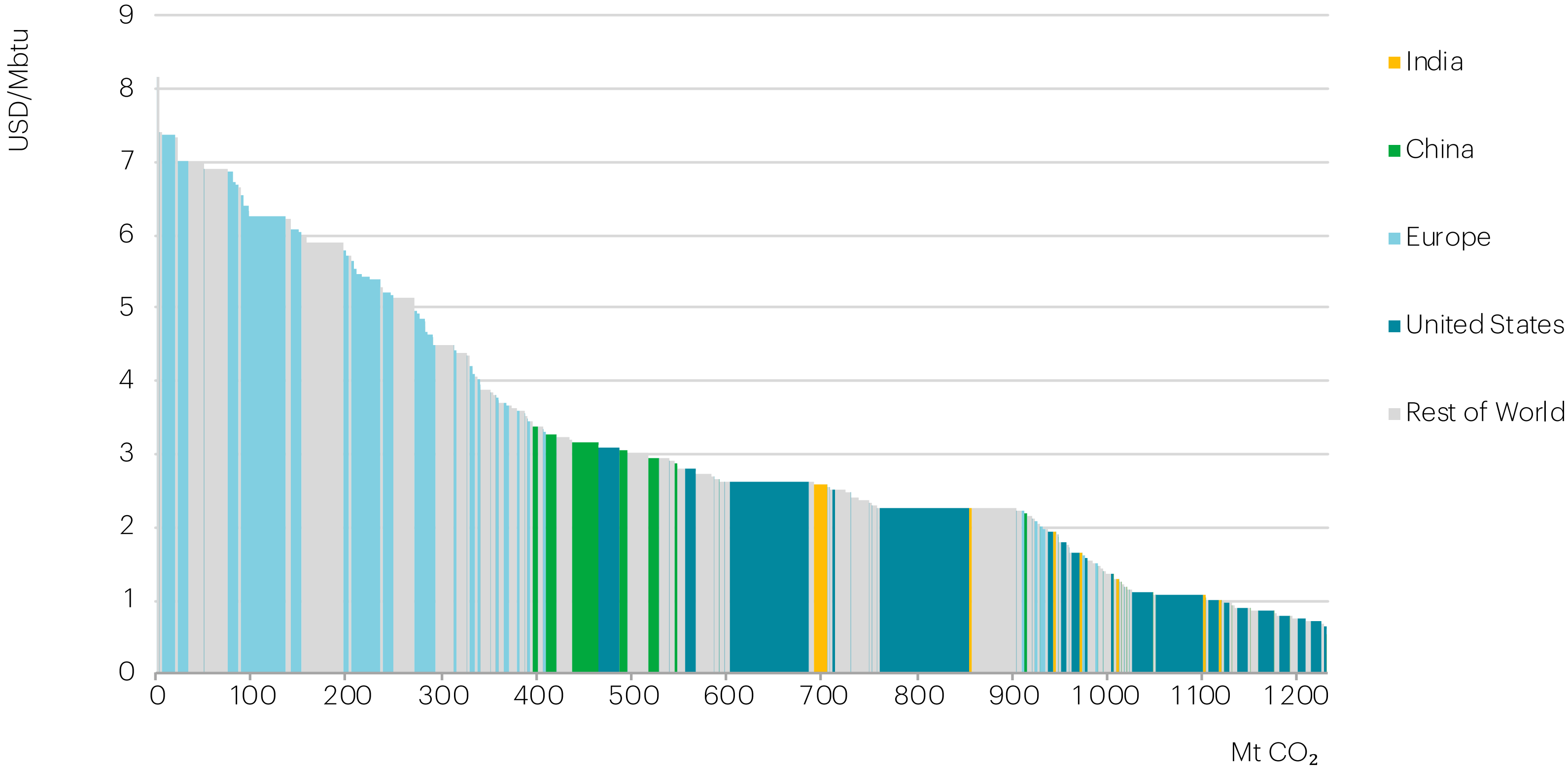
In China, gas demand has risen very quickly in recent years because of a major policy push to improve air quality. Gas has substituted for coal-fired industrial and residential boilers in many urban areas, but switching is much less evident in the power sector.

With the notable exception of the United Kingdom, coal-to-gas switching has not been a major factor in Europe in recent years, but today's configuration of low gas prices and higher CO_2 prices in the European Union is now giving this process renewed momentum.

In India, gas currently has a small share of the energy mix. Large-scale switching has been held back by supply constraints and affordability issues, as well as a lack of infrastructure.

Existing power infrastructure offers a "quick win" for emissions reductions, with further potential savings in excess of 1 Gt of CO_2

Potential CO_2 savings from coal-to-gas switching in the power sector at different gas prices, 2019



Note: MBtu = million British thermal units. Values refer to the average gas price needed for spare available natural gas-fired power generation capacity to be used to displace coal in 2019. Each region's average plant efficiencies, maximum capacities, and load factors are taken from the *World Energy Outlook's* New Policies Scenario. Average delivered coal cost to power plants (per MBtu): **United States**: USD 2.50 **European Union**: USD 5.00; **China**: USD 3.50 **India**: USD 3.00. Carbon prices applied to Europe (EUR 15/t CO_2), Canada, Japan, South Korea, South Africa, Chile and Mexico.

Europe has the largest immediate gas switching opportunity with current fuel and CO_2 prices

The clearest case for switching from coal to gas comes when there is the possibility to use existing infrastructure to provide the same energy services but with lower emissions. Given the time it takes to build up new renewables and to implement energy efficiency improvements, this also represents the quickest route to emissions reductions.

The vast majority of near-term switching potential lies in the electricity sector: we estimate that up to 1 200 Mt CO_2 could be abated worldwide by switching from coal to existing natural gas-fired power plants.

If all of this were to be utilised, it would reduce global coal demand by 15%, bring down global power sector emissions by 10% and total energy-related CO_2 emissions by 4%.

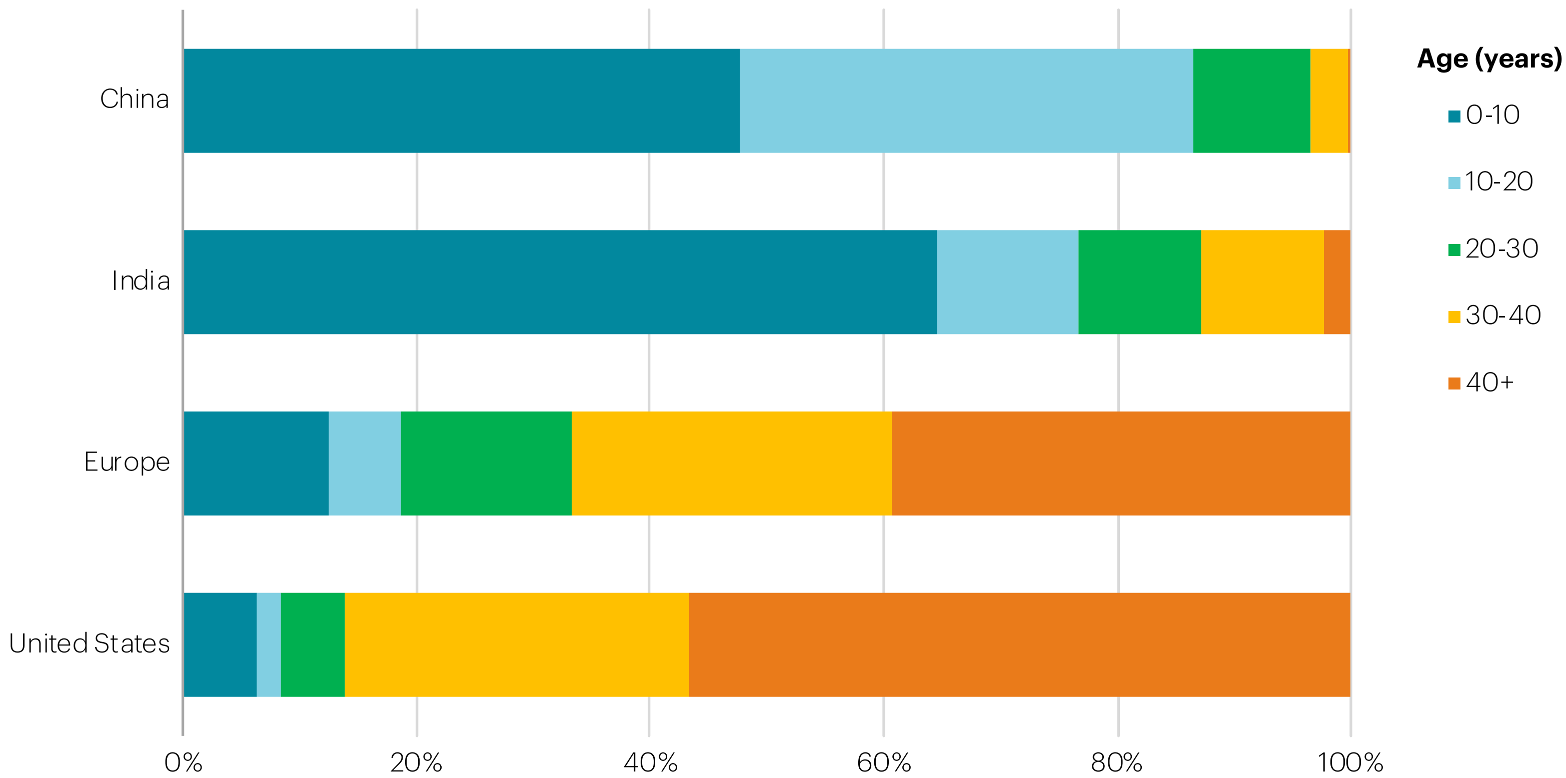
Most of these potential savings lie in mature energy markets with relatively flat electricity demand growth and significant spare gas capacity, notably the United States and Europe. These markets could displace around half of their respective coal-fired power output.

The scale of switching depends on relative prices and on regulation. Ample supply from new liquefied natural gas capacity has helped push spot prices in Europe below USD 5/MBtu in 2019; with a rising carbon price, this has put more than two-thirds of the European Union's gas-fired capacity within a competitive switching range. In the United States, a further 200 Mt CO_2 can be avoided in the United States if prices fall by USD 1/MBtu.

Realising the full global potential for switching would require an extra 450 billion cubic metres (bcm) of gas each year, some 12% of today's global gas production.

The potential to switch away from Asia’s young coal-fired fleet is more limited…

Share of coal-fired plants in selected countries/regions by age



… and gas is not the main challenger to coal for electricity generation in China and India

Using existing power sector infrastructure to switch from coal to gas is one of the least-expensive abatement options in the United States and Europe. But it is a much more difficult proposition in China and India, where electricity market dynamics, demand trends, and relative prices are different, and there is not much spare gas-fired capacity.

China has a large, young, and highly efficient coal-fired fleet. Investment decisions for new gas-fired power stations in China were slightly higher than coal-fired plants in 2018, for the first time, but the coal fleet is nonetheless ten times larger than the gas-fired fleet. Potential savings of around 100 Mt CO_2 from switching are small relative to China's overall power sector emissions of 4 500 Mt CO_2 .

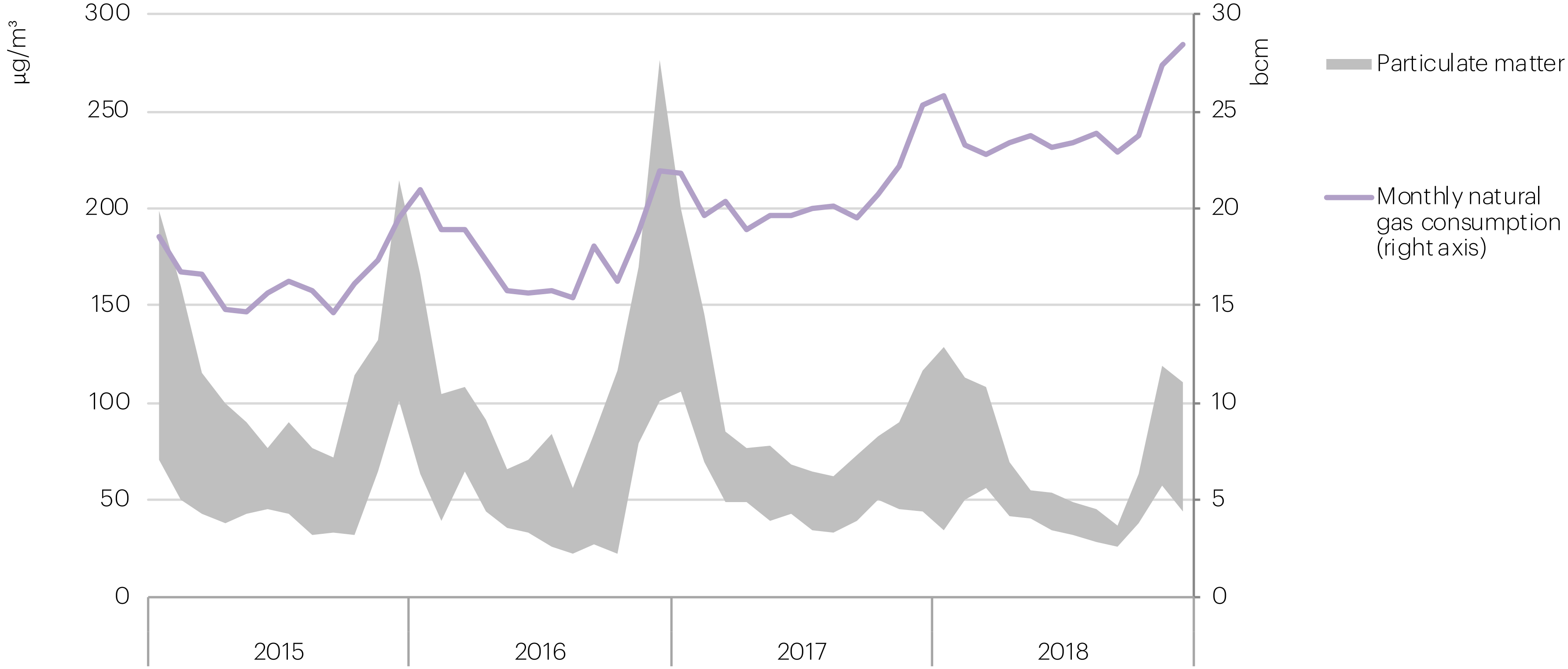
Relative prices make switching challenging, even with the planned introduction of a CO_2 price in China from 2020. We estimate that gas prices would need to fall below USD 4/MBtu to generate market-based switching at scale; this is less than half the cost of today's imported gas.

India does have spare gas-fired capacity, and running it at higher utilisation rates could reduce power sector emissions by around 25 Mt CO_2 . However, much of this capacity is sitting idle because an expected wave of cheaper domestic gas never materialized and – as in China – imported gas is too expensive to find a place in the merit order.

In both countries, at the prevailing gas prices, new onshore wind and solar photovoltaic (PV) are much cheaper ways to generate electricity than new combined-cycle gas turbines (CCGTs). Under these circumstances, the major contribution of gas-fired generation to displacing coal is likely to be an indirect one, by aiding the integration of renewables.

In China, coal-to-gas switching is underway in industry and in the residential sector as part of the fight for cleaner air

Range of air quality measurements for the "2+26" cities and Chinese monthly gas consumption



Note: µg/m³ = microgramme per cubic metre. The "2+26" cities are Beijing and Tianjin, plus an additional 26 cities in the surrounding provinces of Hebei, Henan, Shanxi, and Shandong.

Sources: IEA analysis based on air quality data from the Ministry of Ecology and Environment.

Further switching in China – and the outlook for India – will depend on policies, prices and infrastructure

Gas has low or zero emissions of the main air pollutants: the policy push for coal-to-gas switching in China has been concentrated in urban areas, with the objective to replace coal-fired boilers in industrial facilities and residential buildings. These smaller-scale boilers (unlike those at large coal-fired power plants) are rarely equipped with advanced pollution controls and are a major contributor to poor air quality. Reducing their use, particularly for winter heating, is a key part of the effort to "make China's skies blue again".

In the industrial sector, improved access to gas for Chinese consumers is an important complement to the country's gradual shift towards lighter manufacturing sectors. In the residential sector, an extra 27 million households were connected to the gas grid in 2005-16 and an additional 7 million in 2017-18 alone. China, unlike India, has a significant requirement for residential winter heating.

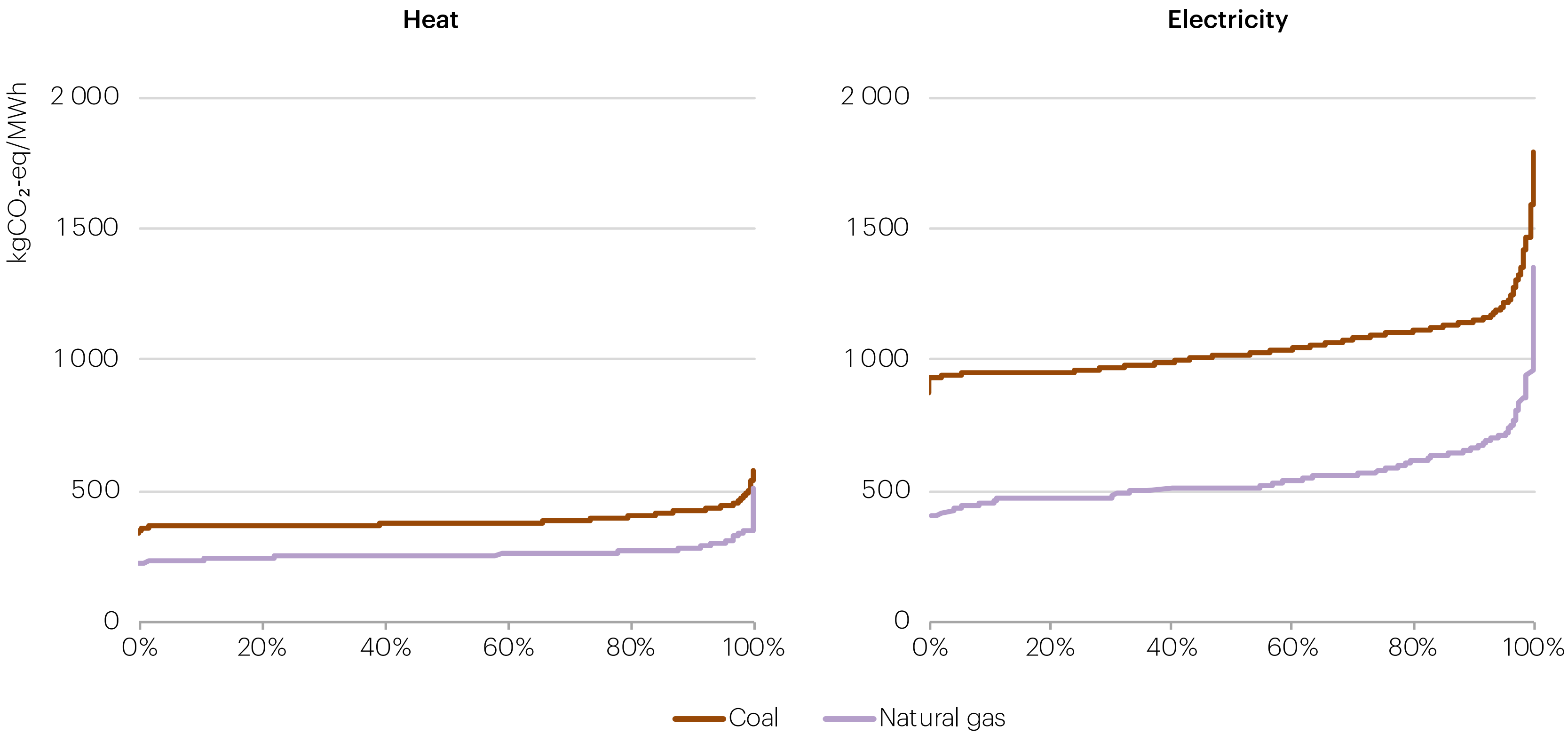
Electricity provides the main alternative route away from reliance on coal. However, not all industrial applications can easily switch to electricity, and the number of new residential gas users in 2018 was twice as high as those opting for electric heating, suggesting that Chinese provincial governments still back the expansion of gas networks, despite concerns about affordability and higher imports.

India, like China, has ambitions to expand the role of gas in its energy mix. The example of the state of Gujarat, on the country's west coast where per capita gas use is ten times the national average, shows that gas can gain ground. Bidding rounds in 2018 and 2019 reflect a major ambition to expand India's city gas infrastructure for industry, residential cooking and water heating, and urban compressed natural gas (CNG) transport.

However, gas networks in India have faced numerous permitting and financing issues, and affordability remains a major hurdle. In the absence of sufficient access to gas, the expansion of India's industrial base may continue to be characterised by a high reliance on coal.

A full lifecycle analysis shows the emissions benefits of gas versus coal …

Full lifecycle emissions intensity of global coal and gas supply, 2018



Note: kg CO_2-eq = kilogrammes carbon dioxide equivalent; MWh = megawatt hours; Mtoe = million tonnes of oil equivalent. Emissions intensities include both indirect and combustion emissions for coal and gas. Horizontal axes equal the total gas and coal used for heat and electricity in 2018 (this excludes coking coal). Heat includes 1 000 Mtoe of coal and 1 300 Mtoe of gas used for heat in industry and buildings in 2018. Electricity includes 2 600 Mtoe of coal and 1 300 Mtoe of gas used in power plants. For electricity, coal and gas are converted to electricity using the average efficiency of power plants across the 25 regions included in the World Energy Model. One tonne of methane is assumed to be equal to 30 tonnes of CO_2-equivalent (the 100-year global warming potential).

… and suppliers can enhance these benefits with high standards all along the gas value chain

Natural gas releases less CO_2 than coal when combusted, but a complete comparison of the climate impacts of the two fuels must also incorporate their indirect emissions – the CO_2 and methane released during production, transport and processing.

Our detailed assessment of today's lifecycle emissions of gas and coal supply finds that switching to natural gas yields significant emissions reductions in nearly all cases. In 2018, gas on average resulted in 33% fewer emissions than coal per unit of heat used in industry and buildings, and 50% fewer emissions than coal per unit of electricity generated.

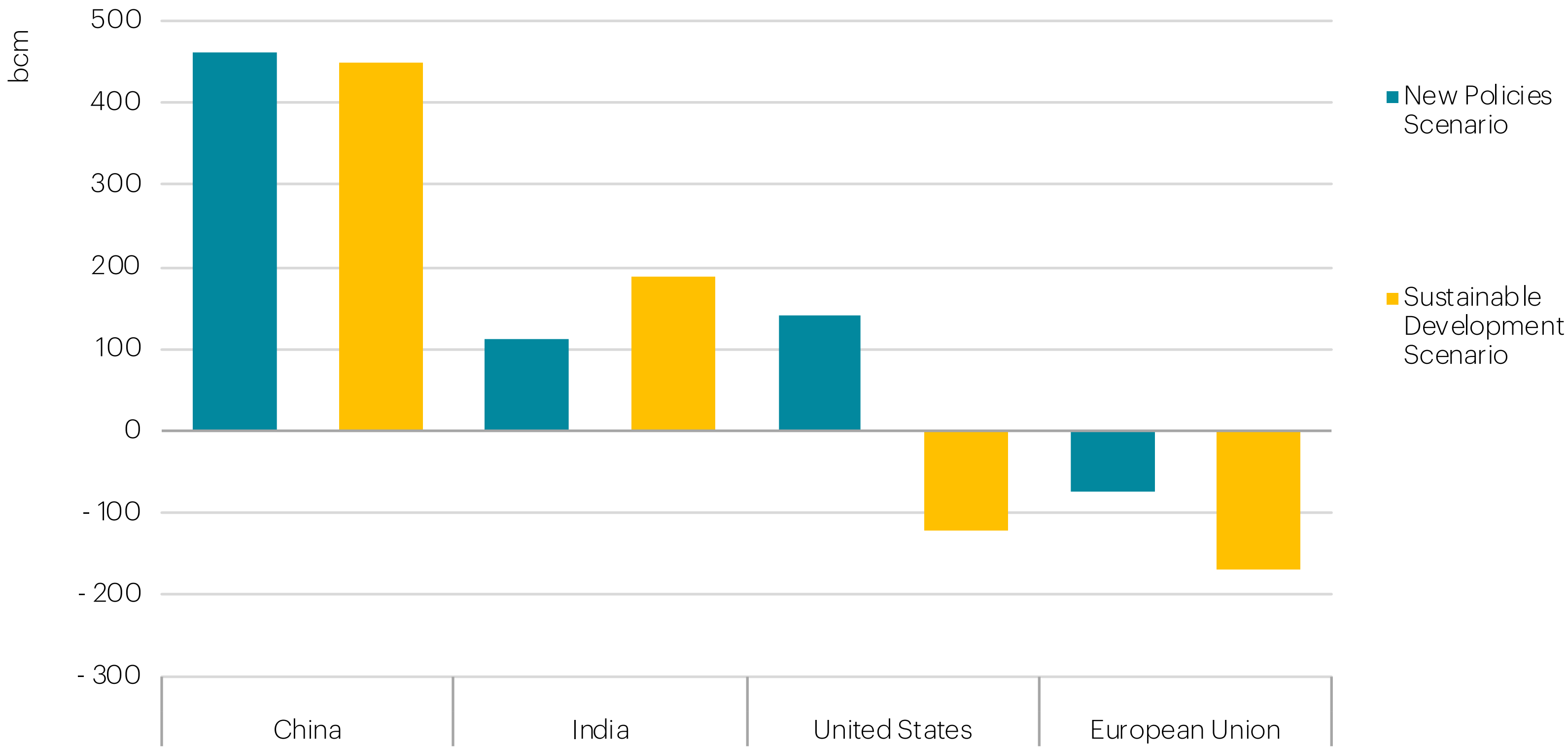
While there is a wide variation across different sources of coal and gas, we estimate that over 98% of gas consumed today has a lower lifecycle emissions intensity than coal when used for power or heat (coking coal is excluded from this comparison since it is used as a reducing agent in steel production).

There is significant scope to further measure and address indirect emissions from oil and gas supply. For example, upstream leak detection and repair programmes or the electrification of liquefied natural gas (LNG) liquefaction have the potential to further reduce the emissions intensity of natural gas. The oil and gas industry is placing increased emphasis on reducing methane emissions along the supply chain, while some governments are considering measures to ensure gas is produced and delivered in as clean and environmentally conscious a manner as possible.

Beating coal on environmental grounds sets a low bar for natural gas, given there are lower-emissions and lower-cost alternatives to both fuels. The falling cost of renewable technologies in the power sector is the clearest case in point. In many power markets, wind and solar PV are already among the cheapest options for new generation, and the role of gas is coming under pressure as a result. The volume of electricity generated by gas-fired plants can be squeezed, but they can nonetheless provide important value by guaranteeing flexible and reliable operation of fast-changing power systems.

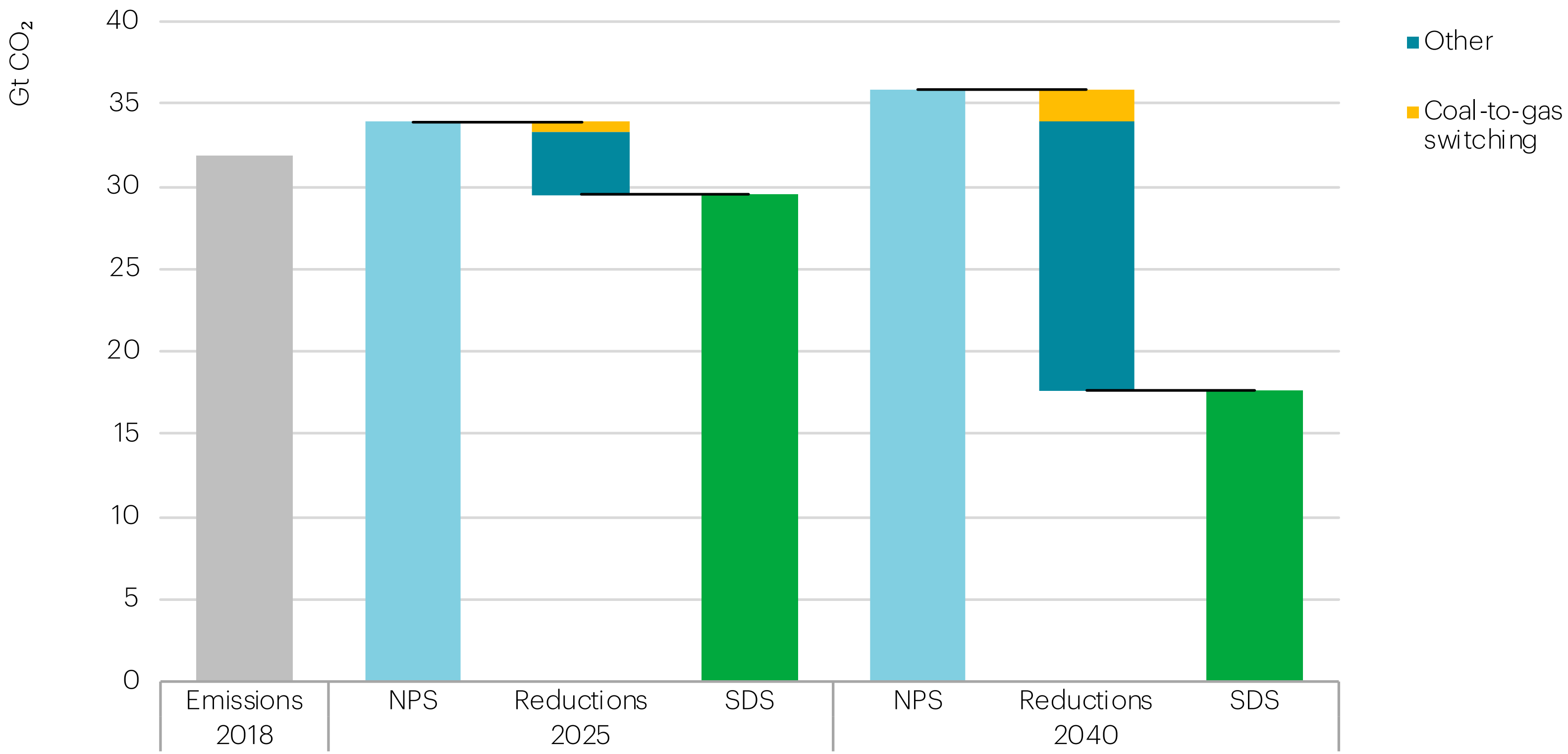
Looking ahead, the opportunity for gas to contribute to further emissions reductions differs by region

Change in gas demand in the New Policies Scenario and Sustainable Development Scenario, 2017 versus 2040



Overall, coal-to-gas switching provides around 8% of the emissions reductions needed in the Sustainable Development Scenario …

The contribution of coal-to-gas switching to global emissions reductions in the Sustainable Development Scenario



Note: NPS = New Policies Scenario; SDS = Sustainable Development Scenario. *Coal-to-gas switching* includes the contribution of gas fitted with carbon capture, storage, and utilisation technology. *Other* includes emissions reductions from improvements in end-use efficiency; greater deployment of renewables, biofuels, and nuclear energy; reducing upstream emissions; and other fuel switching.

… but the benefits provided by gas need to be weighed against the risks of locking in future gas-related emissions

In the World Energy Outlook New Policies Scenario to 2040, gas use increases by an average of 1.6% each year, helping to meet existing energy policy commitments and ambitions. However, the New Policies Scenario puts energy-related CO_2 emissions on an upward trend to 2040, far from the emissions trajectory required to tackle climate change.

Renewable energy and efficiency measures are the most important drivers of the energy sector transition of the Sustainable Development Scenario – a scenario that is fully consistent with the Paris Agreement. Natural gas still plays a role in this scenario, although this varies by country, sector, and timeframe.

In mature markets like the United States and European Union, coal-to-gas switching is a compelling near-term option for reducing emissions, given existing infrastructure and spare capacity. Gas can also contribute to security of supply by balancing variable renewables and meeting peaks in demand. However, given the need for decarbonisation efforts to intensify, a role for unabated gas in the energy mix becomes increasingly challenging beyond 2030.

Gas plays a more prolonged role in emerging economies that are very carbon-intensive today, helping to push more polluting fuels out of the system, notably in China and India's industrial sectors. Gas demand is, therefore, similar in China between the New Policies Scenario and the Sustainable Development Scenario and is higher in India.

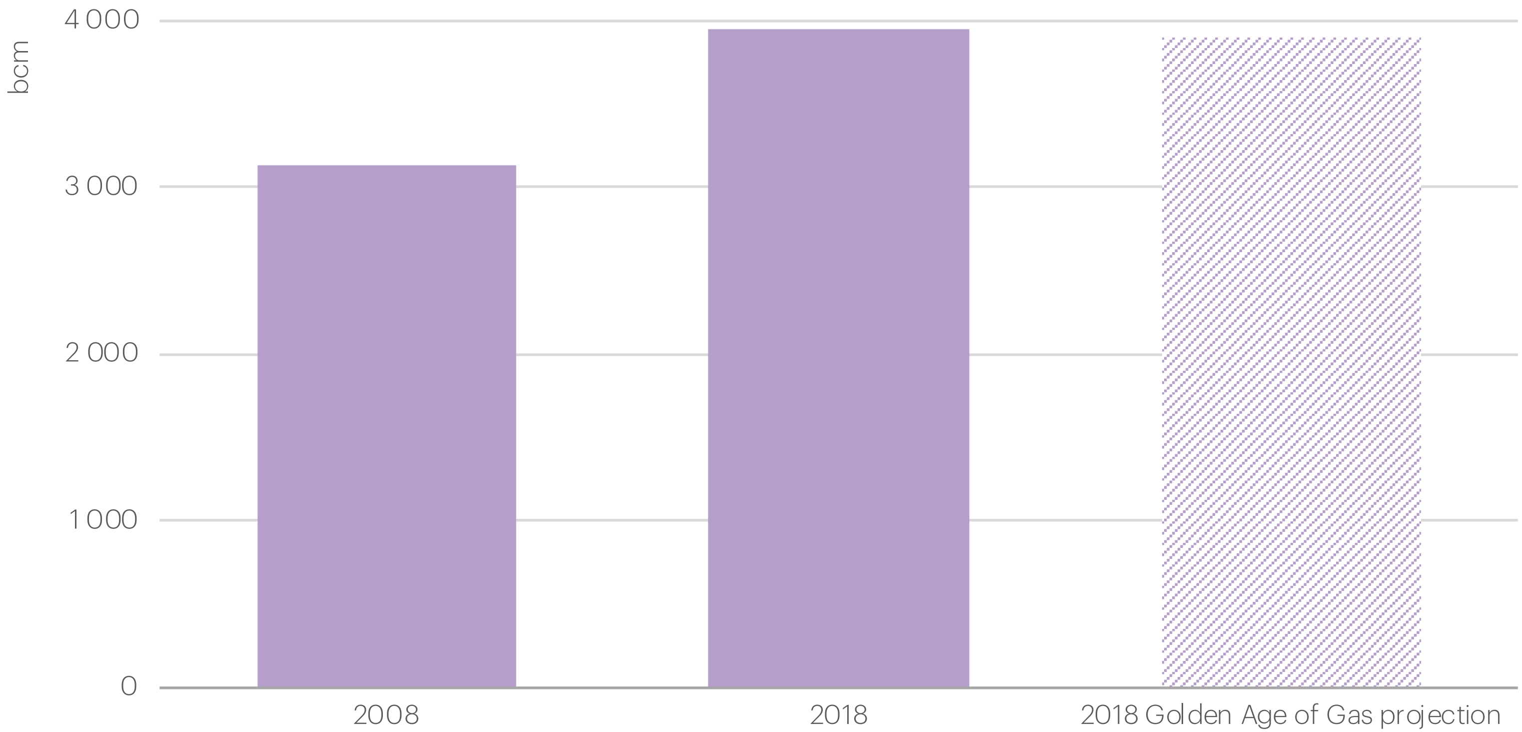
While renewables and efficiency do the heavy lifting, coal-to-gas switching contributes around 8% of the emissions savings required in the Sustainable Development Scenario. Switching also helps to improve air quality, especially in the near term; it contributes to the 50% reduction in coal-based sulphur dioxide (SO_2), and particulate matter ($PM_{2.5}$) emissions in the period 2015-25.

A crucial variable for the future is the extent to which carbon capture, storage and utilisation (CCUS) technologies are deployed. CCUS can reduce emissions from the combustion of coal and gas in power generation and deliver deep emissions reductions in industrial sectors such as steel, cement and chemicals. CCUS plays a role in the Sustainable Development Scenario, especially for industry, but this would require a major acceleration in deployment compared with today.

Natural gas and its competitors

Gas has had a golden run

Gas demand for 2018 compared with projections from the IEA report, *Golden Age of Gas* (2011)



Renewables and gas have been the major growth stories of recent years …

In 2011, a World Energy Outlook special report asked whether the world might be poised to enter a "golden age of gas". This upside scenario for gas was based on supportive assumptions about gas availability and price, as well as policies on the demand side that could promote its use in certain countries, notably China.

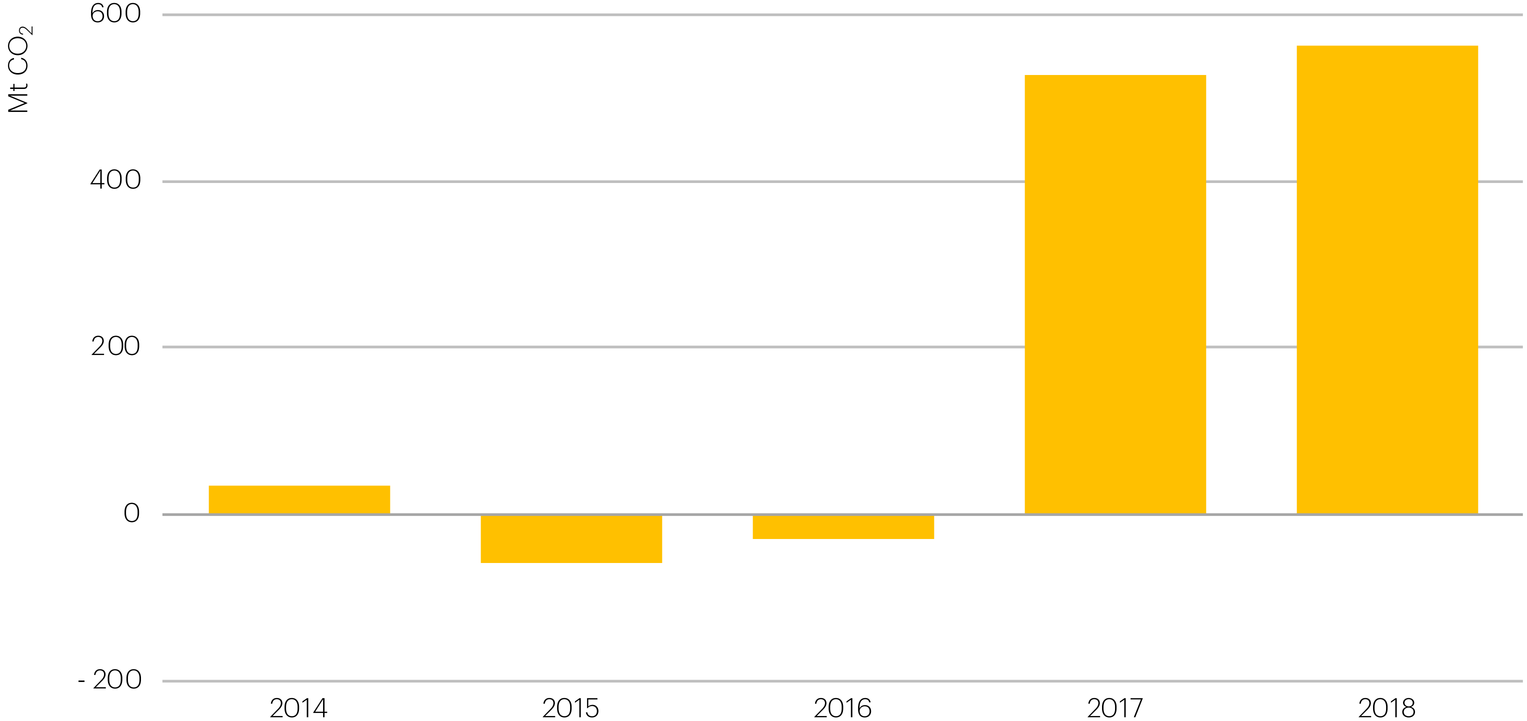
A few years on, global gas consumption is now very close to this golden age projection; the story of a relative abundance of gas – led by the United States – has come to fruition, and economic expansion and air quality concerns have underpinned rapid growth in China. Natural gas accounted for 45% of the increase in global energy demand in 2018.

The rise of natural gas has been accompanied by a strong increase in renewable energy, particularly in the power sector, where renewables accounted for 45% of the growth in power generation in 2018. Renewables now account for around one-quarter of total power generation worldwide, second only to coal (at 38%). Expanding the use of low-carbon electricity is a major vector for energy transitions.

There have been noticeable shifts in individual sectors and countries, but the growth in renewables and gas – alongside steady improvements in energy efficiency – has not yet pushed the consumption of other fuels into decline. Global coal use did fall in 2015-16 but has since bounced back. Oil demand has been robust, rising at an annual rate of well above 1 million barrels per day.

… but global CO_2 emissions have yet to turn a corner

Change in global energy-related CO_2 emissions by year



Is gas part of the solution, or part of the problem?

After three flat years, global energy-related CO_2 emissions resumed growth in 2017 and 2018, a trajectory that represents a dangerous disconnect with global climate objectives.

Natural gas has low air pollutant emissions, giving it the potential to rapidly improve air quality when substituting other combustible fuels. Switching from coal to gas also reduces CO_2 emissions by around 40% for each unit of energy output. Methane leaks to the atmosphere along the gas and coal value chains (considered in detail below) are also an important part of the picture.

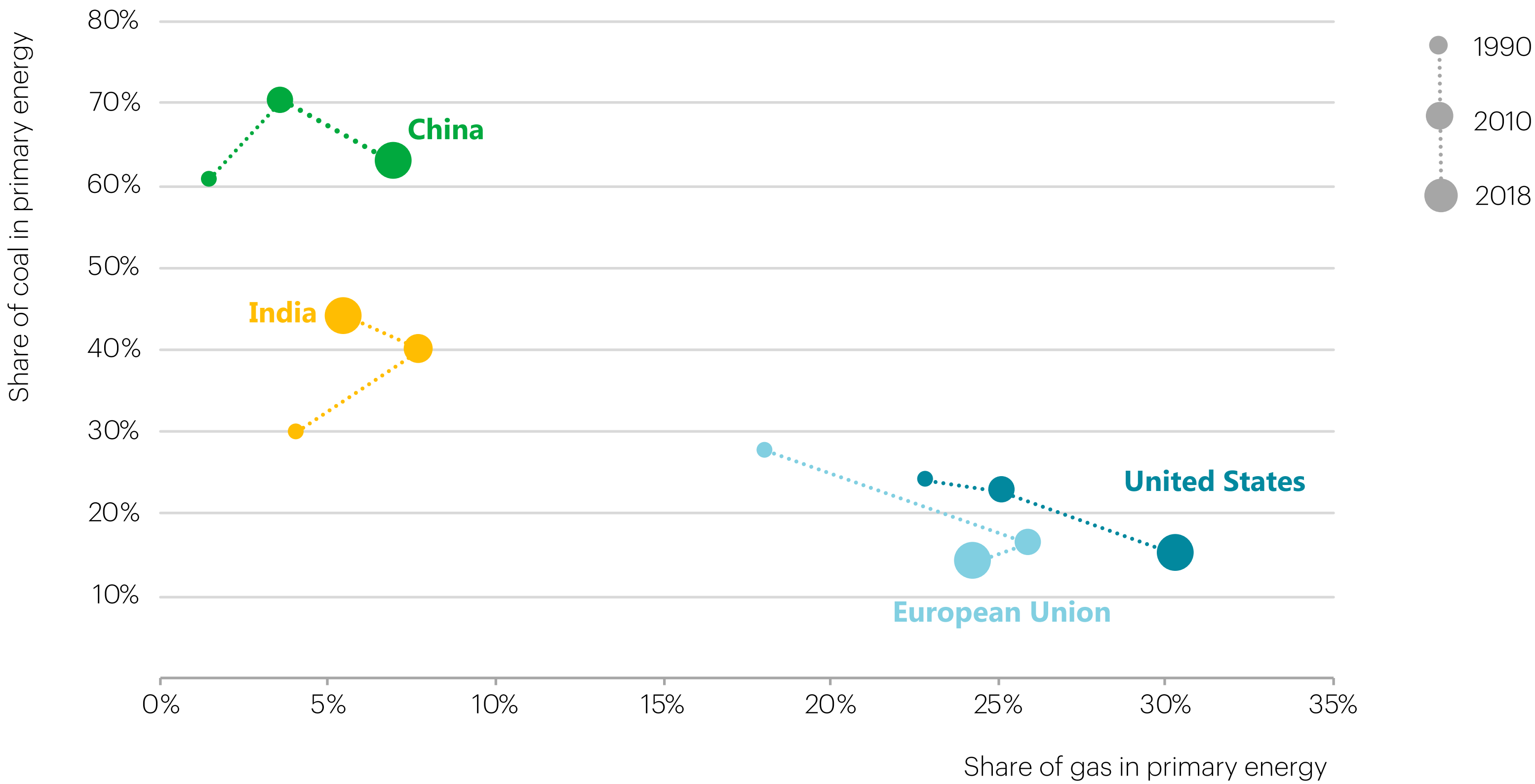
It is evident that switching between the unabated combustion of fossil fuels, on its own, is not going to provide the answer to the challenge of climate change. This was recognised in our 2011 analysis: a golden age of gas does not mean a golden age of emissions reductions.

But this does not preclude a role for gas in the transformation of the energy sector. There is no single solution to turn emissions around: multiple approaches, policies, and technologies will be required at different times. These will be led by renewables and efficiency, but – in certain timeframes and sectors – we find that switching away from more polluting fuels to gas can play an important role.

Gas delivers valuable energy services, some of which – notably seasonal storage, high-temperature heat for industry, and winter heating for buildings – are difficult to replicate cost-effectively with low-carbon alternatives. The problem lies with the related emissions, either from combustion or from methane leaks. As discussed below, these emissions can be reduced.

There have been major shifts in the coal–gas balance in key markets

Change in shares of coal and gas in primary energy in selected countries and regions between 1990 and 2018



Gas plays very different roles in the four countries and regions examined in this report

The four countries and regions chosen for in-depth analysis in this report – the United States, Europe, China and India – display a wide range of market and policy dynamics, which affects the ways in which coal and gas compete.

Thus far, gas has played a relatively minor role in the energy mix in both China and India. In both cases, the energy mix is dominated by coal: China and India account together for more than 60% of global coal demand today. Both countries are large producers of coal, and the affordability, convenience, security and economic activity associated with domestic coal supply features in policy discussions alongside the undoubted environmental downsides of its use.

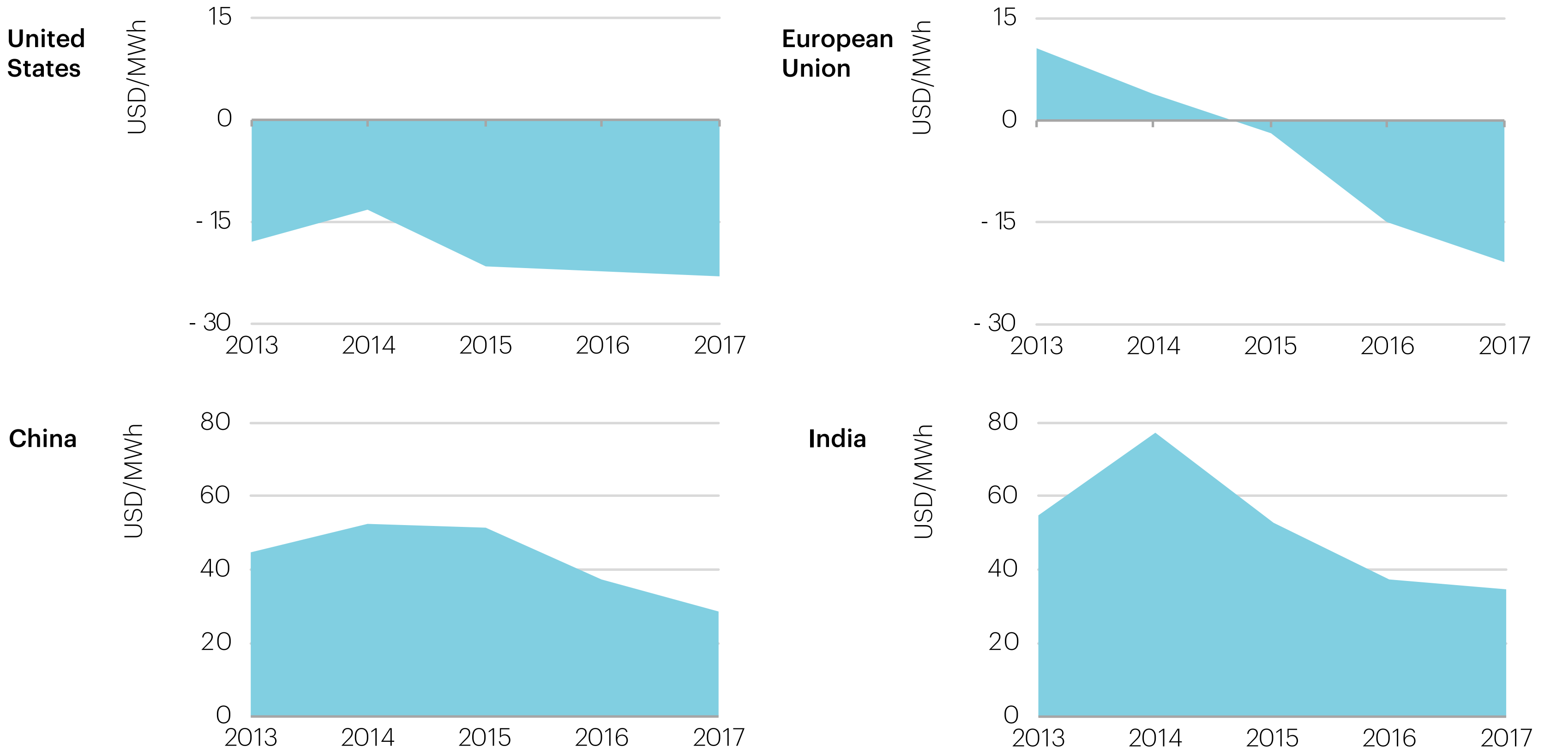
In recent years, gas consumption and imports have grown very strongly in China, pushed primarily by increasing Chinese concerns about the quality of the country's development, and the quality of the air in particular. These policy efforts have produced a 30% increase in gas demand in the last two years. India also has ambitions to expand the role of gas in its energy mix, but these have not yet been realised because of supply, infrastructure and affordability issues.

Switching to natural gas has a long history in Europe; the development of indigenous gas resources in northwest Europe during the 1960s and 1970s supported a move away from oil and coal in the residential heating sector, and there were also notable shifts away from coal to gas in industry and in power. However, since 2010, the shares of both coal and gas have fallen as policy support for renewables and efficiency has accelerated.

In the United States, the shale revolution has had a dramatic effect on gas supply and prices. Alongside some state-level as well as federal-level environmental policies – such as Mercury and Toxic Standards (MATS) regulations governing industrial pollutant emissions – this has pushed gas into the energy mix while pushing out coal. Since 2005, the market share of gas has increased more than any other energy source.

Helped by the US shale revolution, gas is becoming more competitive versus coal worldwide...

Difference in levelised cost of electricity from natural gas (CCGT) versus coal plants (supercritical) in selected regions



Notes: Levelised cost of electricity (LCOE) is calculated as LCOE of gas CCGT minus LCOE of supercritical coal in each region.

… but the economic case for gas varies widely by region

The shale revolution in the United States has brought down the prices at which gas markets find equilibrium around the world, first indirectly – as gas originally developed for the US market sought alternative consumers – and now directly via US gas exports. The growth of destination-flexible, hub-priced LNG exports from the United States is providing a catalyst for a more liquid global gas market.

However, even though global gas markets are becoming more interconnected, there is still no "global gas price". The lower energy density of gas compared to oil or coal means that transportation by pipeline or as LNG takes a relatively high share of the delivered cost, making geographical proximity to resource-rich areas an important determining factor for affordability.

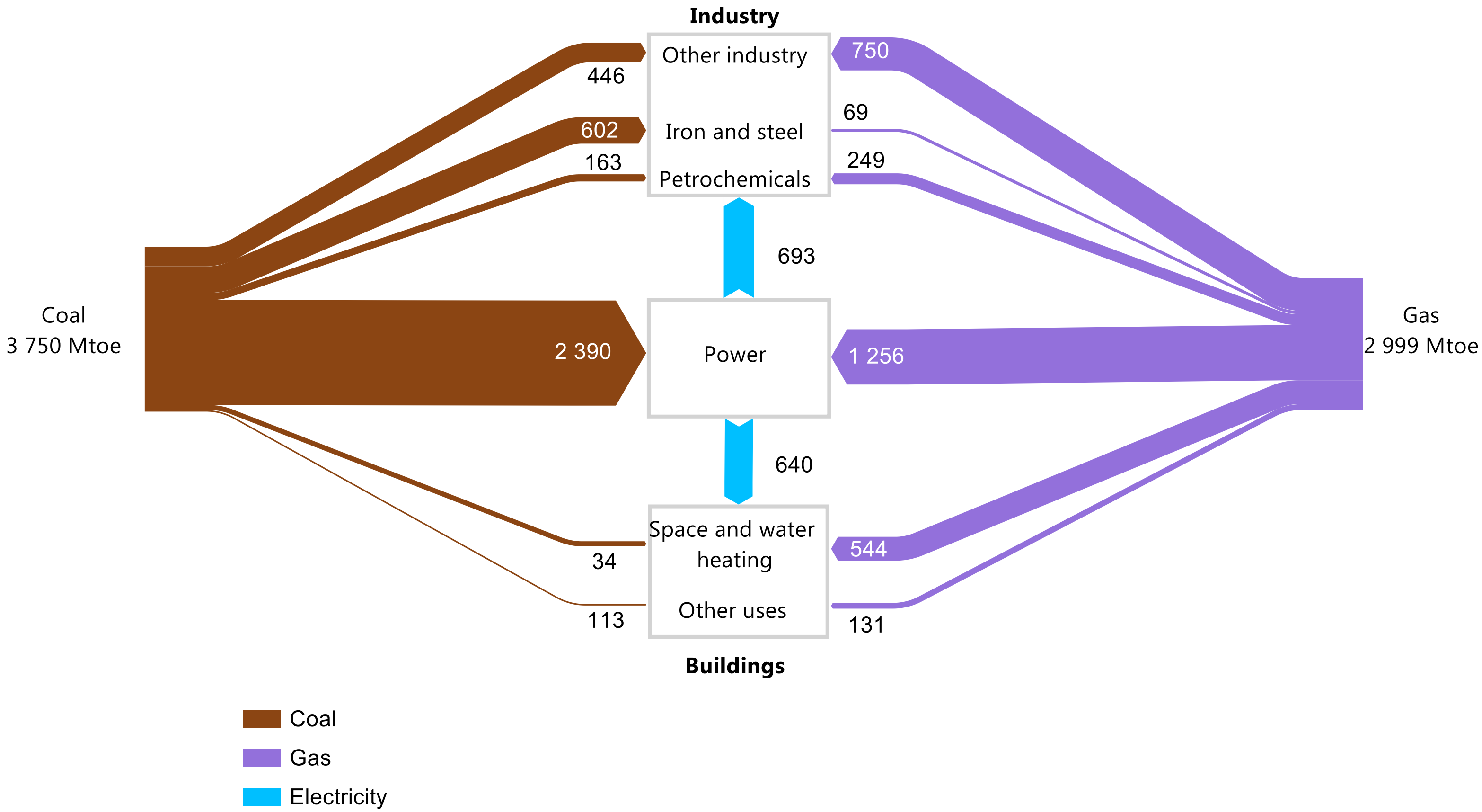
In regions and countries that import gas over long distances, as is the case for Europe, India and China, processing and transport costs push up the price of gas significantly compared with exporting countries like the United States. These regional price differentials, relative to the United States, settle in the New Policies Scenario at around USD 4/MBtu to USD 4.5/MBtu for Europe and USD 5/MBtu to USD 5.5/MBtu for Asian destinations.

While subject to variation, these costs alone (excluding the underlying costs of the gas itself) already exceed the delivered costs of coal imports at USD 100/t. This means that a policy push is typically required in gas-importing markets to bolster the case for coal-to-gas switching. This can take the form of a CO_2 price or other regulations that tilt the calculation in favour of gas.

How the economics work for gas depends also on how the fuel is used and what alternatives are available. This can vary widely across different parts of the energy sector and will also vary over time with the falling cost of key renewable technologies.

Gas is going head-to-head with coal in power and industry...

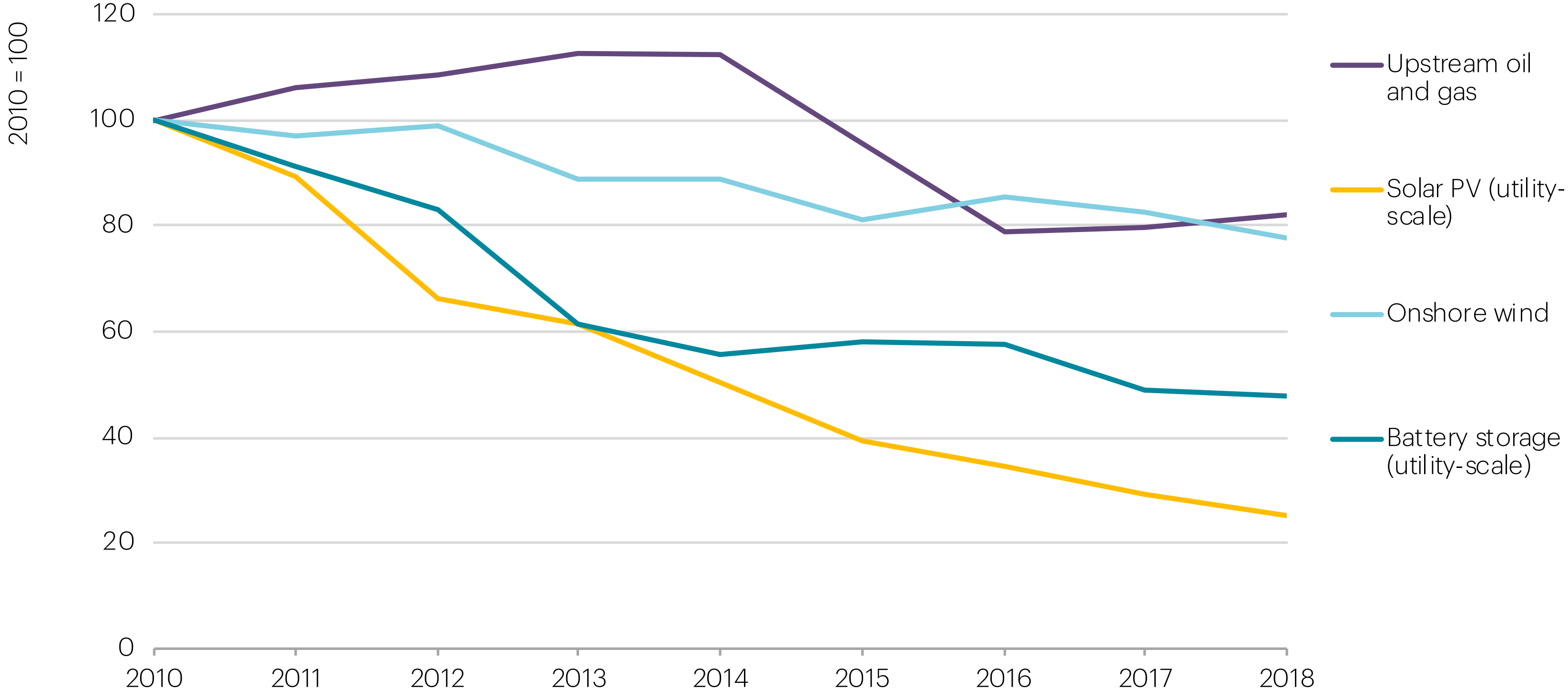
Selected flows of coal and gas in the global energy balance, 2017



Note: *Industry* includes other energy sector and other non-energy use. Figure excludes gas and coal use in the transport sector.

… but there are alternatives beyond gas, and their costs are falling faster

Change in capital costs of selected fuels and energy technologies



Source: IEA analysis using calculations for solar PV and wind costs based on data from International Renewable Energy Agency (IRENA).

The competitive landscape for gas therefore varies substantially by sector

The switching calculation for gas, and the competing fuel, changes across different parts of the energy sector. The main arena for competition between coal and gas in the United States and Europe has been electricity generation, but – as we discuss below in the case studies – this is not necessarily the case in the emerging markets of Asia.

Among the end-use sectors, industry is a major source of projected growth in gas demand. Gas has a clear competitive advantage in industrial applications where it displaces more costly oil products. Light industries (e.g. manufacturing, textiles, and food and beverages) that rely on coal may also be willing to switch to gas even if it is more costly, simply because gas is more convenient and cleaner.

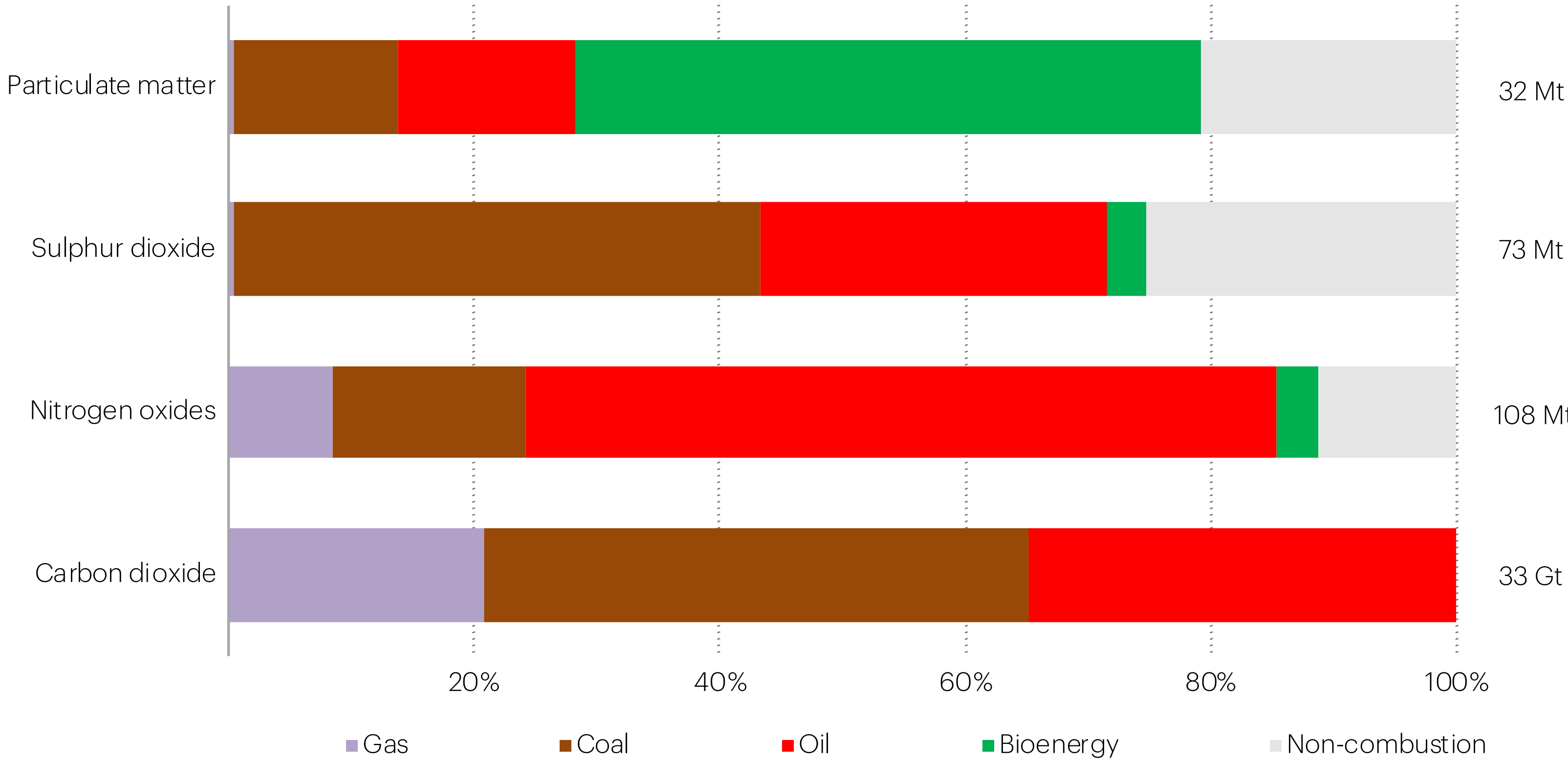
The majority of gas used in buildings today is for space heating. However, demand for space heating in most developing countries is limited (with the important exception of China), even though other end uses, such as cooking and water heating, are increasing in importance. The competition for gas in the buildings sector comes from electricity, the direct application of renewables, e.g. from heat pumps, and from energy efficiency.

In the transport sector, natural gas can provide an alternative to oil products for passenger, freight, and maritime uses. Gas is often cheaper (USD 70/barrel of oil is equivalent to USD 12.50/MBtu gas) and offers advantages in terms of pollutant emissions – although only a 20% reduction in CO_2 emissions. However, refuelling infrastructure is typically a constraint, and in most countries, electricity is emerging as the preferred way to move away from oil for passenger vehicles.

What is the environmental case for switching?

Gas makes a relatively small contribution to today's emissions...

Share of gas in total energy-related emissions of selected air pollutants (2015) and CO_2 (2018)

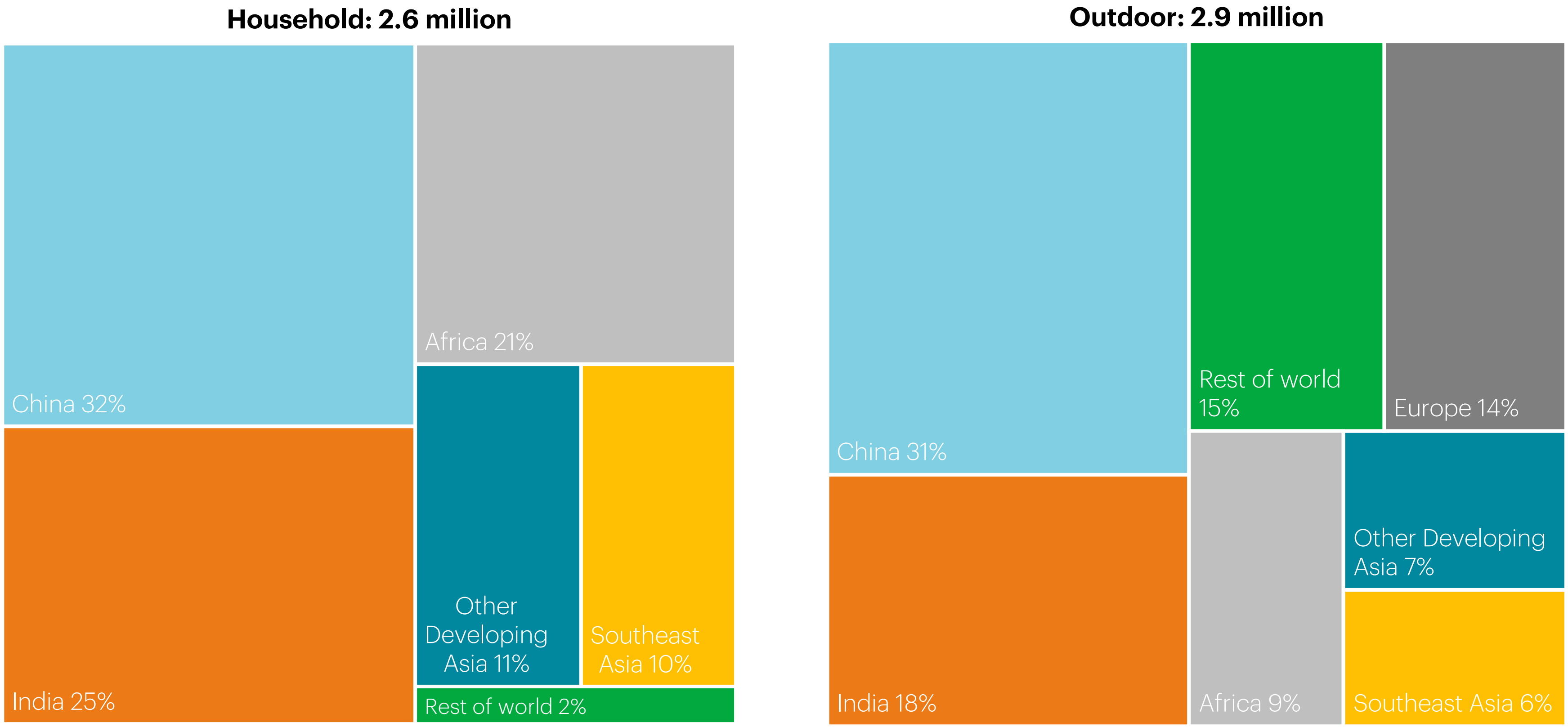


Note: Non-combustion emissions are process emissions in industry and non-exhaust emissions in transport.

Source: IEA analysis based on data from International Institute for Applied Systems Analysis (IIASA).

…Making gas an ally in the fight to curb the health impacts of poor air quality

Premature deaths attributable to household and outdoor air pollution, 2015



Source: IEA analysis based on data from International Institute for Applied Systems Analysis (IIASA).

Combustion emissions from gas are limited but rising as gas use grows

The emissions that arise from the combustion of natural gas show clear advantages for gas relative to other fossil fuels and, for particulate emissions, a favourable comparison with bioenergy.

In relation to CO_2, the combustion of natural gas results in emissions savings of some 40% relative to coal for each unit of energy output. The advantage over oil is less striking but still substantial: CO_2 emissions from gas combustion are around 20% lower than for oil.

The edge of natural gas over other combustible fuels is reinforced by looking at the emissions of the main air pollutants: $PM_{2.5}$; sulfur oxides, mainly SO_2; and nitrogen oxides (NO_X). These three are responsible for the most widespread impacts of air pollution, either directly or once transformed into other pollutants via chemical reactions in the atmosphere.

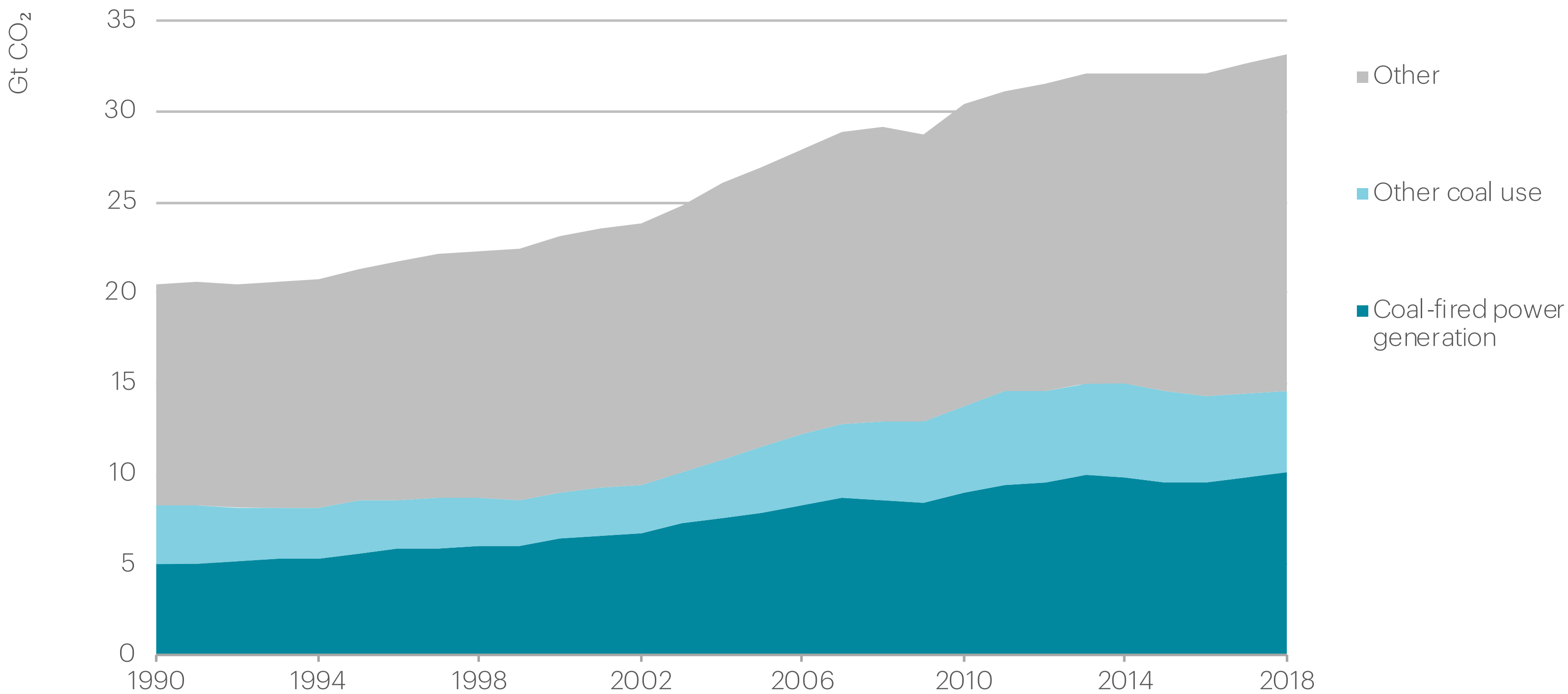
The controlled burning of natural gas releases very few particulate emissions into the air, while nearly all SO_2 naturally present in natural gas is removed prior to transport. The combustion of natural gas does produce NO_X, although gas accounts for less than 10% of global energy-related NO_X emissions.

As of 2018, the combustion of gas was responsible for 21% of energy sector CO_2 emissions, well behind the shares of coal (44%) and oil (35%). However, the share of gas in global CO_2 emissions is edging higher as its role in the energy system expands, in some areas at the expense of coal.

In the New Policies Scenario, gas-related CO_2 emissions rise from just under 7 Gt today to almost 10 Gt in 2040, corresponding to an increase in the share of gas in total emissions from 21% to 27%. In the Sustainable Development Scenario, gas-related CO_2 emissions in 2040 are around today's levels but comprise a much larger share of the total, at almost 40%.

Coal-fired power is by far the largest component of today's CO_2 emissions

Global energy-related CO_2 emissions



There is a huge disconnect between today's emissions trends and global climate goals

Driven by higher energy demand, in 2018 global energy-related CO_2 emissions rose by 1.7% to a historic high of 33.1 Gt CO_2. Emissions from all fossil fuels increased, and the power sector accounted for nearly two-thirds of emissions growth.

Coal-fired power plants were the single largest contributor to the growth in emissions observed in 2018, with an increase of 2.9%, or 280 Mt, compared with 2017 levels. Nearly 10 Gt of CO_2 emissions – around one-third of global energy sector emissions – comes from coal-fired power generation, making this by far the largest single category of emissions.

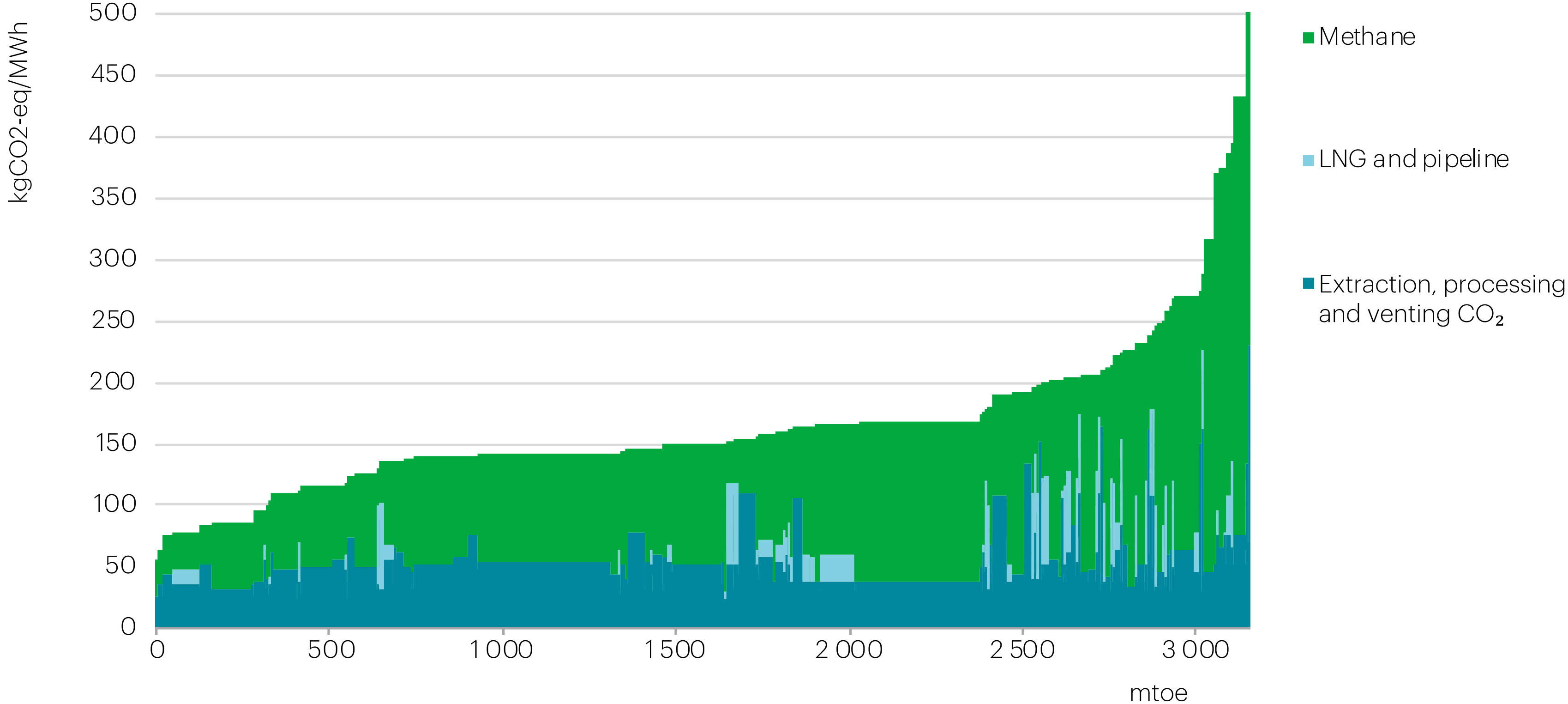
Coal's shift to Asia continued in 2018. The growth in demand for coal took place in only some countries in Asia – China, India, and a few other countries in South and Southeast Asia – primarily because of the increased demand for electricity in these countries. Southeast Asia was the only region where the share of coal-fired generation in the power mix increased in 2018: coal use in Indonesia, Viet Nam, the Philippines, and Malaysia increased significantly.

In addition to coal used for power generation, there is just under 4.5 Gt of coal-related emissions in end-use sectors; most of this is for industrial use (steam coal and coking coal), although there is also some continued use of coal for municipal and residential heating.

Global energy-related CO_2 emissions need to fall below 18 Gt by 2040 to meet the objectives of the Sustainable Development Scenario. This includes a 75% reduction in coal-related emissions compared to today's levels.

Indirect emissions along the gas supply chain are dominated by methane …

Indirect GHG emissions intensity from global gas production, processing, and transport in 2017



Notes: *Extraction, processing, and venting CO_2* includes emissions from the energy used to power the drilling equipment, maintain pressure in the reservoir, power auxiliary services, and process the natural gas, and emissions of any naturally-occurring CO_2 that is vented to the atmosphere. *LNG and pipeline* includes emissions that occur during the liquefaction, shipping, and regasification of LNG or emissions from pipeline compressor stations. *Methane* includes both upstream and downstream emissions; one tonne of methane is assumed to be equal to 30 tonnes of CO_2-equivalent (the 100-year global warming potential).

… which is an increasing focus for both industry and policy makers

The environmental impact of coal-to-gas switching needs to consider all sources of emissions that occur, including those prior to consumption: CO_2 and methane are released during producing, transporting, and processing gas and coal (these are known as "indirect emissions").

For this study, we conducted a new comprehensive global assessment of the emissions arising from coal supply, complementing our earlier analysis (in the World Energy Outlook 2017 and 2018 editions) of emissions along the gas value chain. This analysis takes into account how gas and coal are produced, processed, transported, and ultimately consumed across different regions.

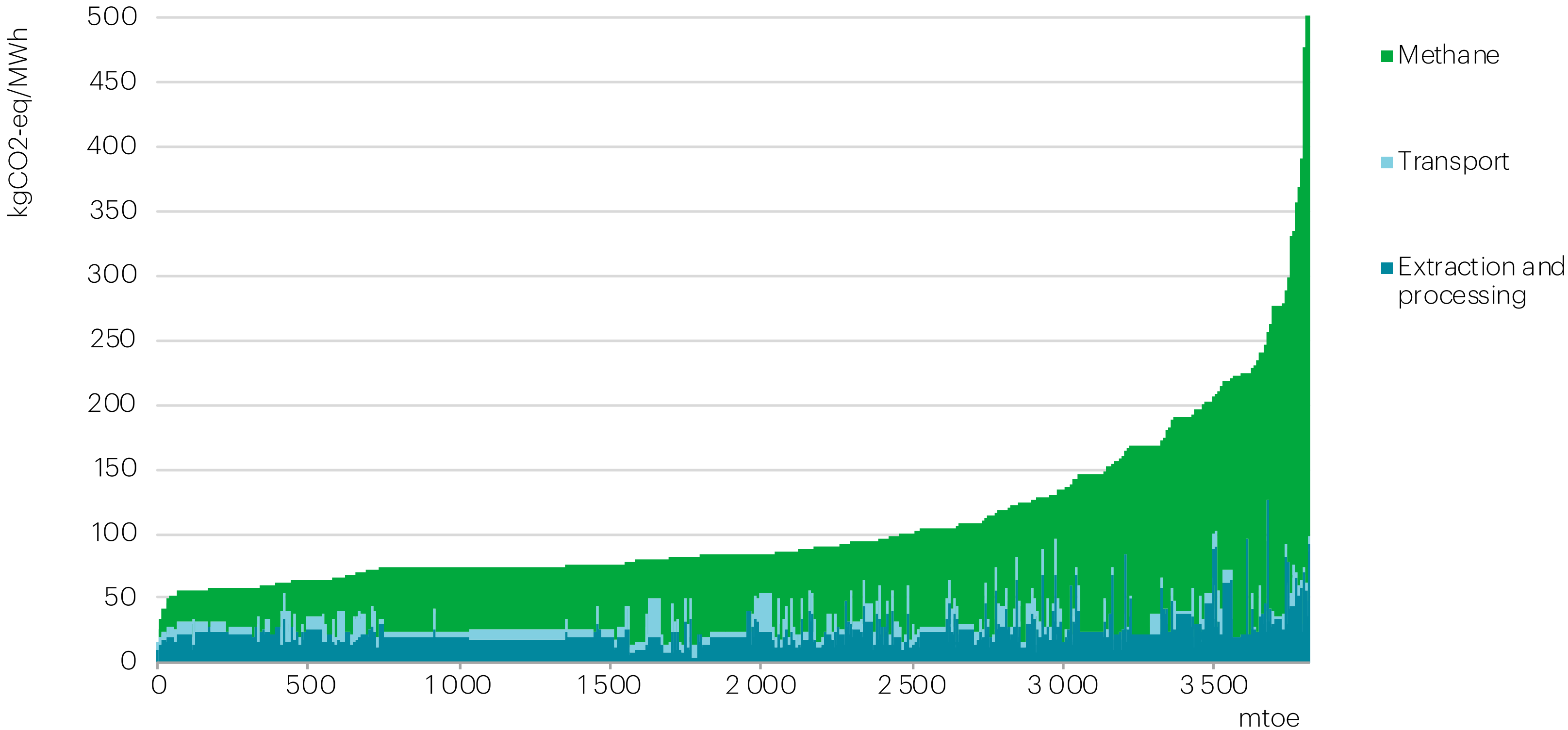
Methane emissions from gas operations can occur both from unintended leakages and intentional releases (e.g. for safety reasons). Emissions are highly variable across regions, supply chain routes, processes, and equipment. While there is a high degree of uncertainty surrounding the level of emissions today, we estimate that natural gas operations result in around 40 Mt of methane globally today.

These emissions dominate the indirect emissions intensity of gas supply, and minimising methane is the key mechanism for reducing the environmental impact of gas supply.

A number of policy and industry initiatives are underway to improve the understanding of methane emissions from oil and gas operations and to reduce these emissions. Canada has a target to reduce oil and gas methane emissions by 40-45% below the 2012 level by 2025. The Oil and Gas Climate Initiative aims to improve methane data collection, develop and deploy cost-effective methane management technologies, and reduce emissions by one-third by 2025.

Indirect emissions from coal are lower than gas but display an even broader range

Indirect GHG emission intensity from global coal supply, 2018



Notes: GHG = greenhouse gas. *Extraction and processing* includes emissions from the energy used to power the mining equipment, coal washing, and auxiliary services. *Transport* includes emissions that occur during shipping or rail transport. *Methane* includes emissions from active surface and underground mines; one tonne of methane is assumed to be equal to 30 tonnes of CO_2-equivalent (the 100-year global warming potential).

Source: IEA analysis based on data from CRU group.

Gas is nearly always better than coal on a lifecycle basis

There are also major indirect emissions from coal production. For this report, we developed new estimates of the CO_2 and methane emissions that occur in the global coal supply chain.

Methane can be released in various ways during coal mining, including from the degasification and ventilation systems in underground coal mines, exposed coal seams in surface mines, abandoned mines, and post-mining activities, such as storage and transport. The type of coal and geological conditions at the time of formation and burial affect how much methane is present in coal seams.

Globally, we estimate that there is close to 40 Mt of methane emitted as a result of coal supply. Underground coal mines contain greater volumes of methane than surface mines, but emissions can often be captured more easily since the concentration of methane in the emitted air is greater. Coal mine methane can be used as a fuel at the mine site or sold, making an economic case for investing in methane recovery systems.

Coal mining also requires energy to extract, process, and transport the coal. On average, coal supply results in around 120 kg CO_2-eq/MWh coal delivered to consumers. There is a very wide variation in the full indirect emissions intensity of different sources of coal: the highest 10% emissions-intensive coal results in five times more indirect emissions than the lowest 10%. Indirect emissions from gas are greater at 170 kg CO_2-eq/MWh, reflecting the additional processing required for gas and the difficulty in transporting gas over long distances.

Coal combustion, however, results in much higher emissions than natural gas. On a full lifecycle basis, comparing coal and gas used for power generation or for heat, we find that 98% of gas consumed today has a lower emissions intensity than coal.

The lifecycle emissions intensity of gas and coal is subject to a high degree of uncertainty. Harmonised approaches to measurement as well as verification procedures are required to reconcile wide disparities in top-down and bottom-up estimates.

But “beating coal” is not enough to make a case for gas

The emissions reductions from coal-to-gas switching are significant, but beating the most carbon-intensive fuel is not in itself a persuasive case for gas if there are lower-emissions and lower-cost alternatives to both fuels. The falling cost of renewable technologies in the power sector is the clearest case in point. In many markets, wind and solar PV are already among the cheapest options for new generation.

Moreover, the increased combustion of natural gas does not provide a long-term pathway to global climate objectives, so policy makers need to be wary about locking in gas-related emissions even as they reduce emissions from coal.

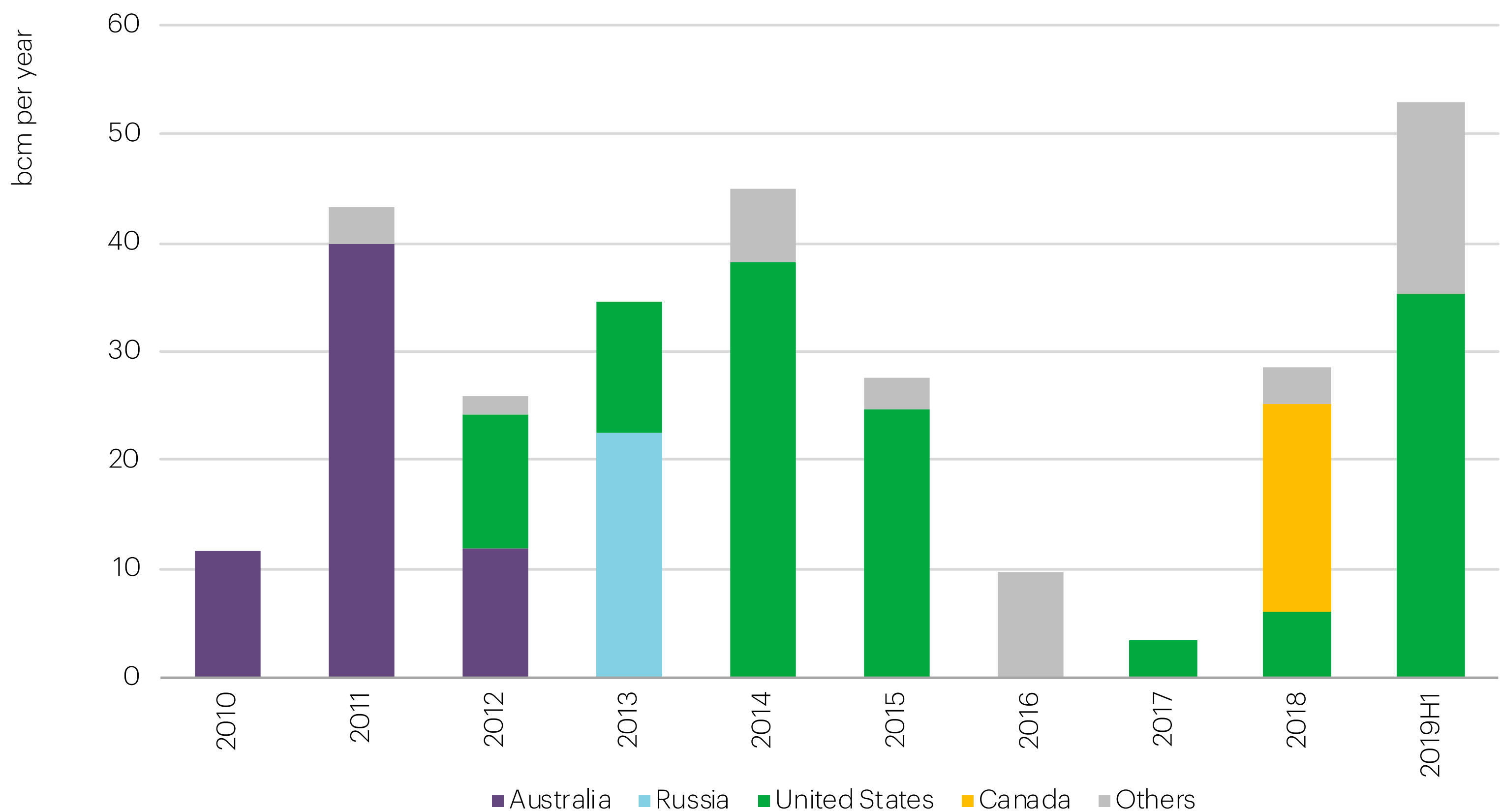
The discussion about coal-to-gas switching has to be framed carefully, and we consider the different aspects of this in the case studies below. The clearest case is when there is the potential to switch to gas using the existing infrastructure. This opens up the possibility of quick wins for emissions reductions, which is particularly important given the cumulative nature of carbon budgets.

Where new gas infrastructure is required, the situation is more complex. If new gas infrastructure prevents the combustion of more polluting fuels, this can increase absolute emissions but reduce them relative to what they would have been. In some instances, new gas infrastructure may also deliver services that cannot be cost-effectively provided by low-carbon alternatives, e.g. peak winter heating, seasonal storage, or high-temperature heat for industry.

From a policy perspective, a key comparison is between the costs and feasibility of expanding the electricity grid versus the expansion of a gas grid that could eventually also deliver decarbonised gases (renewable methane or hydrogen) as well as providing important energy security benefits.

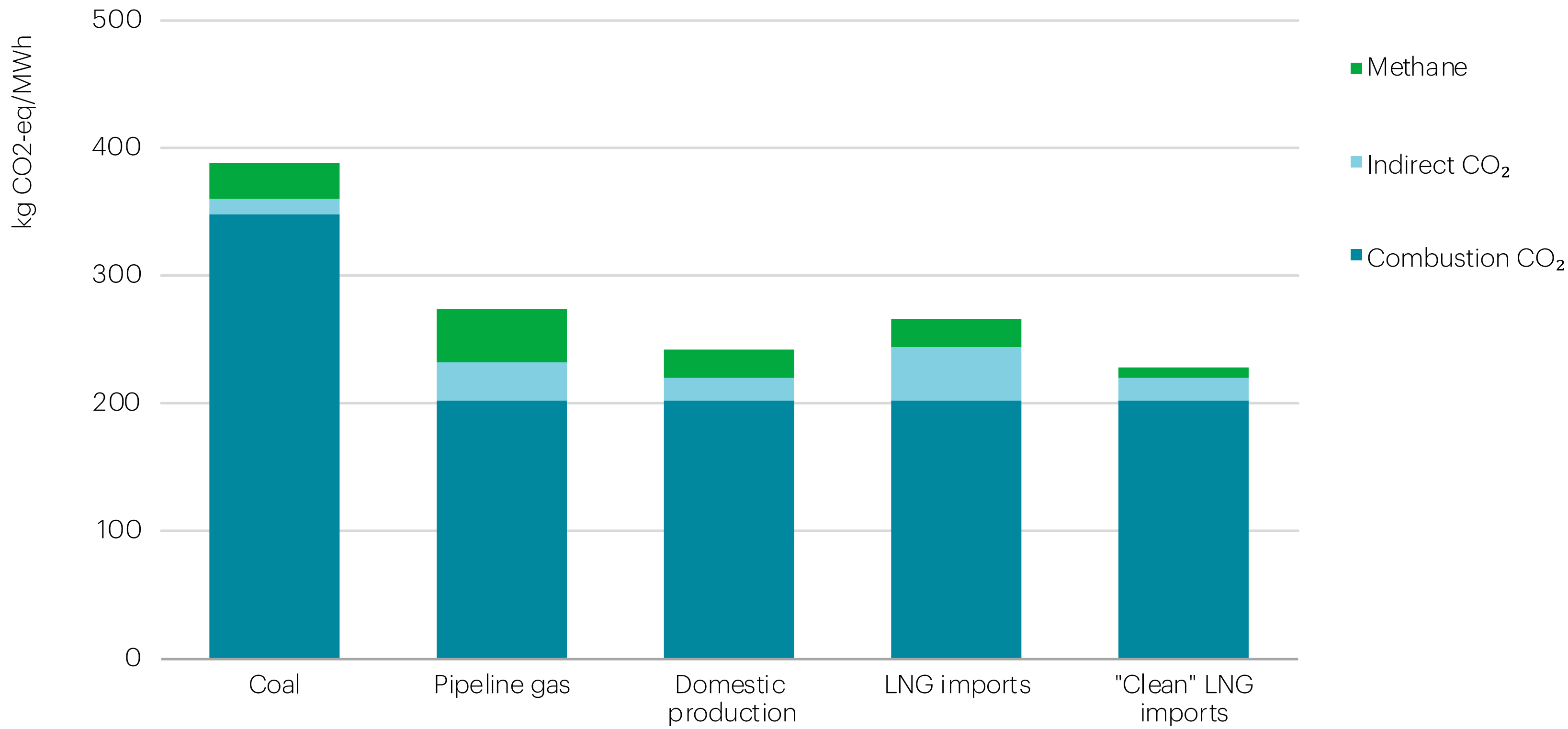
LNG is playing an increasingly important role in global trade in gas

Final investment decisions in new LNG liquefaction capacity



Best practices all along the gas supply value chain can enhance the climate gains from switching

Average lifecycle GHG emissions for coal and sources of natural gas for China in 2025



Note: *Indirect* emissions are any CO_2 emissions that occur during the production, processing, and transport of the coal or gas. *Methane* includes both upstream and downstream emissions; one tonne of methane is assumed to be equal to 30 tonnes of CO_2-equivalent (the 100-year global warming potential). *Clean LNG* assumes that methane emissions from upstream operations and transmission are eliminated and that the LNG liquefaction process is powered by zero-carbon electricity.

Suppliers can shape the environmental case for gas

A key factor in the emissions spectrum is the delivery method for natural gas. In the New Policies Scenario, over 80% of the growth in global gas trade to 2040 comes in the form of LNG, with the majority making its way to Asia. The total spectrum of emissions arising from the production, transport, and delivery of LNG from around the world to Asia is, therefore, an important part of the environmental calculation for coal-to-gas switching.

The liquefaction process for LNG is energy intensive and often emissions intensive (since gas is itself usually used to provide this energy). Pipeline transport also results in emissions (gas is used in compressor stations along the pipeline), but LNG transport is, in general, more emissions intensive than pipeline transport.

In our estimates, LNG imports to China result in fewer emissions than pipeline imports, given the methane emissions that occur along the value chains (this is not always the case, and in Europe, for example, the emissions intensity of pipeline gas today is lower than LNG).

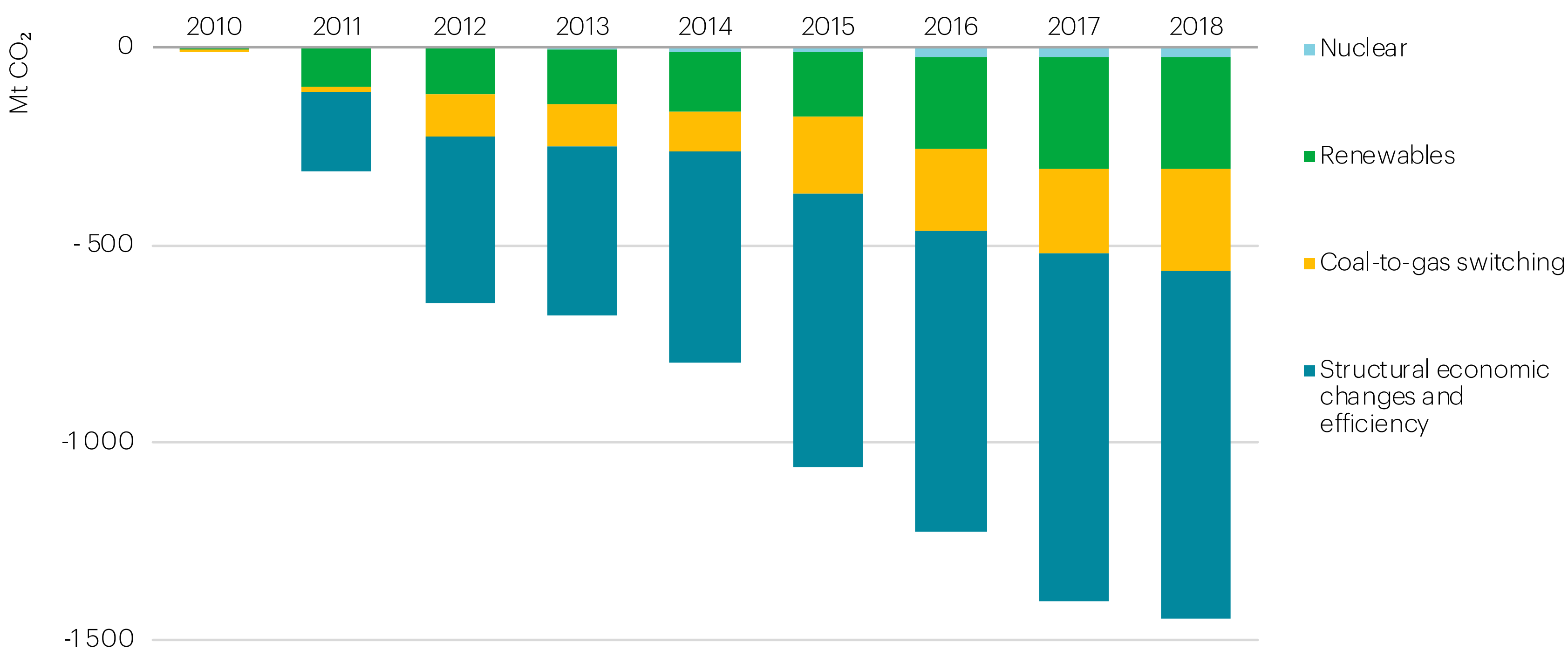
There are promising avenues to further reducing the emissions arising from LNG imports, including minimising methane emissions and electrifying the liquefaction process using low-carbon electricity (which can eliminate nearly all of the emissions associated with the LNG process). There is one electric LNG plant currently in operation (the Snøhvit facility), and others are under construction or under consideration (Freeport LNG in Texas, as well as a number of projects in Canada, such as LNG Canada, Woodfibre, and Kitimat).

This “cleaner” LNG would provide a 40% reduction in GHG emissions from coal-to-gas switching (for production of heat), compared with a 30% reduction if these mitigation strategies were not in place.

Case study: United States

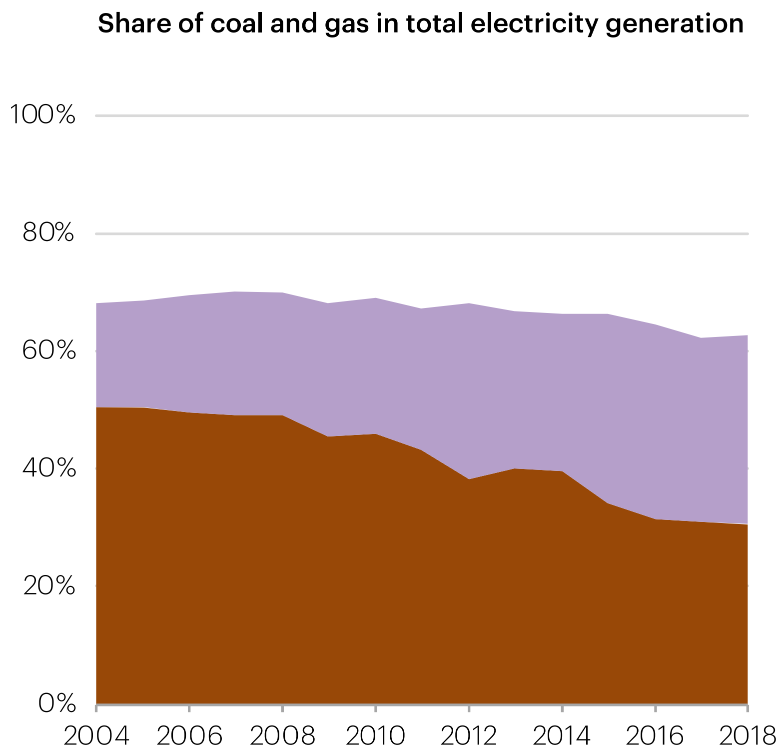
Coal-to-gas switching has been responsible for nearly one-fifth of total US emissions savings since 2010

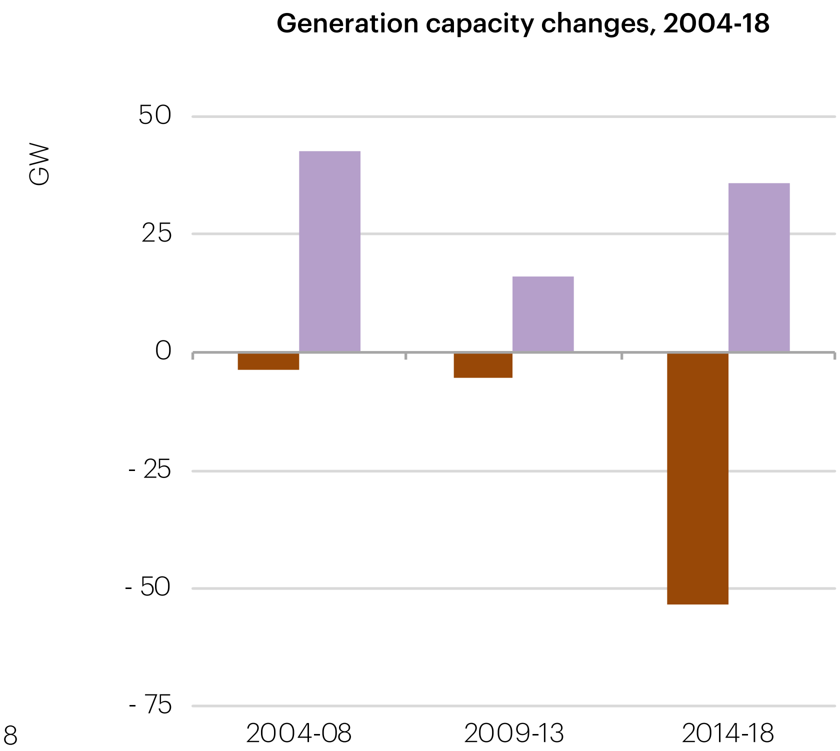
Breakdown of cumulative emissions reductions in the United States versus baseline projection since 2010



Note: Chart shows emissions reductions compared to a baseline in which there are no improvements in energy intensity.

The power sector has been the key arena for coal-to-gas switching





■ Coal ■ Natural gas

Increased natural gas use has made a visible impact on US CO_2 emissions

The environmental benefits of using natural gas in power generation depends on whether it is displacing more polluting fuels, i.e. coal and oil, or whether it is satisfying incremental demand that could be met by lower-carbon sources.

In the case of the United States, coal-to-gas switching has been responsible for around 18% of carbon emission savings since 2010, with the remaining reductions mainly attributable to structural economic changes, energy efficiency, and renewables.

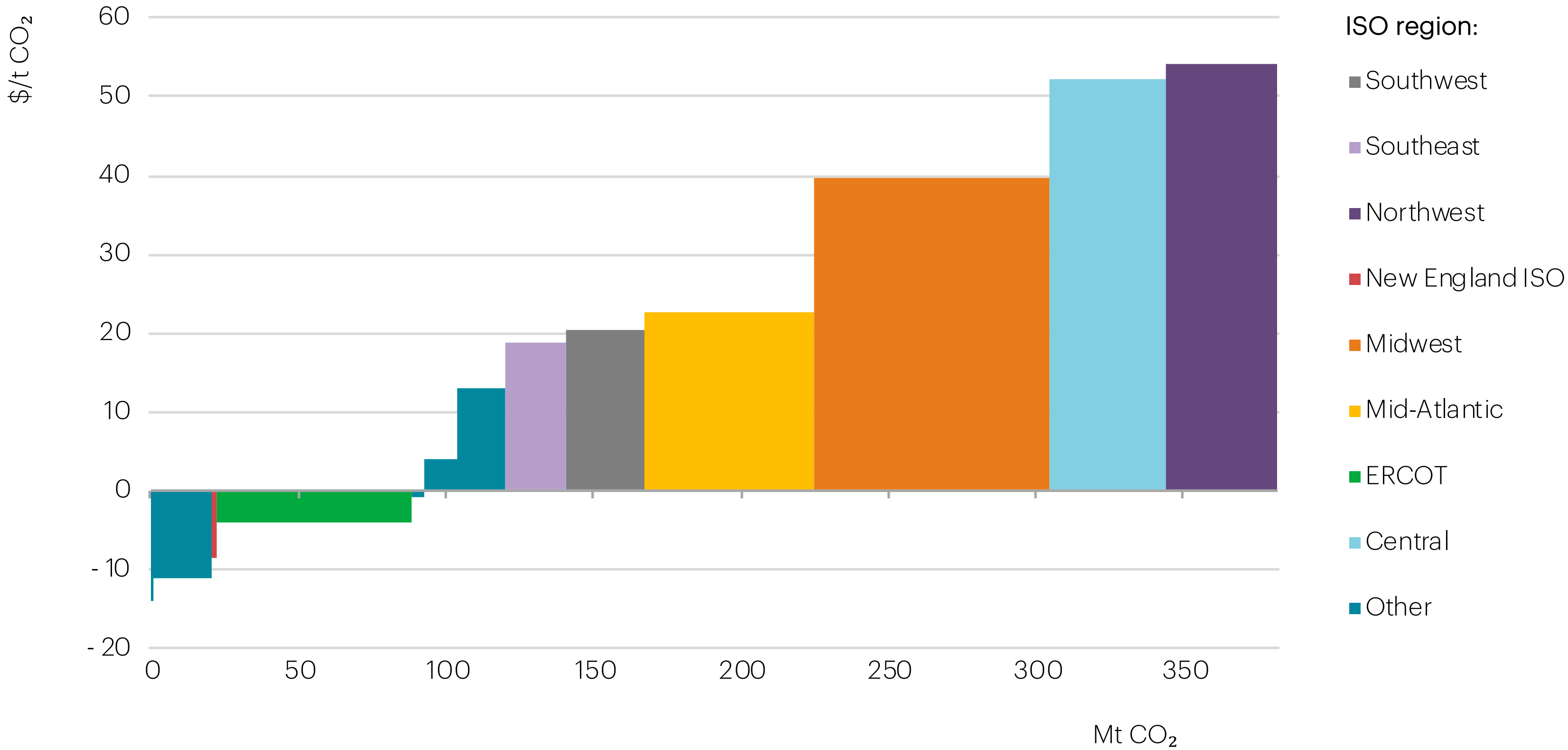
The increase in natural gas use in power generation has been a market-driven phenomenon, underpinned by ample supplies of low-cost natural gas, significant spare capacity, and the relatively low costs of adding incremental gas capacity. Within an established liberalised power market, in which different sources of power compete on a marginal cost basis, lower gas prices have fed through smoothly to changes in the power mix.

The result has been a 70% increase in natural gas-fired power generation since 2005, with gas now responsible for a third of total US electricity generation. There has been a corresponding decline in the share of coal-based generation from 50% to 30% today. Alongside growth in renewables and advances in efficiency, coal-to-gas switching has contributed to the 21% drop in US power sector emissions intensity since 2010.

In 2018, however, emissions from natural gas grew by 10%, contributing to the year-on-year increase in overall energy-related emissions of nearly 3%. This highlights that increased reliance on gas, on its own, does not provide a pathway to lower emissions.

Existing infrastructure offers significant potential for further coal-to-gas switching…

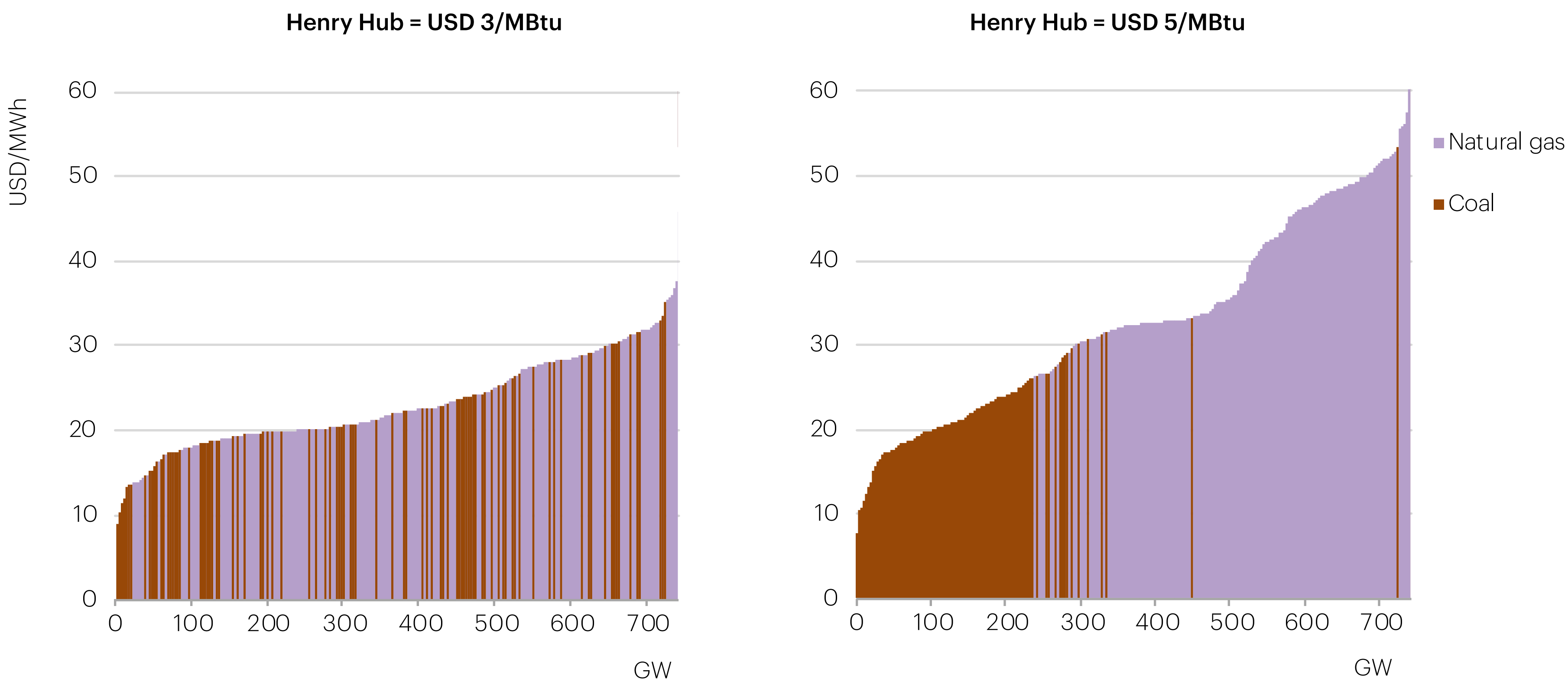
Cost of potential emissions abated from coal-to-gas switching in the United States in 2020



Note: ERCOT = Electricity Reliability Council of Texas; ISO = independent system operator. The values refer to the average CO_2 price needed for spare available natural gas-fired power generation capacity to be used to displace coal in 2020. Savings are calculated by taking plant-level generation and emissions from existing coal and gas plants in 2017 as a baseline, applying net capacity changes by 2020 and calculating switching costs using regional commodity prices for 2018.

... but this is very sensitive to natural gas prices

Coal and gas power plant cost curve at different gas prices



What is the potential for further coal-gas switching in the US power sector?

Coal-to-gas switching avoided 200 Mt CO_2 in emissions in 2017 compared to 2010. This was below the reductions that could be possible using existing gas plants. Technically, almost 400 Mt CO_2, or 20% of total US power sector emissions, could be avoided in a single year if the spare available gas capacity were used to replace the output from coal-fired power.

With the load factors for the gas fleet averaging 32% over the past five years, unlocking further switching potential relies on supportive economics. However, the relative costs of switching differ across the electricity balancing regions of the United States, depending on the composition, age, and operating costs of their respective coal and gas fleets.

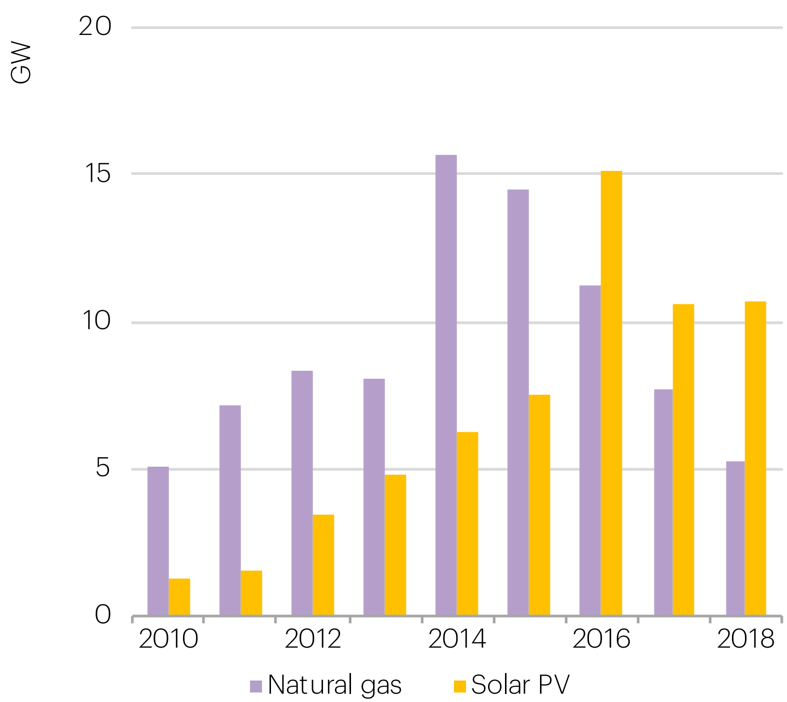
In states with ample CCGT capacity and access to a low-cost gas supply, up to 100 Mt CO_2 can be saved from switching at little to no net cost, whereas switching in major coal-producing states would require a further swing in relative prices in favour of natural gas (or, alternatively, a carbon price in a range of USD 40/t CO_2 to USD 55/t CO_2).

However, a carbon price above USD 35/t would also favour alternatives to gas, such as solar PV and onshore wind. The costs of these technologies are falling, bolstering the economic case to switch from coal directly to renewable energy.

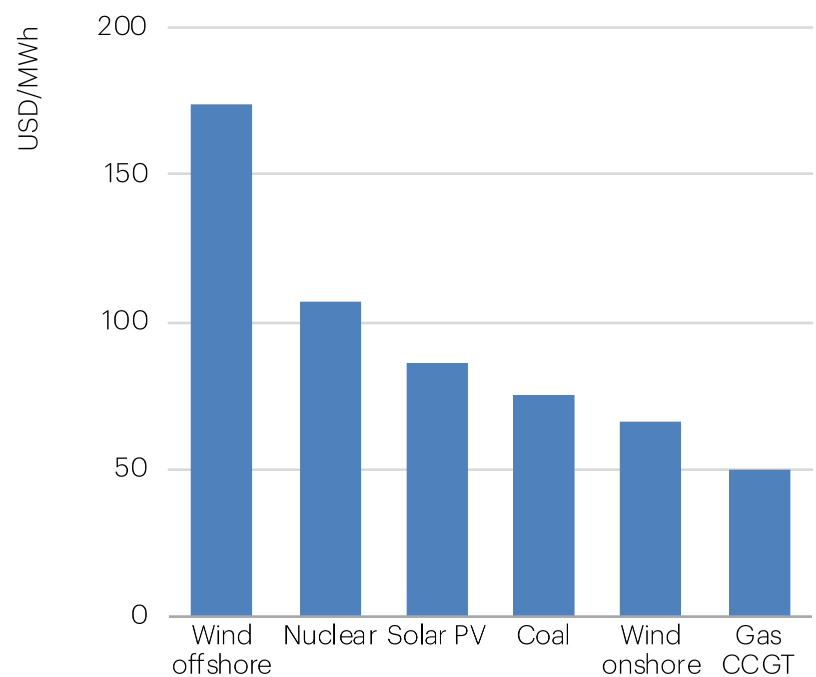
Much depends on the price level at which gas is available in different parts of the United States. On the one hand, a significant rise in Henry Hub prices, for example, would shift the majority of coal-fired power capacity back to the bottom of the merit order. On the other, persistently low gas prices may accelerate the retirement of coal-fired capacity: a large proportion of the US coal fleet is facing the need for significant near-term investment in order to continue operations, and anticipation of low natural gas prices may deter operators of coal-fired capacity from committing to this expenditure.

Anticipated cost reductions in renewables narrow the opportunity for gas to aid emissions reductions …

Capacity receiving final investment decision



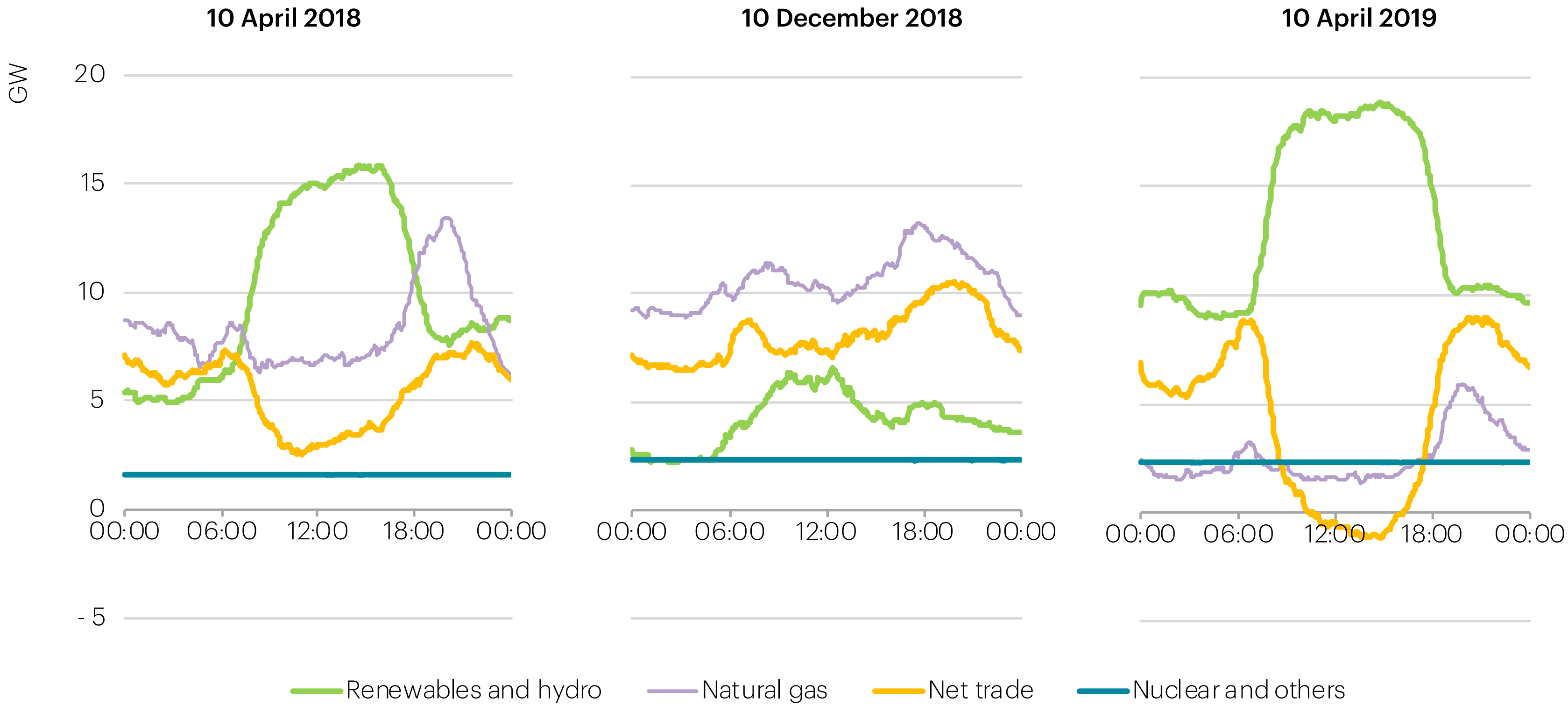
Value-adjusted levelised cost of generation in 2020



Note: The value-adjusted levelised costs of generation (VALCOE) combine the projected levelised costs of electricity with the simulated energy value, flexibility value, and capacity value by technology (but excluding network integration costs).

… and renewables are changing the role of gas in some US states

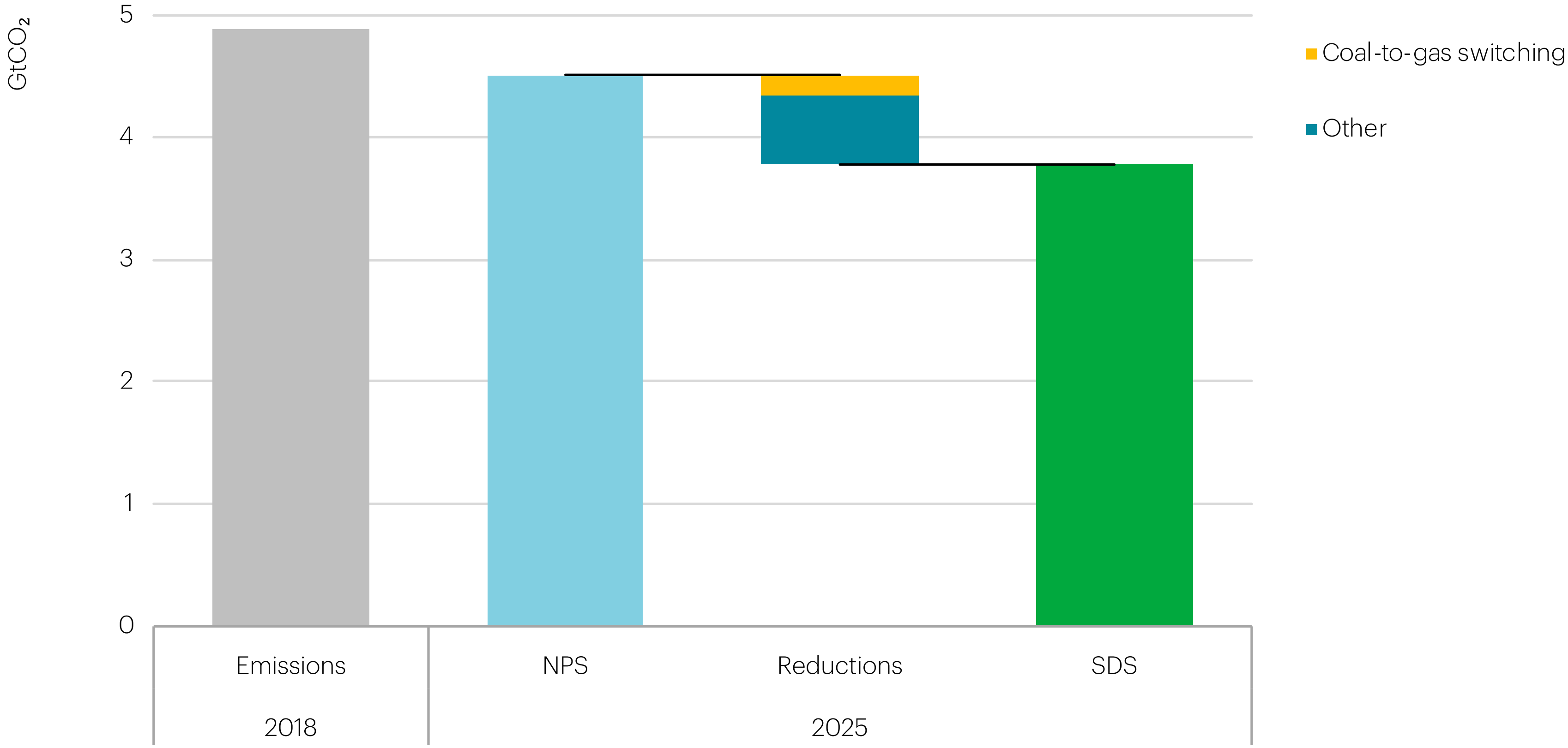
Daily electricity generation profiles in California



Source: IEA analysis based on data from California Independent System Operator (CAISO).

Switching provides a significant contribution to additional emissions reductions in the United States in the Sustainable Development Scenario

The contribution of coal-to-gas switching to US emissions reductions in the Sustainable Development Scenario



Note: NPS = New Policies Scenario; SDS = Sustainable Development Scenario.

Renewables and storage can potentially displace gas in some states, but the case for quick wins through coal-to-gas substitution remains strong

Year-on-year declines in investment in gas-fired generating capacity since 2014, and the falling costs of renewables and battery storage technologies are clear signs of the competitive pressures on natural gas.

Some US states are already moving beyond coal-gas switching. California is one of the few states that has seen reductions in natural gas-fired power generation, as ambitious decarbonisation targets are translating into the rapid deployment of renewables.

As the case of California demonstrates, the daily generation profile of natural gas (and electricity trade with neighbouring states) is being reshaped by renewables. Depending on the renewables output, which varies on both a daily and seasonal basis, gas is variably required to step in to provide baseload, peak, or back-up capacity to balance the electricity grid.

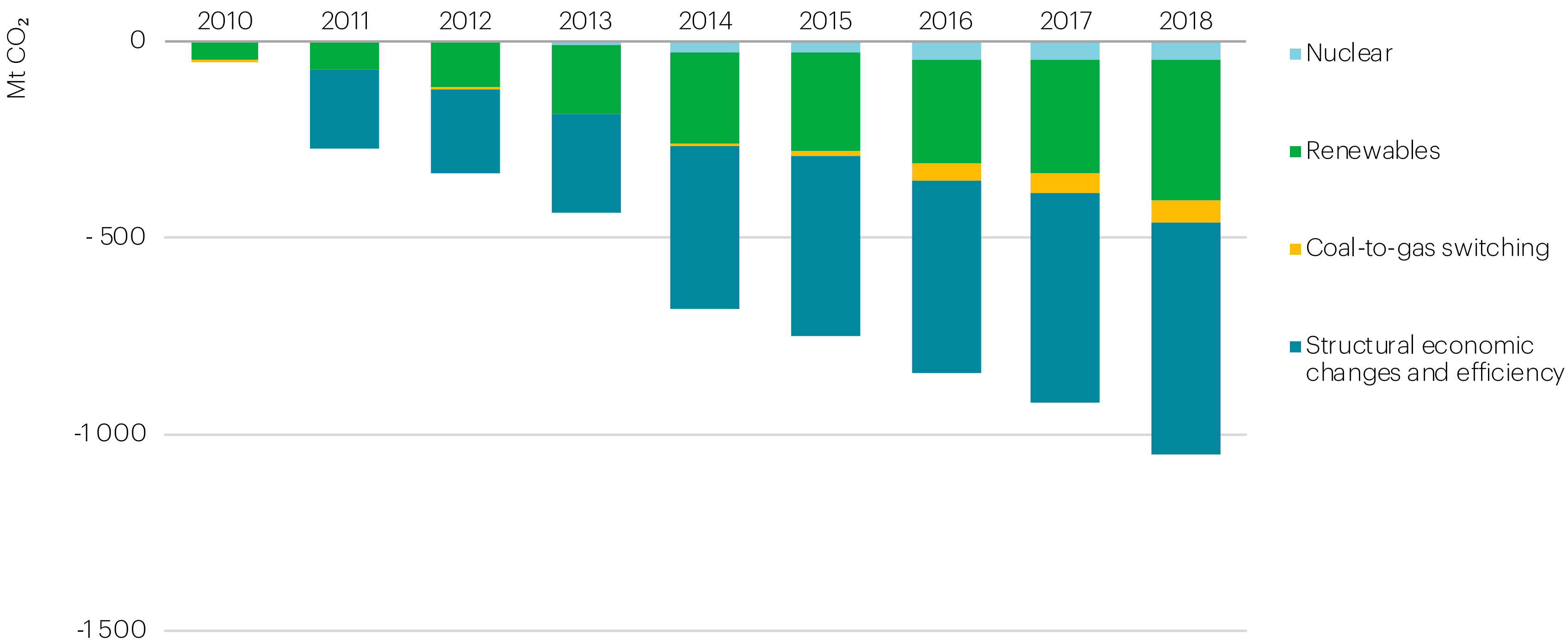
Even with falling battery costs, natural gas is currently the most viable near-term option in most parts of the United States for balancing variable renewable energy at scale and providing essential load-following services. While this raises the capacity value of natural gas power plants (reflected in the IEA's value-adjusted levelised cost of electricity generation), it does not automatically translate into increased natural gas use in power generation.

In the Sustainable Development Scenario, switching from coal to natural gas saves a further 160 Mt CO2 in 2025, equal to nearly a quarter of the required emissions reductions. Beyond this period, conventional gas power plants play an increasingly important role in providing system flexibility, while baseload generation is met by plants fitted with carbon capture, storage and utilisation technology.

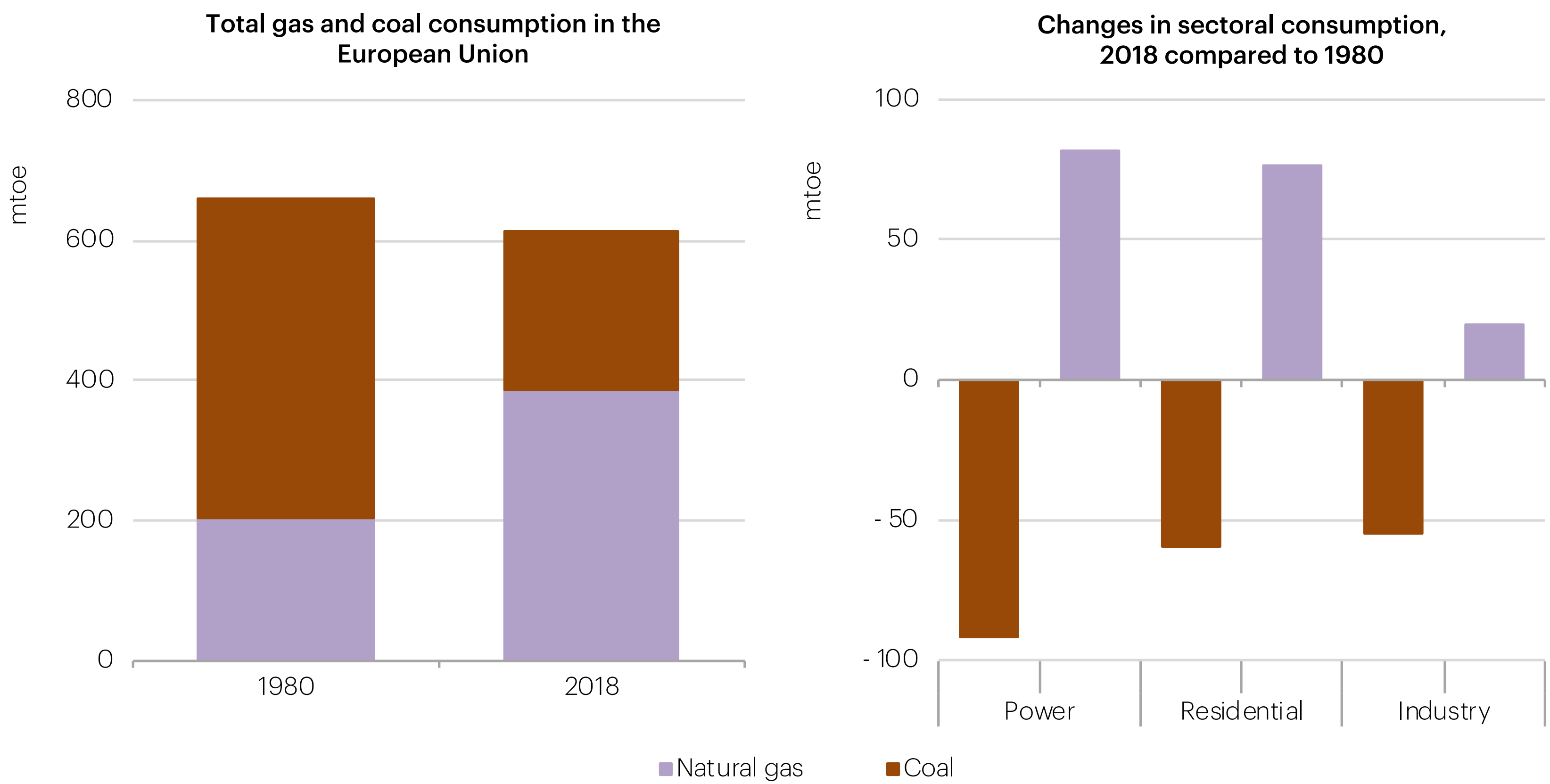
Case study: European Union

Since 2010, high natural gas prices and low CO_2 prices have ruled out significant coal-to-gas switching in most European Union countries ...

Breakdown of cumulative emissions reductions in the European Union versus the baseline projection since 2010

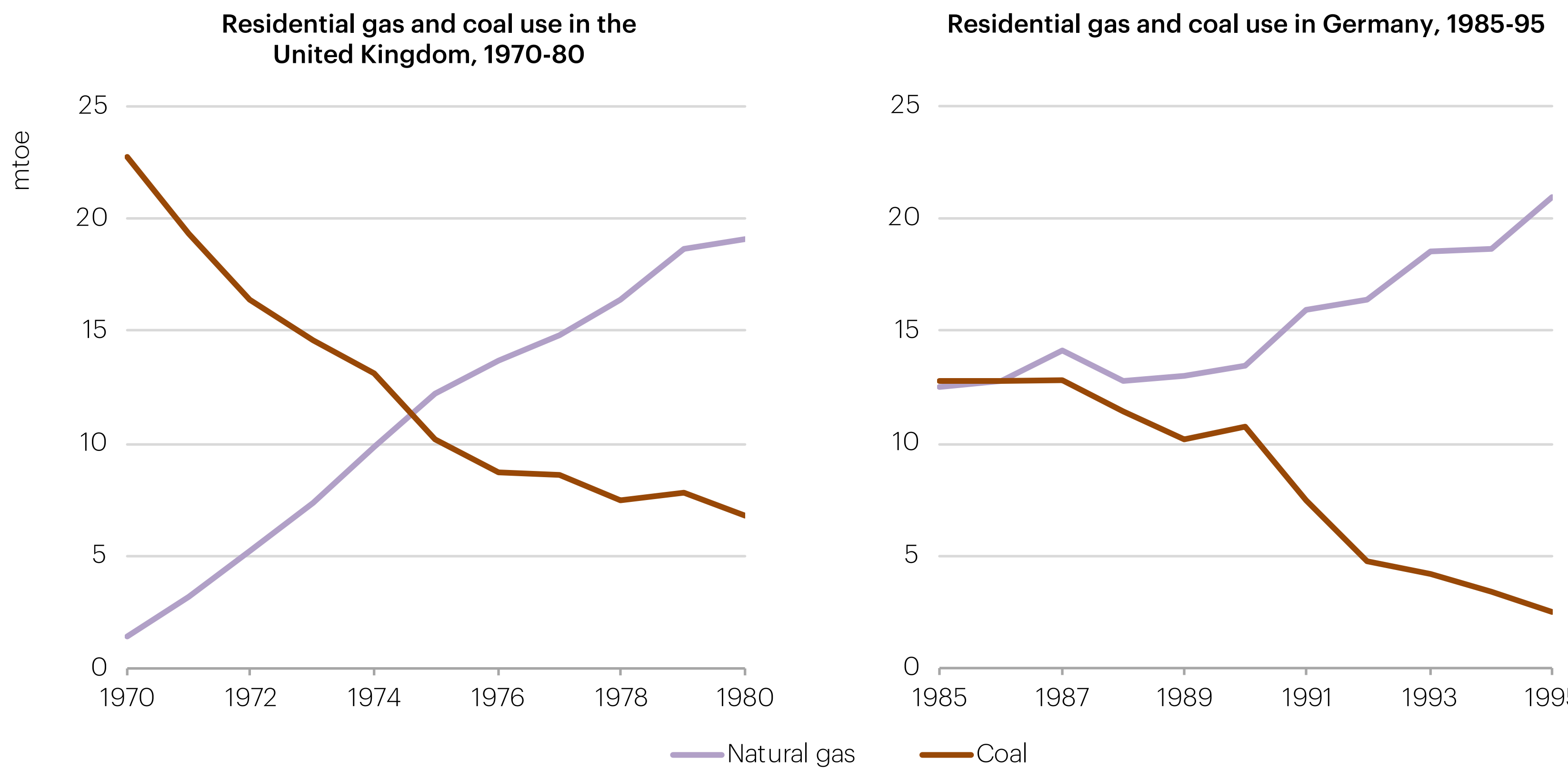


… but switching to gas has a longer history in Europe



Note: European Union grouping consists of all 28 member states in 1980.

The residential sector was the first to move in many countries



Divergent pathways for coal and gas in the European Union

The combined share of gas and coal in the EU energy mix has stayed relatively stable since 1980. However, the roles of the two fuels have swapped: gas use has grown from 11% of the European Union energy mix in 1980 to around a quarter today, while there has been a corresponding decline in coal, with its share halving to 15%.

Switching was underpinned by both demand- and supply-side developments. The discoveries of large gas resources in the United Kingdom and the Netherlands provided the catalyst for the expanded use of gas in the 1960s and 1970s, which largely replaced coal as well as gasoil. In Germany, household gas use further expanded following structural changes in the economy after reunification in 1990.

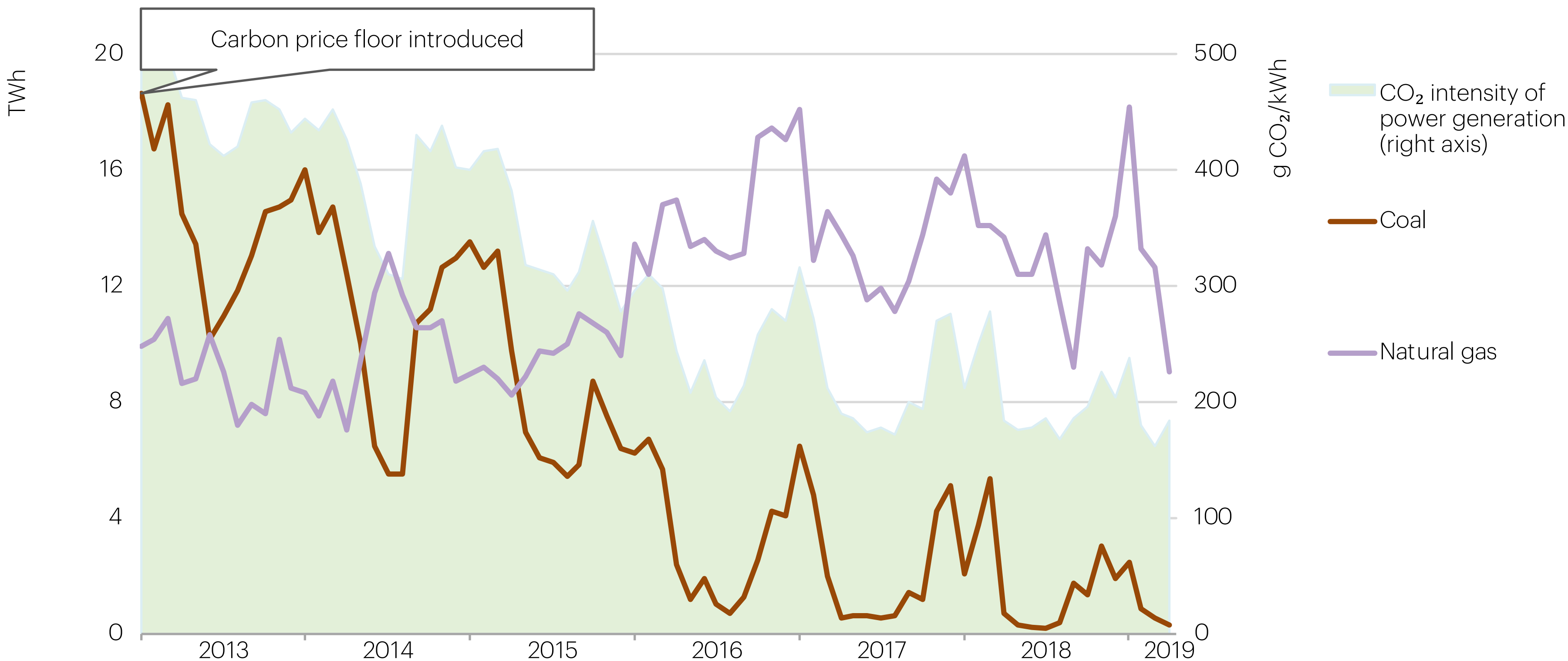
Today, 75% of the coal remaining in the European Union is consumed in the power sector, with most of the remainder used in energy-intensive industries. Around a quarter of coal-based electricity generation comes from lignite, which has higher combustion emissions but is typically priced at a level much lower than hard coal.

Due to muted electricity demand growth and large investments made in the early part of the century, the European Union has significant gas-fired generation capacity. This makes gas a candidate for stepping in to replace the gap left by declining coal (as well as nuclear) baseload power.

However, for most of the 2010s, high gas prices and low carbon prices have prevented gas from challenging coal-fired power plants in providing thermal baseload electricity. Coupled with the strong growth in renewables, this has left gas plants struggling to find a place in the merit order in parts of continental Europe.

The United Kingdom's carbon price floor accelerated the phase-out of coal-fired power

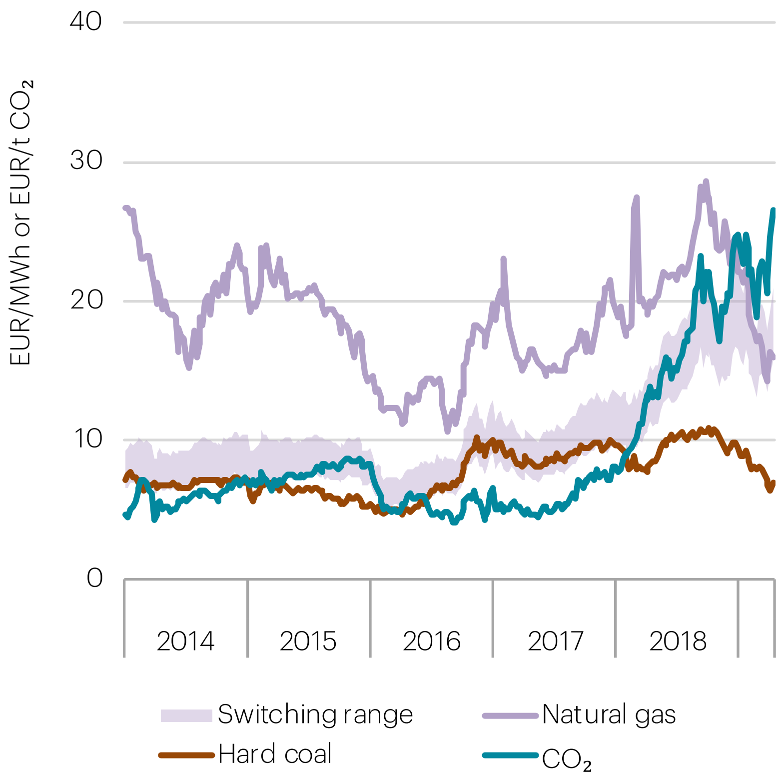
UK electricity generation from coal and gas

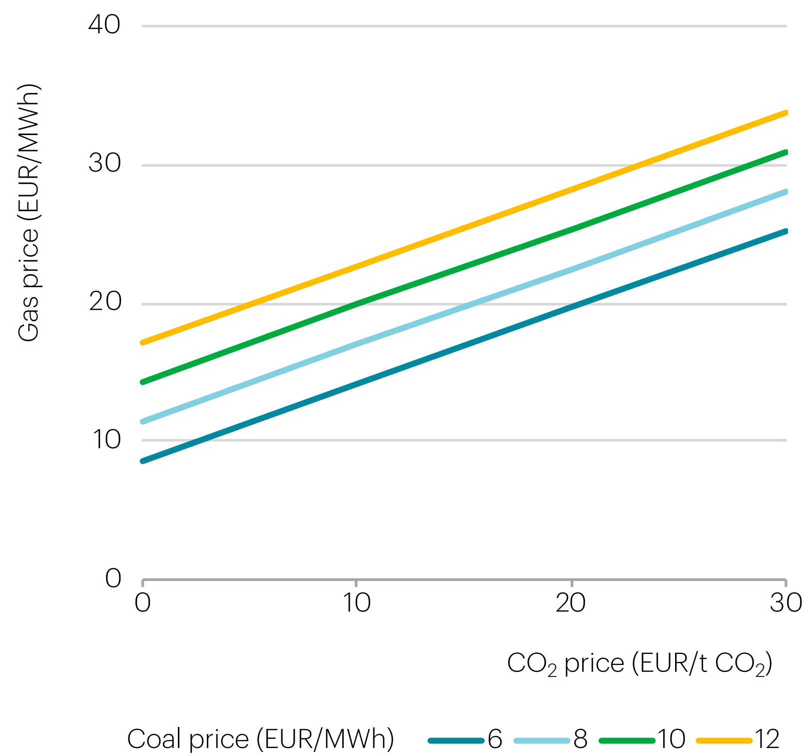


Source: IEA analysis based on Balancing Mechanism Reporting Service (BMRS) data © ELEXON Limited.

With higher CO_2 prices, the economics of coal-to-gas switching in the EU power sector are becoming more favourable …

Historic gas, coal, and CO_2 prices in the European Union and gas price economics that would stimulate coal-to-gas switching

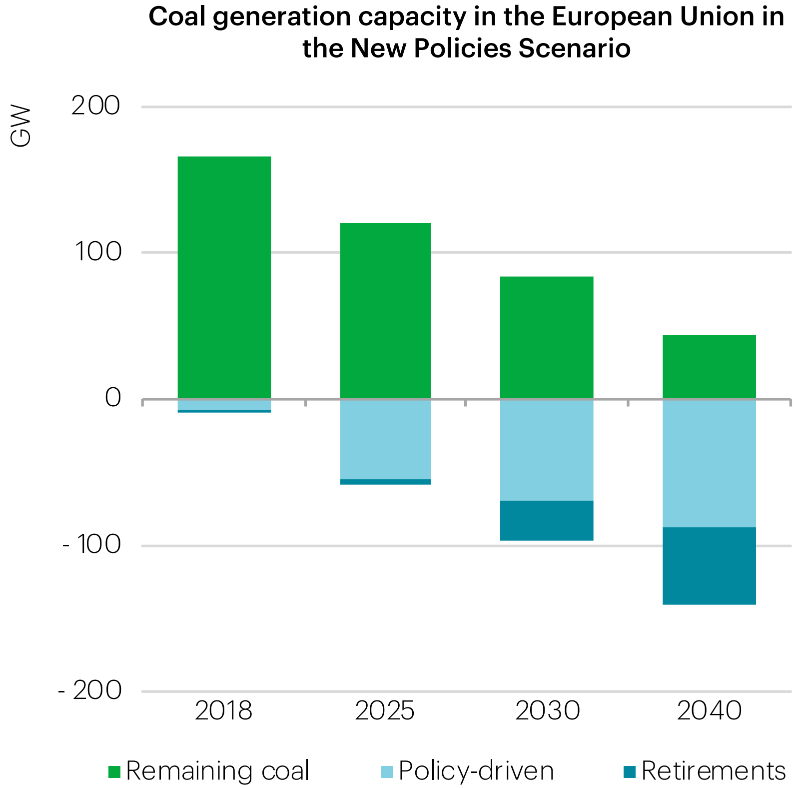


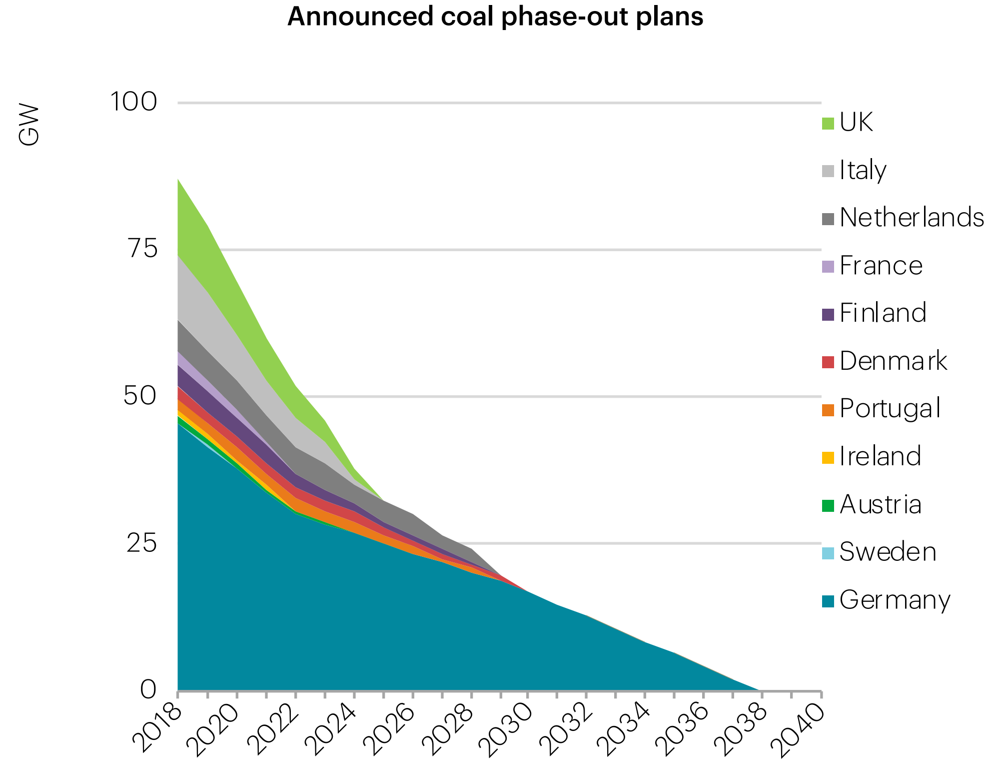


Note: The "switching range" in the left-hand chart is the level below which gas prices need to lie to encourage coal-to-gas switching; the range indicates the price levels in which most of this switching would occur across the European Union's power fleet. The lines on the right-hand chart show the level below which gas prices need to fall for a 55% efficiency gas plant to replace a 38% efficiency coal plant in the merit order (efficiencies represent weighted averages for the European fleet).

Source: IEA analysis based on Bloomberg data.

… and the phaseout of coal could provide additional short-term opportunities for gas





Note: Policy-driven refers to coal-fired capacity in countries that have announced coal phase-out plans; Germany is still consulting on its coal phase-out plan. Other retirements refer to assumed capacity retired in the New Policies Scenario in other countries (due to factors such as economics and plant age); by 2040, most of the remaining coal lies in European Union member countries that currently have no coal phase-out policies (i.e. Bulgaria, Croatia, Czech Republic, Greece, Poland, Romania and Slovak Republic).

The power sector is the final frontier for coal-to-gas switching in the European Union

In the United Kingdom, coal-gas switching has contributed to a drop of 50% in the emissions intensity of power generation since 2010. Changes in the United Kingdom's power mix preceded those in much of continental Europe; one of the key reasons was the introduction of a carbon price floor in 2013, which imposed a minimum cost to generators of GBP 9/t CO_2. This was doubled in 2015.

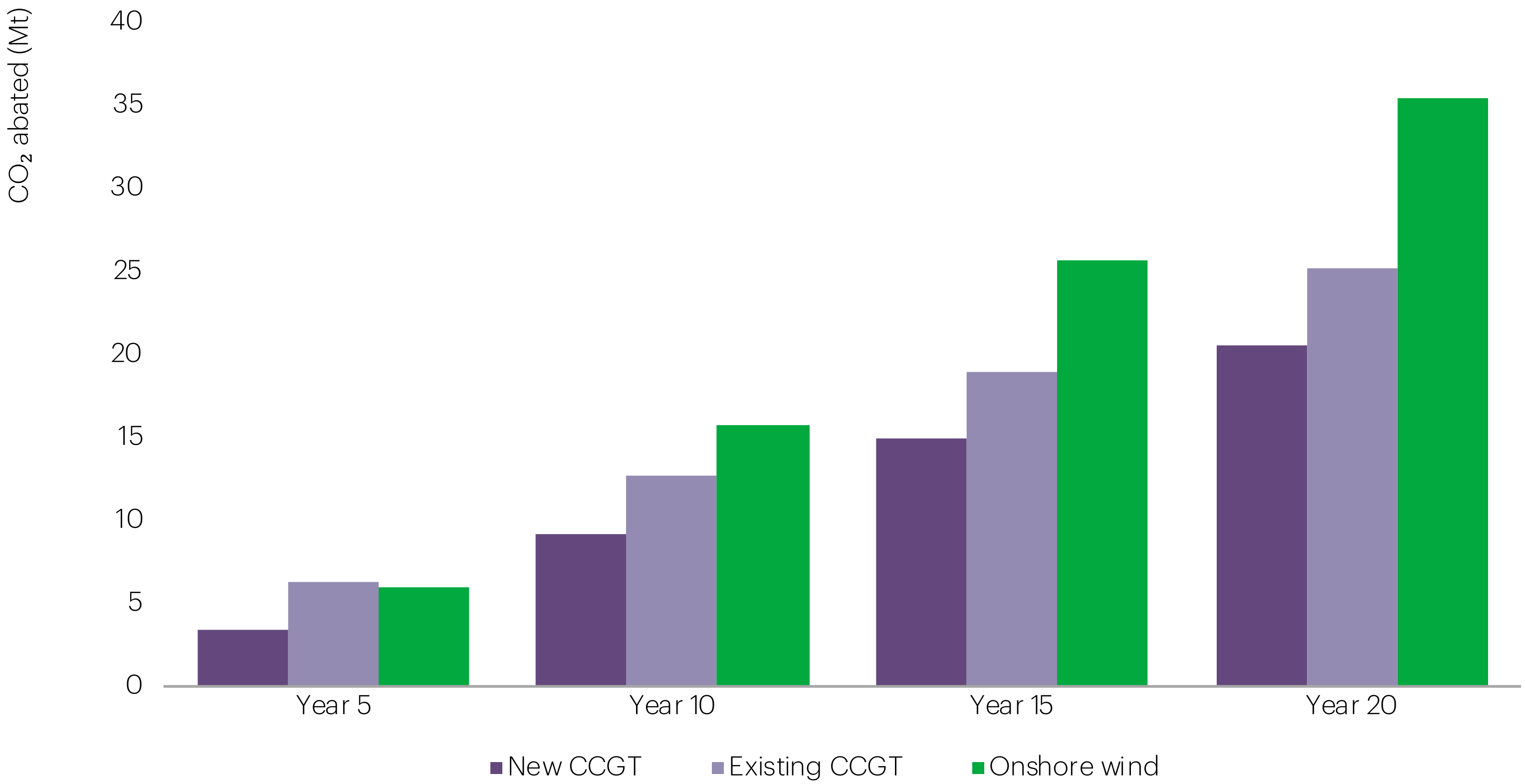
A reform of the EU Emissions Trading Scheme (which will place surplus carbon allowances in a Market Stability Reserve from 2021) has raised the generating costs for fossil fuel plants, particularly coal. The favourable combination of low gas prices and high coal and carbon prices has recently put a large portion of Europe's gas fleet within a switching range. However, the switch has also provoked a drop in coal prices, making the range a moving target.

With gas, coal, and CO_2 prices lying in respective ranges of EUR 15-20/MWh, EUR 6-10/MWh, and EUR 20-25/t CO_2, existing gas capacity could step in to replace up to half of the European Union's coal-fired power. This would save around 220 Mt CO_2, equivalent to 20% of the European Union's power sector emissions (or 6% of its annual energy-related CO_2 emissions). Some lignite plants and coal-based combined heat and power (CHP) units, however, would require far higher CO_2 prices to eventually lose their place in the merit order.

Coal phase-out policies also provide an opening for natural gas, along with renewables, to replace the retiring coal capacity. Sixteen European countries are part of the Powering Past Coal Alliance, which is pushing for the closure of existing coal-fired power plants over the coming decades. In the New Policies Scenario, these plans lead to the retirement of over 80 GW (or half of the total coal capacity) by 2040, with the remainder subject to strong competitive pressures due to higher CO_2 prices.

While existing gas can provide "quick wins" for emissions, the case for building new baseload gas capacity is challenged by renewables

Indicative emissions savings over a 20-year period when spending EUR 5 billion on a European power project



Notes: Assumes each technology's total electricity output (Existing CCGT = 50 terawatt hours [TWh], Onshore wind = 41 TWh, New CCGT = 39 TWh) replaces the equivalent output of a supercritical coal plant with 42% efficiency. *Existing CCGT* efficiency = 55%. *New CCGT* efficiency = 62%. Investment costs in new capacity are those borne by plant owners and do not take into account integration costs or revenue from non-energy markets. Commodity prices, capital costs, and financial and operational assumptions, including construction lead times, are derived from *WEO 2018*.

How wide is the switching window?

There is around 220 GW of installed gas capacity in the European Union, with utilisation rates over the past five years averaging 28%.

Compared with building new renewables, switching to existing gas plants can provide faster emissions reductions. This can be an important consideration for a European energy system focused on delivering a rapid turnaround in emissions. For example, replacing a supercritical coal plant with an existing 400 MW combined cycle gas power plant could provide a slightly higher level of CO_2 savings in the first five years of operation than a new onshore wind project (given the time needed to commission new renewable capacity).

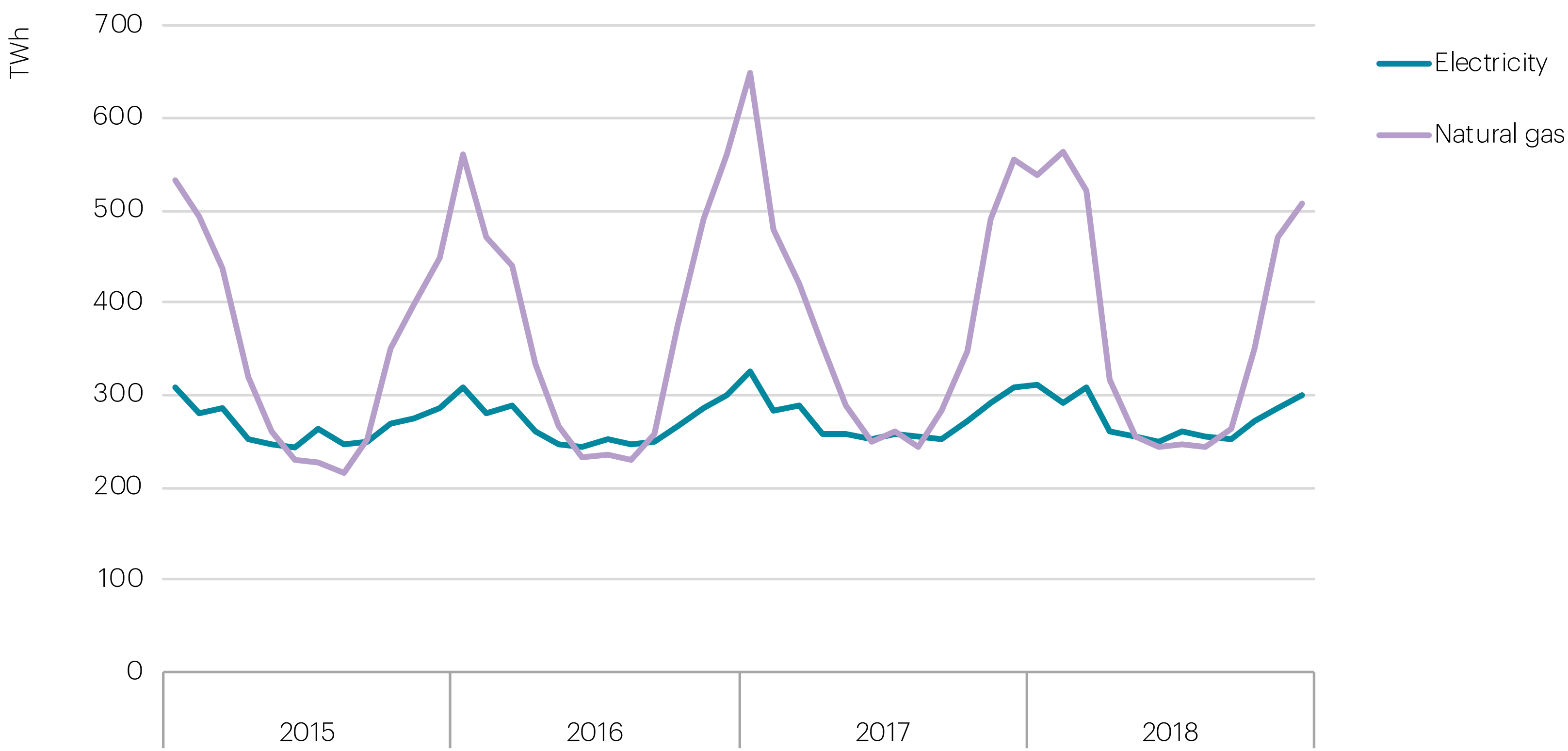
However, the costs of renewables are falling rapidly, making several mature technologies, such as onshore wind and solar PV, very competitive with the costs of generating electricity from existing gas-fired power plants. By extending the timeline in the example above to 20 years, a new onshore wind project would ultimately provide 30% more CO_2 savings than the existing gas plant (even when accounting for construction times and lower power output).

As in the United States, the role of switching in Europe is therefore time-limited. The retirements in coal capacity do not translate automatically into increased gas use: the combination of government support and higher carbon prices provides strong incentives for an increased market share for renewables.

The business case for new gas-fired capacity to reduce emissions is also challenging. Weak wholesale power prices in renewables-rich systems are not incentivising investments in new thermal capacity; over half of the revenue from a new combined cycle gas turbine would, therefore, need to come from sources other than wholesale power prices. As a result, gas plants may largely remain on standby and recover their costs by fulfilling balancing functions, rather than providing significant quantities of baseload power.

Gas infrastructure is sized to meet significant peaks in Europe's energy service demand

Comparing the monthly consumption of electricity and gas in the European Union



... meaning gas fulfils security and seasonal balancing functions that are not easily replicated by a renewables-based power system

Europe's gas infrastructure comprises an annual energy delivery capacity of nearly 1 000 bcm – nearly twice that of the electricity grid on an energy-equivalent basis.

Significant demand for heat in buildings means gas plays a crucial seasonal balancing role that is difficult to replicate using electricity. While seasonal peaks gradually reduce over time thanks to ambitious efficiency policies, the European Union in aggregate still requires a gas delivery capacity of at least 60 bcm per month in 2040 to meet normal peak winter load.

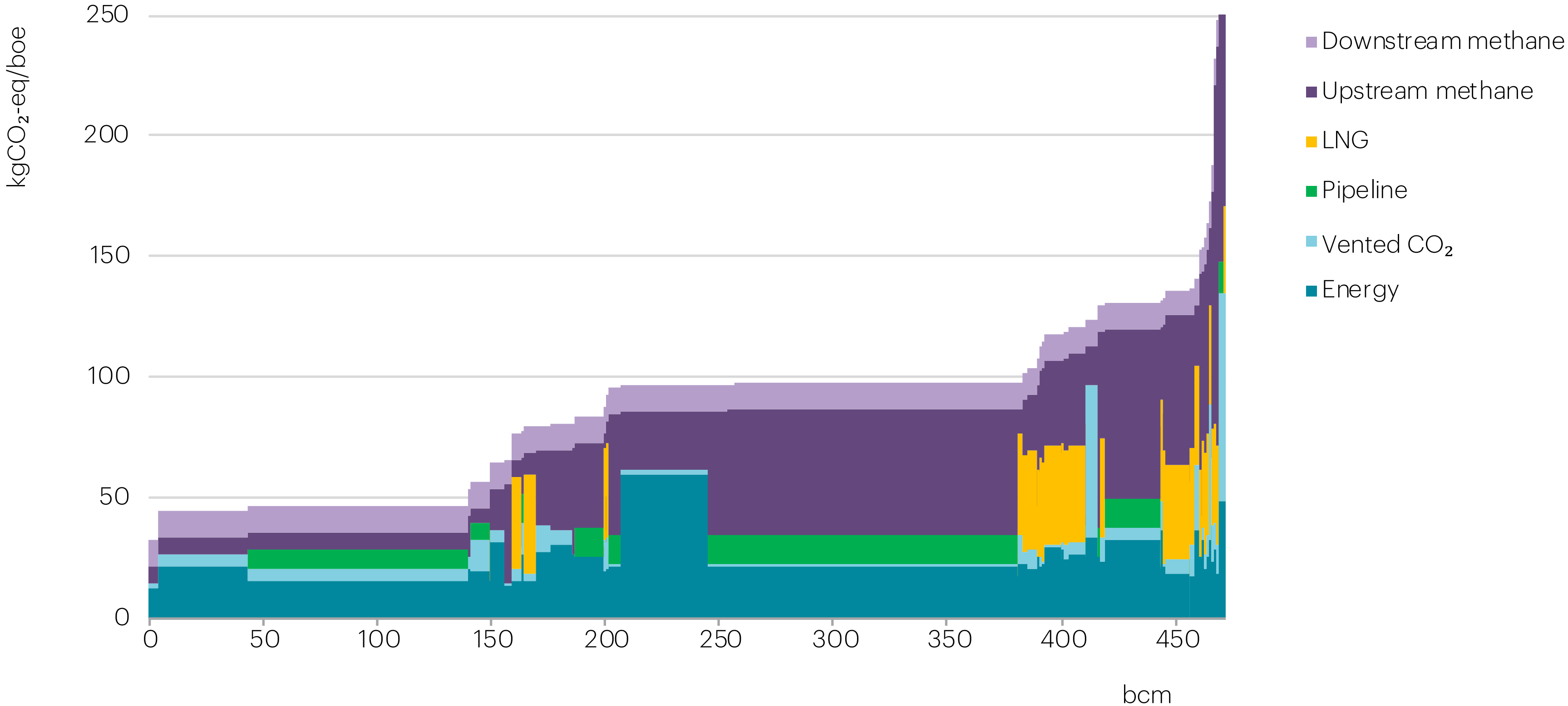
Short-term peaks in the demand for gas in the power sector are set to rise in order to help integrate larger shares of renewables. There is, therefore, a strong case for gas-based infrastructure for the flexibility and back-up capabilities it provides for power systems with high levels of intermittent renewable energy, such as solar and wind.

This case is being challenged, in some respects, by increasing investments in battery storage and grid management capabilities, which – if brought to scale – could fulfil the same short-term flexibility functions as gas. The technological potential is promising but not yet definitive; demand-side response, for example, can reduce peak loads in Europe by up to 25% by 2040, while cheaper battery storage could obviate the need for a further 5 GW of peaking gas plant capacity (or around 10% of the fleet).

The future for gas in Europe's electricity market depends, in particular, on how services such as flexibility and capacity provision are remunerated and incentivised in a system with increasingly variable power delivery, and how quickly renewables can be added. There remain, however, fewer low-carbon alternatives to gas in meeting seasonal heat demand, a consideration that is spurring interest in the costs and supply potentials for low- or zero-carbon gases (a topic that we will take up in the 2019 edition of the World Energy Outlook).

Minimising indirect emissions is critical to the environmental case for natural gas in the European Union

Indirect GHG emission intensity from the production, processing, and transport of gas consumed in the European Union, 2018



Note: boe = barrel of oil equivalent. One tonne of methane is assumed to be equal to 30 tonnes of CO_2-equivalent (the 100-year global warming potential).

Gas supply and infrastructure need to adapt to the demands of decarbonisation

The European Union is currently examining the pathways to reach a CO_2 neutral energy system by 2050, exploring options to decarbonise gas as well as repurpose gas-based infrastructure – which represents a large sunk cost – to support other low-carbon options for providing heat and mobility. The debate is also moving ahead on how and where in the supply chain carbon can be captured and then either utilised or stored.

Recent research and development (R&D) efforts, particularly in northwest Europe, have focused on the potential to blend hydrogen in the existing network, though the higher the percentage the more substantive are the changes required along the supply chain.

There is also increasing interest in the possibility to expand use of biomethane, a pure source of methane mainly upgraded from biogas. While the current production of biomethane is only around 2 bcm (or 0.4% of EU gas demand), several European countries are exploring ways to scale-up biomethane production as a means to decarbonise the gas supply while retaining the use of well-established gas networks.

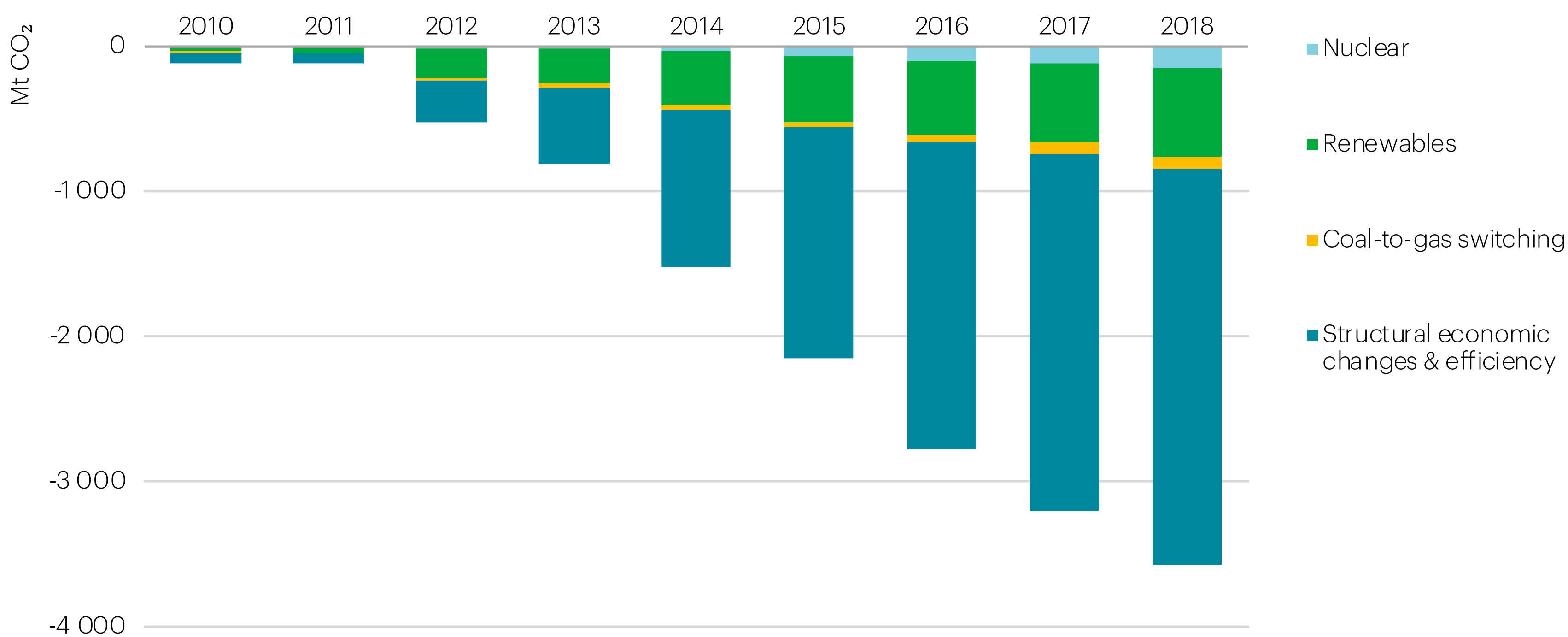
The need to ensure that conventional gas is as "clean" as possible is also receiving an increasing amount of attention. There is a wide range in the emissions intensity of natural gas consumed in Europe today, with estimated methane leaks along the value chain the most important factor in the ranking of domestic production and imports. Differentiating sources of gas by their emissions intensities would be a powerful tool to encourage gas suppliers to improve the environmental performance of operations.

While switching from coal to gas provides immediate emissions reductions, and existing infrastructure can support wider decarbonisation efforts, the case for new gas infrastructure needs careful evaluation. New projects can contribute to Europe's gas security and a well-functioning single market, but also need to find a place in Europe's clean energy transitions.

Case study:
People's Republic of China

Coal-to-gas switching in China is aimed at improving air quality, but has also helped to limit the growth in CO_2 emissions

Breakdown of cumulative emissions reductions in China vs baseline projection since 2010



Gas has been a key ally in China's war on pollution

A strong policy push to improve air quality is the main factor behind the strong growth in demand for natural gas in China in recent years. Air quality concerns have been high on the political agenda since 2013, when the Air Pollution Action Plan kick-started a period of progressively more stringent restrictions on coal use in certain areas, tied to measurable targets for air quality improvements.

Early efforts imposed restrictions on small coal-fired boilers in urban areas, particularly in the Beijing-Tianjin-Hebei (BTH) areas, with a corresponding emphasis on the expansion of city gas use. The 2014 Strategic Action Plan for Energy Development set the target of increasing the share of natural gas in China's energy mix from 6% to 10% by 2020.

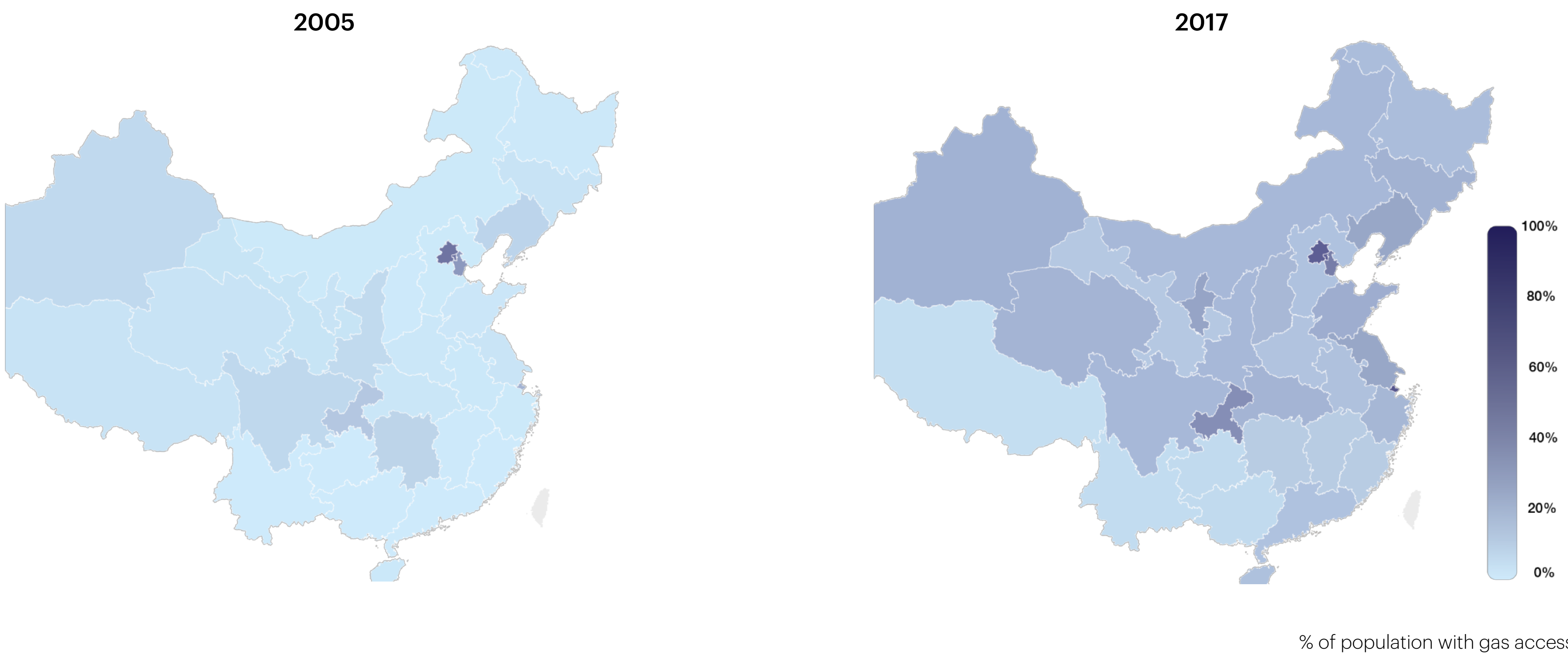
Policies and enforcement measures have become tighter. Current efforts under the Clean Winter Heating and Blue Sky action plans set specific goals for the expansion of natural gas, as well as for electricity, geothermal, and "clean coal" technologies, to replace coal use for heat demand; this is intended to combat peaks in air pollutant emissions during the winter heating season.

The BTH areas were since expanded to cover the "2+26" cities (Beijing and Tianjin, plus an additional 26 cities in the surrounding provinces of Hebei, Henan, Shanxi, and Shandong) in an accelerated effort to improve air quality.

Under the Clean Winter Heating Plan, almost 2 billion square metres of floor area within the "2+26" cities is intended to be heated using natural gas. Provincial and municipal government subsidies have been made available for installing natural gas boilers; up to half the costs of grid connection and appliance installation are subsidised, with additional support covering a portion of household gas bills.

Access to natural gas in China has greatly increased in recent years

Percentage of the population with access to natural gas

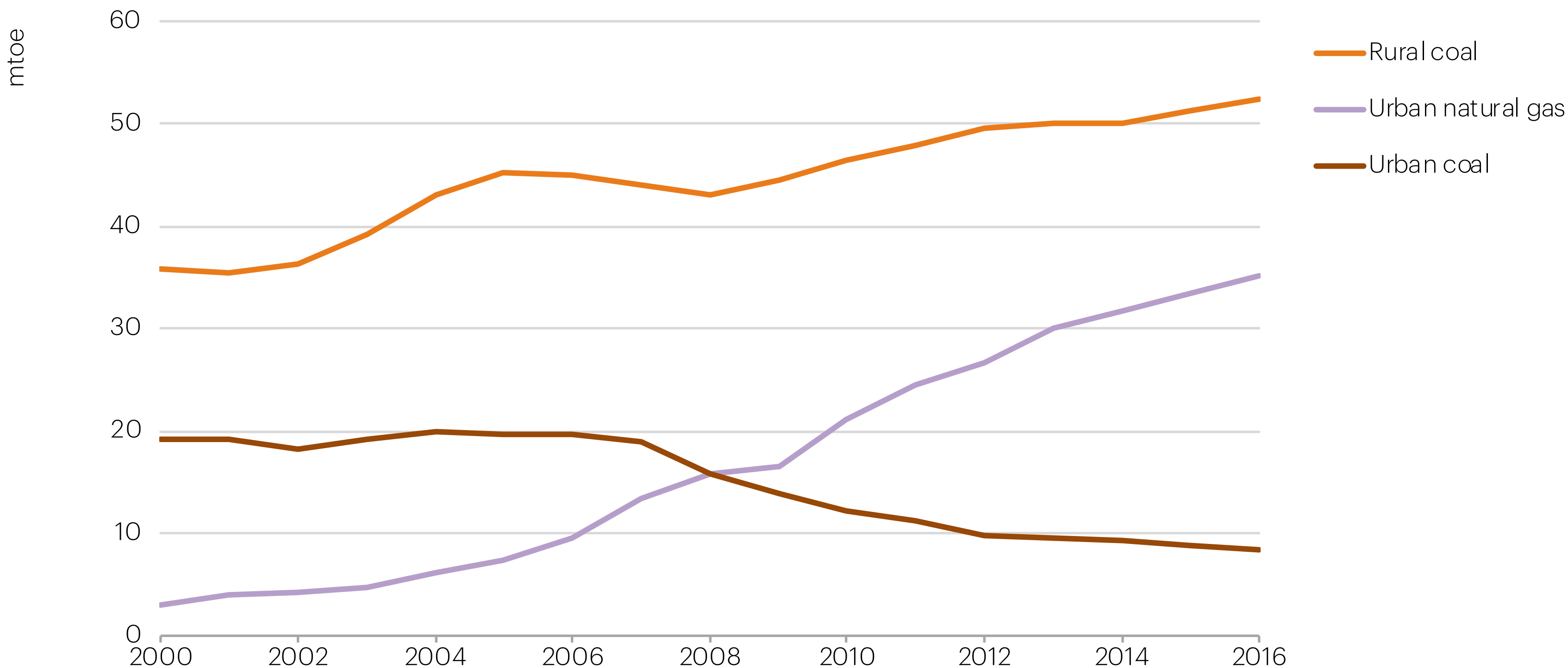


These maps are without prejudice to the status of or sovereignty over any territory, to the definition of international frontiers and boundaries and to the name of any territory, city, or area.

Source: IEA analysis based on data from National Bureau of Statistics of China.

Household coal-to-gas switching has taken place mainly in urban areas, while rural coal use continues to increase

Rural and urban coal and urban gas use in China



Note: In 2016, there was less than 0.1 Mtoe of rural natural gas use in China.

Source: IEA analysis based on data from National Bureau of Statistics of China.

Policies have underpinned substantial household switching

Access to natural gas in the residential sector expanded fivefold during 2005-16, connecting an additional 27 million households. Since then, air pollution measures have resulted in nearly 7 million additional households switching from coal to natural gas or electricity for heating in 2017/18, with a further 3 million conversions planned to be completed by 2021.

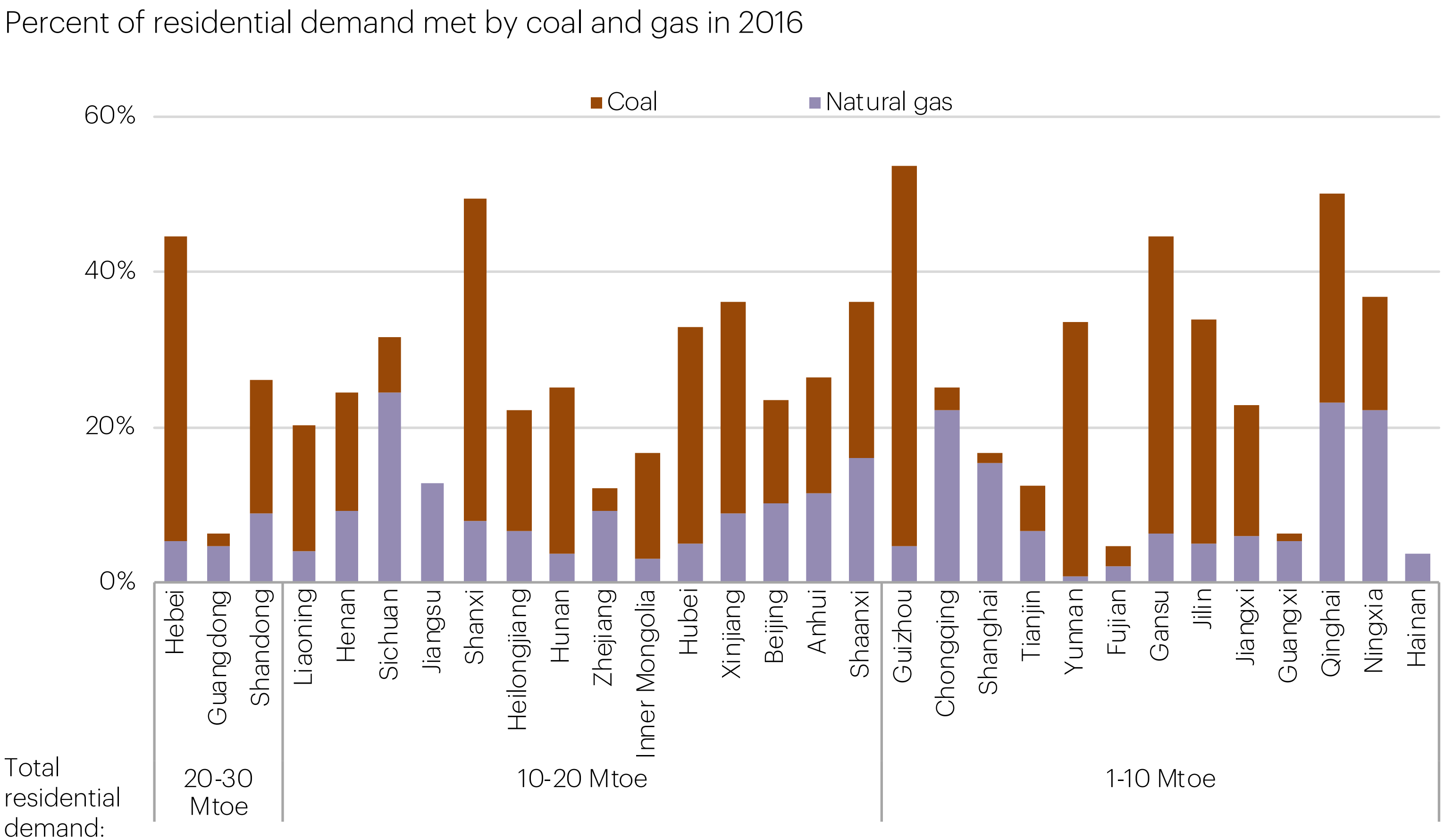
China's efforts to expand gas use have helped to bring $PM_{2.5}$ concentrations in the 2+26 cities down from the significant peaks seen during the winter of 2016/17, but they still lie largely above China's national air quality standards, which cannot exceed 35 µg/m³ on an annual basis (or up to 75 µg/m³ daily).

On a provincial level, most of the increase in gasification has occurred in provinces near to where gas is produced (Sichuan, Chongqing, Qinghai, and Xinjiang), as well as large urban centres, such as Beijing and Shanghai. Several northern provinces targeted for clean heating have also seen significant increases. Much of the switching to date has occurred in urban areas as the costs and the long-term business case for connecting rural customers are more challenging.

Rural residential coal contains higher quantities of sulphur, nitrogen, and ash than the more refined coal available to large-scale industrial users, which also have air quality control systems. Although this lower quality coal accounts for only 10% of total coal consumption in the 2+26 cities, it is responsible for half of air pollutant emissions. This implies greater air pollution reduction benefits from effecting a switch away from coal in rural areas.

China's National Energy Administration is seeking to expand biogas production to promote rural coal-to-gas switching, with plans to reach a level of 30 bcm by 2030 (from less than 10 bcm today). Liquids such as fuel oil or propane, or electricity, also represent viable alternatives to gas in rural households.

There is significant further potential for switching in the residential sector …

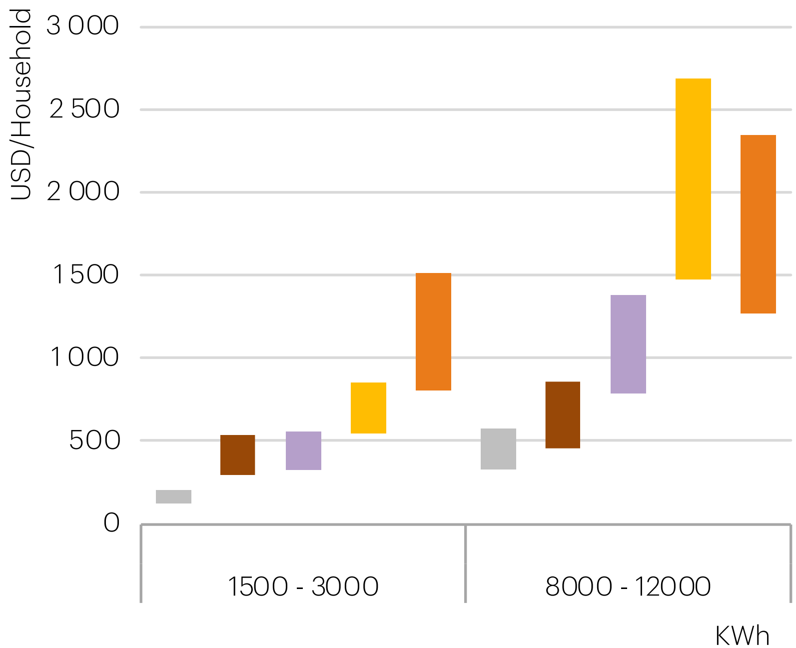


Notes: *Coal* refers to direct use; some provinces, particularly in Northern China, rely on district heating which comes primarily from coal-based co-generation. *Co-generation* refers to the combined production of heat and power.

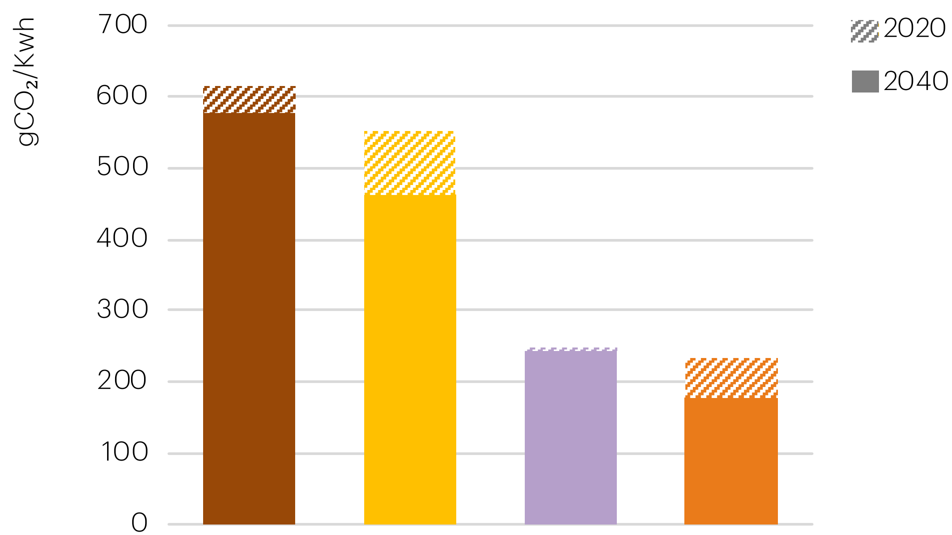
Source: IEA analysis based on data from National Bureau of Statistics of China.

… even though gas is not the only game in town

Range of costs for low versus high annual household heating requirements, 2020



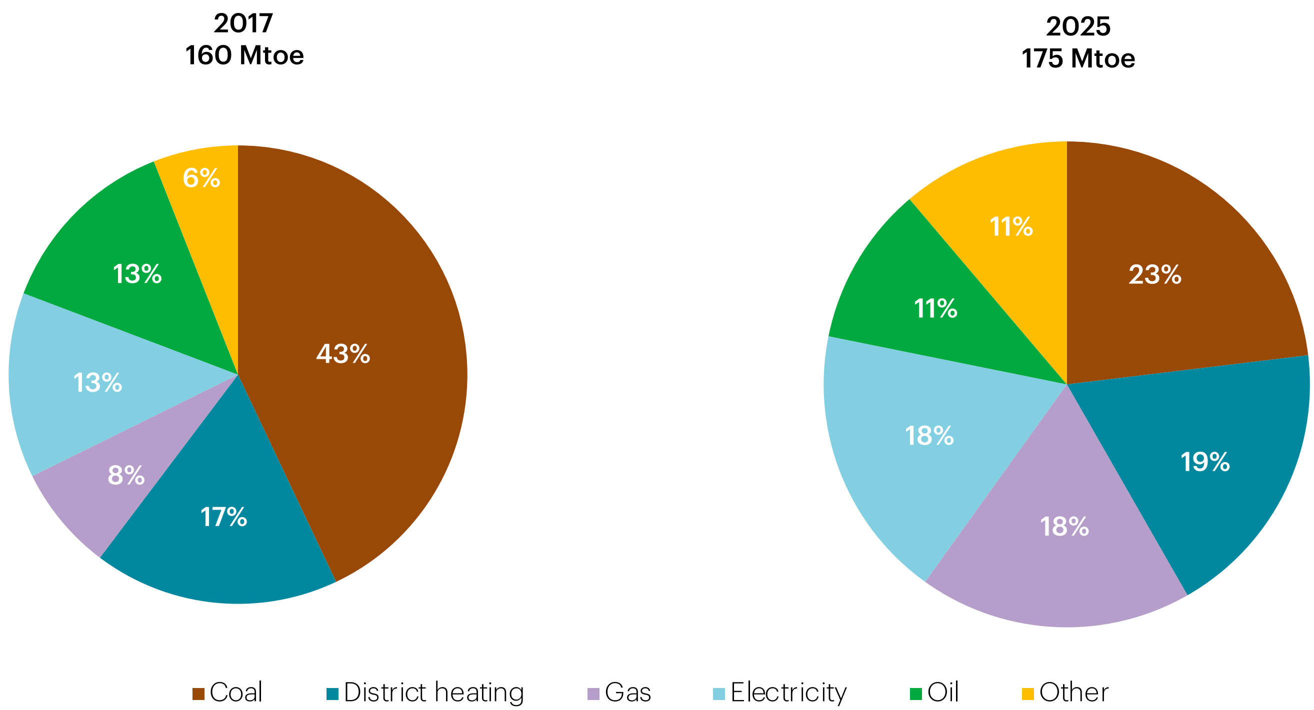
Emissions intensity of household heating options in the New Policies Scenario, 2020 versus 2040



Note: KWh = kilowatt hour. The values in the left-hand chart refer to the capital costs of each heating technology, excluding the associated costs of infrastructure (e.g. new gas distribution or electricity networks) as well as operation and maintenance costs. Any applicable subsidies are excluded from this figure. Currently, over 90% of district heating is provided by coal combustion.

Overall, there is the prospect for a significant near-term boost to gas use in China's buildings sector…

Chinese space heating demand for buildings in the New Policies Scenario



Note: Excludes bioenergy.

… as gas appears well placed to see off heated competition

China's air quality efforts are not only focused on gas. There are also efforts to promote "clean coal" technologies by replacing small coal-fired boilers with both centralised and decentralised co-generation systems (combined heat and power, or CHP), most of which currently run on coal.

Some provinces have supported heat pumps and electric heaters. In places such as Beijing, Shandong, and Shaanxi, the majority of new customers opted for electricity over gas in 2018. In some cases, electric space heaters are able to compete with gas for households with lower heating requirements, i.e. in southern areas of China. For households in the north with greater space heating needs, gas has a competitive advantage against electricity-based options.

Since the majority of electricity comes from coal, there are currently fewer environmental advantages of using electric heaters; the average CO_2 intensity of gas boilers (250 grammes of CO_2/kWh) is less than half that of electric heaters today, and this sizeable gap narrows only slightly in the New Policies Scenario by 2040.

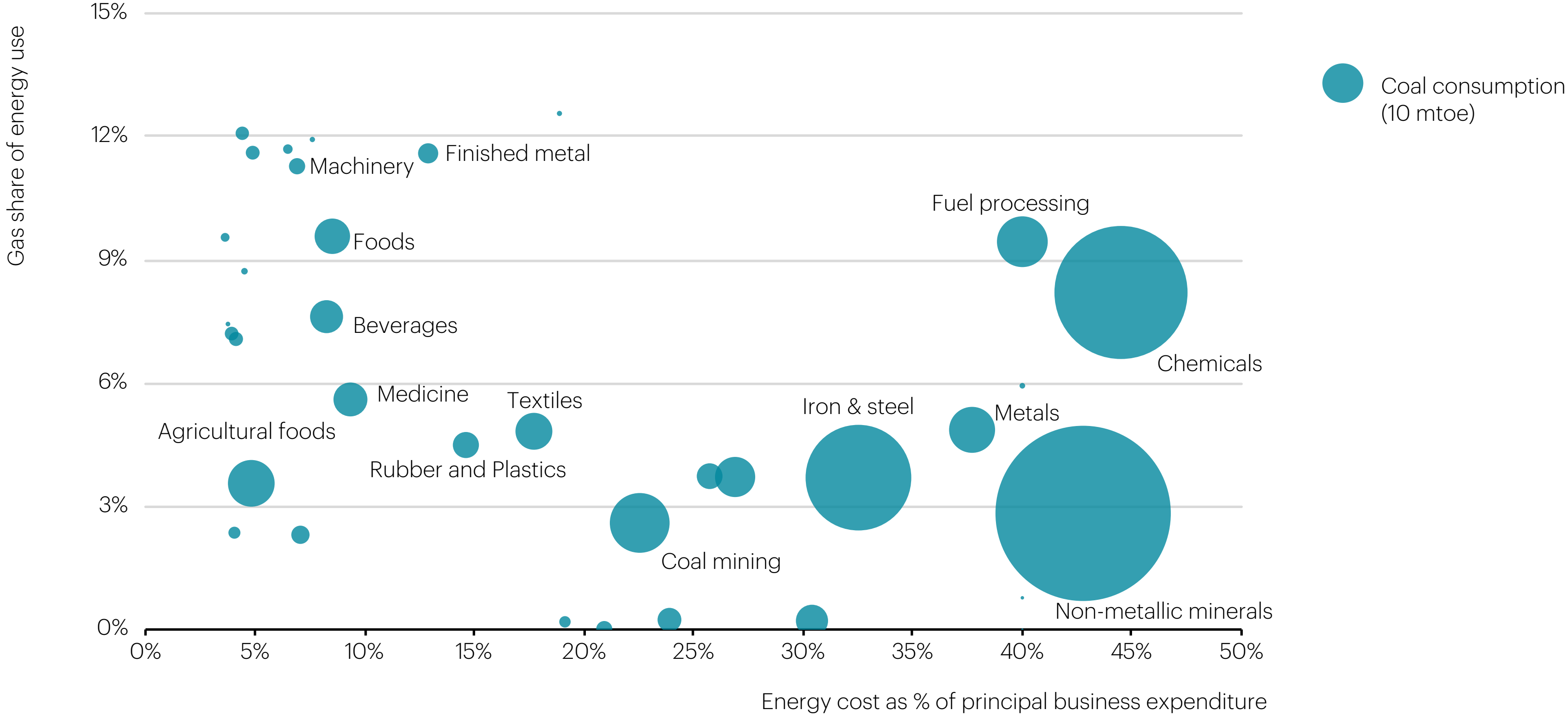
Because of greater efficiency, air source heat pumps have a similar emissions intensity to gas boilers, but they represent a higher cost option whose uptake depends on stronger government subsidies.

The momentum behind gas remains strong: the total number of new gas users in 2018 was twice as high as those opting for electric heating, suggesting that provincial governments are continuing to support the expansion of natural gas networks, despite recent difficulties caused by winter supply shortages (discussed below).

Over the period to 2025, gas more than doubles its market share in the heating demand for buildings from 8% to 20%, while coal (including for CHP) drops from 60% to 42%. Electricity use also sees modest growth, claiming nearly a fifth of the total. China's district heat network – the world's largest – remains dominated by coal but sees growing levels of switching toward natural gas.

In industry, the possibilities for gas vary by subsector

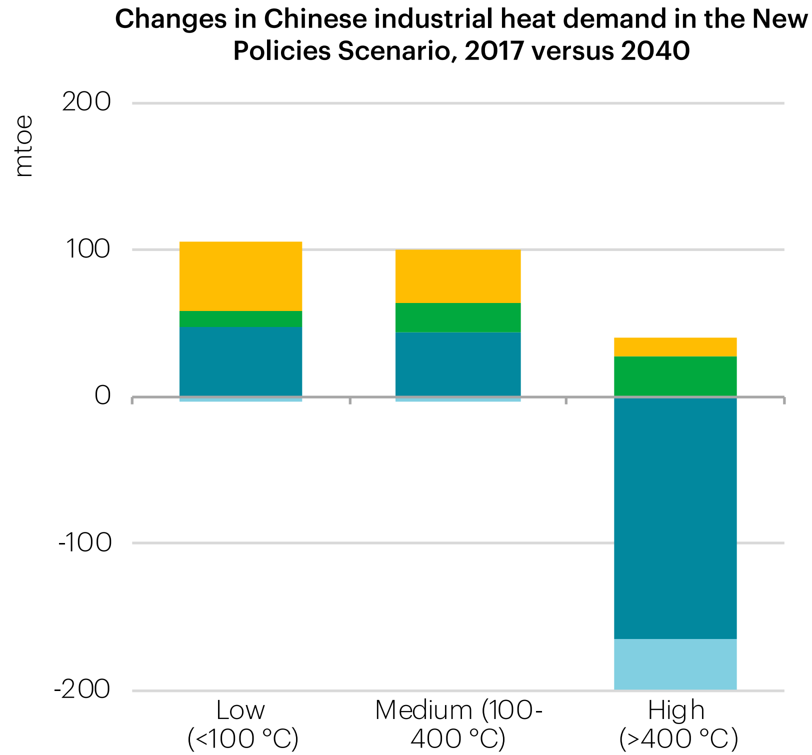
Gas and coal usage and energy costs in China's industrial subsectors in 2016

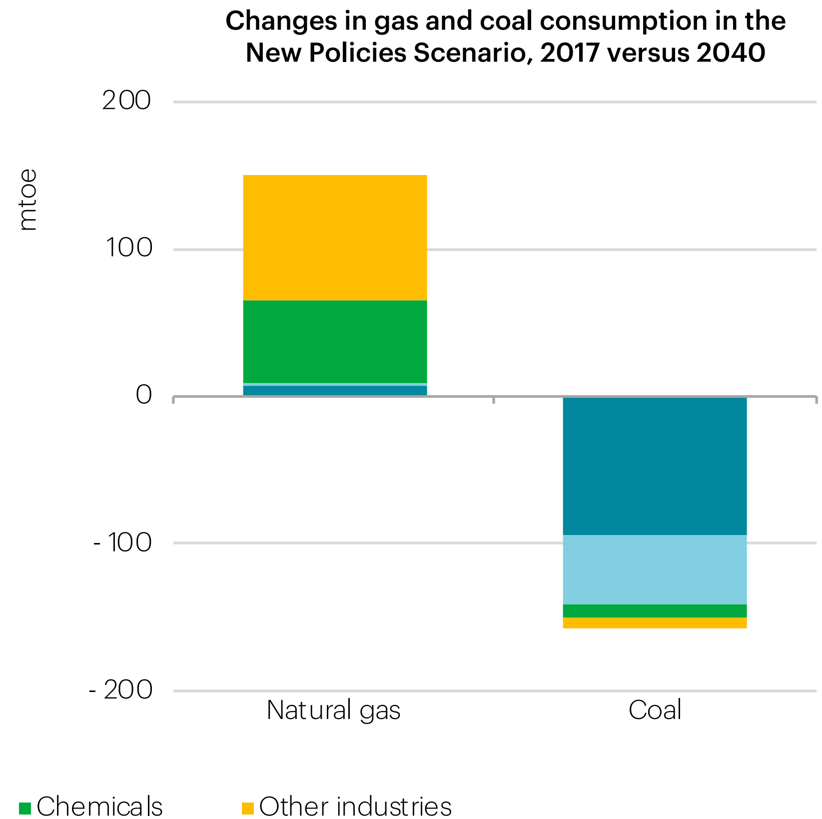


Note: Projections based on the New Policies Scenario. *Principal business expenditure* refers to the total costs incurred by the main business activity as reported to China's National Bureau of Statistics.

Source: IEA analysis based on National Bureau of Statistics of China.

Gas stands to benefit from changes in China's industrial heat demand





Note: Projections based on the New Policies Scenario.

Can China provoke an industrial switch?

Natural gas use makes up only 5% of total industrial energy demand, compared with a global average of 22%. There is significant potential for gas to make inroads into coal's market share, which is currently over half of total industrial energy demand.

The majority of coal use in industry is used in iron and steel, petrochemicals, and cement. The prospects for switching in these subsectors are more challenging, as a significant portion of coal is used for non-combustion processes, and their emissions therefore cannot be easily avoided by a switch to alternative fuels. Carbon capture, storage and utilization technology is a critical route to reduce emissions in these subsectors.

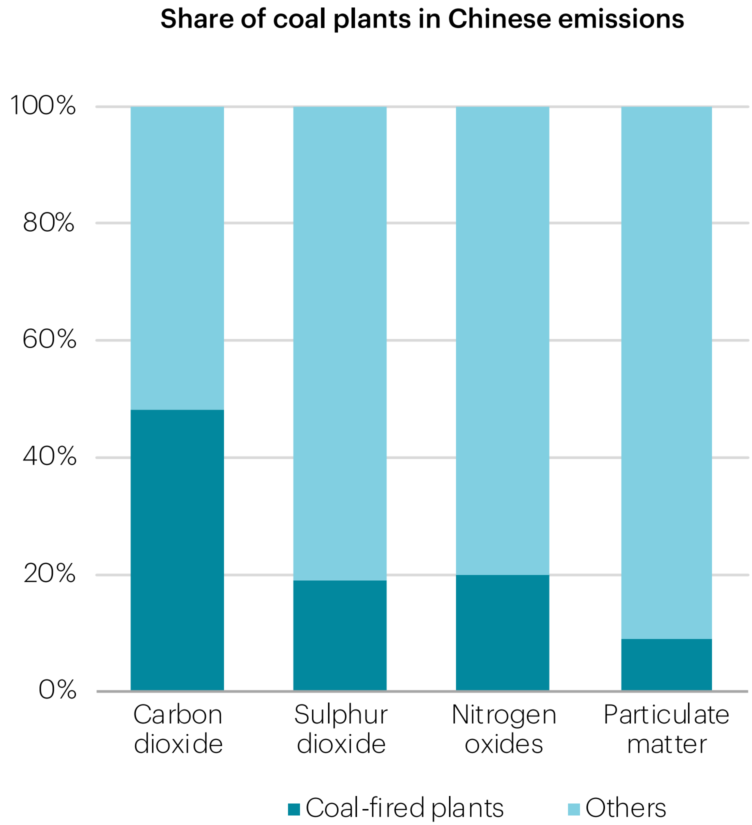
Where fuel costs form a significant part of the operating expenditure, replacing coal with gas also depends on government policy choices for limiting pollutants, including the extent to which smaller-scale coal boilers can be made to install anti-pollution equipment. The need to modernise and upgrade energy-consuming industrial equipment can also be a key factor underpinning the decision to switch fuels.

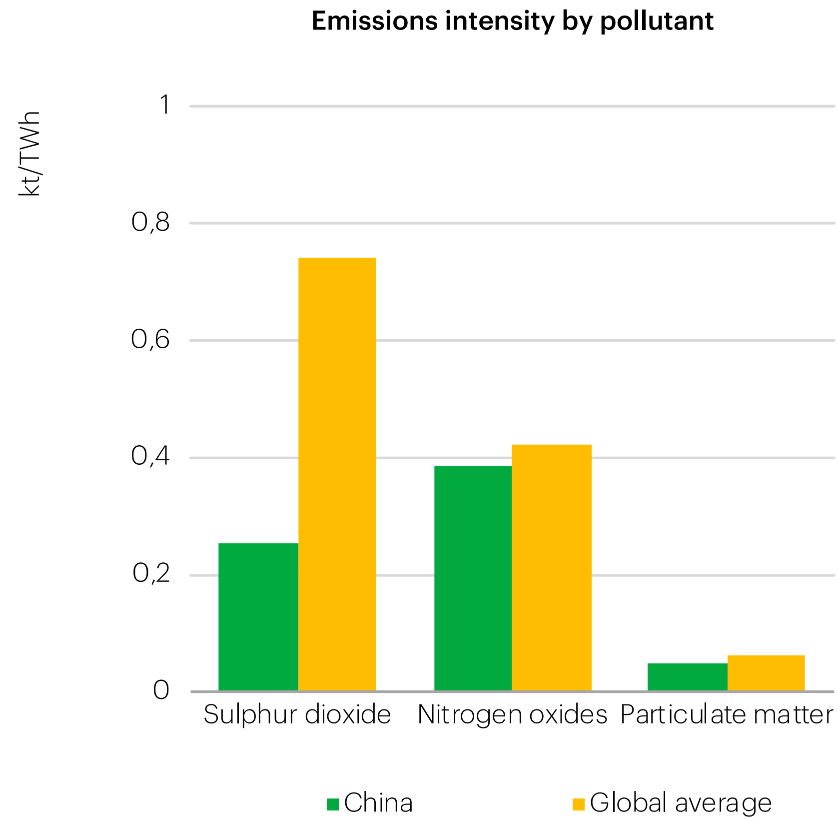
On a fuel cost basis, the prospects for gas are better for lighter industries, such as manufacturing, textiles, or ceramics. For these consumers, gas has other advantages, such as greater efficiency, reduced energy storage costs, lower air pollutants, and more flexibility.

In the New Policies Scenario, declines in industrial coal demand to 2040 are driven by reductions in the high temperature segment – mainly iron & steel and cement, as China's economy undergoes structural change. Gas increases its overall share in industrial energy demand to almost 20%.

Natural gas performs equally well in the Sustainable Development Scenario; gas replaces a greater share of coal in energy-intensive processes (particularly China's methanol and ammonia production, which uniquely rely on coal for feedstock). This offsets declines elsewhere in gas use that arise from greater efficiency and from electricity, which captures a greater share of the demand for low-temperature heat.

China's coal-fired power plants are modern and subject to strict controls on pollutant emissions



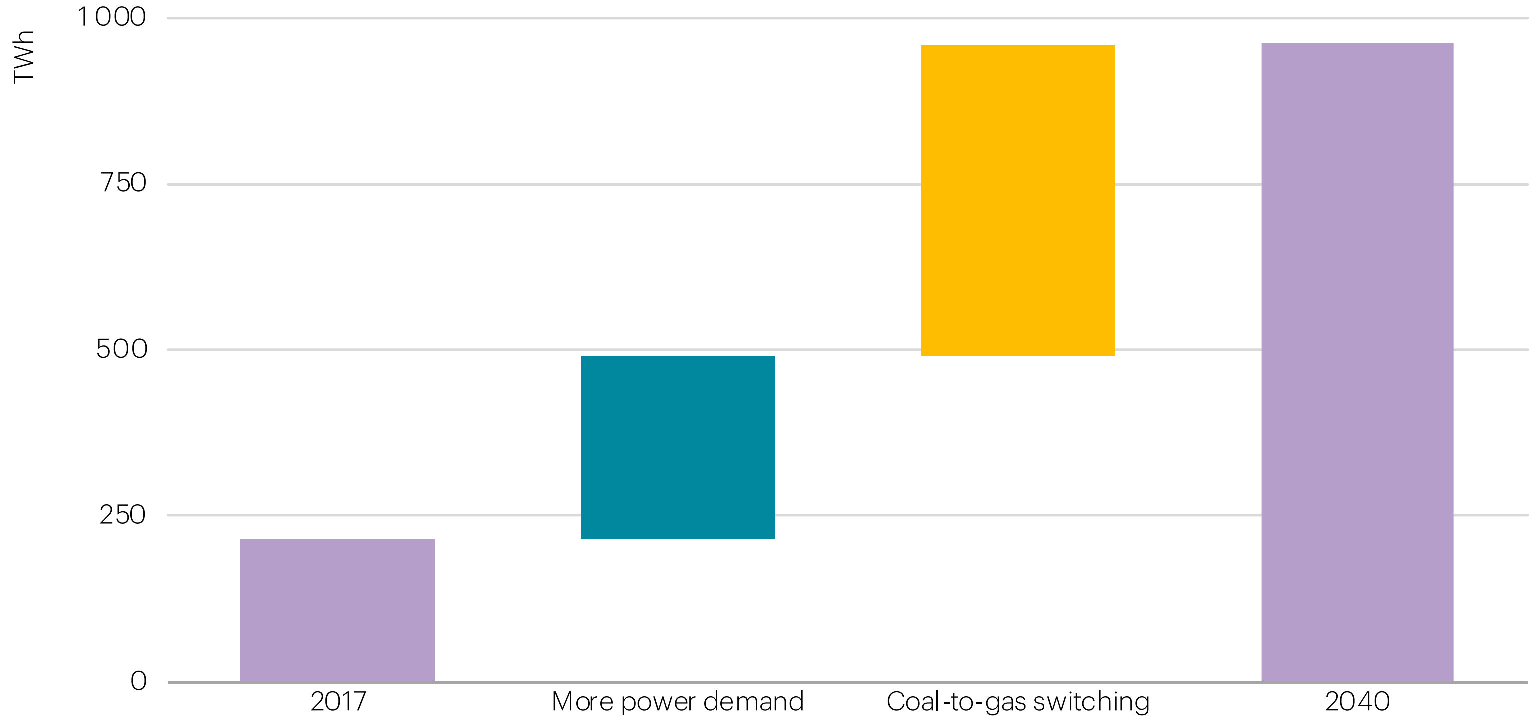


Note: kt/TWh = kilotonnes per terawatt hour.

Source: IEA analysis based on data from IIASA.

Over half of the projected growth in gas-fired power generation to 2040 serves to displace coal

Contribution of switching to natural gas-fired power generation in the New Policies Scenario



Notes: Carbon and commodity prices derived from *WEO 2018*.

Does the electricity sector have the power to switch?

China's coal-fired power capacity is six times larger than that of the whole of the European Union. The significant use of coal in power generation would appear an attractive switching target. However, China's coal fleet is also among the most efficient in the world. The share of super-critical and ultra-supercritical coal plants in the fleet has risen from 3% in 2005 to almost 40% in 2017. Power plants have modernised quickly, adapting to stricter regulations governing air pollutant emissions.

The gas fleet is less than one-tenth the size of coal, meaning the current savings potential from switching (around 100 Mt CO_2) is small relative to China's overall power sector emissions (4 500 Mt CO_2). The switching potential increases as China adds more CCGTs to the fleet, but gas prices would need to fall below USD 4/MBtu in most cases to provoke any meaningful market-based switching.

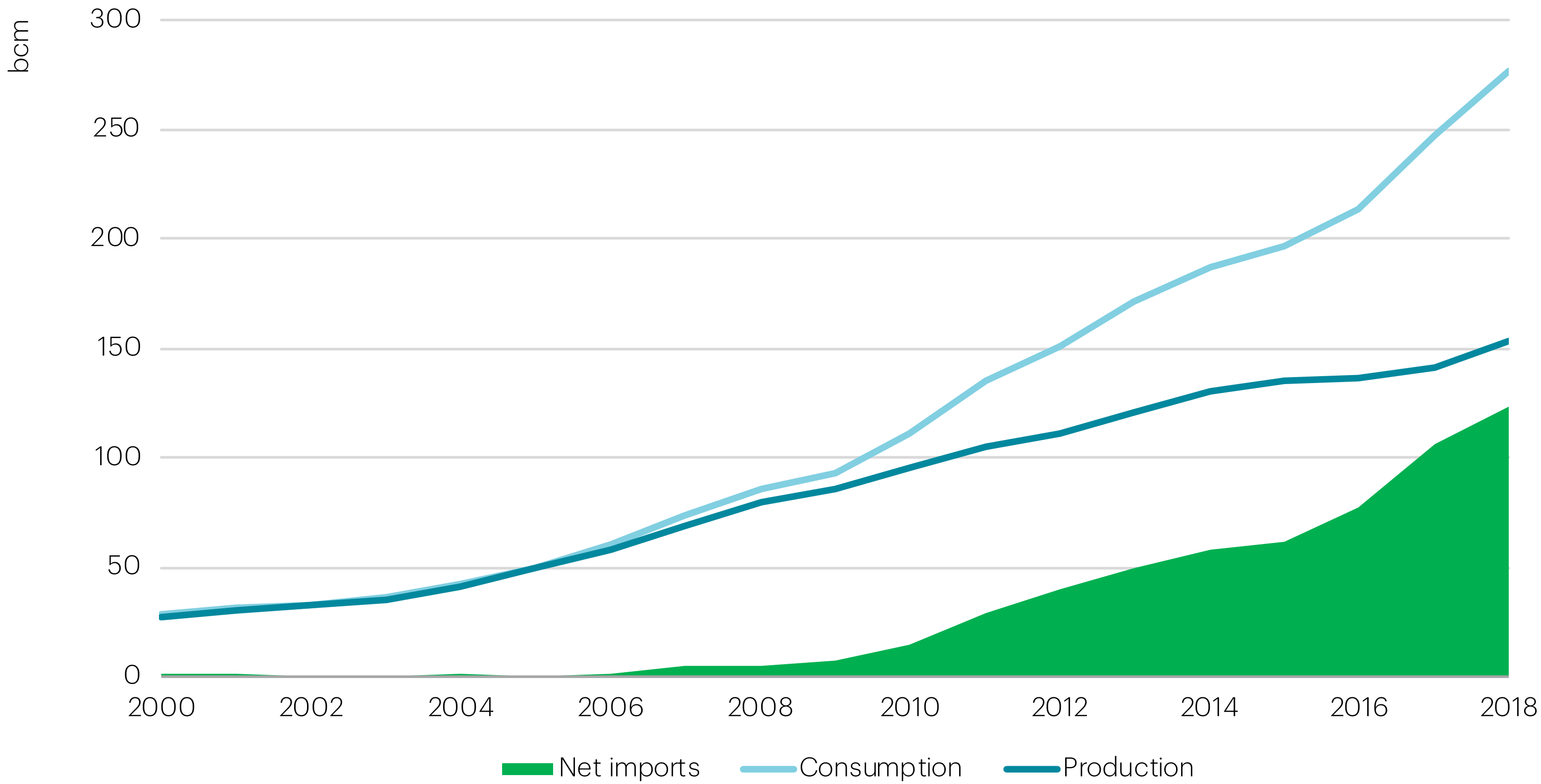
China's emerging carbon market may offer an opening for natural gas to gain market share against coal. However, with a cost gap between coal and gas-fired power generation of USD 30/MWh to USD 40/MWh, a CO_2 price in the range between USD 60/t CO_2 and USD 85/t CO_2 would be needed to provide enough support for gas. Moreover, the rise of renewables (solar PV and onshore wind are already cheaper than new CCGTs), planned increases in nuclear power and the possibility for coal plants to be fitted with carbon capture and storage technology present alternative longer-term solutions to using gas to reduce emissions in the power sector.

Gas generation is growing, however. For the first time, in 2018, China invested more in CCGTs than in coal-based power generation, suggesting that the relatively rapid build out of gas infrastructure for industry and buildings is having positive knock-on effects for gas-based power generation.

Looking ahead, the share of gas in China's power mix rises to nearly 10% by 2040 in the New Policies Scenario, with more than two-thirds of the growth attributable to coal-to-gas switching, leading to an emissions saving of 250 Mt CO_2.

The recent surge in gas consumption has run well ahead of domestic supply

Gas consumption, production, and imports in China since 2000



How can gas supply keep pace with the demand for switching?

Although domestic production has grown at an impressive annual average rate of 10% since 2000, it has been unable to keep pace with the tripling of demand over the last decade. Imported gas – particularly LNG – has grown more quickly in percentage terms than natural gas demand as a whole.

Higher-than-expected growth in new gas connections led to supply shortages in the winter of 2017/18, particularly in the northern parts of China, which were compounded by insufficient storage and LNG regasification capacity, shortfalls in piped imports, and internal south-north infrastructure bottlenecks.

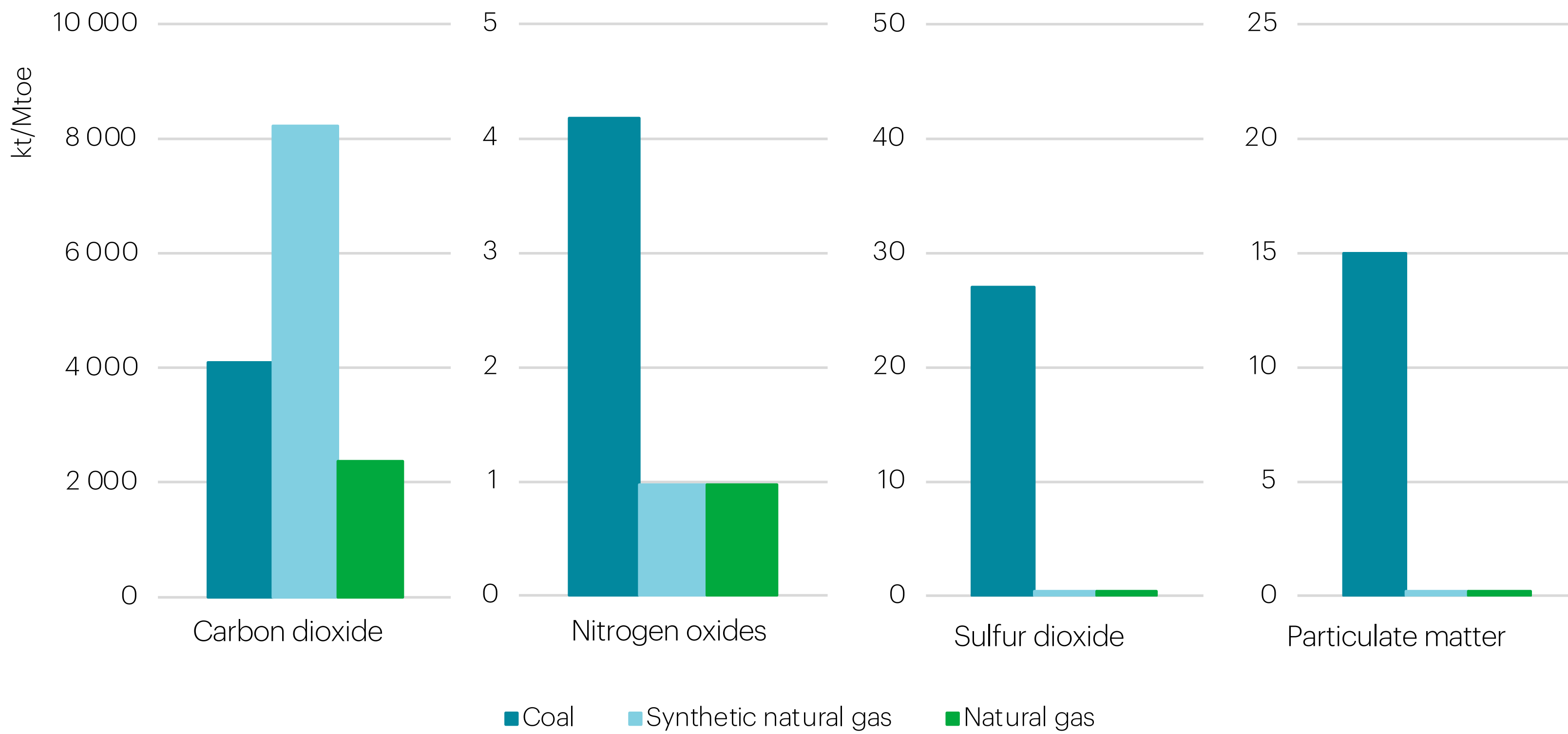
Deregulated LNG prices rose sharply as provincial governments resorted to measures such as trucking LNG and reducing supplies to power plants and industrial customers, many of whom had recently completed a coal-to-gas switch. These shortages led to rapid investment in pipeline infrastructure and significant pre-seasonal procurement by Chinese buyers in the winter of 2018/19.

The prospects for gas supply and demand in China will also be shaped by an ongoing process of gas market and pricing reforms, and the need to encourage investment in domestic production, storage, and import infrastructure while keeping gas affordable to end users.

Progress has been made in recent years. Industrial prices have been deregulated since 2015 and, as of mid-2018, city-gate tariffs for residential users are no longer set by the government, allowing the prices paid by households to gradually rise to reflect the cost of supply of imported and domestically produced gas, as well as seasonal increases in demand. However, the persistence of upstream market concentration remains a barrier to unlocking the benefits of downstream price liberalisation.

Coal gasification is an option to increase domestic supply and reduce air pollution, but could also lead to a large increase in CO_2 emissions

CO_2 and air pollutant (NO_X, SO_2 and $PM_{2.5}$) emissions intensities of coal, synthetic natural gas produced from coal, and natural gas in the residential sector in China



China's supply options come with different environmental credentials

To supplement conventional domestic production and imports, China has been investing in coal gasification technology, which produces synthetic natural gas (SNG) by way of a process of methanation. This process requires large amounts of low-grade coal as well as water resources.

The use of SNG provides an example of a trade-off between climate change and air quality goals. The conversion of coal to gas is done at a 50% rate of efficiency, meaning two units of coal are required to produce one unit of natural gas. Although burning SNG provides the same relatively low level of air pollutants as conventional gas, the supply chain used to produce it generates almost four times as much CO_2– double the amount from direct coal use.

China's ambitions for SNG, with targets of up to 57 bcm of capacity by 2020, have not yet come to fruition, largely owing to the high costs and logistical hurdles (most of the planned facilities are in the more remote northwestern regions of Xinjiang and Inner Mongolia). Current production of SNG today is 5 bcm; however, this increases to 45 bcm by 2040 in the New Policies Scenario, resulting in 110 Mt of CO_2 emissions.

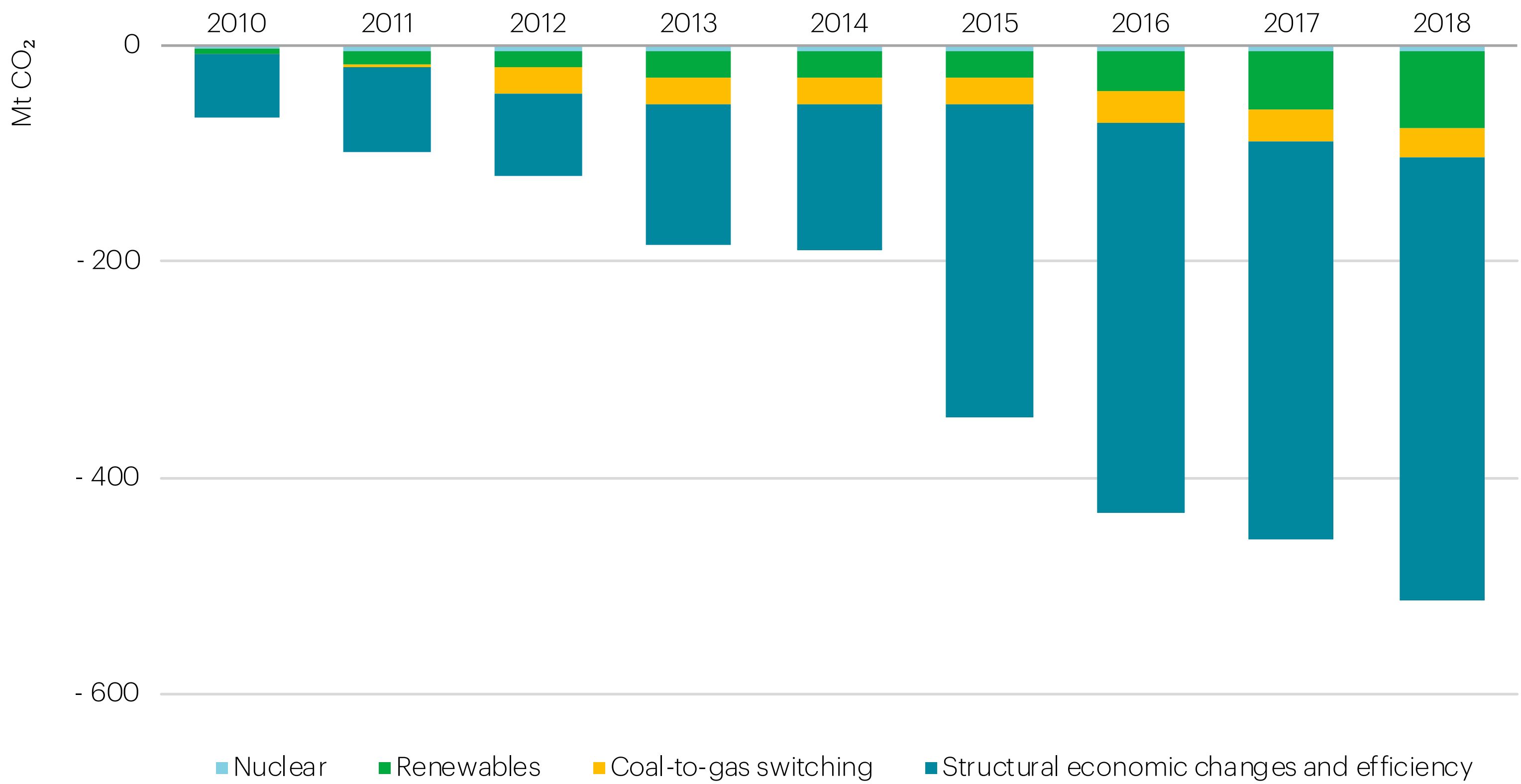
The environmental footprints of China's imported and domestic natural gas are also increasingly relevant as gas expands its market share. As noted in the overview, there is the potential for suppliers of LNG to bring down their upstream emissions intensity to a level similar to that of domestically produced gas, bolstering the environmental case for switching from coal to natural gas.

Overall, China's efforts to improve air quality by choosing gas provide important indirect benefits for carbon emissions. By 2040, coal-to-gas switching abates nearly 1 Gt CO_2, providing 15% of the additional savings required in the Sustainable Development Scenario.

Case study: India

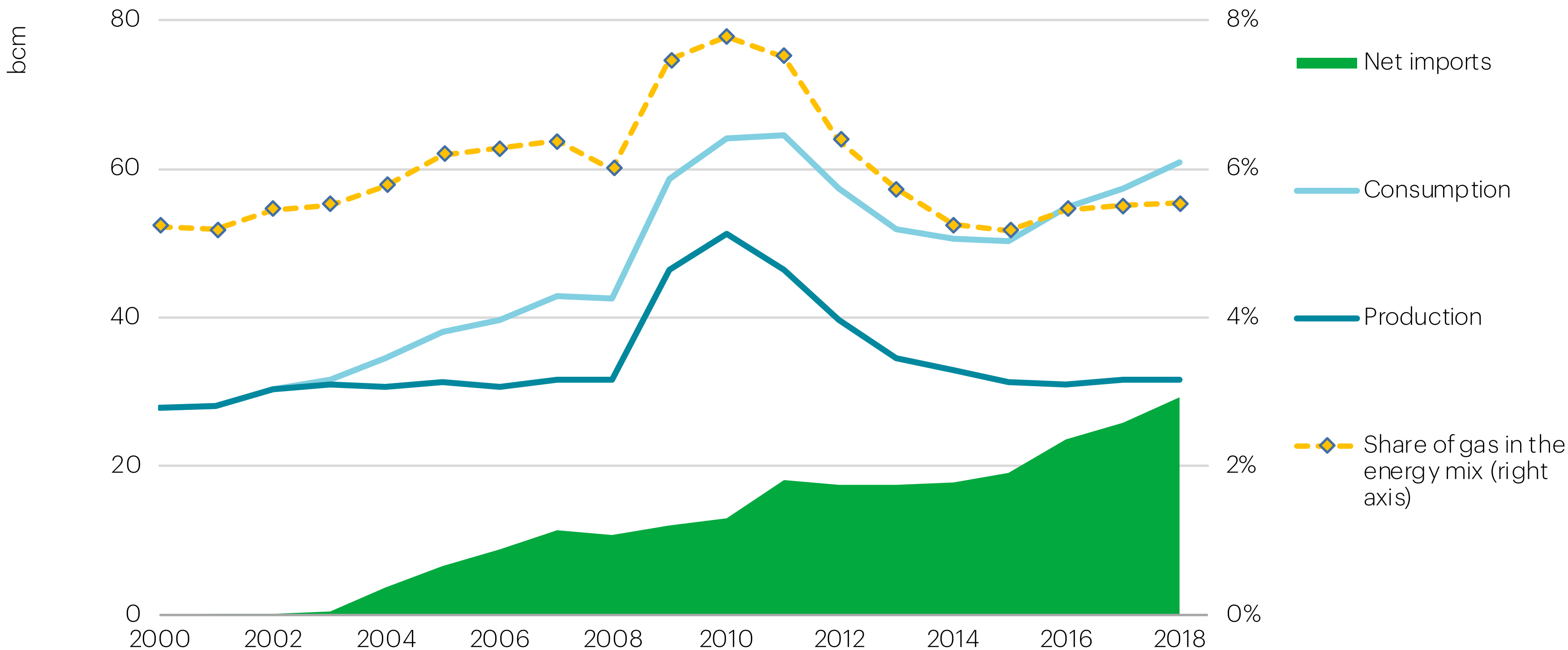
Emissions savings from coal-to-gas switching in India were visible in the early 2010s, but did not pick up

Breakdown of cumulative emissions reductions in India versus baseline projection since 2010



High hopes for domestic gas production in the early 2010s did not materialise

Gas consumption, production, and imports in India since 2000



An uphill struggle for gas in India?

Coal is by far the largest element in India's energy mix, accounting for 74% of electricity generation and 45% of primary energy demand. High coal use, combined with growing oil use for transport and continued reliance on solid biomass as a cooking fuel, means that India's air pollutant emissions are very high. In the latest World Health Organization air quality database, nine out of the ten cities with the highest measured concentrations of fine particulate matter ($PM_{2.5}$) are in India.

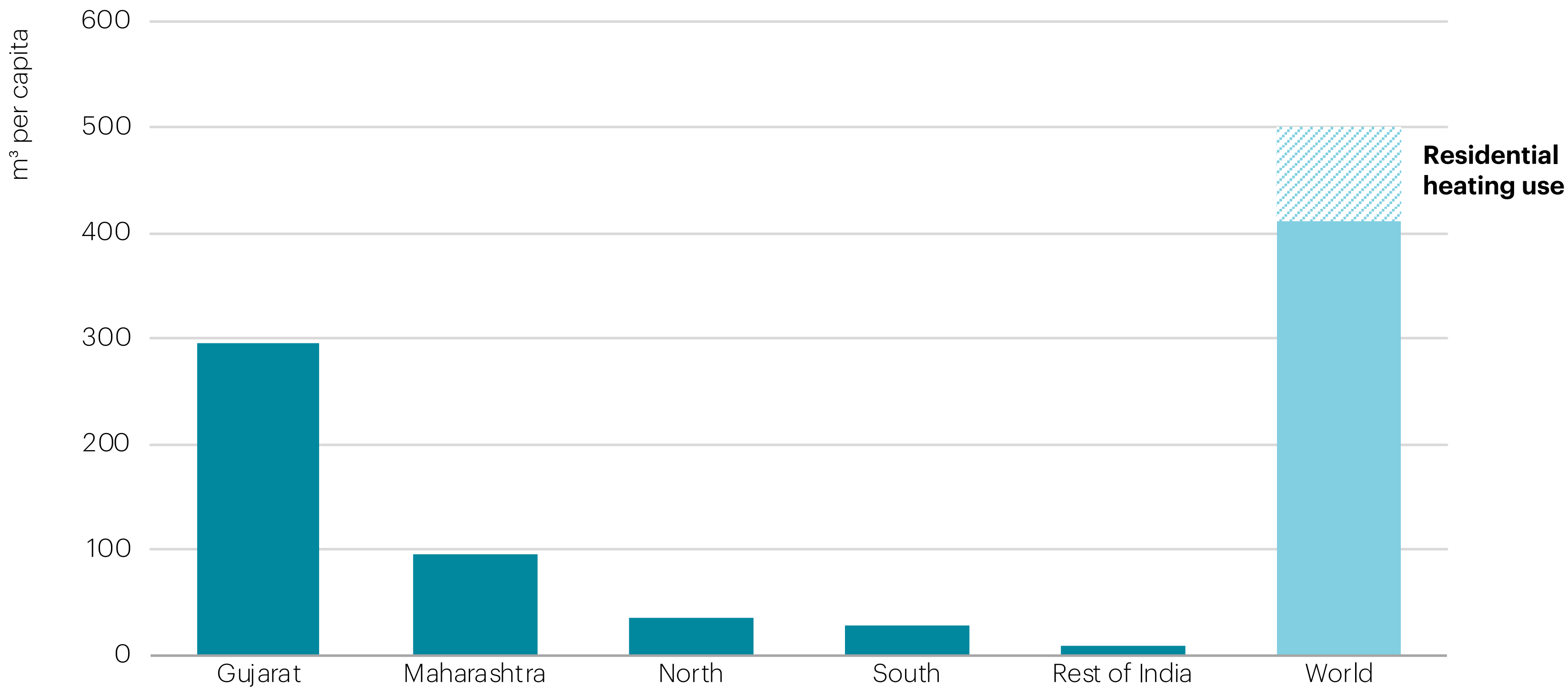
These factors would appear to provide an opening for natural gas. Successive policy documents have targeted a more prominent role for gas in the energy mix, and the aspiration at present is to reach a 15% share for gas in primary demand by 2030. But in practice, the share of gas has actually declined in recent years, from 10% in 2010 to 6% in 2017; coal-to-gas switching has contributed to a modest reduction in CO_2 emissions of around 30 Mt since 2010.

Offshore gas discoveries in the early 2000s fueled a period of optimism about domestic supply and prompted a build-out of gas infrastructure. Production from the much-awaited KG-D6 field in the Krishna Godavari Basin off India's east coast started in 2009 but did not match expectations and fell away quickly. Gas consumers seeking cheaper domestic supply were left short of gas or became reliant on more expensive LNG.

Investment is now picking up in India's domestic gas supply, with activity focused again on the Krishna Godavari Basin. There are also new domestic pipeline connections and LNG import projects that should enter into operation in the coming years (the latest addition being the 5 million tonnes per annum Ennore LNG terminal, the first on India's east coast). But pricing policies, regulation, and affordability remain key constraints, especially now that falling costs have made solar PV the main vector to challenge coal in the power sector.

Gujarat shows that gas can work ...

Per capita gas consumption by region in India, 2017



… if supply is close by and infrastructure gets built

The perception that gas is not a good fit for India is countered by the example of Gujarat, one of India's most industrialised states that is situated on the west coast adjacent to Pakistan. Natural gas accounts for up to one-quarter of the state's energy mix, well above the national average.

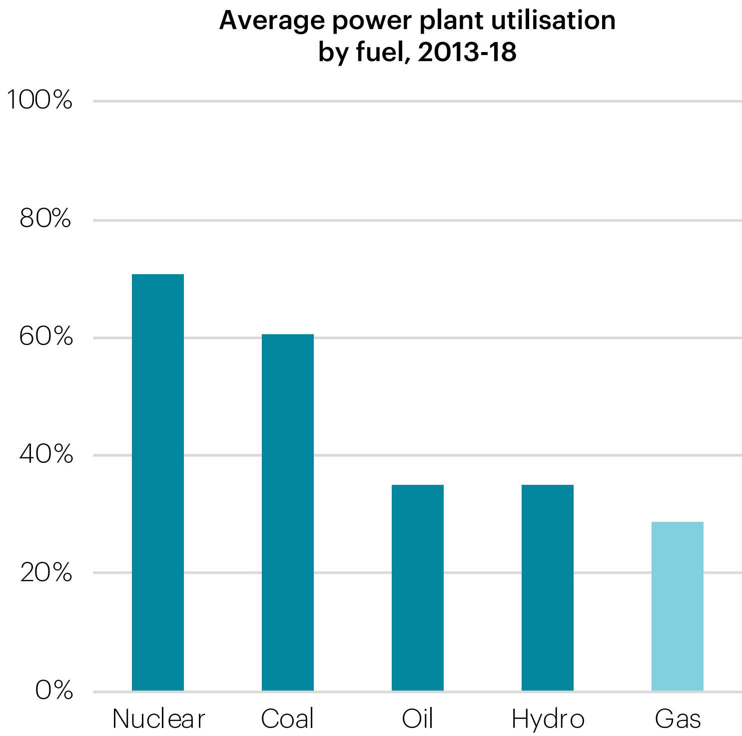
Gujarat has around 5% of India's population but accounts for 60% of the country's industrial gas consumers (4 551 out of 7 601, as of 2018) and nearly 70% of the commercial consumers. It was one of the earliest gas-producing regions in the country and remains the second-largest onshore producing state (after Assam), with proximity also to the Oil and Natural Gas Corporation's (ONGC) western offshore fields.

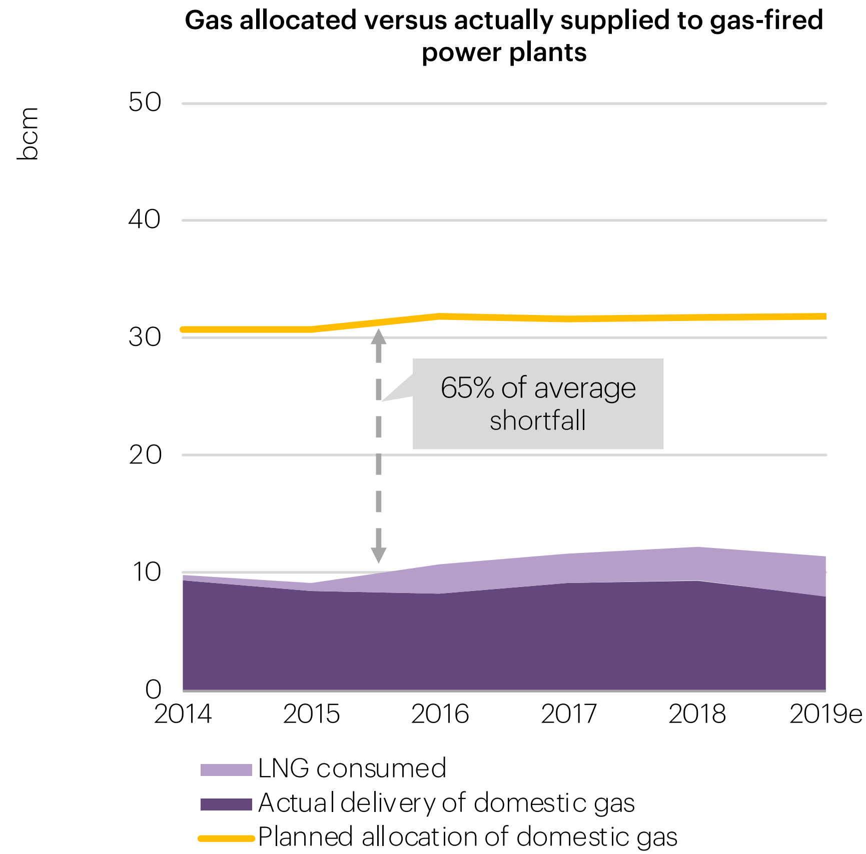
Gujarat is relatively far from India's main coal-producing regions, and it hosts the main LNG import terminals in Dahej (since 2004, import capacity of 15 Mt of LNG per year) and Hazira (2005, capacity of 5 Mt), which still account for the vast majority of the country's LNG imports, primarily from Qatar.

Access to a balance of domestic and international sources of gas have underpinned gas use in Gujarat – and, to an extent, in neighbouring Maharashtra, which, since 2013, has also had its LNG import terminal at Dabhol (where import capacity is being expanded to 10 Mt). This area is by far the densest in terms of pipeline infrastructure – Gujarat is set to become the first Indian state to be completely covered by a piped gas distribution network.

Gas infrastructure build-out in many other parts of India has faced persistent problems with financing and delays. India's fourth LNG terminal – at Kochi in the southern state of Kerala – has been operating at well under 10% capacity because of a lack of pipeline connections inland.

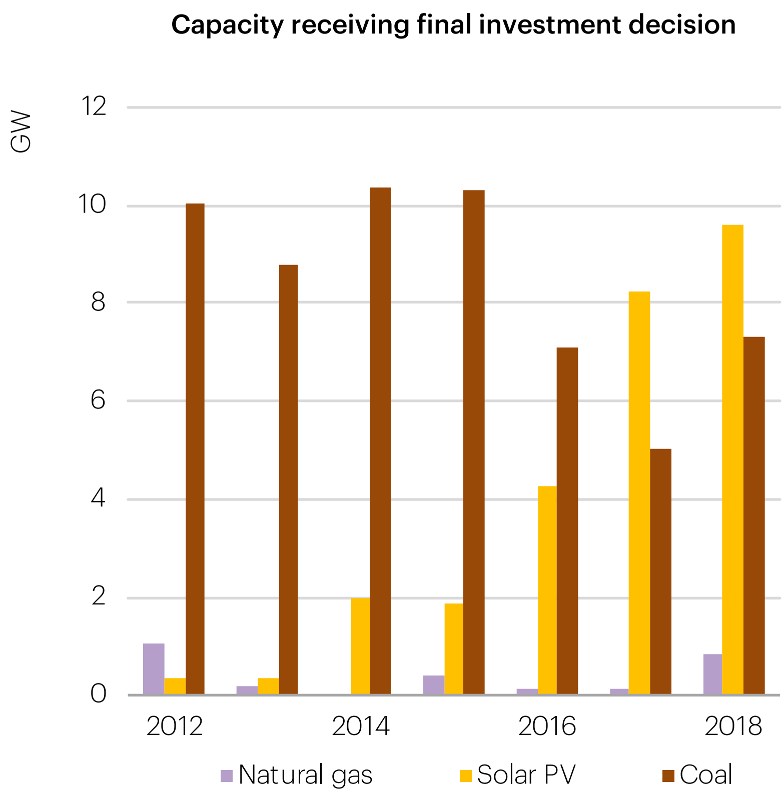
India has spare gas-fired power capacity, but is constrained by a lack of available gas supply

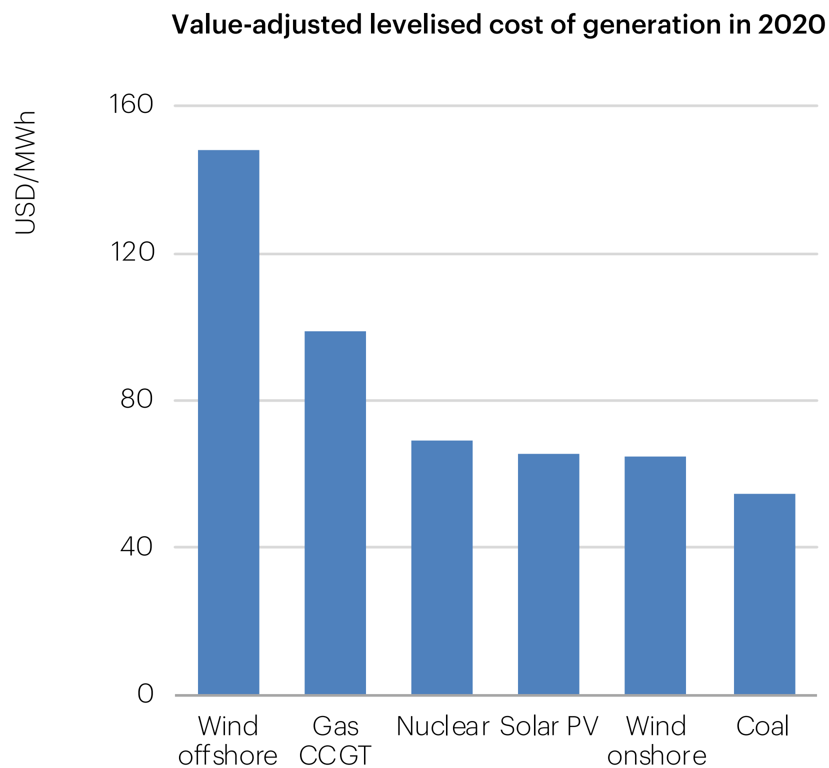




Source: IEA analysis based on 2019 data from Indian Ministry of Power.

Gas for power is being squeezed hard by coal and renewables





Note: The values for solar PV represent overnight investment in capacity in the respective year.

Without cheaper domestic supply, gas is being priced out of power

India fulfils one of the key conditions for coal-to-gas switching in the power sector – it has significant under-utilised gas capacity. In recent years, the country's gas-fired plants have been in operation only around 30% of the time; if they were to run at 80% and displace the equivalent output from coal, they could bring an annual CO_2 saving of over 60 Mt. But this outcome appears unlikely.

India has 29 GW of gas-fired capacity, of which around half are in dire financial straits. Most of the latter plants were built by the private sector in anticipation of rising volumes of relatively cheap domestic gas, notably from the KG-D6 field. Domestic gas is priced and allocated by the government, but it has had to be rationed in practice because of the shortage of domestic gas output.

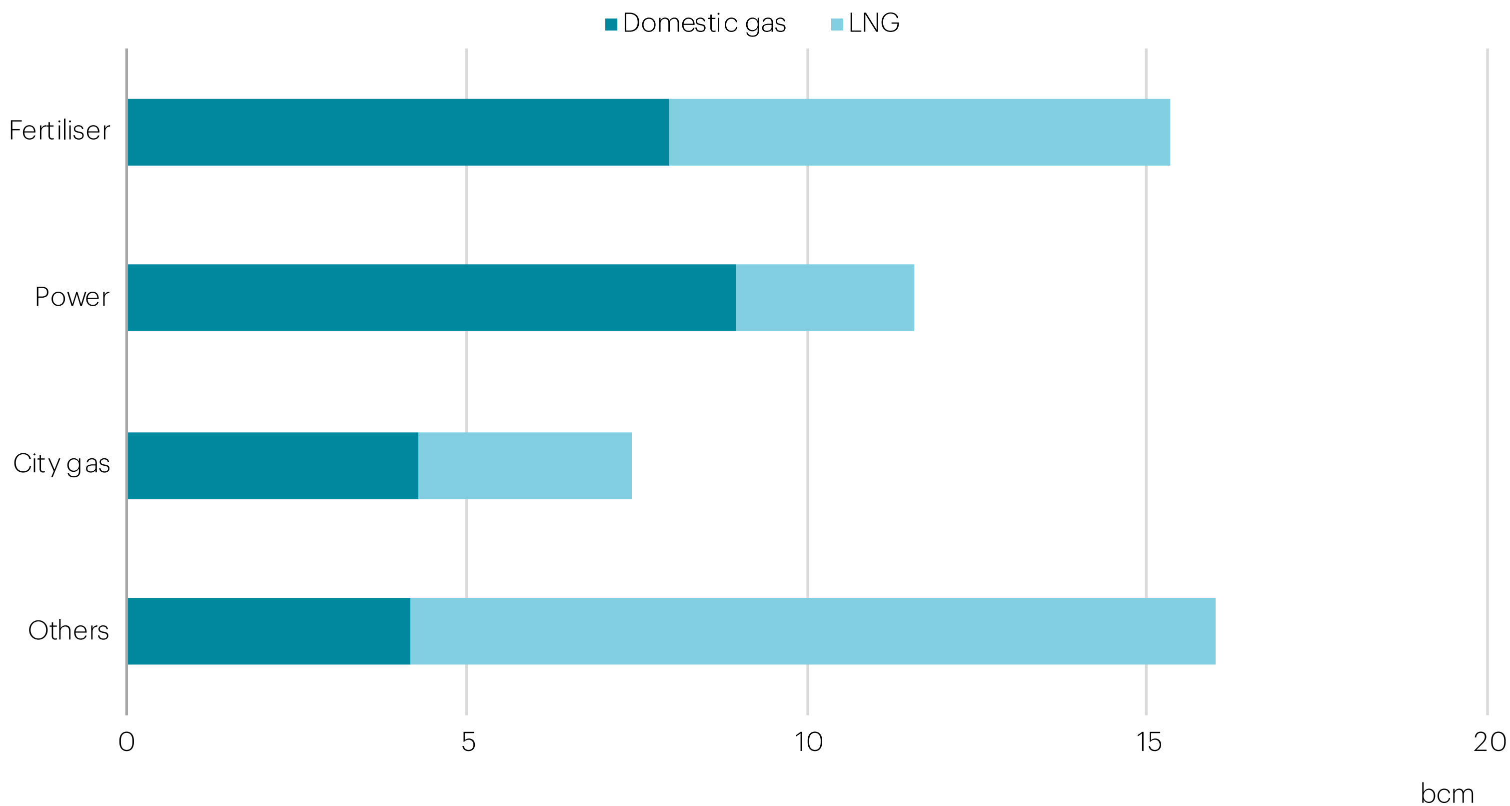
Domestic gas supply to the power sector has reached only around 25% of its planned allocation since 2013. LNG has filled part of the gap, but LNG is too expensive to produce power competitively. The circumstances vary by region, but we estimate that gas needs to be available to power generators at less than USD 3/MBtu for gas-fired power to find a place in the merit order.

Various options are being considered to throw a lifeline to this sector, at least until domestic gas supply picks up again in the early 2020s. However, the falling costs of solar and wind anticipated in the New Policies Scenario mean that renewables – not gas – are widely seen as the main "cleaner" alternatives to coal for electricity generation in India.

Against this backdrop, the more likely perspective for gas-fired power is its deployment in a balancing role in an increasingly solar-rich mix. This provides a valuable service to the system and – indirectly – helps solar to displace coal from the power mix but leaves little scope for direct coal-to-gas switching.

Who, if not power, can afford higher-priced imported gas?

Users of domestic gas versus LNG, by gas-consuming sector in India, average of FY 2015-18



Note: *Others* include large industrial users. *City gas* refers to demand connected to the gas distribution grid, such as buildings and enterprises.
Source: IEA analysis based on data from the Ministry of Power (2019).

Urban consumers could offer an upside for gas

Outside the power sector, gas is an option for industrial consumers in India (including fertiliser production, which is already a major gas user), the residential sector and transport. Based on data for 2015-18, these sectors appear better able than gas-fired power plants to absorb higher-priced gas.

The potential for industrial gas growth is heightened by the "Make in India" target to increase the share of manufacturing in India's GDP. For the moment, industrial energy use in India is weighted heavily towards coal, with a 44% share in industry that is well above the 28% global average.

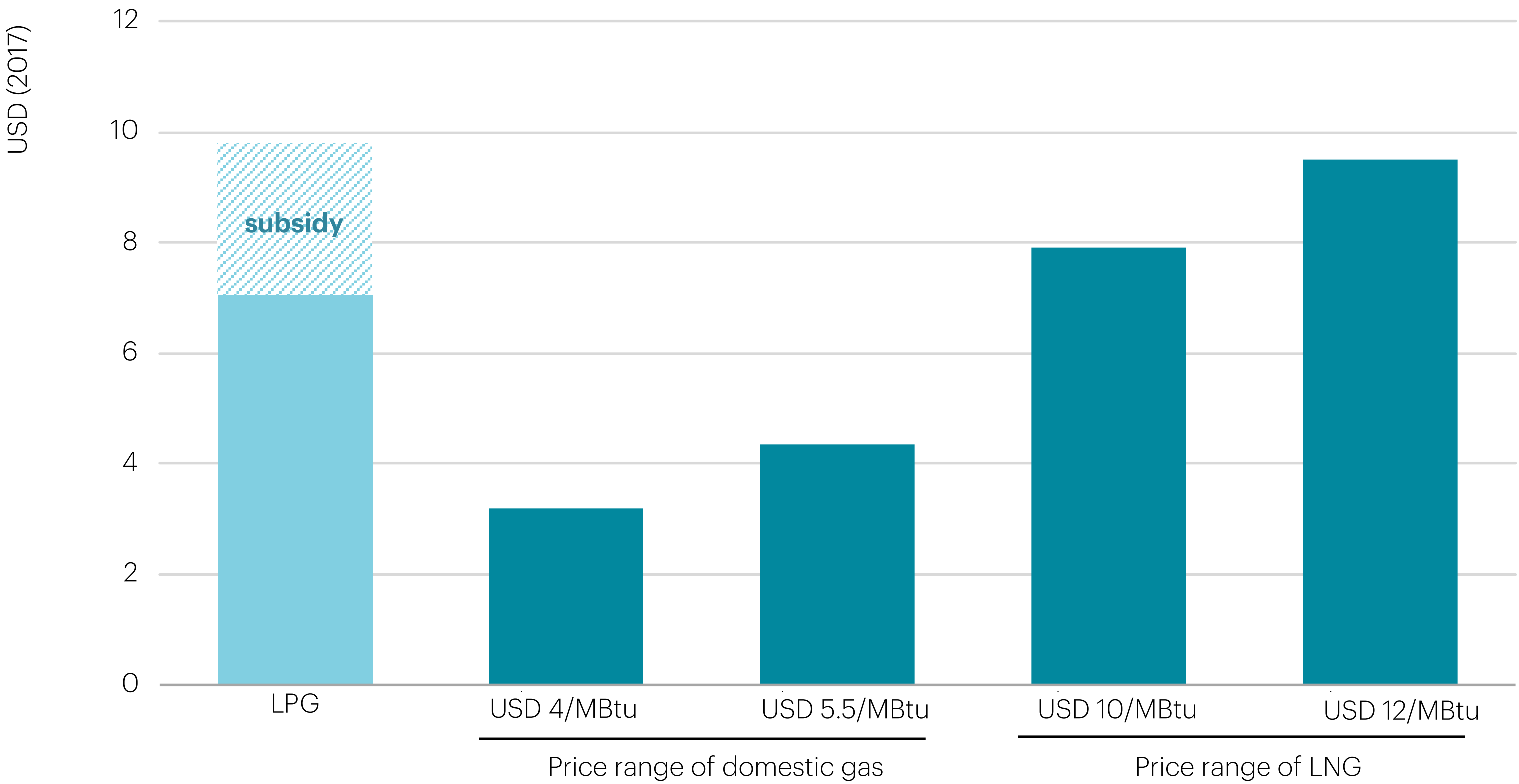
The example of China suggests that urban air quality concerns and a shift towards lighter industrial sectors could push industrial consumption towards gas, but also shows that this requires a concerted policy push to build out gas infrastructure and encourage a shift away from industrial coal boilers.

The scale of the ninth (in 2018) and tenth (in 2019) bidding rounds for city gas distribution licences underlined India's ambitions to extend the gas grid, although a host of permitting and financing challenges remain before these plans can be realised.

The absence of a winter heating load means that residential demand is limited to water heating and cooking, and compressed natural gas for transport, but this also means that consumption is less variable over the course of the year.

If the upfront costs and infrastructure issues are addressed, gas use in urban areas has the potential to free up liquefied petroleum gas (LPG) for use in the countryside

Fuel cost comparison between LPG and natural gas in Delhi at different delivered gas prices (to meet energy demand equivalent to 1 LPG cylinder, 14.2 kg)



Note: Based on 2019 January LPG prices. The values do not include costs for equipment and infrastructure construction.

Infrastructure is the missing link for gas in India

In the urban residential, and transport sectors, gas would displace LPG for cooking (freeing up LPG for clean cooking in the countryside) and liquid fuels from the transport sector. Displacing higher-priced liquid fuels is a manageable economic task for gas.

As of 2018, there were already some 4.3 million residential households connected to the gas grid (and an ambitious target for 10 million connections by 2020), and 1 500 CNG filling stations servicing a fleet of around 3 million natural gas vehicles. An open question for India is how the build-up of CNG infrastructure can co-exist with initiatives to promote electric mobility; whether gas is a stop-gap until affordable electric vehicles are widely available or a lasting vector in India's transport policy.

The major variables here are the speed and extent to which infrastructure is built out. Some major pipeline projects are planned or under construction, such as the Urja Ganga pipeline that is designed to bring gas into some of India's most populous states (West Bengal, Bihar, and Uttar Pradesh), and the first phase of this project was inaugurated in early 2019.

Aside from infrastructure, there are also policy and regulatory measures that could narrow the price gap between gas and competing fuels. At present, for example, coal is subject to the 2017 Goods and Services Tax (GST) and therefore taxed at 5%, while natural gas is outside the purview of the GST and typically taxed at a higher rate.

Annex

Acknowledgements

This report was prepared by the Energy Supply and Investment Outlook (ESIO) Division of the Directorate of Sustainability, Technology and Outlooks (STO). The principal author was Peter Zeniewski, with major contributions from Christophe McGlade, Tae-Yoon Kim and Tim Gould (Head of Division), who designed and directed the analysis. Other key contributors from the World Energy Outlook/World Energy Investment team were Yasmine Arsalane, Stéphanie Bouckaert, Olivia Chen, Davide d'Ambrosio, Timothy Goodson, Yoko Nobuoka, and Andreas Schroeder.

The report benefited from contributions from other experts within the IEA: Raimund Malischek, Christina Morillas, Peter Levi, and Jing Wang for useful data assistance.

Internal feedback and peer-review provided by: Carlos Fernandez Alvarez, Alessandro Blasi, Araceli Fernandez-Pales, Peter Fraser, Gergely Molnar, Bruce Murphy, Alan Searl, Tristan Stanley and Laszlo Varro.

Thanks also go to Astrid Dumond, Christopher Gully, Robert Stone, Sabrina Tan and Therese Walsh of the Communications and Digital Office, as well as the Energy Data Centre. Adam Majoe edited the manuscript.

The work could not have been achieved without the support provided by the Norwegian Ministry of Petroleum and Energy and Natural Resources Canada.

Many experts from outside of the IEA provided input, commented on the underlying analytical work, and reviewed the report. Their comments and suggestions were of great value. They include:

Acknowledgements

Jørgen Bækken	The Permanent Norwegian Delegation to the OECD and UNESCO
Christian Besson	Independent consultant
Xavier Chen	ENN
Vidar Christensen	Norwegian Ministry of Petroleum and Energy
Scott Clausen	Natural Resources Canada
Ralf Dickel	Oxford Institute for Energy Studies
Daniel Dorner	United Kingdom Department for Business, Energy & Industrial Strategy
Francesco Ferioli	European Commission
Mike Fulwood	Nexant
Jean-Francois Gagne	Natural Resources Canada
Fiji George	Cheniere Energy, Inc.
David Goldwyn	Atlantic Council
James Henderson	Oxford Institute for Energy Studies
Masazumi Hirono	Tokyo Gas
Bai Jun	Beijing Gas Group
Isabel Murray	Natural Resources Canada
Sanjoy Rajan	European Investment Bank
Robert Schwiers	Chevron
Jonathan Stern	Oxford Institute for Energy Studies
Joseph Tortorelli	Natural Resources Canada
Johannes Trueby	Deloitte
Nikos Tsafos	Centre for Strategic and International Studies
Tomasz Wroblewicz	Shell

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A brief note on methods

In this study, emission reductions from coal-to-gas switching are decomposed based on changes in fuel market shares. For example, switching occurs when the market share of coal decreases and the market share of gas increases in a given region over a given year. If this is not the case, there is no emissions saving from switching. Increases in natural gas consumption can either arise from a "structure" effect (e.g. gas increases or decreases its market share in a given subsector) or an "activity" effect (e.g. gas demand increases because overall energy demand increases). Only structure effects are considered as coal-to-gas switching.

The conversion efficiency of gas power plants is typically higher than that of coal plants, leading to an energy efficiency improvement and a reduction in the emissions intensity of power generation. Given the decomposition method used, emissions savings from the latter are attributed to coal-to-gas switching, and savings from the former to "structural economic changes and efficiency".

Historical emissions savings are calculated assuming there were no further improvements in the energy- and CO_2-intensities of gross domestic product since the base year.

The potential for coal-to-gas switching is calculated as the additional amount of gas that can replace coal after accounting for the estimated gas demand in a given year in a given scenario. In most cases, realising the additional potential involves additional costs, but there are also cases where switching entails a net negative cost (e.g. when, on a short-run basis, gas appears able to displace what may be system-relevant or must-run coal plants in the power sector).

Throughout the study, we make use of scenario analyses to explore the contribution of coal-to-gas switching using the World Energy Outlook's central New Policies Scenario as well as the Sustainable Development Scenario. A description of these scenarios is available at www.iea.org/weo2018/scenarios/.

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Design in France by IEA – July 2019