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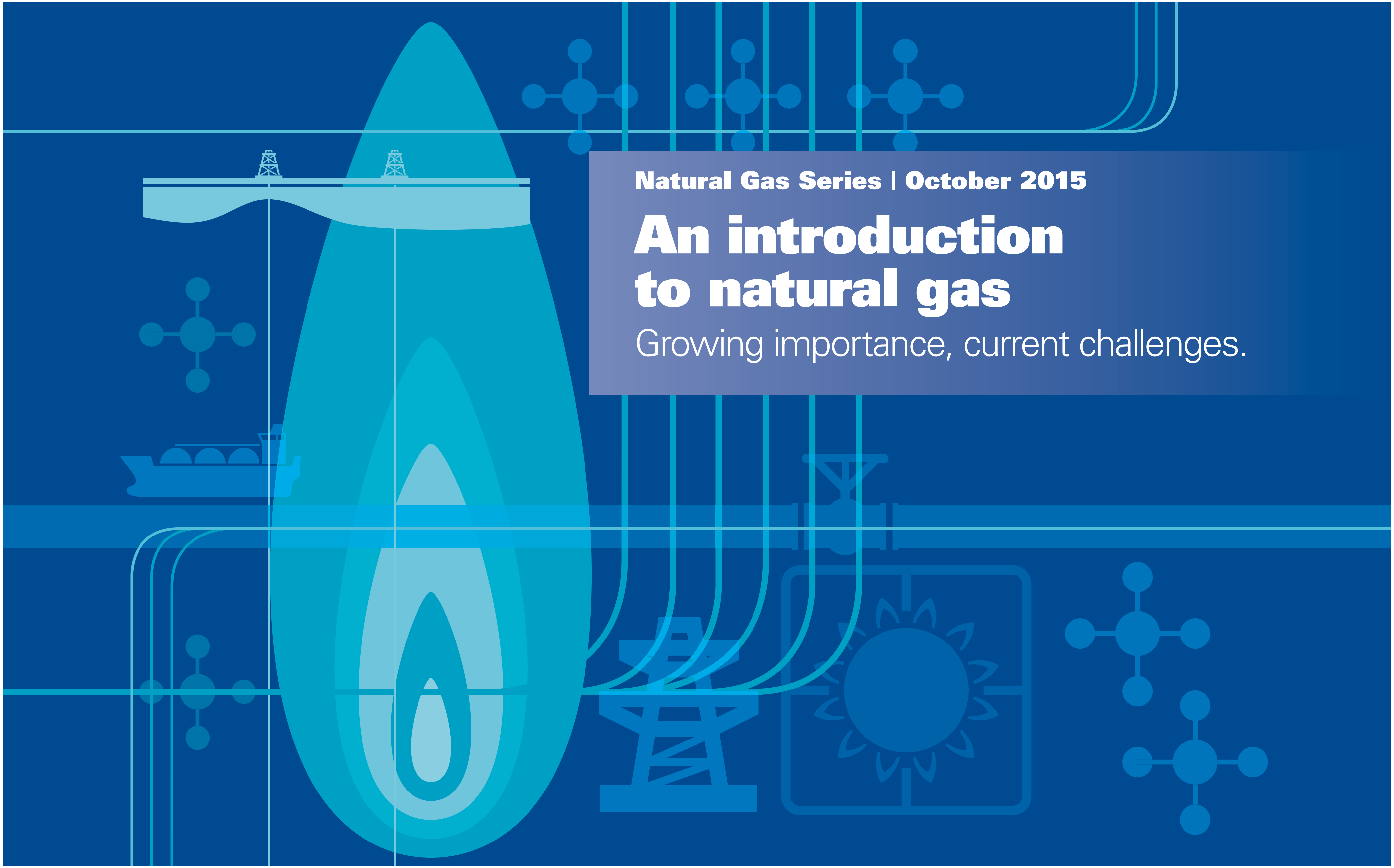

Natural Gas Series | October 2015

# An introduction to natural gas

## Growing importance, current challenges.

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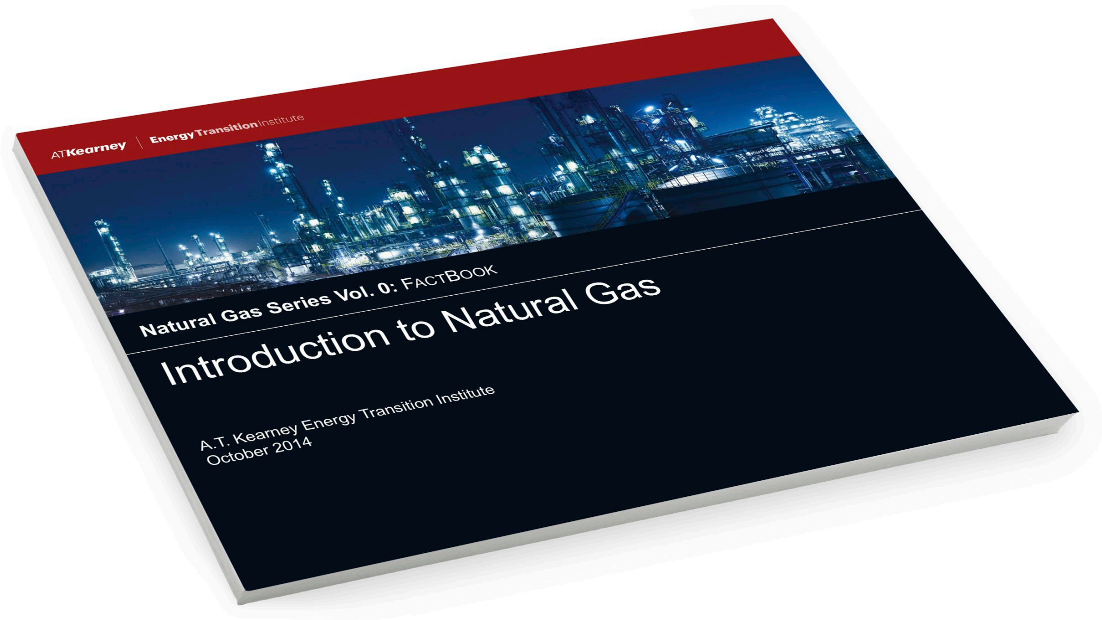
**Natural gas has become a key resource for global energy needs and is abundant, versatile and clean burning. It is used in power generation, for industrial applications, buildings, and transportation. Though historically it has been extracted through conventional means, unconventional extraction processes play a part in regions such as North America. Natural gas is being traded globally, facilitated by investments in transport technology and increased global demand. Future demand for natural gas is likely to grow, especially for power generation, where it can be used to replace coal power and to fill power gaps created by intermittent renewable energy sources.**




The content of this summary is based upon the Introduction to Natural Gas FactBook.

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# Having long been overlooked as an energy source, natural gas has become a crucial part of the energy mix in the past two decades

### Interest in natural gas has been bolstered

Natural gas was, for an extended time, an unwanted by-product of oil production. Without economic methods of bringing it to market, gas was mostly flared or released to the atmosphere. However, in recent decades, its abundance and low carbon content compared with other fossil fuels have considerably bolstered interest in natural gas.

### Natural gas is not solely methane

Natural gas is composed of a mixture of hydrocarbon components, including methane but also ethane, propane, butane and pentane – commonly known as natural gas liquids (NGLs) – and of impurities such as carbon dioxide ($CO_2$), hydrogen sulfide ($H_2S$), water and nitrogen. The composition is highly variable and depends on the resource's location. In some fields contaminants, especially those that characterize sour gas ($CO_2$ or $H_2S$), represent a high proportion of the natural gas mixture, making exploitation harder and more expensive. Sometimes NGLs account for a significant share of natural gas; a mix rich in NGLs, known as wet gas. In 2013, wet gas yielded 9 million barrels of oil equivalent a day, contributing 10% to global liquid hydrocarbon supply. In all situations, natural gas must be processed to remove NGLs and contaminants.

**Natural gas composition is highly variable and depends on the resource's location.**

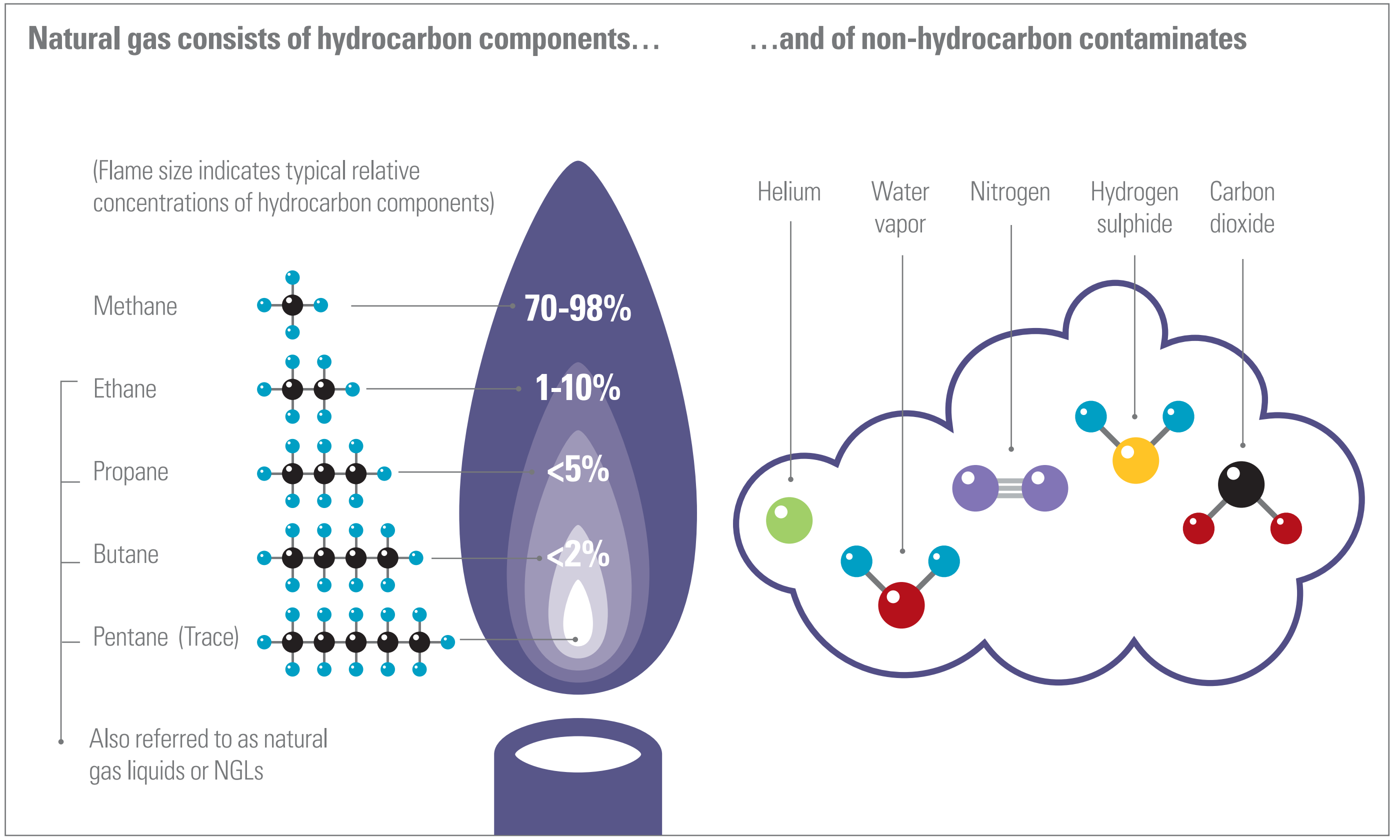
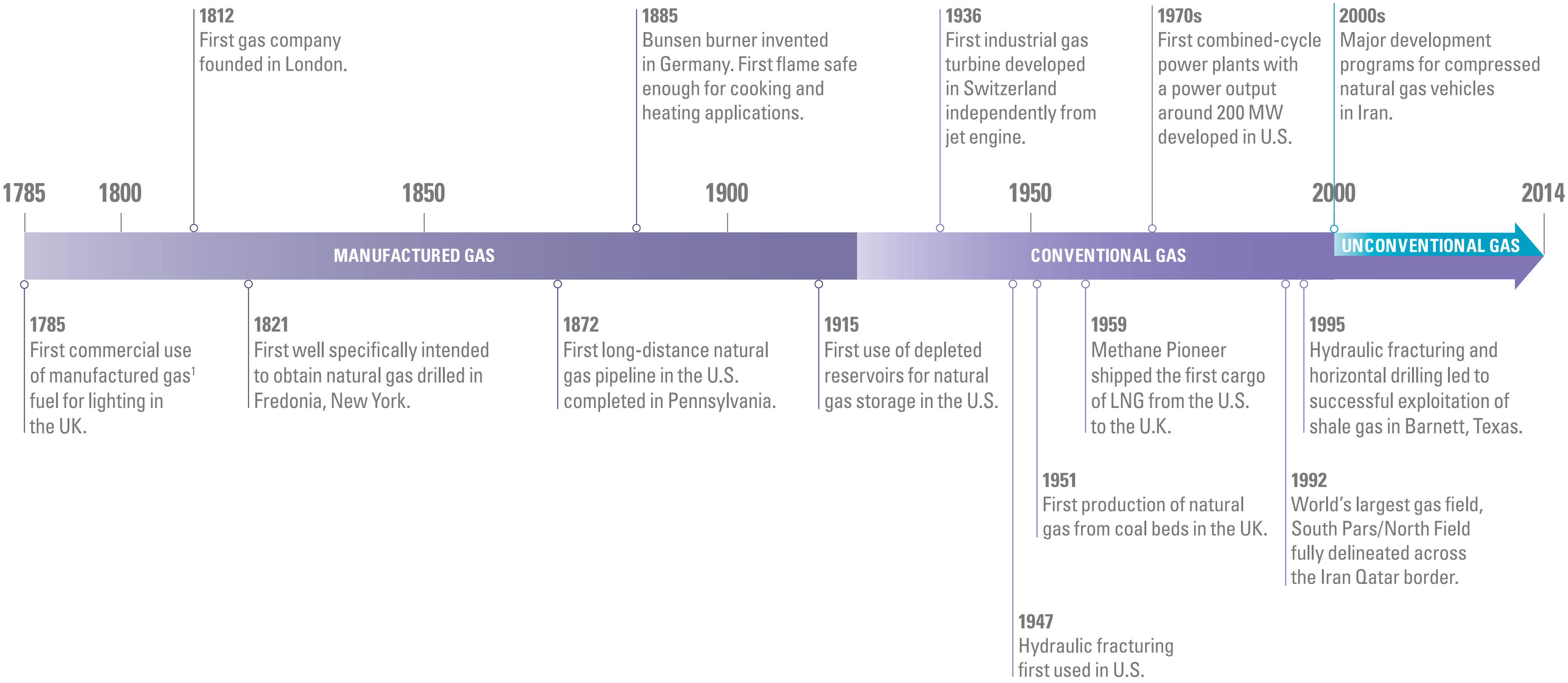


**Figure 1: Natural gas development timeline**

**Abundance and low carbon content compared with other fossil fuels have considerably bolstered interest in natural gas**




Source: UKERC (2012), "The development of the CCGT and the 'dash for gas' in the U.K. power industry (1987-2000)"; EIA (2010), "Natural Gas Timeline"; GE (2013), "The Age of Gas & the Power of Networks"

### Natural gas is a versatile energy carrier

Natural gas is an energy source that can be used as gaseous fuel, but also in non-gaseous forms – for instance, as electricity after conversion in a turbine or as a liquid after conversion in a gas-to-liquids plant. Furthermore, natural gas is not the only primary source of methane. Methane can also be produced by gasifying coal – as synthetic natural gas; from biomass and waste – as biogas; and through power-to-gas conversion, from renewables and nuclear energy. The latter two categories are seen as potential levers for reducing the carbon footprint of natural gas even further. Thanks to its versatility, natural gas plays a major role in all end-use sectors, except for transport.

### Natural gas handling is challenging

The main drawbacks of natural gas relative to other hydrocarbon fuels are its low volumetric energy density and gaseous nature, which makes it harder to handle than solid or liquid fuels. In order to be transported, natural gas needs to be conditioned in some way – either by compression or by liquefaction. This increases shipping costs and results in limited fungibility. The global-warming potential of its main constituent, methane, presents another problem. Similar to $CO_2$, methane is a potent greenhouse gas. However, an equivalent quantity of methane emitted into the atmosphere impacts climate change 84 and 28 times more over 20 and 100 year horizons than $CO_2$, respectively. As a consequence, methane emissions from natural gas systems, if significant and not mitigated, could negate the climate benefit of natural gas compared with other fuels.

### Natural gas systems rely on a complex value chain

The technological landscape that makes up the natural gas ecosystem is largely mature, although a few technologies are still in the "valley of death" of investment, when capital requirements and risks are difficult to overcome.

Nonetheless, research, development and demonstration efforts are under way with the aim of: expanding the uses of natural gas, especially in transport; increasing the available gas resource (for example, by investigating the potential of methane hydrates and unlocking gas resources that are currently non-economic to exploit); and minimizing methane's environmental footprint (e.g. by developing carbon, capture and storage operations, reducing methane emissions and enhancing water treatment).

**In 2013, wet gas yielded 9 million barrels of oil equivalent a day, contributing 10% to global liquid hydrocarbon supply**

**Figure 2. The natural gas value chain**

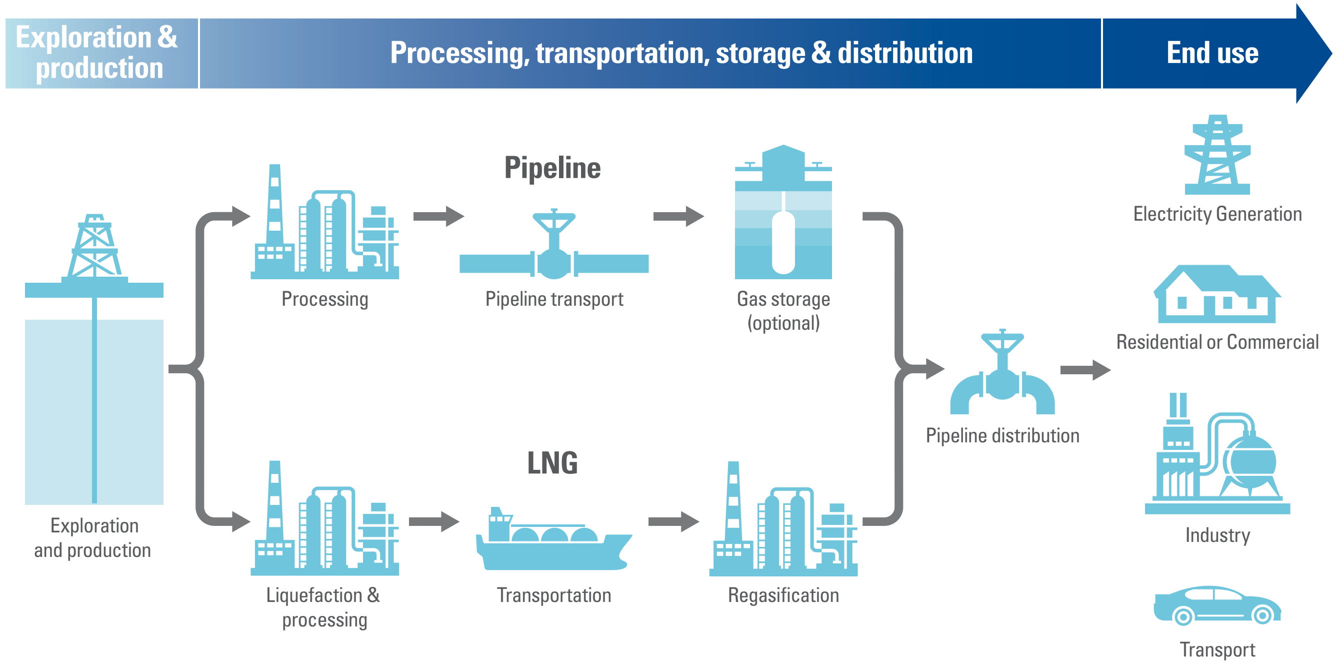
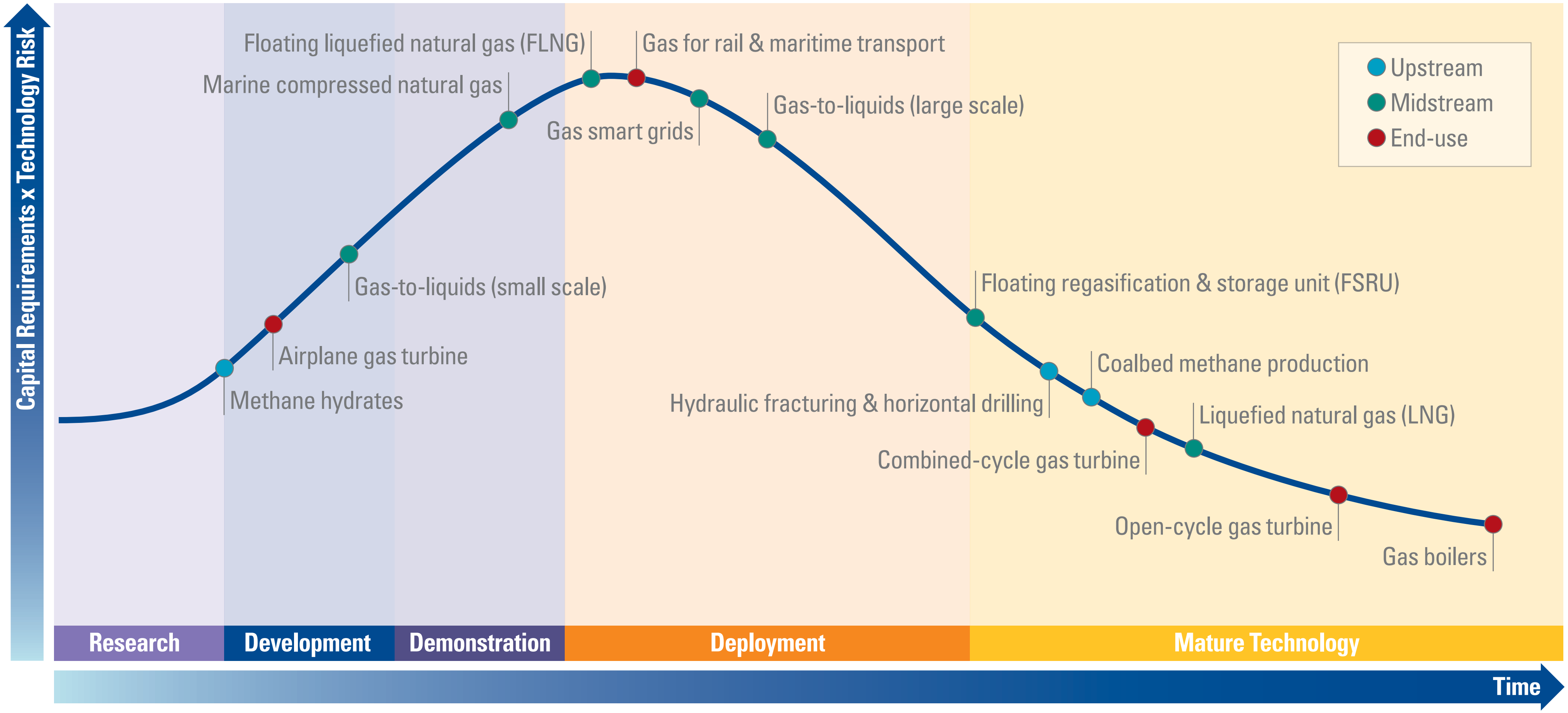


Figure 3. Technology maturity curve




Note: Investment valley of death refers to two critical stages: the early demonstration stage, in which capital required tends to outstrip the resources of a typical lab and where the high technology risk deters some private-sector investors; and the early deployment stage, in which high investment requirements and further risk taking are needed to push the project from demonstration to deployment.

Source: A.T. Kearney Energy Transition Institute analysis

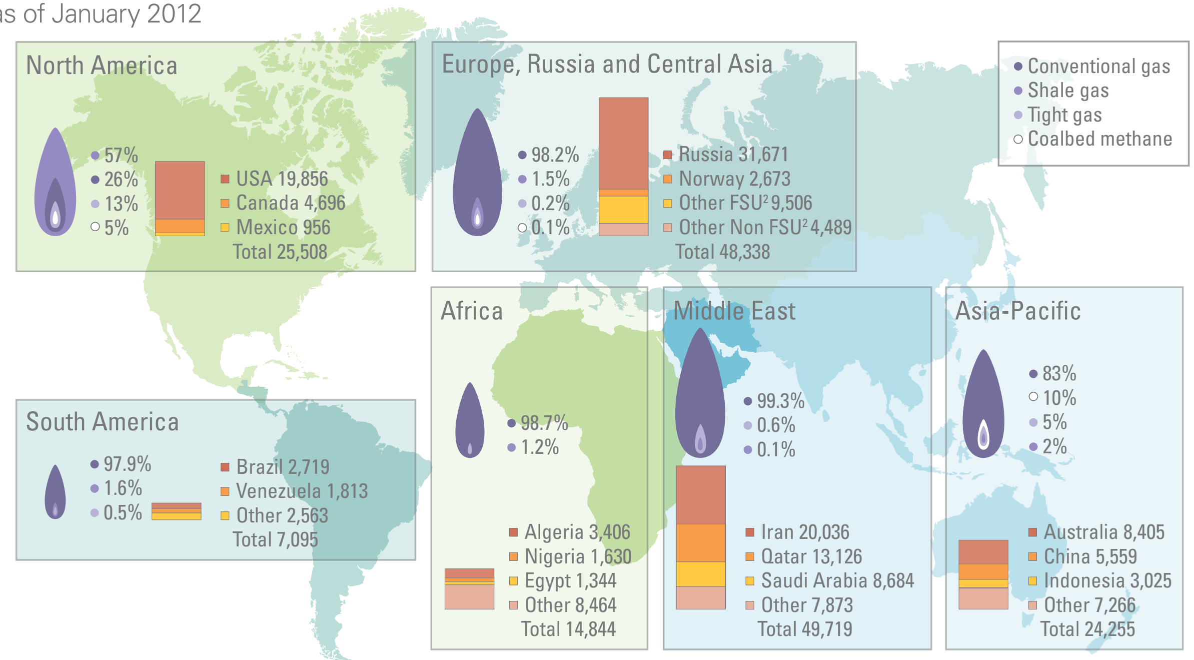
# Natural gas resources are sizeable and relatively widespread thanks to the development of unconventional reservoirs

**Natural gas resources are classified according to the properties of the reservoir in which they are trapped**
Resources are referred to as conventional when accumulated in a reservoir whose permeability characteristics permit natural gas to flow readily into a wellbore; and as unconventional when buoyancy forces are insufficient and intervention is required to make the gas flow. Conventional reservoirs are further broken down in to non-associated for gas found in isolation and associated for gas dissolved in oil.

**There are four main types of unconventional reservoir**
Unconventional gas reservoirs include tight, shale, coalbed and gas hydrates. Tight and shale accumulations refer to low-permeability formations. However, unlike in tight reservoirs, gas in shale rocks has remained in the rock where it formed, making exploration and production more difficult. Coalbed methane (CBM) is generated during the formation of coal and is contained to varying degrees within all coal microstructures. The presence of this gas is well known from underground coal mining, where it presents a serious safety risk. It is called coal-seam methane in Australia, where it is an important resource. However, producing from CBM wells can be difficult because of the low permeability of most coal seams and the associated production of large volumes of water. The fourth type, methane hydrates, is promising but still in the development phase.

**Reserves would last around 58 years, based on OPEC figures for gas consumption in 2013 of 3.5 tcm**

**Figure 4: Natural gas 3P reserves[1] – breakdown by type of reservoir and by region**
bcm, as of January 2012




Note: 1 3P reserves, as extracted from Rystad database (sum of P90, P50, Pmean). They correspond to the sum of proved, probable, and possible reserves.For more information on the definition of reserves, please refer to the Society of Petroleum Engineers website. Note that data vary considerably, depending on the source and the definition of reserves used; 2 FSU stands for Former Soviet Union.Source: A.T. Kearney Energy Transition Institute analysis

Source: Rystad database Resource Based Appraisal, which includes all known resources (accessed April 2014)

**Technology has played a crucial role in the development of unconventional reservoirs**

In general, unconventional reservoirs tend to yield lower recovery rates than conventional reservoirs, and usually require more technology. Two technologies have been instrumental in exploiting unconventional resources. Hydraulic fracturing, which involves creating cracks in the rock through which the gas can flow to the wells; and horizontal drilling, which enables wells to penetrate a greater length of the reservoir than is possible with vertical wells, thereby increasing contact with the production zone.

**Natural gas is abundant and geographically widespread**

Taken together, natural gas resources are abundant. Depending on data sources and the definition used for reserves, reserves amount to around 200 trillion cubic meters (tcm) and technically recoverable resources amount to up to 855 tcm. Reserves would, therefore, last around 58 years, based on a figure for gas consumption in 2013 of 3.5 tcm. Technically recoverable resources, meanwhile, would last over 200 years. While abundant, the largest conventional gas resources are concentrated in a small number of countries. In the 2000s, it was thought that Russia, Iran and Qatar owned more than 70% of known conventional gas resources. However, unconventional resources are much more widespread and recent discoveries of conventional reservoirs in East Africa and the Mediterranean Sea have opened up new gas frontiers, reducing the concentration of natural gas reserves.

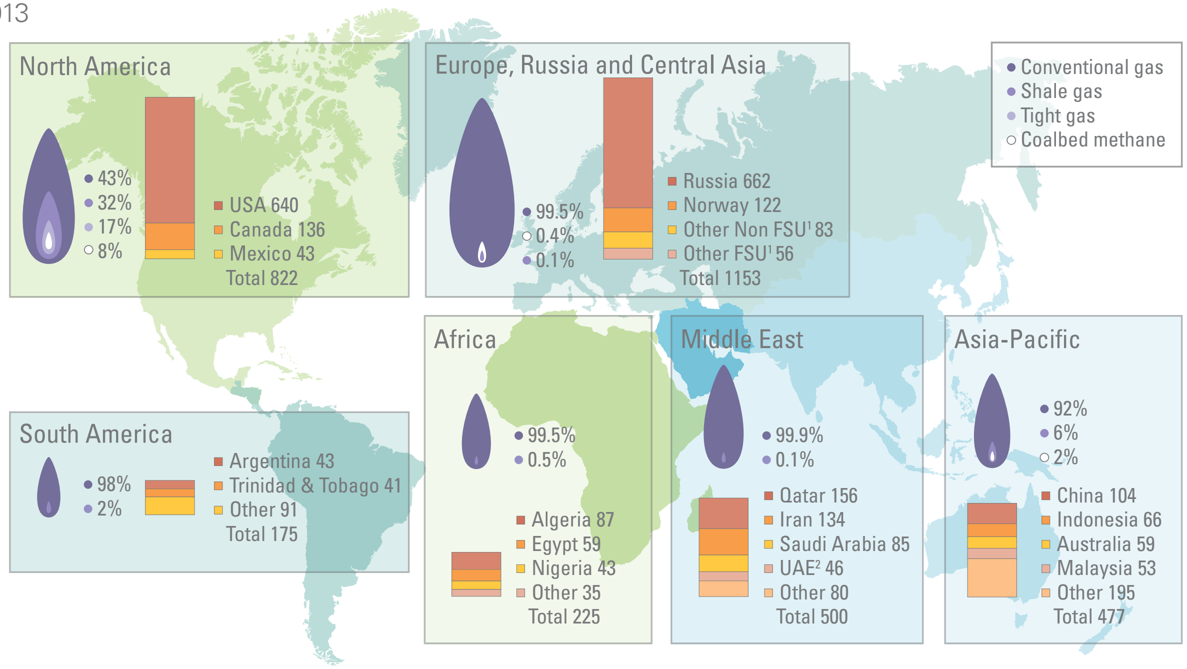
**Natural gas production should keep increasing**

According to the Organization of the Petroleum Exporting Countries, natural gas production reached 3.5 tcm in 2013, led by North America, Russia, and the Middle East; of this, 83% came from conventional reservoirs. However, while conventional reservoirs continue to dominate production, output from unconventional accumulations grew faster than conventional production in 2013, reaching 0.6 tcm. Production from shale reservoirs in the U.S. has been the main driver of growth and now represents 43% of global unconventional gas production. Going forward, natural gas production is expected to continue to increase, driven by unconventional resources and new conventional resources (associated and non-associated gas).

**Production from shale reservoirs in the U.S. has been the main driver of growth and now represents 43% of global unconventional gas production**

**Figure 5: Natural gas marketed production – breakdown by reservoir type and region**

bcm/Y, 2013




Note: 1 FSU stands for Former Soviet Union; 2 UAE for United Arab Emirates.

Source: Rystad database (accessed April 2014); OPEC (2014), "Annual Statistical Bulletin"

# Complex infrastructure is needed to get natural gas to end-users – processing plants, transport & distribution grids, and storage units

**Natural gas is now traded internationally, about 21% by pipelines and 10% via LNG**

### Processing is an essential step

Raw natural gas collected at the wellhead needs to be processed to meet pipeline quality standards, to ensure safe and clean operations, and to extract valuable NGLs. As of 2013, there are close to 2,000 gas-processing plants operating worldwide, with a global capacity of around 7.6 billion cubic meter (bcm) per day. More than half of capacity is located in North America, but the Middle East and Asia, where utilization rates are much higher than in the U.S., are expected to take over as market drivers.

### Long-distance transport technologies have played an important role in developing natural gas trade

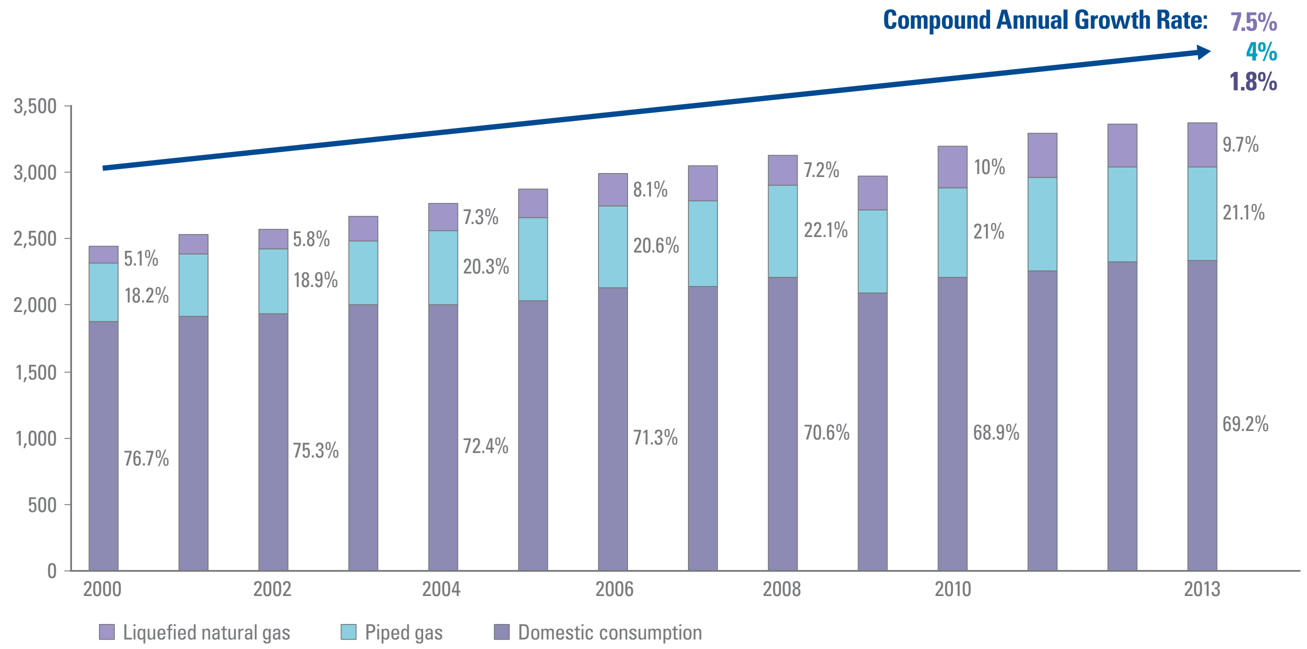
The low energy density of natural gas has long been an impediment to long-distance transportation, and most natural gas is still consumed close to production centres. However, long-distance trade has increased steadily in recent decades. Along with pipelines, which have been in use since the 19th century, liquefied natural gas (LNG) is playing a growing role in long-distance shipping. About 21% and 10% of all produced natural gas is now traded internationally via pipelines and LNG respectively. As a rule of thumb, the longer the shipping distance, the more economically attractive LNG tends to become compared with pipelines. Growth in the LNG trade has been made possible by the expansion of LNG infrastructure. With new export and regasification facilities under construction, this expansion is expected to continue. Meanwhile, floating liquefaction and regasification concepts have garnered attention as a way to reduce development time, increase flexibility and lower capital costs. The first floating storage and regasification units have already been commissioned. Four floating liquefaction projects have achieved a final investment decision.

### Many gas fields are too small or remote to justify pipelines or LNG investment

In order to tap these resources, known as stranded gas, two alternative technologies are being considered: compressed natural gas and gas-to-liquids. The former is already in use onshore, but its application offshore is still at an early deployment phase. The latter is technically mature but is still in its commercial infancy, with only four plants operating worldwide and the technology being subject to the development of economically viable small-scale modular systems.

**Figure 6: Global gas trade volume**

bcm/y




Source: BP (2013), "BP Statistical World Energy Review 2013"; IGU (2013), "World LNG Report – 2014 Edition"; GE (2013), "The Age of Gas & the Power of Networks"

### Natural gas markets are becoming more liquid and less indexed to oil prices

Improvements in natural-gas transportation, the development of trading hubs, and significant regulatory changes have combined to create a more dynamic economic environment for the natural gas business. Indexation of gas prices to the oil price is becoming less common, especially in the U.S., whose gas market is the most liquid in the world. As a result, the price spreads between three main regional blocs – North America, Europe and Asia – have widened. In order to balance seasonal demand variations and ensure supply security, natural gas can be stored, both underground and above ground.

### Gas storage has become an important consideration

As markets mature, storage is becoming increasingly important in stabilizing prices. Underground storage vessels include depleted oil and gas fields, aquifers and salt formations; the best choice depends on local geology and how the storage facility will be used. Flexibility in storage capacity has become an important parameter because of growth in the use of natural gas in power generation and because of the limited flexibility of production from unconventional gas reservoirs. As a result, salt caverns have become popular; although they are relatively expensive, their flexibility is unrivalled.

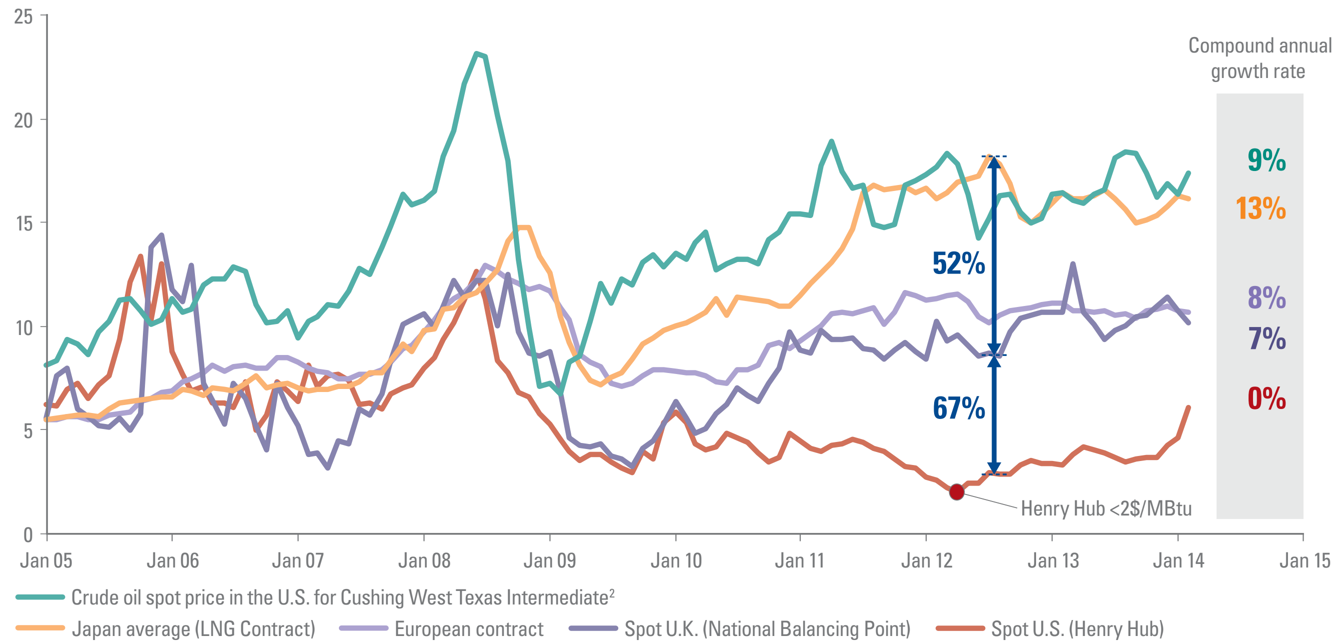
### Gas distribution is becoming smarter and more efficient

Finally, natural gas needs to be pressurized, odorized and controlled to be safely delivered to end customers. Except for a few large customers, most end users are supplied through low-pressure networks. Local distribution involves smaller delivery volumes than long-distance transmission, and delivery over shorter distances to many more locations. As a consequence, distribution lines make up the majority of installed pipelines. Ensuring safety is the main challenge faced by distribution-grid operators. Even if the smart gas-grid concept is less recognized than its power counterpart, natural gas grids are becoming smarter and more efficient as a result of the integration of information and communication technologies.

**Even if the smart gas-grid concept is less recognized than its power counterpart, natural gas grids are becoming smarter and more efficient as a result of the integration of information and communication technologies**

**Figure 7: Crude oil and natural gas: regional spot prices**

$/Mbtu, 2005-2014




Source: IEA (2014),"Energy Technology Perspectives"; EIA online data

# Natural gas accounts for more than 20% of the global primary energy mix and its share is expected to continue to rise, albeit at a slower pace than in recent years

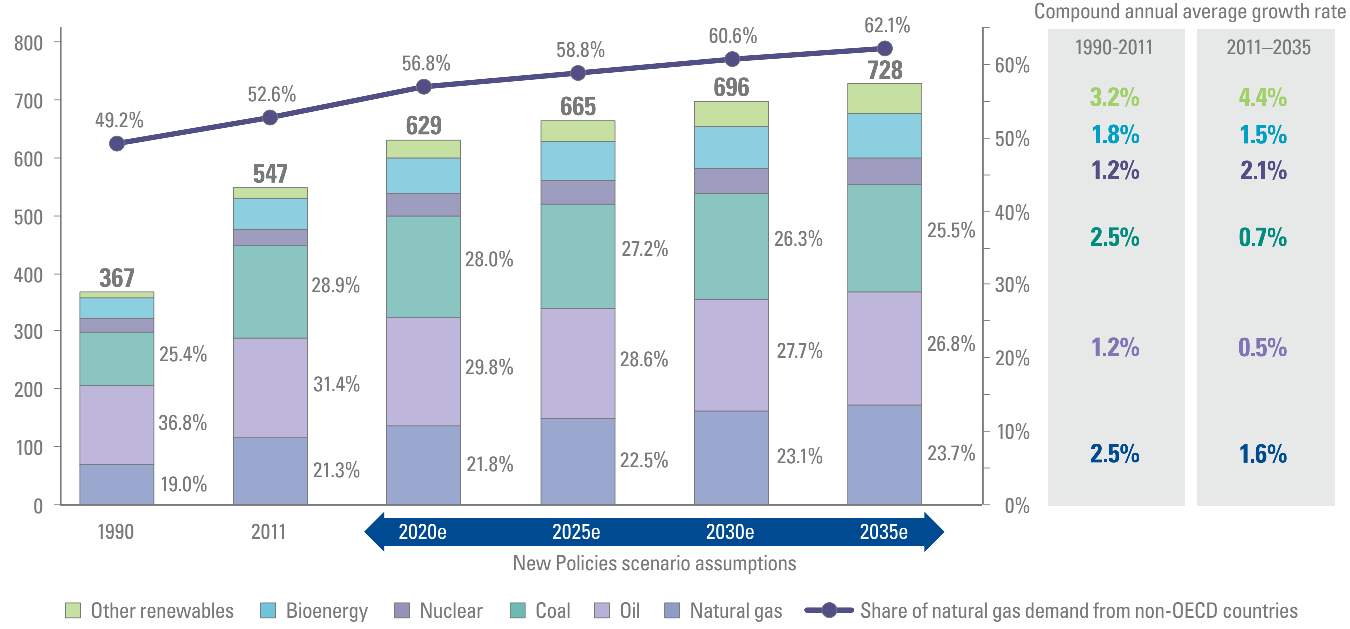
**The role of natural gas in the global energy mix is growing**
Natural gas use has increased at an annual average rate of 2.5% since 1990 and its share of the primary energy demand mix has also risen. Going forward, growth in natural gas use is expected to continue, albeit at a slower pace than in recent years. In its reference scenario, the International Energy Agency assumes an average annual growth rate of 1.6% between now and 2035. In this scenario, natural gas demand would grow faster than demand for other fossil fuels, but slower than demand for some other low-carbon energy sources, such as wind and solar. However, this figure is global and masks regional disparities, not to mention absolute value. Natural gas use in China, for example, is expected to multiply four-fold between now and 2035. Over that period, non-OECD (Organisation for Economic Co-operation and Development) countries will collectively account for an estimated 82% of incremental gas demand.

**The power sector is the largest and fastest-growing driver for natural gas demand**
Power represents 40% of gas demand globally, up from 35% in 1990. Natural gas is now the second most important fuel in the power mix, after coal. However, the role of natural gas in power generation varies widely from region to region. It tends to dominate in gas-rich regions, such as Russia or the Middle East. In North America, lower gas prices resulting from the shale gas boom have encouraged a switch from coal to gas in power generation. In the Asia-Pacific region, demand for natural gas in power generation has increased strongly in absolute terms, but its share of the power-generation mix has remained steady.

In Europe, meanwhile, the share of natural gas in the power mix has recently declined. Going forward, many experts believe it will play a vital role in facilitating the transition to a low-carbon economy by replacing coal-fired generation capacity and by compensating for shortfalls in output from intermittent renewables. Indeed, gas-generation technologies benefit from strong flexibility and efficiency performances.

**Between now and 2035 non-OECD countries will collectively account for an estimated 82% of incremental gas demand**

**Figure 8: Total world primary energy demand[1]**
Exajoules (EJ), IEA New Policies Scenario for the Forecast[2]




Note: 1 This takes into account direct fuel demand and fuel used for power and heat generation; 2 The New Policies Scenario is the IEA's reference scenario. It assumes recent government policy commitments will be implemented even if they have not yet been ratified

Source: IEA (2013), "World Energy Outlook 2013"

### The direct use of natural gas in buildings is predominantly for thermal end uses

For many years, the use of natural gas in commercial and residential buildings was the backbone of natural gas demand. The buildings segment still accounts for 22% of direct natural gas demand and this share is expected to remain stable in the next few decades. Thermal applications are dominant: space heating, water heating and cooking account for 54%, 22% and 11% of natural gas demand in the buildings sector, respectively. The use of natural gas in buildings varies significantly, depending on climate, urbanization patterns, and building design and insulation.

**For many years the use of natural gas in commercial and residential buildings was the backbone of natural gas demand**

### In industrial applications, natural gas is used as a heat source, but also as a chemical feedstock

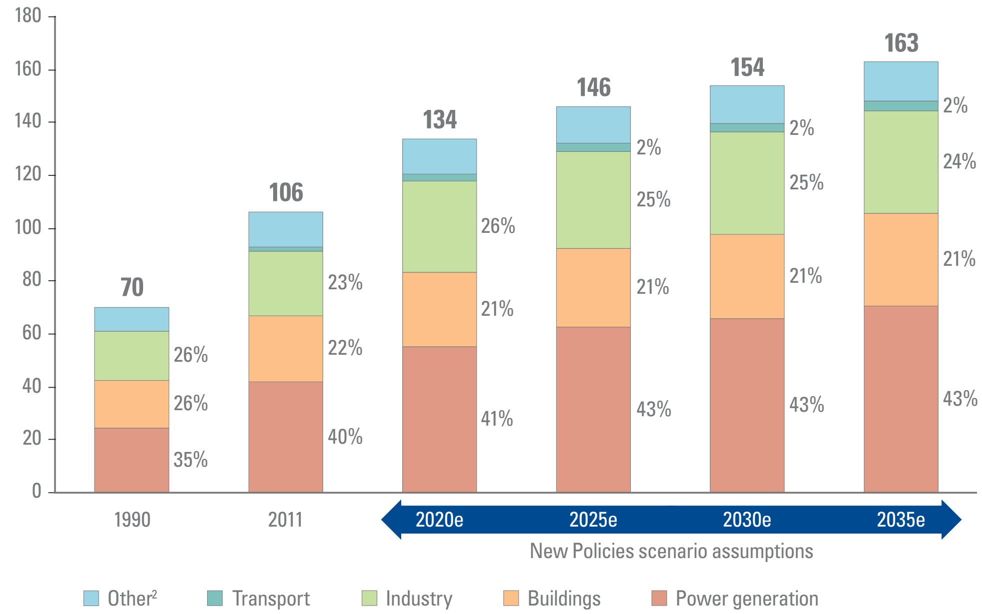
Direct natural gas consumption represents around 18% of final energy consumption in industrial applications. The chemicals and petrochemicals sectors are by far the most important consumers (accounting for 44% of total industrial demand for gas). This is because natural gas is largely used as a source of heat in refineries and as feedstock for producing ammonia and methanol. Other than for chemicals, the bulk of industrial gas demand comes from small-scale industrial consumers using natural gas in small-to medium-scale boilers to generate heat. Any switch from coal to gas in the industrial sector is likely to be relatively limited and subject to the development of carbon pricing.

### Natural gas is garnering attention in the transport sector

Even if its role in transportation remains marginal globally, natural gas is already being used on a large scale in passenger vehicles in several Asian and South American countries. The role of natural gas in transport may develop further – not just in passenger vehicles, but also in heavy-duty vehicles and in rail and maritime transport. Using gas instead of oil products has economic, strategic and environmental benefits: gas is, at present, cheaper than oil; it could reduce dependence on imported oil; and burning gas instead of oil could reduce local air pollution significantly. However, it is doubtful whether increasing gas use in vehicles would have a significant beneficial impact on climate change. There is also a shortage of gas infrastructure and a premium capital cost attached to gas-fuelled vehicles. In addition, the energy density of natural gas is much lower than that of oil, making it a less useful fuel in transportation.

**Figure 9: Primary natural gas demand by sector**

Exajoules (EJ), IEA New Policies Scenario for the Forecast[1]




Compound annual average growth rate

| 1990-2011 | 2011–2035 |
|---|---|
| 1.9% | 0.8% |
| n/a | 3.1% |
| 1.3% | 2.1% |
| 1.5% | 1.4% |
| 2.6% | 1.5% |

Note: 1 The New Policies Scenario is the International Energy Agency's reference scenario. It assumes recent government policy commitments will be implemented, even if they have not yet been ratified; 2 Other includes the use of gas for oil & gas extraction, in liquefaction plants and for distribution

Source: IEA (2013), "World Energy Outlook 2013"

## Conclusion

**It is clear that natural gas has become a crucial part of the energy mix and will remain so due to its sizeable and accessible resources, low carbon foot print, and versatility. Even though complex infrastructure is needed to get natural gas to end users, global trade is increasing and the share of energy from natural gas is expected to rise in the future.**

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## Acknowledgements

A.T. Kearney Energy Transition Institute wishes to acknowledge Dr. Anouk Honoré, a Senior Research Fellow in the Natural Gas Research Programme at the Oxford Institute for Energy Studies (OIES), for her detailed review of this FactBook. The Institute also wishes to thank the authors of this FactBook for their contribution: Benoit Decourt, Romain Debarre, and Sylvain Alias.

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