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# The natural gas sector is changing rapidly: Research and technology development remain the keys to overcoming challenges and unlocking opportunities

The natural gas industry has evolved significantly in recent years, driven by various factors, but deployments of new technologies, unlocking of new resources, investment in supply-chain infrastructure, and emergence of more competitive markets are central to the changes witnessed across the globe. Indications are that the sector will need to continue to evolve and adapt to new competition, probably at an even-faster pace than in the past decade.

Innovation, in the technologies developed and deployed, and in optimization of new and existing supply chains and market connectivity, will remain a crucial factor determining the sector's future progress. Despite quite rapid growth in natural gas consumption, i.e., >2.5 percent/year compound annual growth rate since the 1970s (e.g. statistics reported in BP Statistical Review, 2015), natural gas has not had it all its own way. For example, competition to supply the power sector has been fierce from coal and renewable energies, particularly in the past few years with cheap coal displaced by shale gas in the United States and the falling supply costs, extensive subsidies and minimum usage mandates applied to renewable-energy technologies in many high-energy-consuming nations. In the current era of low commodity prices research leading to lower-cost natural gas technologies is essential for natural gas to continue to compete successfully against all forms of alternative energy.

Even with its well-known performance, efficiency and operational advantages, natural gas has found itself squeezed between low-priced coal at the base-load end of power supply and subsidized renewable energies in the peak-load part of the power load profile in many regions. In Europe, for example, this has led to a significant reduction in gas consumed by power utilities in recent years. Hence, natural gas should not be complacent about its ability to displace coal from the power sector over the long term. Although, low-carbon policies and more realistic carbon pricing should promote a power mix dominated by natural gas for base-load power generation and backing up expanded use of intermittent renewables, the sector has a long way to go to achieve this in many countries.

## 1. Changing status of natural gas at the national level

As an industry analyst and practitioner for many years I have found one display to be particularly revealing about the status of nations in the natural gas sector and how that status changes over time. By combining annual statistics at the national level on natural gas production (P), consumption (C), net exports (i.e., exports (E) minus imports (I), such that negative numbers indicate net importing nations) and proved reserves, plots of P/C versus E-I (Wood, 2007a) provide valuable comparisons, both between nations and specific snapshots in time. Figs. 1 and 2 present these displays for selected countries for full-year 2014 and 2006. The size of the bubbles in these displays for each country is proportional to its proven natural gas reserves, i.e., the larger the reserves, the larger the bubble. To the left/south-west quadrant of these diagrams are those nations that are the net natural-gas importers; to the right/north-east quadrant of these diagrams are those nations that are net natural-gas exporters.

There is a significant spread in the natural-gas status of nations at both snapshots in time presented. The main gas importing nations displayed (e.g. Japan, Germany, Italy, Spain, South Korea and Turkey) plot distinctly, with very small reserve bubbles, in the extreme southwest portion of the E/C versus E-I plots. On the other hand, the large gas-exporting nations displayed (e.g. Russia, Qatar and Norway) plot distinctly, with generally large reserve bubbles, in the extreme northeast portion of the E/C versus E-I plots. Russia plots closer to the P/C = 1 line than might be expected due to its high domestic gas consumption at relatively low gas prices, despite being the largest net exporter of natural gas.

Of particular interest here are the nations that have changed their status significantly from 2006 to 2014. Fig. 2 just pre-dates the emergence of shale-gas, which was not foreseen by most of us at the time (e.g. Wood, 2007). Hence, the USA has moved significantly to the right from 2006 to 2014 and its reserve bubble has grown. On the other hand Canada has moved significantly to the left from 2006 to 2014 (i.e., Fig. 1 versus Fig. 2), as about one-third of its gas exports to the United States were replaced by U.S.-produced shale gas. The movement of Qatar significantly to the right on this plot during this timeframe highlights its rapid development as the world's largest LNG exporter. Also, the slight movement of Turkmenistan to the right from 2006 to 2014, accompanied by a large increase in its reserve bubble highlight its emergence as a major gas exporter to China and major exploration success during the period. Australia has also begun its journey in that direction with the commissioning of major new LNG export facilities (2014–2016).

China has moved significantly to the left from 2006 to 2004, illustrating its increased dependence upon natural gas imports. It will be interesting to monitor the position of China on this diagram over coming years: will it follow the United States and rapidly expand its exploitation of shale gas and coal bed methane resources? Or, will it concentrate on expanding its imports of pipeline and shale gas? Cost and technology, together with policy, will likely

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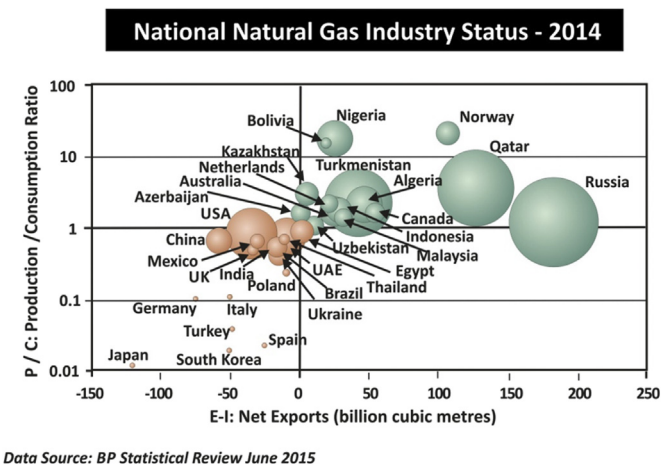


**Fig. 1.** Status of natural gas production, consumption, net exports and proved reserves displayed for selected gas producing and consuming nations, based on full-year 2014 data. Bubble sizes are in proportion to the magnitude of proved natural gas reserve reported (year-end 2014) for the nations. Red bubbles identify net-natural-gas importers; green bubbles identify net-natural-gas exporters. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

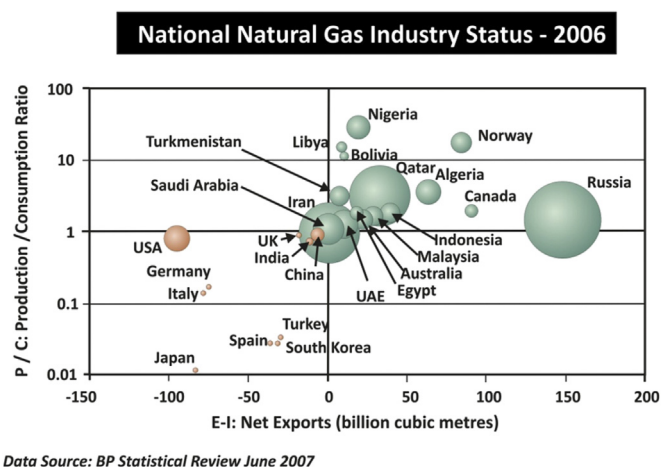


**Fig. 2.** Status of natural gas production, consumption, net exports and proved reserves displayed for selected gas producing and consuming nations, based on full-year 2006 data (Wood, 2007). Bubble sizes are in proportion to the magnitude of proved natural gas reserve reported (year-end 2006) for the nations. Red bubbles identify net-natural-gas importers; green bubbles identify net-natural-gas exporters. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

determine that outcome.

The movement of Algeria, Egypt, UAE and Kuwait (not shown) from right to left is another ongoing trend identified by the P/C versus E-I plots. In the case of the latter three countries this move has repositioned them as net gas importers despite each nation holding significant gas reserves. In the case of Egypt, over the short term, it is expected to become a more significant gas importer; in the longer term, the ability of low-cost technologies to unlock its vast deep-water gas reserves will likely determine its ability to curtail gas imports. In the case of many oil-producing nations of the Middle East and North Africa, and across the globe more generally, the ability of technology to harness currently-flared-associated-gas resources could prevent them from becoming gas-importing nations. Algeria's shift to the left (i.e., Fig. 1 versus Fig. 2) is more a reflection of upheaval in its gas markets (i.e., shale gas displacing its imports to the United States; economic recession and low-priced coal resulting in falling demand from its main European customers), despite increasing natural gas reserves.

Saudi Arabia, Iran and Venezuela are not plotted in Fig. 1, because the large size of their reserve bubble rooted firmly close to the origin (i.e., P/C~1; E-I ~0) would obscure the status of other nations. These large-gas-resource-producing nations are unique in that they are yet to exploit the export potential of their vast gas resources on a large scale. It will be interesting to monitor where each of these nations plots in a decade. Expectations are that Iran will take the necessary commercial steps to establish significant new gas export supply chains, initially to China, India and Pakistan.

Most central, southern and western European nations are clearly positioned in the south-west quadrant and moving further in that direction (e.g. United Kingdom) as they become more dependent on natural gas imports. Norway and the Netherlands are exceptions, but both face significant challenges to avoid movements to the south-west on the P/C versus E-I plots in coming years. For Norway the challenge is replacing reserves sufficiently to maintain gas production and exports at low cost of supply. In the case of the Netherlands, recent problems of subsidence associated with its giant-but-depleting Groningen gas field are likely to hasten its movement into the south-west quadrant of the P/C versus E-I plot.

The positions of Nigeria and Bolivia on the P/C versus E-I plots, show little change between 2006 and 2014. Their unusual position testifies, in both cases, to as-yet- unfulfilled opportunity in indigenous and export markets. Nigeria is the fifth-largest global LNG exporter, yet has failed to grow its exports since 2006, due mainly to political instability, despite its vast resource base and the interest of the industry to do so. Perhaps more frustrating, is the slow pace at which Nigeria is exploiting its gas resources for its own energy requirements. Although gas infrastructure and local gas markets are emerging, the situation of vast amounts of gas being flared in the Niger Delta, whilst the residents of Lagos run off-grid-diesel generators to enable them to function in the face of frequent grid power cuts persists. Land-locked Bolivia, with its vast gas resources could be the power house of South America's Southern Cone and use more of those resources for indigenous energy supply to develop its economy. Political fragmentation in the Southern Cone has led to the main gas-consuming nations developing their own LNG import supply chains, which has diminished Bolivia's opportunity to commercially exploit its gas resources to the level once deemed likely.

## 2. Prospects for the natural gas sector

The foregoing discussion reveals, not only the differing status among gas producing, exporting and importing nations, but also the dynamic nature of the natural gas sector and the speed with which major changes are occurring around the globe. Much more comment could be added about the situations and prospects for different nations based upon the trends identified from the comparisons across the time period that is the focus of Figs. 1 and 2. The objective here though is to consider what this information tell us about where the gas sector is heading and why the need for it to innovate has never been so pressing.

The recent global accord (i.e., the adoption by United Nations Framework Convention on Climate Change (UN FCCC) of the Paris Agreement in December, 2015) on climate change by some 190 nations to accelerate moves towards a low-carbon energy mix has short-term negative implications for all fossil fuels. The focus of that accord on urgency is what requires the immediate attention of the industry. For example "*Emphasizing with serious concern the*

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*urgent need to address the significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above preindustrial levels*" (United Nations, 2015).

Although the Paris Accord initially places only voluntary commitments on nations its principles and objective will undoubtedly lead to and stimulate many low-carbon energy initiatives across the globe and unlock substantial financial support for such initiatives at favourable interest rates. This is a double-edged sword for the natural gas industry. On the one hand, such low-carbon moves should help it compete with coal in the short-term; on the other hand, many policy makers are now likely to focus on zero-carbon visions for their long-term energy mix, which will make it hard for natural gas to justify and secure long-term investments.

On the first point, recent developments in Europe are encouraging. For example, A British auction for backup electricity plants for 2019/20 awarded in December 2015 nearly half of the capacity available for bidding, or 21.8 GW (GW), to gas-fired power plants (Reuters, 2015). However, the natural gas industry should not kid itself; the coal industry is not simply going to fade away in the medium term without a fight. The strong coal extraction industries of Australia, China, India, United States, amongst others, with vast resources, large numbers of employees and strong political backing, is not going to be easy for the gas industry to displaced based on voluntary high-level political policies. It will be a long slow fight, which natural gas has the ability to win, but will stand a better chance of doing so through embracing innovation and technology breakthrough than relying on the whims of fickle energy policy makers.

In the light of growing support to move completely away from fossil fuels in attempts to stabilize global climate, the gas sector urgently needs to re-state and re-frame its case, i.e., emphasizing why it deserves to be part of the climate-change solution, based upon its reliable performance, efficiency, operational flexibility and low-carbon credentials. Research that focuses on these objectives, such as carbon capture and hybrid natural gas-renewable systems, is essential for the sector secure part of the funding being unlocked for further research and development aimed at low-carbon/zero-carbon initiatives. In order to be able to unlock our vast resources of conventional and non-conventional of natural gas globally, not only do we need to develop low-cost production technologies, we also need to convince public, policy makers and politicians of the long-term value of our resource.

IPIECA, the body representing the gas and oil industry globally on environmental and social issues, introduced its pilot guidance framework for climate change reporting in December 2015 to coincide with the UN FCCC Paris meeting (IPIECA, 2015). The framework identifies the need for the industry to re-focus on climate change issues and proposes ten suggested topic areas necessary for comprehensive sustainability reporting. The onus is on the natural gas industry and academia together to come up with scientific and technological solutions to the challenges facing the industry.

The challenges confronting the natural gas sector, and the opportunities available to it, if those challenges can be overcome, are both immense. The issues are diverse and vary significantly from nation to nation, in line with the diverse status of the gas sector across the globe, and its dynamism (e.g. Figs. 1 and 2). Continued Innovative research on low-cost, efficient and low-carbon natural gas production, processing, transport and storage technologies is essential. This journal has published much research relevant to such objectives in recent years. It plans to continue to spearhead the quest to overcome the identified challenges and gain access to the opportunities that are within the sector's grasp.

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David A. Wood, Editor-in-Chief
*DWA Energy Limited, Lincoln, United Kingdom*
*E-mail address:* dw@dwasolutions.com.

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