Natural Gas in the Transition of Energy

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Natural gas is considered an important bridge in the transition of energy in the world. However, the development and management of unconventional gas now face many challenges. Natural gas consumption and population have a long-run relationship with CO_2 emissions. Consistent with other studies, there is a positive relationship between CO_2 emissions and natural gas consumption, GDP, and population.

natural gas unconventional gas shale gas energy transition

1. Natural Gas Consumption

Although natural gas has been known for a long time, its exploitation and widespread use developed in the early twentieth century due to scientific and technological development. According to BP data, the demand for natural gas around the world has increased very rapidly in recent decades. Natural gas is the world's third-most used energy source after oil and coal [1]. According to BP statistics in 2019, over the past five decades, natural gas consumption has increased almost fourfold from 891 Mtoe in 1970 to 2209 Mtoe in 2018. Its share of total energy consumption global growth increased from 18% in 1970 to 25% in 2018 [2].

Natural gas plays an increasingly important role in many economic sectors. Its use has extended to most sectors of energy consumption. The main industries using natural gas are electricity, residential, industry, and transportation, while the electricity generation sector accounts for the most significant proportion of the distribution of natural gas by fields of use [2].

The consumption of natural gas in the world has increased year by year. In particular, the growth of global natural gas demand after 2000 mainly came from Asian countries (mainly China, India), the Middle East and the recovery of demand for natural gas in the United States from 2007. According to BP data in 2019, the average growth rate of natural gas consumption in the world between 2007 and 2017 was 2.2% per year. The Middle East and Asia-Pacific region have the highest growth rate, with the corresponding rate of 5.6% and 5.0% per year. In 1980, gas consumption was mainly concentrated in North America and Europe, with nearly 90% of the total world output. By 2018, these two regions' total consumption volume only accounts for nearly 41% of the total worldwide consumption; the Middle East and Asia-Pacific region increasingly consume about 36% of the total world consumption [2].

2. Natural Gas Reserves

According to estimates of recent studies, global natural gas reserves are plentiful and progressive due to technological development. Because of improved exploration methods, the world's natural gas reserves are increasing. In particular, the rapid development of recent technology has allowed for the exploitation of unconventional gases that are considered to have very large reserves, most notably the recent shale oil and gas revolution in the United States. The discovery of non-traditional natural gas fields has changed the natural gas reserve picture and has affected geopolitics in many regions of the world. For example, according to [3], in the US, shale gas reserves account for more than four times the reserves of conventional gas, which greatly impacts the US's future energy development strategy.

At the end of 2018, according to [2] statistics, proven natural gas reserves were about 197 Tm^3 and equivalent to over 51 years of consumption at current levels. The increase in proven natural gas reserves over the years has been much faster than gas production in some countries. The average annual growth rate of the world's natural gas reserves over the last ten years is 1.9% per year. From 2007 to now, North America has the highest natural gas reserve growth rate globally, with an average growth rate of 5.3%. Mainly contributing to this increase in reserves is the development of non-traditional gases, especially the shale gas revolution in the last decade in the United States. In addition, there is an increase in the area of the former Soviet Union countries and the Asia-Pacific region with an average growth rate of 4.4% and 3.0% per year, respectively. Natural gas reserves are still concentrated mainly in the Middle East, where huge reserves account for 38.4% of world reserves, followed by regions of the former Soviet Union with 31.9% [2]. The natural gas reserves in the world are still on an increasing trend. In the future, traditional natural gas may still be found in unknown areas or recovered from known sedimentary basins. Furthermore, there is also the development trend of non-traditional gas in many countries and regions around the world.

3. Forecasts for the Demand for Natural Gas

The growth of the global economy and population growth leads to an increase in energy demand and consumption. However, it is forecasted that energy consumption growth will begin to slow down after 2040 compared to the recent period. According to the International Energy Agency's 2018 energy outlook report, the growth rate of world demand from 2017 to 2040 in the New Policy scenario is about 1.1% per year [4].

According to forecast scenarios [5][6][7][8][9][10][11][12][13], the world's energy demand is likely to increase by 40% between now and 2040. Much of the most significant energy demand increase will come from developing countries (non-OECD). Developing countries in Asia and the Middle East will account for three-quarters of the increase in global demand by 2040. In Asia, China and India are the two countries with the largest energy demand growth rates globally. India's energy demand up to 2040 will be twice that of the current level and approximately half of China's demand. Other regions of the world, such as the Middle East and Africa, also have very high demand growth—demand by 2040 will be 60% greater than now [4]. According to scientists, energy consumption is the largest cause of climate change, with about two-thirds of all human-made greenhouse gas emissions [14]. Therefore, there is a need to establish a sustainable and environmentally friendly energy system. This is a priority for energy and climate policymakers worldwide, with natural gas being an important bridge in the energy transition.

Consequently, according to many estimates, the demand for natural gas is expected to increase more than any other fossil energy source. All energy scenarios of energy organizations in the world, such as the International Energy Agency (IEA), World Energy Council (WEC), or oil companies such as Shell, ExxonMobil, and BP, offer a promising long-term future gas. In many scenarios, natural gas will be the world's leading energy source by 2050 [15]. For example, according to ExxonMobil's analysis, 40% of global energy demand growth between 2014 and 2020 is expected to be met by natural gas [16].

Similarly, according to the IEA in the report, "Are We Entering a Golden Age of Gas?", due to more natural gas consumption, the world could achieve the overall goal of reducing CO_2 emissions [7]. According to the IEA, global natural gas demand is expected to grow 50% between 2014 and 2040, which is faster than other fuels and twice as fast as oil. Most of the increase in natural gas demand comes from emerging economies, with China and India accounting for about 30% of the increase and the Middle East at more than 20% [7][8][9][10][11].

According to the IEA and the scenarios in their "World Energy Outlook" reports from 2010 to 2018 [4][5][6][7][8][9][10][11][12][13][14][15], demand for natural gas will steadily increase. Still, the rate of increase varies from year to year and from region to region.

The demand for natural gas increases faster than any other energy source. According to the [4][5][6][7][8][9][10][11][12][13][14][15] outlook forecasts for the last 10 years, the average increase in world demand for natural gas has ranged from 1.4% to 1.7% per year, while the largest increase for coal and oil is only 0.8% per year; even in recent forecasts, this growth rate tended to decrease sharply. According to the IEA's forecast, by 2040, natural gas will overtake coal as the second-largest source of energy in total primary energy demand. Around the world, the Asian region will be the main driver of growth in future natural gas demand, with a very high growth rate of 3.0% to 4.3% per year compared with 1.4% to 1.7% of the average worldwide growth rate.

4. The Need for a New Energy Management Model

Unlike conventional gas, unconventional gas extraction is more complex and challenging due to its low permeability. Unconventional gas development is complex and multi-faceted, with economic, environmental, public health, social and technological components to consider. Unconventional gas exploitation projects often require large investment capital and different technologies. While the project life is short, production output declines rapidly. The development of unconventional oil and gas projects is vulnerable to market fluctuations, especially price factors.

Therefore, it is necessary to have an appropriate management model for developing unconventional gas sustainably, including all aspects related to its development, including finance and non-financial factors such as drilling, mine development, capital management, water resource management and use, and health and safety issues, etc.

In fact, the development of unconventional oil and gas companies has been facing many risks and difficulties in maintaining their development. From 2015 to the end of 2020, about 500 oil and gas companies have declared bankruptcy in North America, including the US oil and gas giant and a pioneer in shale oil exploitation (Chesapeake Energy), which filed for bankruptcy in June 2020 [17]. The collapse was that the companies did not have a suitable management model in the context of oversupply, leading to low energy prices, especially in the context of the significant impact of the COVID-19 pandemic. As the reaction to such a crisis, the advancement of sustainable solutions has confirmed their capabilities as an auspicious and useful strategy. To adequately consider the current consequences of the COVID-19 pandemic on renewable energy increase strategies, first, the short-term management concerns should be recognized. In contrast, the mid-and long-term approaches should be specified to attain precise renewable energy goals and proceed to a more socially and environmentally energy prospect [18]. Finally, despite the downturn, the energy sector is still one of the most significant areas in the world economy [19], which is undeniably an imperative determinant of searching for improvements within the management processes.

5. Unconventional Gas Evolution and Its Effects

Although unconventional gases have been known for a long time, the potential and development of non-traditional gases and their impact on the energy market are only about a decade ago. Today, known unconventional gases include coal-bed methane (CBM), shale gas, tight gas and hydrate gas. Since 2005, the development of shale gas in the US has become a phenomenon—a revolution in the energy field. This development has had many impacts not only on the US gas market but also on the global gas market.

Unconventional gas production is also growing rapidly in other parts of the world. In 2010, Australia produced only a small amount of coal-bed methane (about 5 billion m^3 of gas, in 2015) and became a liquid gas producer from coal-bed methane. Other countries such as China, India and Indonesia also have activities to find and develop non-traditional gas energy sources, including coal-bed methane and shale gas. With the development of shale gas, the proven reserves of natural gas in the United States have increased significantly. Shale gas has helped the USA to overtake Russia to become the largest gas producer in the world since 2009 [20].

The shale gas revolution has led to economic benefits and cost reduction at the state and local levels, individual sectors, and the nation. The exploitation of unconventional gas fields, particularly shale gas, influenced the economic growth of the United States. According to a study in 2014 [21], the macroeconomic impact is relatively limited: around 0.88% growth in the gross domestic product (GDP) between 2007 and 2012. According to the International Monetary Fund report in 2013, the shale gas revolution's macroeconomic impact is between 0.3% and 1% of the US GDP for that year [3]. The shale gas contribution to the American gross domestic product was more than $76.9 billion in 2010; in 2015 it was $118.2 billion and will triple to $230 billion in 2035 [22].

The development of shale gas has helped the US achieve self-sufficiency in energy, improvements in the trade balance and tax revenues. It helped reduce the import of fossil fuels, therefore improving trade balance and simultaneously representing a supplement to the federal budget. In 2012, the sector also generated $62 billion in additional tax revenue for the federal budget, the States, and the concerned municipalities [23].

The development of shale gas in the United States has been the catalyst for the recovery of traditional industries. The products of natural gas-intensive industries can serve as raw materials for the petrochemical industry, fertilizer producers, plastics and other industries that consume a great deal of energy, such as aluminium smelters, steel mills and refineries, etc. The decline of gas prices contributed to the competitiveness enhancement of these sectors in the global competition [2].

6. Potential of Unconventional Gas

Unconventional gas is considered to play an increasingly important role in securing the global natural gas supply. According to forecasts by the International Energy Organization, non-traditional gas will account for more than 60% of the increase in total gas production from now to 2040.

However, forecasts on natural gas resources still retain a level of uncertainty, especially unconventional natural gas. According to the forecasts in 2017 [4], the renewable resource of traditional natural gas is about 430 trillion m^3, allowing about 120 years to be exploited at current production levels. For unconventional gas, the forecasted total recoverable shale gas resources are 239 trillion m^3, coal-bed methane is 50 trillion m^3 and tight gas is 81 trillion m^3. The forecast for hydrate gas is 10 times that of shale gas; however, its exploitation technology is complicated. If adding both conventional and non-traditional gas as resources, about 250 years of demand can be satisfied if exploited at their current production rates.

Of the unconventional natural gases, shale gas is the potential gas resource with the largest reserves. Recent studies by scientists have shown that shale gas’s potential is huge, its forecast reserves are increasing, and it is widely distributed in many continental countries. This opens many opportunities for its exploitation and uses in the future, further contributing to satisfying the demand for natural gas. According to recent publications by the US Energy Agency and the American Geological Association, the total recoverable resource reserves of shale gas in 46 countries were assessed by the organization to be 7577 Tcf. Shale gas resources are concentrated mainly in China, Argentina, Algeria, and the United States [20][24][25][26][27].

7. The Challenges of Unconventional Gas Development—The Case of Shale Gas

The impact of the production of shale gas on the environment is very strong. The development of shale gas has created significant levels of public concern, and the proportion of its opponents has risen sharply.

To exploit shale gas, here must use hydraulic fracturing technology. The hydraulic fracturing technology consumes a significant amount of water and chemicals, so it can lead to pollution in the environment throughout the drilling and exploitation process. The production of shale gas consumes a large volume of freshwater. The amount of water needed in the hydraulic fracturing process depends on the type of shale gas and the fracturing operations, such as well depth and length, fracturing fluid properties and fracture job design. In general, 19 million water liters are typically needed per horizontal well in shale gas production [27]. The water consumption will grow with the increase in the number of wells and shale gas production. Certainly, such a large volume of water and a high rate of withdrawals from local surface or groundwater sources has a significant impact on the local water system. Water consumption is particularly important in areas where drought conditions often strictly limit water availability and its use [28][29]. Therefore, the development of shale gas is not recommended in regions or countries that lack water.

8. The Capacity of Pollution of the Groundwater and Surface Water

The production of shale gas without good practices can contaminate the environment. The chemicals represent from 0.5 to 2% in fluids of hydraulic fracturing; many of them are toxic and carcinogenic. According to an investigative report on the chemicals used in hydraulic fracturing, among the 2500 hydraulic fracturing products, more than 650 are known or possible human carcinogens [22]. Another study identified 632 chemicals used in shale gas operations; more than 75% of the chemicals on the list can affect different organ systems in the body, and more than 50% of chemicals indicate effects on the brain and nervous system. These hydraulic fracturing fluids are injected directly into the ground, and they can influence on groundwater sources. In addition, the flowback or "produced" water from fracturing fluid might contaminate the water surface. They may adversely influence human health and the environment quality if they are untreated or directly discharged onto the land or into streams, rivers, and lakes.

9. Generation of Greenhouse Gases

Shale gas is a type of natural gas that provides cleaner energy than other fossil fuels. However, shale gas contains more than 90% methane (CH_4), which may contaminate the air and the water. Methane is a very powerful greenhouse gas compared to carbon dioxide. The effects of shale gas on climate change have become more complex to evaluate and controversial, partly because of uncertainty about the scale of methane leaks. Although it stays only one-tenth of the period compared to carbon dioxide in the atmosphere, methane has a global warming potential 72-fold greater than carbon dioxide when viewed over 20 years and 33-fold greater when viewed over 100 years. Some researchers worry that the expanded production of shale gas could increase methane release as fugitive emissions during the drilling, completion, production, transportation, and the use of natural gas. This is a principal concern because methane is a more potent "greenhouse gas" than CO_2, and thus the fugitive emissions in the process of shale gas development may have led to a net increase in greenhouse gas emissions.

10. The Price of Natural Gas Does Not Cover Operating Costs

The exploitation of shale gas is profitable if the price of natural gas can offset the operational costs. The current price of natural gas in the United States is extremely low—perhaps lower than the actual production cost.

Economists believe that natural gas production marginal cost could certainly reach $4 to $5 per Mbtu [25]. The actual price was approximately $3 per Mbtu in 2012 but was over $4 per Mbtu in 2013 and 2014. This price could be less than the marginal cost of production in the long term with shale gas. In addition, the life of the operation of well shale gas is shorter than that of the production well for conventional gas. Moreover, the life cycle of well shale gas is shorter than the well conventional natural gas, and the production of shale gas declines rapidly after the peak of production. As such, it is necessary to continue the supply of investment capital. At present, some gas producers in the United States are going to reduce their production and their investments in shale gas development activities.

11. The Opposition from the Population

An essential aspect of the development of shale gas and unconventional gas, in general, is the “social license to operate” for activities in this field. According to EIA, the need to build a “social license to operate” was emphasized [25]. The community needs all related information regarding shale gas operations to understand the environmental risks associated with shale gas production. As noted above, shale gas development has created a significant amount of public concern; the percentage of opponents has increased significantly. According to the survey results in Europe, the rate of people who opposed shale gas development in 2013 was over 60% [30]. Another example in Quebec, Canada, shows a rate of opposition at 67%. Therefore, the absence of social acceptability and the hostility of most of the population toward shale gas development will cause significant restrictions in the future.

12. The Uncertainty of Resource Estimation

The estimates of resources in shale gas are variable and uncertain. There is a lack of serious geological research in the world about the real scope of unconventional reserves. This leads to several different estimates about the shale gas in place and the technically and economically recoverable amount of shale gas in the world [31]. The uncertainty of the estimates will strongly influence the industry’s future and the national energy policy. Therefore, the profitability potential of shale gas is still hard to predict. Except for the United States, other countries that are considered to hold significant potential for shale gas resources lack reliable estimates on the technically recoverable resources and economically recoverable resources, which could be a great obstacle in developing shale gases among those countries.

Besides the above challenges, other reasons may constitute obstacles to the development of shale gas, such as the hydraulic fracturing with induced earthquakes, or the operating processes of shale gas with the destruction of landscapes, the influence on wildlife, and the generation of large amounts of noise.

References

1. International Energy Agency. World Energy Outlook. 2017. Available online: http://public.eblib.com/choice/publicfullrecord.aspx?p=5160837 (accessed on 15 December 2021).
2. BP. BP Statistical Review of World Energy. 2019. Available online: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf (accessed on 2 December 2021).
3. International Monetary Fund. United States: Staff Report for the 2012 Article IV Consultation. Available online: http://site.ebrary.com/id/10757267 (accessed on 3 November 2021).
4. International Energy Agency. World Energy Outlook. 2018. Available online: https://iea.blob.core.windows.net/assets/77ecf96c-5f4b-4d0d-9d93-d81b938217cb/World_Energy_Outlook_2018.pdf (accessed on 17 November 2021).
5. International Energy Agency. World energy Outlook. 2010. Available online: http://site.ebrary.com/id/10435936 (accessed on 23 November 2021).
6. International Energy Agency. World Energy Outlook. 2011. Available online: https://iea.blob.core.windows.net/assets/cc401107-a401-40cb-b6ce-c9832bb88d85/WorldEnergyOutlook2011.pdf (accessed on 25 November 2021).
7. International Energy Agency. World Energy Outlook—Are we Entering a Golden Age of Gas? Available online: https://iea.blob.core.windows.net/assets/8caa3d14-5005-437d-b180-06b8824d28c8/WEO2011_GoldenAgeofGasReport.pdf (accessed on 28 November 2021).
8. Aoun, M.C.; Cornot-Gandolphe, S. L’Europe du Gaz a la Recherché de Son Age d’or. Available online: https://www.ifri.org/sites/default/files/atoms/files/etude_aoun-cornot_europe_gaz.pdf (accessed on 12 October 2021).
9. International Energy Agency. World Energy Outlook. 2012. Available online: https://iea.blob.core.windows.net/assets/ebe15dfb-30c8-42cf-8733-672b3500aed7/WEO2012_free.pdf (accessed on 17 October 2021).
10. International Energy Agency. World Energy Outlook. 2013. Available online: https://iea.blob.core.windows.net/assets/a22dedb8-c2c3-448c-b104-051236618b38/WEO2013.pdf (accessed on 20 October 2021).
11. International Energy Agency. World Energy Outlook. 2014. Available online: https://iea.blob.core.windows.net/assets/e6f58562-203e-474c-97a3-486f409aa7ff/WEO2014.pdf (accessed on 27 October 2021).
12. International Energy Agency. World Energy Outlook. 2015. Available online: http://www.myilibrary.com?id=876457 (accessed on 30 October 2021).

13. International Energy Agency. World Energy Outlook. 2016. Available online: https://iea.blob.core.windows.net/assets/680c05c8-1d6e-42ae-b953-68e0420d46d5/WEO2016.pdf (accessed on 8 December 2021).

14. Intergovernmental Panel on Climate Change. Climate Change 2014. Synthesis Report. 2014. Available online: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf (accessed on 13 December 2021).

15. International Geographical Union. Prospects for Natural Gas: Identifying the Key Developments that Will Shape the Gas Market in 2050—Update of the IGU 2015 Report. Available online: https://www.igu.org/wp-content/uploads/2016/10/160303-IGU-follow-up-prospects-for-natural-gas-Berlin-clean.pdf (accessed on 16 December 2021).

16. ExxonMobil. The outlook for energy: A View to 2040. 2019. Available online: https://www.ief.org/_resources/files/events/ief-lecture-exxonmobils-2019-outlook-for-energy-a-perspective-to-2040/exxonmobil-2019-outlook-for-energy-a-perspective-to-2040.pdf (accessed on 20 December 2021).

17. Takahashi, P. Over 100 Oil and Gas Companies Went Bankrupt in 2020. Available online: https://www.houstonchronicle.com/business/energy/article/More-than-100-oil-and-gas-companies-filed-for-15884538.php (accessed on 14 October 2021).

18. Hoang, A.T.; Nižetić, S.; Olcer, A.I.; Ong, H.C.; Chen, W.H.; Chong, C.T.; Thomas, S.; Bandh, S.A.; Nguyen, X.P. Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: Opportunities, challenges, and policy implications. Energy Policy 2021, 154, 112322.

19. Raźniak, P.; Dorocki, S.; Rachwał, T.; Winiarczyk-Raźniak, A. The Role of the Energy Sector in the Command-and-Control Function of Cities in Conditions of Sustainability Transitions. Energies 2021, 14, 7579.

20. Energy Information Administration. Where Our Natural Gas Comes from—U.S. Energy Information Administration (EIA). Available online: https://www.eia.gov/energyexplained/natural-gas/where-our-natural-gas-comes-from.php (accessed on 5 January 2022).

21. Spencer, T.; Sartor, O.; Mathieu, M. Unconventional wisdom—Economic analysis of US shale gas and implication for the EU. Studies 2014, 2, 14.

22. Wang, Q.; Chen, X.; Jha, A.N.; Rogers, H. Natural gas from shale formation—The evolution, evidence and challenges of shale gas revolution in United States. Renew. Sust. Energ. Rev. 2014, 30, 1–28.

23. Office Parlementaire D'évaluation des Choix Scientifiques et Technologiques. Rapport sur Les Techniques Alternatives à la Fracturation Hydraulique Pour L'exploration et L'exploitation des

Hydrocarbures non Conventionnels. Available online: https://www.senat.fr/rap/r13-174/r13-1741.pdf (accessed on 11 January 2022).

24. Bros, T. After the US Shale Gas Revolution; Editions Technip: Paris, France, 2012.
25. Energy Information Administration. Annual Energy Outlook. 2013. Available online: https://www.eia.gov/outlooks/ieo/pdf/0484(2013).pdf (accessed on 16 January 2022).
26. Energy Information Administration. Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. Available online: https://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf (accessed on 10 January 2022).
27. Energy Information Administration. World Shale Resource Assessments. Available online: https://www.eia.gov/analysis/studies/worldshalegas/ (accessed on 19 January 2022).
28. Kofod, J. Impact Economique et Strategique de la Revolution des Petrole et Gaz Non Conventionnels. Available online: https://www.nato-pa.int/sites/default/files/documents/2013%20-%20150%20ESC%2013%20F%20REV1%20-%20PETROLE%20ET%20GAS%20NON%20CONVENTIONNELS%20-%20RAPPORT%20KOFOD.doc. (accessed on 14 October 2021).
29. Richardson, N.; Fraas, A.G. Comparing the Clean Air Act and a Carbon Price; Resources for the Future Discussion Paper No. 13-13; SSRN: Rochester, NY, USA, 2013; pp. 1–27.
30. Anderson, O.L. Shale Gas Revolution or Evolution: Opportunities and Challenges for Europe. Oil Gas Nat. Resour. Energy J. 2017, 3, 106–133.
31. Bocora, J. Global Prospects for the Development of Unconventional Gas. Procedia Soc. Behav. Sci. 2012, 65, 436–442.