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Recent Trends in the World Gas Market: Economical, Geopolitical and Environmental Aspects

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Abstract: Natural gas is considered by energy experts to be the most promising fossil fuel for the 21st century, and as a matter of fact, the International Energy Agency (IEA) introduced for the first time in the 2011 World Energy Outlook a high gas use scenario called the "Golden Age of Gas". Natural gas is an easy to burn and clean fuel; its proven reserves are large and furthermore, enormous possibilities are offered by unconventional resources. There are anyway some geopolitical concerns in the global gas market, since the most important reserves are concentrated in a limited number of countries; the environmental impacts in the extraction of shale gas should also be taken into account. The paper presents an updated and thorough overview of recent advances and trends in the global gas market, highlighting the role of Europe in the World scenario. Statistical data from the main international reports are presented; economical, geopolitical and especially environmental aspects are presented and discussed.

Keywords: natural gas; market; shale gas; world market; energy policy; costs; environmental impacts

1. Introduction

According to the International Energy Agency (IEA), total primary energy demand will grow by 31% by 2040 with respect to the 2013 data, reaching about 17 billion of toe [1].

Moreover, IEA projections show that fossil fuels will satisfy 75% of global primary energy demand in 2035 (oil 27%, coal 24% and natural gas 24%), while renewables and nuclear power will account for the remaining 25%. Although renewable energy sources will grow at a faster rate than fossil fuels, it is clear that fossil fuels will have a fundamental role in all medium-term scenarios. Among fossil fuels, natural gas is going to have an increasing, predominant role [2].

As a matter of fact, natural gas is used for power generation, industry and domestic heating and its use is increasing in most countries since it provides various energy and environmental benefits compared to other fossil fuels [3]. The increase in natural gas use can be related to the general trend of de-carbonation of the world energy supply The ratio between hydrogen and carbon was close to 0.1 when wood was the main fuel (mid 19th century), it increased to 1 in the coal era (mid 20th century), it became equal to 2 in the oil era (1980s) and currently, with the natural gas rise, it is almost equal to 4. According to many economists, energy cycles last approximately 50 years, so coal had its peak in 1930, oil in 1980 and gas will reach its peak in 2030 (Figure 1).

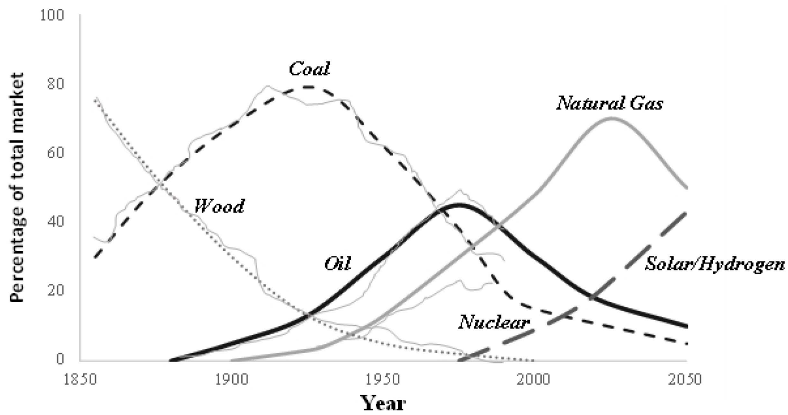


Figure 1. World energy cycles. (Source: data elaboration from BP 2014 [4]).

Gas resources are plentiful and spread all over the world, and thanks to the technological advances the world global trade has been developed fast in recent years. As a matter of fact, IEA introduced for the first time in the 2011 World Energy Outlook the so called "Golden Age of Gas", a high gas use scenario, which is projected to continue over the next 25 years, due to large available supplies and low prices [5]. BP evaluates that the proved natural gas resources all over the world are about 5.26 trillion cubic meters, a quantity which represents about 55 times the natural gas that is currently consumed in a year. Estimations of recoverable gas have doubled in the last 10 to 15 years as hydraulic fracturing and horizontal drilling technologies have unlocked the prospect of recovering unconventional gas. Conventional gas composes approximately 60% of the world's remaining recoverable gas resource, of which about 55% is in the Middle East and Russia/Caspian. Unconventional gas, including shale gas, tight gas and coalbed methane, found in highly compact rock or coalbeds, accounts for about 40% of the world's remaining recoverable gas resource [6].

In the next decades, North America and Russia/Caspian will continue to be the two leading natural gas-producing regions. Moreover, other regions will see strong growth, such as Asia Pacific, Africa and Latin America. This growth will be encouraged by both strong regional demand and export projects [6]. The rise of unconventional gas is going to influence in the following years the natural gas world market and to reduce the importance of the biggest producers such as Russia and Middle East and North Africa (MENA) countries.

There are some weak points regarding the environmental impact of unconventional gas production, in terms of land use, water use and air emissions. In particular, the aspect that is the main cause for concern is the consequences of hydraulic fracturing.

Within this contest, the present paper aims to provide an overview of recent advances and trends in the global gas market, under an institutional, economical, geopolitical and environmental point of view. The role of Europe in the World contest is particularly highlighted. Gas market aspects were analyzed through an overview of the energy market development since 2000 and in future scenarios till 2040. International gas trades and prices were discussed, considering different geopolitical areas and comparing gas market with the oil one. All the steps of the natural gas production chain were taken into account (extraction, transportation, storage), for both conventional and unconventional gas; a particular emphasis was put on environmental impacts and risks.

2. The Global Scenario

2.1. Demand

Due to the global financial crisis, recent data underlines a relative growth—or even a decrease—in gas consumption; the EU market is especially affected by this phenomenon. During the crisis, gas consumption dropped even more significantly than electricity one as it was hit by direct consumption reductions and indirectly by the decrease in consumption at gas fired electricity plants [7]. Gas demand in Europe peaked in 2010 and in 2014 it was the lowest since 1995. This is due to the shifts in the European economy, changing consumption patterns and substantial improvements on energy efficiency. Gas demand is not equally spread across the EU. Eighty percent comes from seven western European countries, while only 12% of gas demand comes from seven Central and Eastern European countries. Due to this, most of Europe's gas demand occurs in countries characterized by strong energy efficiency and renewables distribution programs in place, which are likely to further decrease demand in future.

World natural gas consumption grew by 0.4% in 2014 (see Table 1), a value which is lower than the 10-year average (2004–2014) growth of 2.4%. Growth was below average in both the OECD and developing economies, with consumption in the EU (−11.6%) experiencing its greatest volumetric and percentage drops on record. The Europe and Eurasia region (−4.8%) had the five biggest volumetric declines in the world in Germany, Italy, the Ukraine, France and the UK. The US (+2.9%), China (+8.6%) and Iran (+6.8%) recorded the largest growth rises. Worldwide, natural gas accounted for 23.7% of primary energy consumption [8].

Global natural gas trade recorded a rare contraction in 2014, dropping by 3.4%. Pipeline shipments declined by 6.2%, the largest decline on record, driven by decreases in net pipeline exports from Russia (−11.8%) and the Netherlands (−29.9%). The UK (−28.2%), Germany (−10.1%) and the Ukraine (−29.9%) all reduced their pipeline imports significantly. Total liquefied natural gas (LNG) trade increased by 2.4%. Higher imports by China (+10.8%) and the UK (+20.1%) were partly counterbalanced by decays in South Korea (−6.0%) and Spain (−15.7%). International natural gas trade accounted for 29.4% of total gas consumption; LNG's share of global gas trade increased to 33.4% [8].

In the first quarter of 2015, gas consumption in the EU was the largest year-on-year increase in EU consumption since 2010. In Germany, consumption improved by 19% and an additional eleven Member States experienced growths: Belgium (23%), Croatia (13%), France (17%), Hungary (13%), Italy (11%), Luxembourg (19%), the Netherlands (12%), Portugal (13%), Slovakia (24%), Slovenia (14%) and the UK (11%). On the other hand, Greece, Finland, Sweden and the Baltic States experienced a decrease. The aforementioned growth can be mainly ascribed to the weather: in many European countries, temperatures were drastically lower than in the unusually mild first three months of 2014 [9].

In the U.S, the end of 2014 marked the end of the Vermont Yankee nuclear power plant (620 MW of electrical power), which was turned off after 42 years. The reason was essentially economic: the price of the electricity generated by the nuclear plant is no longer competitive in the US energy market, completely revolutionized by the unconventional gas resources, which acted as a powerful flywheel for the US GDP (Gross Domestic Product) growth. This change depends on the use of the hydraulic fracturing technique, developed to release the natural gas and the oil trapped in the rocks. This technique, although widely used, does not have the total approval, as discussed in Section 5. Despite this, many turn a blind eye for the economic advantages [10].

In Asia, demand for natural gas is expected to rise substantially in the coming years, driven by the significant growth in China, India and Southeast Asia. This trend is already evident in China, where natural gas consumption has risen by 4% to 14.5 billion cubic meters (bcm) in October 2015 compared with 2014. China is the world's third largest importer of gas and has a yearly gas demand equal to 49.3 bcm but this country has only 3% of the world's gas reserves, leading to a 41.3% spike in natural gas imports in March 2015, compared with the same period in 2014 [1].

In the Middle East natural gas was overshadowed by the region's dominant energy source: oil. Indeed, most of the natural gas in this region was only revealed while looking for oil. Due to continued growth in world demand [11], Middle East governments and industry are now increasing natural gas production infrastructure for extracting and monetizing the region's extensive supply. The biggest jump in consumption results from the power sector. In Saudi Arabia, rising electricity demand is mainly the result of population growth and the continual drive to meet its existing supply gap. Natural gas-based power plants are one of the most appealing solutions to satisfy this demand according to their lower carbon emissions, higher efficiency and shorter lead-time to commission.

It is worth noticing that the natural gas worldwide demand is also driving the need for higher production.

2.2. Production and Reserves

World natural gas production grew by 1.6% in 2014, a value that is below the 10-year average (2004–2014) of 2.5%. Growth was below average in all regions except North America. European production fell quickly (−9.8%) to the lowest level reached since 1971. The US (+6.1%) recorded the world's biggest increase, accounting for 77% of net global growth. The greatest volumetric declines were seen in Russia (−4.3%) and the Netherlands (−18.7%) [8]. Table 2 shows a brief summary of the natural gas volumes produced from 2004 until 2014. Gas production in 2014, compared to 2013, was characterized by percentage increases from 1% to 5.3% in all the macro-geographical areas, except for Europe and Africa. Africa's net gas exports have been in decline in recent years. This drop is mainly due to decreasing gas production and increasing gas consumption in North Africa. In Algeria, adverse fiscal terms, a challenging business environment and security risk lead to a lack of investment in the hydrocarbon sector. In Egypt, although substantial discoveries have been made (mostly in the deep offshore Mediterranean), due to low gas prices and arrears to be paid to foreign companies, many fields could not be developed. In Libya, civil war has often led to damage to gas infrastructure and blockages at production facilities and export terminals [12].

Iran and its near countries hold more than 70% of world's total gas reserves. Iran, Russia, Qatar and Turkmenistan are respectively the world's largest owners of gas reserves. However, none of Iran's neighbors, except for certain projects, have any interaction with others in the gas industry. They ignore the available cooperation opportunities, viewing each other as tough rivals. Iran's littoral neighbors in both the north and south enjoy significant gas reserves. On the other hand, Iran's eastern and western neighbors strongly need gas and power. Consequently, Iran can play the role of a regional hub for gas or power exports. Nonetheless, Iran is importing and exporting only a reduced amount of gas and power. With the recent joint gas markets in the region, it seems we will see an intense competition between regional countries to increase their share in the global gas markets (see Section 4.4).

Taking into account Latin America, while Argentina has the third-largest recoverable shale gas reserves in the world, it has nevertheless found itself as a significant premium-market importer of LNG. At the same time, Mexico has found itself contemplating as many as four LNG export projects along its Pacific coast, while looking towards US pipeline imports to satisfy its increasing domestic demand. Peru continues to export LNG at a reliable rate, and LNG has become increasingly critical to Brazil's power generation mix as a reliable, flexible source of power to complement and provide a crucial balancing fuel to the country's abundant yet intermittent hydroelectricity capacity. In the Caribbean, the landscape is also changing. While the natural gas industry in the region had previously focused on the LNG export facility at Trinidad's Point Fortin, a rising number of suppliers from integrated LNG-to-power solutions to small-scale services are increasingly concentrating on the significant growth potential of the Caribbean islands.

Since few years, the United States of America are the main natural gas producers, thanks to the discovery of shale gas underground reserves, extracted due to the fracking technique, consisting in pumping water at high pressure to create fractures into the subsoil, thus favoring the release of fuel fossil. Natural gas in the United States was the nation's second-largest source of energy in 2014, after petroleum [13].

Other big reserves are located in Siberia, in North Africa (Libya and Algeria), in the former Soviet republics (Turkmenistan and Azerbaijan), in some countries of South America and the Middle East. Before the discovery of the shale gas in the U.S., Russia, Iran and the Gulf monarchies (Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates and Oman) drove this ranking.

Table 1. Natural gas consumption. (Source: BP Statistical review of World Energy, June 2015 [8]).

Billion Cubic Meters	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2014 Share of Total**
Total North America	783.7	782.1	778.0	813.8	821.5	815.9	849.6	870.6	903.4	928.5	949.4	28.3%
Total S. & Cent. America	119.0	124.0	136.0	142.7	143.7	139.1	148.6	152.1	161.7	168.4	170.1	5.0%
Total Europe & Eurasia	1077.9	1098.4	1122.0	1127.2	1135.8	1041.5	1121.3	1097.8	1080.9	1060.8	1009.6	29.6%
Total Middle East	259.3	277.0	294.7	315.7	347.0	361.1	395.4	418.7	430.5	437.7	465.2	13.7%
Total Africa	81.1	85.5	89.1	96.0	100.9	99.6	107.2	113.9	121.8	120.3	120.1	3.5%
Total Asia Pacific	377.7	408.2	436.3	468.9	499.3	512.6	571.6	612.2	647.6	665.3	678.6	19.9%
Total World	**2698.8**	**2775.2**	**2856.1**	**2964.4**	**3048.2**	**2969.9**	**3193.7**	**3265.3**	**3345.8**	**3381.0**	**3393.0**	**100.0%**

Table 2. Natural gas production. (Source: BP Statistical review of World Energy, June 2015 [8]).

Billion Cubic Meters	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2014 Share of Total**
Total North America	753.5	750.5	769.7	781.8	800.8	807.3	821.1	866.5	893.8	903.3	948.4	27.7%
Total S. & Cent. America	134.7	140.7	154.3	162.3	163.2	158.5	163.2	167.2	173.7	173.3	175.0	5.0%
Total Europe & Eurasia	1025.3	1028.8	1043.0	1041.2	1070.0	950.3	1021.7	1034.2	1028.2	1034.7	1002.4	28.8%
Total Middle East	296.6	318.7	341.6	370.8	400.3	425.1	488.6	540.7	565.1	580.5	601.0	17.3%
Total Africa	156.4	177.3	192.2	204.7	212.3	200.0	213.3	210.2	215.4	204.7	202.6	5.8%
Total Asia Pacific	344.8	373.4	391.7	407.3	426.9	448.2	494.7	496.9	504.0	512.3	531.2	15.3%
Total World	**2711.3**	**2789.3**	**2892.5**	**2968.1**	**3073.4**	**2989.4**	**3202.6**	**3315.7**	**3380.2**	**3408.8**	**3460.6**	**100.0%**

The amount of natural gas in the ground is estimated by different techniques, taking into account the technology available to extract the gas. Analysts use different methods to make estimates. Natural gas supplies are characterized as production, resources and proved reserves. Resources can be defined as the total natural gas estimated to exist in a specific geological area. The estimated size of resources is different from the amount of natural gas that can or will be produced from that area. On the other hand, proved reserves can be defined as estimated amount that based on analysis of geologic and engineering data gathered though drilling and testing, can be reasonably projected to be recoverable under existing economic and operating conditions. Since economic and operating conditions change continuously, the estimates for proven reserves also changes often [14]. Resources are the biggest category, which describes the total potential of natural gas supply. Proved reserves take into account the feasibility and economics of extracting the natural gas. Finally, production describes the amount of natural gas removed from the ground. According to the BP Statistical review of World Energy 2015 [8], Table 3 and Figure 2 show the distribution of proved reserves in 1994, 2004, 2013 and 2014 [8].

Table 3. Natural gas proved reserves. (Source: BP Statistical review of World Energy, June 2015 [8]).

	At End 1994	At End 2004	At End 2013	At End 2014	
	Trillion Cubic Meters	Trillion Cubic Meters	Trillion Cubic Meters	Trillion Cubic Meters	Share of Total (%)
Total North America	8.5	7.5	12	12.1	6.5
Total S. & Cent. America	5.7	7.0	7.7	7.7	4.1
Total Europe & Eurasia	40.6	42.7	57.5	58.0	31.0
Total Middle East	45.5	72.2	80.0	79.8	42.7
Total Africa	9.1	14.2	14.2	14.2	7.6
Total Asia Pacific	9.7	13.0	15.2	15.3	8.2
Total World	**119.1**	**156.5**	**186.5**	**187.1**	**100**

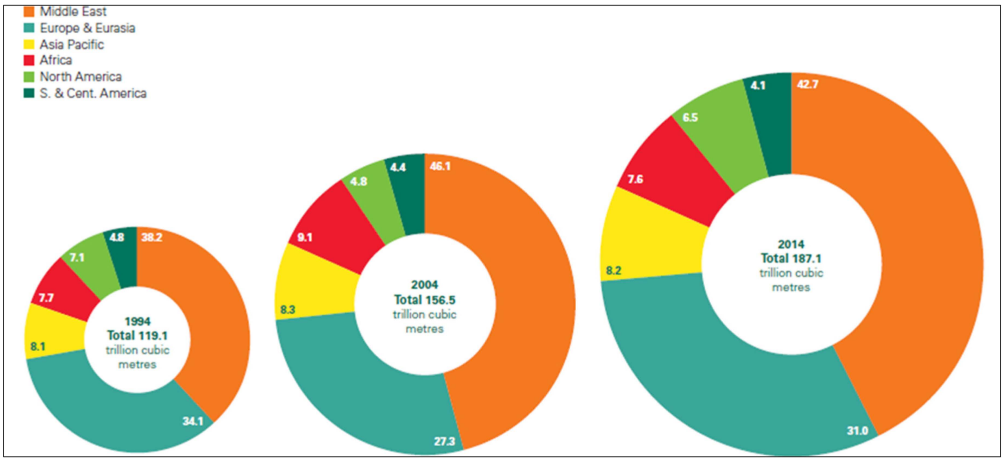


Figure 2. Distribution of proved reserves in 1994, 2004 and 2014. (Source: BP Statistical review of World Energy, June 2015 [8]).

Conventional gas currently dominates worldwide natural gas production, accounting for over 85% of total marketed output today. In recent years, however, two key developments have shifted the focus to so-called "unconventional". The first has been mounting concern that growing demand for energy worldwide would outstrip supply. The second factor has been a dramatic increase in unconventional gas production in North America, to roughly 50% of domestic production, notwithstanding the fact that there may be several negative environmental and climatic impacts caused by its production [15].

2.3. The Natural Gas Storage

Natural gas, like other fossil fuels, can be stored for an indefinite period, even though the storage is generally seasonal.

The exploration, production, and transportation of natural gas takes time, and the natural gas that reaches its destination is not always needed right away, so it is injected into underground storage facilities. These storage facilities can be located near market centers that do not have a ready supply of locally produced natural gas. Typically, natural gas has been a seasonal fuel, its demand being usually higher during the winter because it is used for heat in residential and commercial settings. Stored natural gas plays a crucial role in ensuring that any excess supply delivered during the summer months is not wasted and as insurance against any unforeseen accidents, natural disasters, or other occurrences may affect the production or delivery of natural gas. This Reservoirs cycle of loading and unloading is shown in Figure 3 on a quality level.

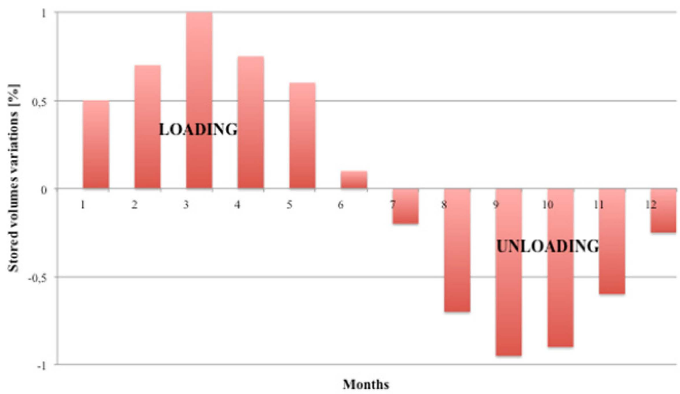


Figure 3. Reservoirs cycle of loading and unloading.

The most important type of gas storage is in underground reservoirs. There are three principal types: depleted gas reservoirs, aquifer reservoirs and salt cavern reservoirs. There are also other types of storage such as LNG facilities. Moreover, natural gas can be provisionally stored in the pipeline system itself, through a process called "line packing" (this is done by packing more gas into the pipeline by a pressure increase) or gas can be stored above ground in a gasholder (or gasometer) [14].

The United States has a high degree of natural gas infrastructure consistency supporting its security of supply, including the diversification of supply routes and substantial storage capacity. There are many natural gas underground storage facilities with a total working gas capacity of 275 bcm (about 38% of annual consumption) [16]. These facilities are widely dispersed geographically and consist of a combination of salt caverns, aquifers and depleted reservoirs. The advantage of the significant amount of salt caverns is that it allows rapid injection and withdrawal to respond to market conditions and other short-term events [17].

Analyzing the Asia Pacific area, Japan has the main import capacity in the world. The country has no underground storage for natural gas in its gaseous state, but has 31 LNG receiving terminals with around 10 bcm of natural gas storage capacity. Nevertheless, LNG storage in tanks is expensive and difficult under a technical point of view, therefore Japan can rely on a total storage capacity that meets only 30 days of domestic natural gas consumption [17].

Most European countries hold storage commercial capacities, except for Austria, the Netherlands, Poland and the UK, which have some capacities reserved to operational needs related to transmission and/or production, or strategic stocks. Over 50% of total storage capacity in Europe is located in three countries: Germany, Italy and France. The same three countries have the highest concentration of storage sites and they account for 54% of the total number of European facilities [17].

2.4. International Trade

In 2014, the highest imports by pipelines were registered in North America and Europe, followed by the Former Soviet Union. On the other hand, the highest exports occurred from Canada, Norway and Russian federation. Comparing the trade movements as liquefied natural gas and pipeline, it is possible to observe that North America total imports are essentially related to pipelines: in 2014, 11.6 bcm of LNG were imported *versus* 116.9 bcm by pipeline. This did not happen in South and Central America where 21.4 bcm of LNG were imported against 17.8 bcm by pipeline. Europe was characterized by the same scenario of the North America: 361.9 bcm were imported by pipeline and only 52.1 bcm as LNG. Middle East trade movements are essentially based on pipeline: only 5.4 bcm of natural gas were imported as LNG. Opposite scenario for Asia Pacific, where most of the gas imports are related to LNG (242.7 bcm imported as LNG *versus* 57.8 bcm by pipeline) [8].

It is worth noticing that, comparing 2013 and 2014 gas trade, total world pipeline gas imports/exports decreased by approximately 6% and, on the other hand, LNG imports/exports increased of about 2.5%. The observed differences are related to the typical break even distances between pipeline and LNG, among 1000 and 2000 nautical miles. Figure 4 shows trade routes between faraway countries, such as Africa and Asia Pacific [8].

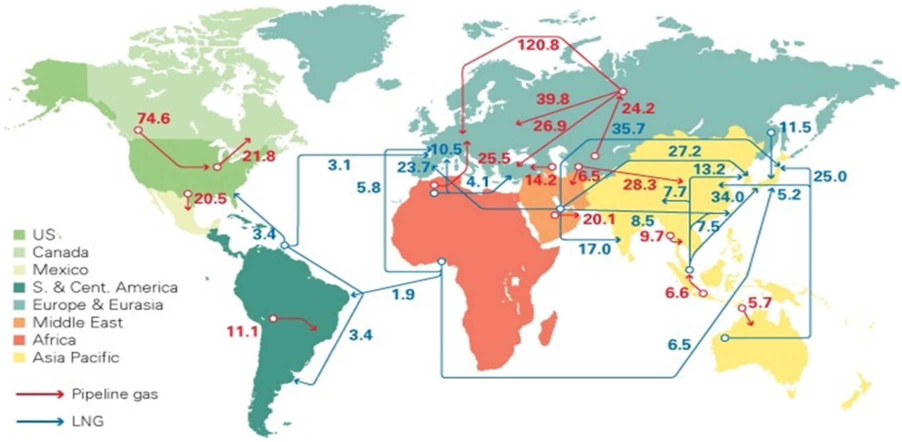


Figure 4. Trade flows worldwide. (Source: BP Statistical review of World Energy, June 2015 [8]).

2.5. Future Scenarios

According to ExxonMobil, The Outlook for Energy: A View to 2040 [6], natural gas will be the world's fastest-growing major energy source through 2040. From 2010 to 2040 global demand is expected to rise by close to 65% and account for about 40% of the growth in global energy needs. By roughly 2025, natural gas probably will overtake coal as the second-largest energy source, behind oil. Non-OECD countries will drive 80% of the projected global growth in natural gas demand, about 50% of the growth is expected from Pacific Asia, China accounting for half that increase. In OECD countries, demand for natural gas is expected to rise through 2035, about two-thirds of this increase will likely occur in North America, supported by their own resources. The International Energy Agency (IEA) estimates the remaining recoverable natural gas resource worldwide to be about 810 trillion cubic meters (tcm), which is about 240 times the natural gas the world currently consumes in a year [6]. Estimates of recoverable gas have doubled in the last 10 to 15 years as hydraulic fracturing and horizontal drilling technologies have unlocked the prospect of recovering unconventional gas. Over the last decades, the unconventional gas, particularly shale gas, has played a key role for growth in North America.

Several countries are interested in unconventional resources because they account for 42% of the recoverable ones [18]. The IEA has estimated that unconventional gas may meet more than 40% of the increased global demand for gas by the year 2035. However, many questions still remain about how easily unconventional gas resources can be developed outside North America. Unconventional gas resources are geographically, broadly distributed across all continents, including Europe. Their potential development may therefore offer a number of security-of-supply benefits for the Union: lower natural gas prices more readily available gas on the European market easing tightness in global energy markets and adding diversity to the EU's gas supplies. However, the growing focus on unconventional gas has not come without controversy because of need of advanced technologies and potentially high environmental impacts (see Section 5); furthermore, hydraulic fracturing requires a vast amount of water, which can be challenging obstacle in many countries, such as Arab countries [19].

According to ExxonMobil [6], from 2010 to 2040, as it can be seen in Figure 5, unconventional gas production in North America is expected to grow by around 1.84 billion cubic meters per day, which is about the size of total US gas production today. This abundant supply is expected to enable North America to shift from a net importer to a net exporter of natural gas by 2020 as production outpaces demand. Other countries that have huge unconventional resources are China—double the reserves of the US—Russia and Arab countries.

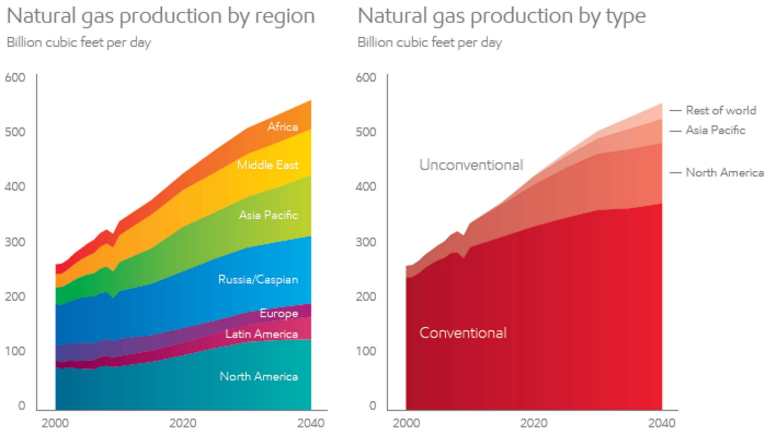


Figure 5. Natural gas production trend to 2040. (Source: ExxonMobil, The Outlook for Energy: A View to 2040 [6]).

International reports have started only recently to recognize a significant role to unconventional gas in future scenarios. In WEO-2011 [20], for the first time, the share of unconventional gas in the future energy mix is projected to significantly rise, accounting of 50% of the increase in gas production over the period 2011 to 2035. Instead, only two years before, WEO-2010 [21] expected a small percentage of increase in the medium-terms, although unconventional gas had already attracted interest in previous years.

Natural gas production will expand and diversify over the coming decades. While North America and Russia/Caspian will continue to be the two leading natural gas-producing regions, other regions will also see strong growth. Pacific Asia, Africa and Latin America are each expected to more than double their gas production over the outlook period. This growth will be spurred by both strong regional demand and export projects.

International trading will play an increasingly important role in meeting global demand for natural gas. Traded volumes of natural gas in 2040 are expected to be two and a half times compared to 2010 level, with most of this growth coming from LNG [22,23].

3. Institutional and Economic Aspects

3.1. Natural Gas Production Costs

Natural gas main costs are related to different steps: exploration, production, transportation (which may include liquefying process, carriage, regasification in the case of LNG), storage.

The natural gas extracting cost is very similar to the oil one and it depends on the deposits depth, the subsurface geology and the localization of the lodes. Every project is characterized by fixed costs (Capex) and variable ones (Opex) that have to be considered in order to verify the project profitability.

Taking into account shale gas, it is possible to affirm that shale reserves were well known even some decades ago, but the production costs, related to the vertical drilling technique, were not competitive compared to conventional gas. New horizontal drilling technique resulted in overtaking of the shale gas on the conventional one. Shale gas reserves are located at different depths and their production costs, for not very deep deposits, are lower than conventional gas deposits located at greater depths [23].

Among fossil fuels, natural gas is the most difficult to handle. Subsequently, its transportation cost is higher than the other fossil fuels. Taking into account LNG gas, it needs a liquefying process, regasification and compression, with a very high resulting transportation cost.

The changes in costs also affect the relative attractiveness of the pipeline and LNG options. In determining the most economic transportation method for a given supply route, distance and the transported volumes are the key factors. For short distances, pipelines, where feasible, are usually more economic, on the other hand, LNG is more competitive for long distance routes. For large deliveries (around 30,109 m^3/year), the transport of gas by high pressure pipelines appears very much competitive (Figure 6). For long distances, LNG appears competitive for capacity below 10,109 m^3/year. For Middle East supply to Europe for instance (between 4500 and 6000 miles), the LNG allows a cost saving of up to 30% with respect to high pressure pipe technology. Therefore, LNG could be preferred for small fields exploitation on a long distance transportation (Figure 7) [24].

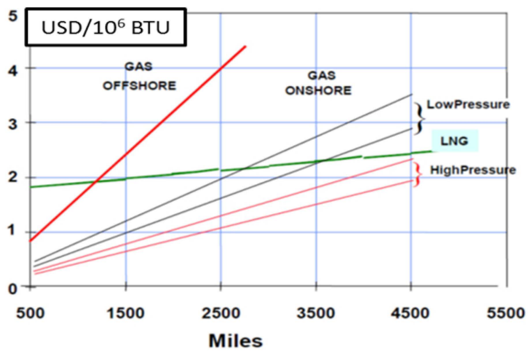


Figure 6. Pipes/LNG competition for 30,109 m^3/year capacity. (Source: Cornot-Gandolphe, S.; Appert, O.; Dickel, R.; Chabrelie, M.F.; Rojey, A. The challenges of further cost reductions for new supply options (pipeline, lng, gtl). In Proceedings of the 22nd World Gas Conference, Tokyo, Japan, 1–5 June 2003. [25]).

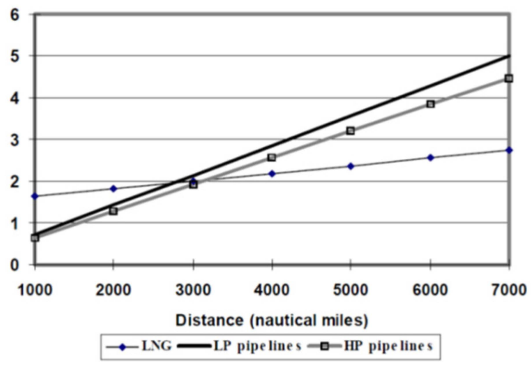


Figure 7. Pipes/LNG competition for 10,109 m^3/year capacity (USD/mmBTU) (Source: Cornot-Gandolphe, S.; Appert, O.; Dickel, R.; Chabrelie, M.F.; Rojey, A. The challenges of further cost reductions for new supply options (pipeline, lng, gtl). In Proceedings of the 22nd World Gas Conference, Tokyo, Japan, 1–5 June 2003. [25]).

3.2. Natural Gas Market Prices

Figure 8 shows a wholesale gas prices comparison. After the reduction seen in 2014 and at the beginning of 2015, wholesale prices have been almost constant since February. In Asia, spot LNG prices were reduced by 65% within a year because of the weak demand and increasing supply compared to the 2011–2013. For the first time since 2011, by February 2015 LNG traded at 7 USD/MMBtu, like the UK gas hub. Then, LNG prices marginally increased, with Japanese landed prices averaging 7.3 USD/MMBtu in the second quarter but their premium over NBP remained less than 1 USD/MMBtu. European prices diminished gradually in the first half of 2015. In the second quarter, NBP averaged 6.8 USD/MMBtu. Growing production, mild weather and high stocks helped to preserve prices down. The ratio of international wholesale prices stabilized after the convergence experienced in 2014 and early 2015 [9].

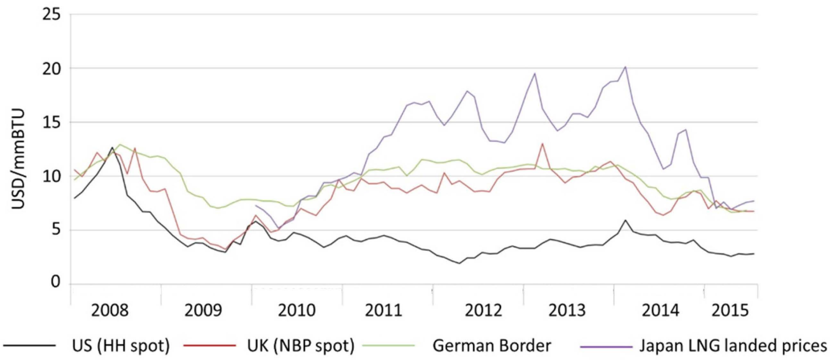


Figure 8. International comparison of wholesale gas prices. (Source: Quarterly report on European gas market, Q2 2015 [9]).

Asian demand continued to be calm in the second quarter of 2015. Compared to the same quarter of 2014, imports diminished into the three largest markets of Japan, Korea and China, which were only partially offset by increases in India, Taiwan and Thailand. Latin American imports also diminished, contributing to the weak global demand scenario [9].

In the second quarter, Japanese imports decreased by 9% year-on-year. In August, Japan reopened Unit 1 of the Sendai Nuclear Power Plant; Unit 2 of the same plant was set to restart in October. Another three reactors received approval from the Nuclear Regulation Authority. Before the Fukushima disaster, nuclear plants were responsible for about 30% of the country's electricity production. In 2015 three new LNG buyers emerged in the market: Egypt, Jordan and Pakistan. Egypt has conventionally been an LNG exporter but increasing domestic demand forced it to deflect most of the local gas to the national market. As a result, both liquefaction plants became idle. Moreover, two floating storage and regasification unit were installed, permitting the country to import LNG. In August, Eni proclaimed the finding of a giant gas field in Egyptian waters, the biggest ever found in the Mediterranean Sea. After its full development, the Zohr field will be able to satisfy the country's gas demand for long time and could allow Egypt to restart LNG exports [25]. While the closure was a bullish factor, new plants coming on stream in Australia and the US in 2015–2018 are estimated to maintain LNG prices at a low level. All around the World, 16 projects with total capacity of 170 bcm are under construction. Many other projects have been suggested but recent low oil prices are likely to delay several of these [26].

3.3. Comparison between Oil and Gas

After accomplishing a six-year low in January 2015, Brent began to rise as the falling number of active rigs in the US and the news about oil companies cutting upstream spending had raised expectations that supply growth could soon ease. Growing tension in the Middle East also reinforced prices. Nevertheless, from May, oil prices started to drop again, driven by the permanent over-supply in the global market. In order to preserve market share, OPEC output remains at near-record levels while so far US tight oil production has proved to be rather strong to low prices. The Iran nuclear deal also extended the specter of permanent over-supply. Taking into account the demand, the Greek debt crisis and interests over China's growth also contributed to the price decrease. These growths suggest that prices will remain moderately low for a long period [9].

The NBP spot price has been unstable in 2014, with the average monthly price dropping by 40% between January and July and then growing by 47% between July and November. Prices were quite stable in the first half of 2015, while there was a clear reduction as falling oil prices and steady LNG supply put down pressure on European hub prices. In the second quarter, NBP has been changing in the range between 20 and 22 Euro/MWh and averaged 21.1 Euro/MWh [9].

The decrease of oil prices influences oil-indexed gas prices, though with a 6–9 month time lag. Oil-indexed prices were estimated to bottom out in mid-2015 but are now set to drop more. In the second quarter of 2015 and by July, Platt's North West Europe Gas Contract Indicator (GCI), an index representing what a gas price linked 100% to oil would be, continued to fall and its premium over NBP has reduced to less than 2 Euro/MWh, the lowest level since December 2010. Oil indexed prices have an important but weakening role in the European market: according to [25], oil-indexation accounted for 32% of gas consumption in 2014, down from 43% in 2013 (Figure 9). This share was about 12% in 2014, in Northwest Europe [9].

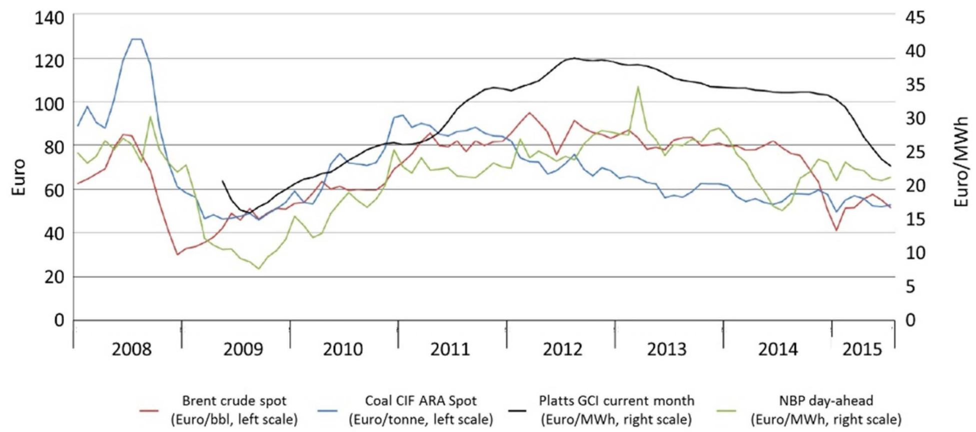


Figure 9. Spot prices of oil, coal and gas in the EU. (Source: BP Statistical review of World Energy, June 2015 [8]).

4. Geopolitical Aspects

4.1. Relationship between European Union and Russia

Europe does not have the same energy self-sufficiency as the US. France has many benefits from nuclear energy, while UK has large coal reserves. Despite a large deposit of natural gas in Netherlands, the other States depend mostly on Russian gas, in fact, many countries in the Baltic and South East Europe depend solely on Russian gas. The old continent imports natural gas from Russia through pipelines including the "Brotherhood" (which dates back to 1967, Russian gas was flowing through Ukraine to Germany and Slovakia), "Soyuz", "Yamal" (directed in Eastern Europe) pipelines and from 2011 the "North stream", which goes to supply Germany (thanks to the Baltic Sea transit), joining the existing networks "OPAL" (the Ostsee-Pipeline-Anbindungsleitung) and "NEL" (nordeuropaische Erdgasleitung).

In the years 2012 and 2013, a significant reduction in LNG imports in the EU was observed as booming demand for LNG in Asia and Latin America led to high LNG prices there. As shown in Table 4, LNG imports decreased by 27% in 2012 and by 24% in 2013.

Table 4. EU gas imports on selected supply routes (BCM). (Source: Bentek/Platts, Thomson-Reuters Waterborne. [27]).

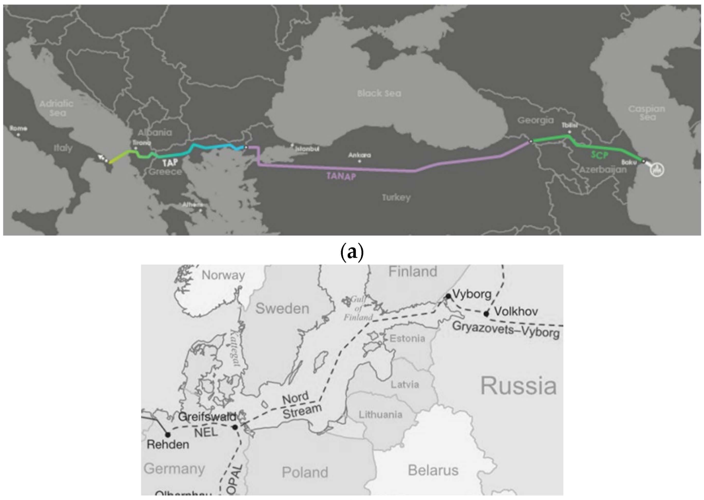
Billion Cubic Meters	2011	2012	2013	2014
Norway	93.6	104.2	101.4	106.3
North Africa	32.9	37.4	31.4	28.5
North Stream	0.5	10.6	22.1	32.8
Yamal pipeline	22.8	25.0	30.6	29.8
Ukraine/Slovakia	70.4	51.8	53.5	31.4
LNG	87.0	63.9	48.5	47.2

The reduction in LNG imports was partly offset by pipeline imports, rising by 3% in 2012 and by 7% in 2013. Most of this rise came from Russia, in fact EU imports from Russia increased by 28% in 2013, after an 8% decline in 2012 [18].

The crisis between Russia and Ukraine in 2014 highlighted the EU dependence from Russian gas and caused a different distribution of flows (as it can be seen from Table 4, there was an increase of North Stream flows).

In response to persistent concerns about the EU's dependence on energy imports (there are some countries, such as Bulgaria, Lithuania, Poland and Slovakia which trust on Russian natural gas for more than 90% of their total energy imports), in 2014 the European Commission published its energy security strategy seeking to ensure the energy stability. In addition to providing short-term measures to address the impact of a gas imports interruption from Russia (or a disruption of imports via Ukraine), the strategy deals with challenges in the long term concerning the security of supply and it proposes the implementation of initiatives in five different areas, such as increasing the production of energy in the EU countries to diversify suppliers and routes [28].

In recent years, new projects, such as Trans-Adriatic Pipeline (TAP), are planning in order to ensure the security and diversification of energy supply in Europe (Figure 10). At the geo-political level, TAP's strategic partnership with the European Union has been evidenced by the strong support of EU Commission and Parliament. TAP has been designated as a Project of Common Interest (PCI) and Europe has named it a Project of Energy Community Interest (PECI). The pipeline starts at the Greece–Turkey border at Kipoi, Evros, where it will be connected with the Trans-Anatolian gas pipeline. It will cross Greece, Albania, the Adriatic Sea and come ashore in Southern Italy.



(**a**)

(**b**)

Figure 10. (**a**) The Southern Gas Corridor Project (Source: Trans Adriatic Pipeline AG [29]); (**b**) Pipelines between Germany and Russia.

4.2. The American Shale Gas Role

The crisis in Ukraine has once again proved the importance of diversified natural gas supplies for Europe. Extending the EU interconnectors network, adopting energy-efficient technologies and exploiting renewable-energy resources may all play a role in that process. However, there is another, more direct solution which is accelerating the import of liquefied natural gas from the United States.

The recent energy-industry revolution in the U.S. has been well-documented. America is now the biggest world producer of natural gas and it is estimated to be a net exporter of energy in the near future. United States LNG exportations will make the global marketplace more competitive and guarantee supply variety and security. Current U.S. law allows export only to those nations with which America has a free-trade agreement or after a lengthy permit process when export is considered in the public interest. Europe wishes to insert an article into the agreement asserting that no limitations should apply to the export of energy goods. However effective the Transatlantic Trade and Investment Partnership (TTIP) agreement may be, it won't give a sudden solution to Europe's natural gas supply problems [30].

4.3. The Agreement between Russia and China

At the end of 2014 Russia and China signed an initial natural gas deal, which opened the doors to a second major supply connection between these two countries and dropping natural gas prices in Asia. Moscow agreed to supply Beijing with 38 billion cubic meters of natural gas annually for 30 years through pipelines into eastern China from eastern Russia. Due to China's negotiation, in order to compete, suppliers from other countries need to reduce prices. The consequences involve higher cost to liquefy and transport natural gas by sea to China and Asian regions from other countries (Australia, Canada, the U.S. and East Africa). The spot price of LNG delivered to North Asia had already dropped to a three-year low of around 9.94 USD/GJ earlier this year, and it is below $7/MMBtu in the second half of 2015. Moscow would like to speed energy exports to Asia because of the European political resistance, in particular after recent troubles in Ukraine. For China, natural gas is important to achieve its clean-energy purpose. However, it currently meets supply limitations and it depends on the high price of the LNG contracts for imports [31].

4.4. The Iranian Impact

Iran is arriving into the oil and gas market. The important agreement between Iran and the P5+1 group (U.S., France, UK, Russia, China and Germany) has many oil majors and refiners taking into account the influences of new Iranian crude hitting the worldwide oil market [32]. Nevertheless, it is not only the oil that the Iranians can provide. The country has the second largest natural gas fields in the World. Much like its oil sector, Iran's natural gas industry has been badly affected by the U.S. and European-led sanctions that have limited the foreign investment flow and the transfer of knowledge. Starting from a new report from Fitch, Iran has about 34 tcm of natural gas reserves (about 18% of the total reserves) [8]. Therefore, Iran has the potential to have a crucial role in the natural gas market as soon as sanctions will be removed. It is worthy noticing that, despite of the western sanctions, Iran's natural gas production improved in 2014. Albeit Iran has one of the biggest natural gas reserves, it contributes just 1% to the global natural gas trade. About 90% of its exports are directed to Turkey and the 10% to Armenia and Azerbaijan.

Iran is an important site where it can benefit from the rising natural gas demand from Asian countries such as India, China and Pakistan. One possible consequence is the possibility for Iran to play a key role in the EU's future energy security scenario, as it could possibly join the Trans Anatolian Pipeline (TANAP), which would go from Azerbaijan through Turkey and Greece before linking with the Trans Adriatic Pipeline (TAP). That could allow Iran to distribute natural gas to Western Europe. The European Commission trusts that, by 2030, the European Nations could import between 25 and 35 bcm of gas a year from Iran. This could put future gas supplies from Iran on a comparable level to existing imports from North Africa and help reduce the European's dependence on shipments from Russia [33].

5. Environmental Risks and Impacts

Environmental advantages of natural gas combustion are well known. Methane—which is the main component of natural gas—is a simple hydrocarbon (alkane) composed by a carbon atom and four hydrogen atoms. Methane is an ecological energy source because its combustion mainly produces water vapor and carbon dioxide. From the combustion, sulfurous products and powders are almost completely absent and nitrogen oxides may develop only at high temperatures, however in limited quantities.

Taking into account all the fossil fuels, natural gas combustion is the one that generates the smallest amount of greenhouse gases: the emissions of carbon dioxide per unit of energy produced are about half of those from coal and about 2/3 of those from oil [34]. For this reason, the use of natural gas instead of other fossil fuels allows reducing the greenhouse gases production, and therefore it reduces the environmental impact of the electricity sector

However, a complete assessment of the environmental impacts of natural gas needs to take into account also the aspects related to gas extraction and transportation. Differences between conventional and unconventional gases can be pointed out. Some focuses need to be done on greenhouse-gas footprint, carbon footprint, water footprint and link with natural events such as earthquakes.

5.1. Conventional Gas Extraction

Conventional gas wells frequently require multiple liquid-unloading events during extraction operations, in order to mitigate water intrusion, to remove (or blowing down) liquids that gradually build up and block flow in wet gas wells, and to regulate reservoir pressure. During such liquid unloading phases additional natural gas ventings occur. Since methane is a greenhouse gas with a Global Warming Potential 20 times higher than carbon dioxide, this results in a significant environmental impact.

The amount of methane vented during liquid unloading has been adjusted significantly by the US Environmental Protection Agency (EPA). EPA evaluated the unmitigated emission factor based upon fluid equilibrium calculations and NG STAR program data for two basins. The Natural Gas STAR Program is a flexible, voluntary-based partnership that encourages oil and natural gas companies in US and also in other parts of the world, to adopt cost-effective technologies and practices that improve operational efficiency and reduce emissions of methane. EPA calculated the amount of gas needed to blow out the liquid from a well as a function of well depth, casing diameter, and shut-in pressure, and the amount of gas vented after the liquid has been blown out. In the evaluations the EPA used the annual recovery data reported by operators adopting automated plunger lift systems to remove liquids and capture gas. The emission factor equal to 11 t of CH_4 per year per well, reported by EPA, includes the assumption, based on the findings from [35], that around 41% of conventional wells require liquid unloadings. This factor suggests that 26.7 t of CH_4 are released per year per well requiring liquid unloadings. It should be remarked that the frequency of liquid unloadings usually depends on the age of the well and varies both between and within basins. In addition, like well completion emission factors, some uncertainty in the estimations can be related with limited testing, with the applicability of the Natural Gas STAR program activities to calculate industry baseline emissions, and with a lack of details for reduction estimates [36]. Blowdowns account for around 50% of the unmitigated emissions from the NG production sector according to EPA and therefore the absence of reliable data on the frequency of these operations and their related emissions leads to a large degree of uncertainty for the conventional NG pathway. The EPA general assumption that liquid unloadings only occur at conventional gas wells is considered reasonable by Burnham *et al.* being shale gas typically a dry gas. On the other hand, some shale formations in the US actually produce water and as consequence may require liquid unloading operations [36].

5.2. Unconventional Gas Extraction

The rapid development of shale gas (Figure 11), especially in the U.S., caused many concerns for the potential negative impacts on the environment: instances of water contamination, air pollution, and earthquakes have been blamed on shale gas extraction activities.

A frequently expressed concern about shale gas is that subsurface hydraulic fracturing operations in deep shale formations might create fractures that may extend well beyond the target formation to water aquifers, allowing methane, contaminants naturally occurring in formation water, and fracturing fluids to migrate from the target formation into drinking water supplies.

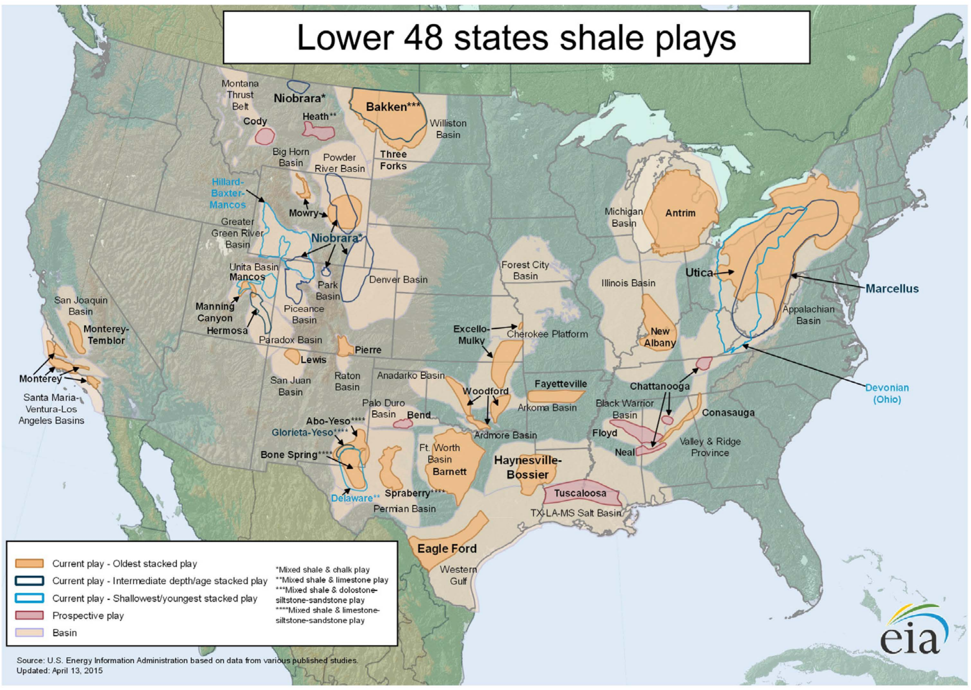


Figure 11. United States shale gas reserves. (Source: Energy Information Administration, 2015 [13]).

Since the advent of hydraulic fracturing, more than one million hydraulic fracturing treatments have been conducted, with perhaps only one documented case of direct groundwater pollution resulting from injection of hydraulic fracturing chemicals used for shale gas extraction. The public and government officials are continuing to raise questions and focus their attention on the issue of the exact composition of the hydrofracturing fluid used in shale formations [37]. In 2010, the U.S. House of Representatives directed the EPA to conduct a study of hydraulic fracturing and its impact on drinking-water resources. This study will add important information to account for the fate of hydraulic fracturing fluid injected into the gas-bearing formation. It is well known that a large portion (as much as 90%) of injected fluid is not recovered during the flowback period, and it is important to document potential transport pathways and ultimate disposition of the injected fluid [37]. In 2000 it has been registered that more than 40 million U.S. citizens drink water from private wells [37]. In some areas, methane seeps into these private wells from either natural or anthropogenic sources. Given its low solubility (26 mg/L at 1 atm, 20 °C), methane entering wells as a solute is not considered a health hazard with respect to ingestion and is therefore not regulated in the United States. However when present, methane can be oxidized by bacteria, resulting in oxygen depletion. Low oxygen concentrations can result in the increased solubility of elements such as arsenic or iron. In addition, anaerobic bacteria that proliferate under such conditions may reduce sulfate to sulfide, creating water and air-quality issues. Moreover, when methane de-gasses, it can also create turbidity and, in extreme cases, explode. Therefore, the U.S. Department of the Interior recommends a warning if water contains 10 mg/L of CH_4 and immediate action if concentrations reach 28 mg/L (Figure 12). Methane concentrations above 10 mg/L indicate that accumulation of gas could result in explosion [37].

Another aspect to be taken into account is related to the large-scale use of water in hydraulic fracturing that inhibits domestic availability and aquatic habituates. The amount of water needed to drill and fracture one horizontal shale gas well ranges from 3–4 million gallons (70,000 to 95,000 barrels) depending on the basin and formation characteristics. Water supply is a major concern of policymakers within the U.S. particularly given heightened competition between competing industries and shrinking supplies [38].

Another subsurface risk that has received attention recently is the possibility that drilling and hydraulically fracturing shale gas wells might cause low-magnitude earthquakes. In 2008 and 2009, the town of Cleburne, Texas, experienced several clusters of weak earthquakes all registering 3.3 or less on the Richter scale. The seismic monitoring of hydraulic fracture jobs is critical to improving understanding of how underground injection might spark unexpectedly high-magnitude seismic activity. United States Geological Survey (USGS) has confirmed that hydraulic fracturing can cause small earthquakes and seismic activity (called induced seismicity), even if in most cases the magnitude is so low that no safety concerns have been actually highlighted [38].

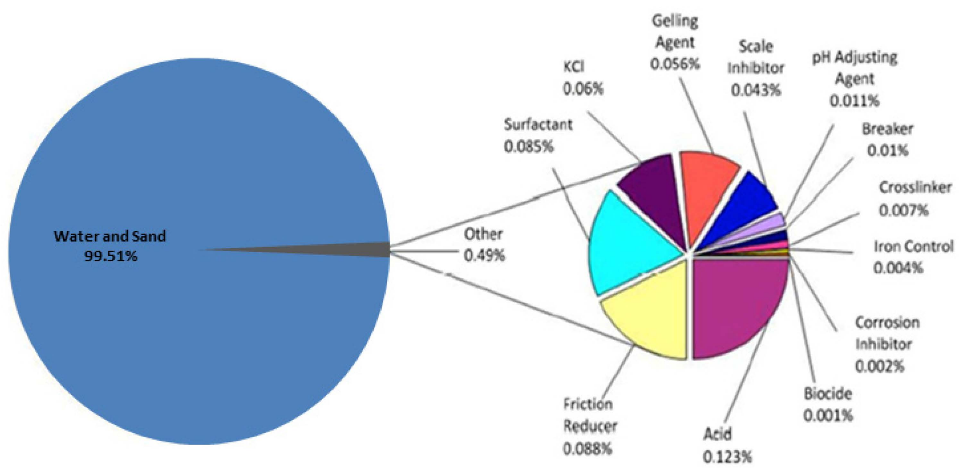


Figure 12. Volumetric composition of a fracture fluid. (Source: ALL Consulting based on data from a fracture operation in the Fayetteville, Shale 2008 [39]).

Because of the quantities of chemicals that must be stored at drilling sites and the volumes of liquid and solid waste that are produced, significant care must be taken that these materials do not contaminate surface water and soil during their transport, storage, and disposal. Fluids used for slick water hydraulic fracturing are typically more than 98% fresh water and sand by volume, with the remainder made up of chemicals that improve the treatment's effectiveness, such as thickeners and friction reducers, and protect the production casing, such as corrosion inhibitors and biocides. Because the fluids in each fracturing treatment would contain a different subset of these chemicals, and because these chemicals could be hazardous in sufficient concentrations, public disclosure of the chemicals used in hydraulic fracturing on a site-by-site basis is necessary to enable regulatory agencies, health professionals, and citizens to conduct baseline water testing and respond appropriately should contamination or exposure occur. A number of companies are investigating use of more environmentally benign fracturing fluids. These would also help limit the environmental and health risks posed by fracturing fluids in the case of contamination.

As previously said, after each fracturing stage, the fracturing fluid, along with any water originally present in the shale formation, is flowed back through the wellbore to the surface. Flowback and water produced during a well's lifetime can contain naturally occurring formation water that is millions of years old and therefore can display high concentrations of salts, naturally occurring radioactive material and other contaminants including arsenic, benzene, and mercury (Figure 13).

Such a wastewater from flow-back containing dissolved chemicals and other contaminants needs treatments before disposal or re-use. Despite the widespread use of fracking in the oil and gas industry in the U.S., many municipal treatment plants are not designed to remove all water constituents associated with shale gas/oil extraction. Disposal of wastewater is typically done using deep injection wells, onsite recycling or re-use or it is sent to a facility equipped to process the contaminated water [19,38].

Another environmental impact to be taken into account is related to the greenhouse gas emissions. Apart from carbon dioxide amount released in the atmosphere during natural gas combustion, contribution to greenhouse gas emissions is due to carbon dioxide and methane leaks during extraction phases. In particular, methane emissions during shale gas extraction are of great interest being at least 30% more than and perhaps more than twice as great as those from conventional gas according to literature [40]. Summing all estimated losses during the life cycle of an average shale-gas well it has been calculated that around 3%–8% of the total production of the well is emitted to the atmosphere as methane. This can be from 30% to 200% larger than the life-cycle methane emissions estimated for conventional gas (1%–6%) [40].

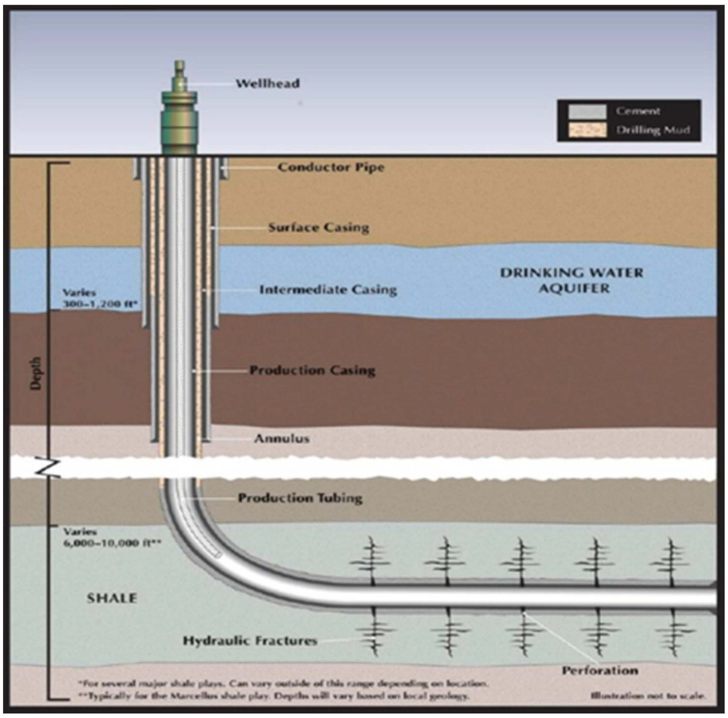


Figure 13. Multi-Stage hydraulic fracturing. (Source: Hamid Majid A., Geo P. Technical Developments in Utilizing Unconventional Resources of Oil and Gas. 10th Arab Energy Conference [19]).

The higher emissions from shale gas would occur during hydraulically fracturing, as methane escapes together with flow-back fluids and during drill out following the fracturing. Methane is a powerful greenhouse gas, with a global warming potential that is far greater than that of carbon dioxide, particularly over the time horizon of the first few decades following emission. It should be remarked in fact that methane is characterized by a tenfold shorter residence time in the atmosphere, so its effect on global warming attenuates more rapidly (Intergovernmental Panel on Climate Change 2007). Consequently, comparing the global warming potential of methane and CO_2 requires a specific time horizon and while over 20 years the impact of shale gas is much higher with respect to conventional gas, on the 100 years' time horizon such a difference is attenuated.

According to some authors [40], the footprint for shale gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so over 20 years, while for others [28] shale gas leads to lower emissions compared to conventional. Compared to coal, the footprint of shale gas would be even 20% greater and perhaps more than twice as great on the 20-year horizon and would be comparable when compared over 100 years [40]. Focusing on natural gas growth over the past decades, such considerations even if still contradicting each other are of great relevance. Part of the NG development is indeed due to the fact that it is considered a kind of transitional fuel within the framework of greenhouse gas reduction, as it is presumed to be a benefit for global warming compared to other fossil fuels. In order to underline the high interests of the international community to these topics it can be remarked as in 2009 the US Research Council noted emissions from shale-gas extraction might be greater than from conventional gas. The Council of Scientific Society Presidents in 2010 wrote to President Obama, warning that some potential energy bridges such as shale gas have received insufficient analysis and may aggravate rather than mitigate global warming. In late 2010, the U.S. Environmental Protection Agency issued a report concluding that fugitive emissions of methane from unconventional gas may be far greater than for conventional gas [40].

Analyzing the production phases of conventional and shale gases it can be noticed how most of the differences associated to methane fugitive emissions are linked to well completion stage, mainly due to the adoption of the hydraulic fracturing technology and related flow back fluid leaks. Looking at emissions during downstream stages no major differences can be highlighted. Routine venting and equipment leaks at well site, emissions during liquid unloading and gas processing are equivalent for shale and conventional gas being largely due to gas composition and to the geological characteristics of the spot. In contrast, according to some other authors [38] the impact of liquid unloadings leads conventional gas to have higher GHG emissions than shale gas. It is evident from the above that these topics are still under discussion and need deeper investigation for proper assessments.

5.3. Gas Flaring and Gas Venting

In an oil field, oil is usually associated with an amount of methane. Modern wells are predisposed for the recovery of the gas being a further resource. However, the recovery process is strictly related to infrastructures able to transport the gas to consumption places. These structures, expensive and not always easy to make, are not built if the gas amount is limited, because the costs of structures would be greater than possible revenues. This raises the problem of what to do with the gas produced in excess.

Gas flaring is a gas combustion (without any energy recovery) through a continual flame located on the top of the towers oil. This practice has wasted energy resources that could be employed for implementing economic growth and has led to high quantities of carbon dioxide, but also sulfur dioxide and nitrous oxide, which contributed to the air pollution. Billions of cubic meters of natural gas is flared at oil production sites all over the world. In many countries, such as Italy, gas flaring is very limited and every year one million tons of carbon dioxide are produced. On the other hand, countries such as Nigeria, where gas flaring is still widely used, produces several hundred million tons of carbon dioxide [41]. Other sources state that around 3.5% of the world's natural-gas supply was wastefully burned, or flared, at oil and gas fields in 2012 [42].

In order to find a strategy to reduce gas flaring, the World Bank Group is very active and has a leadership role through the Global Gas Flaring Reduction Partnership (GGFR). GGFR, which is a public-private initiative comprising oil companies, governments and institutions, works to increase use of natural gas associated with oil production to help removing technical and regulatory barriers to flaring reduction, carrying out researches, spreading best practices and defining country-specific gas flaring reduction programs. Furthermore, the World Bank introduced the "Zero Routine Flaring by 2030" initiative, bringing together the governments, oil companies and development institutions who recognize as unsustainable from a resource management and environmental perspective the flaring situation and who agree to cooperate for eliminating routine flaring within 2030. This Initiative refers to routine flaring and not to flaring for safety reasons or non-routine flaring, which nevertheless should be reduced.

In addition, there is also the gas venting practice. Gas venting consists in releasing gas into the atmosphere, often aimed at ensuring the safety conditions during the machining operations and treatment processes. The emissions from gas venting consist of methane, carbon dioxide, organic volatile compounds, sulfur compounds and gaseous impurities. In many cases, gas can be burned instead of being dispersed as such. In this way, it partially reduces the environmental impact in terms of greenhouse gases, because they are oxidized to CO_2, which has a global warming potential 21 times lower than methane [41]. However, venting cannot be considered an acceptable substitute for flaring.

Currently, these practices are exposed to severe restrictions, both for an economic issue (the produced gas can be sold and consumed, instead of being wasted) and, above all, for an environmental issue. Taking into account the Kyoto Protocol, incentives are provided for the realization of plants with low environmental impact [41].

5.4. Transportation

Fuels in general have to be transported from the place of extraction and production to places of consumption. Natural gas, unlike the other products, can be transported through pipelines built underground, and for this reason it does not need the transport with tankers, which in turn have pollutant emissions, and does not increase the traffic surface, thus helping to decrease the pollution caused by heavy traffic, in addition to the risk of road accidents. On the other hand pipelines have to be constantly monitored and protected from causes of damage, such as earthquakes, nearby fires and explosions, excavations and works, sabotage and corrosion.

Drilling a pipeline can cause fires and explosions, as well as the economic damage of gas leakage.

To avoid gas pipes damage, there are passive and active surveillance systems. The large gas pipelines are daily monitored by dedicated staff, by using helicopters or jeeps.

Along the pipeline, data collection and active protection devices are installed to inspect and counteract corrosion through cathodes protection (electrochemical safeguard technique against corrosion of metal structures exposed to an environment that may be aggressive towards metal). To detect minor leaks, an active technique is the "odorization", which exploits the human sense of smell and supervision of citizens. The odorization is the industrial operation which consists in adding, to substances odorless or nearly so, other substances with penetrating smell, in order to make the presence of the first detectable. Fugitive emissions are defined as unintentional releases that include methane emissions from equipment leaks at sealed surfaces, as well as from underground pipeline leaks. Total fugitive emissions for the natural gas industry are 5.46 Billion cubic meters (Bcm). Underground pipeline leaks account for 1.35 Bcm of emissions, and include leaks from production gathering lines, transmission pipelines and distribution pipe systems. Pipeline leaks are caused by corrosion, material defects and joint and fitting defects/failures [43].

On the other hand, natural gas can be transported through LNG ships, constructed to transport natural gas in the liquid state. The tanks of LNG ships are preserved at constant pressure and temperature levels (in order to store the gas to the liquid state) and thermally insulated from external heat sources. Part of the transported natural gas can be used as fuel by the ship itself. The transport of natural gas through these ships is more expensive than pipelines. LNG ships, however, have the advantage of allowing the supply of natural gas from multiple production sites.

According to the American legislation, enforced by the Coast Guard of the United States in their territorial waters, all vessels are banned within a mile ahead, two miles behind and ½ mile on each side of a gas carrier. This norm is very important to prevent collisions between ships or between LNG ship and submarine (an accident that has occurred in the past: 15 November 2002, to the east of the Strait of Gibraltar, the gas carrier Norman Lady have come into collision with the nuclear submarine USS Oklahoma City). Other risks are related to possible fires on-board that may lead to uncontrolled explosions and leakage of liquid gas or explosions related to possible collisions with rocks.

A simple method to estimate pipeline leakage is to examine the difference between the measured volume of gas at the wellhead and that actually purchased and used by consumers. Such a "rough method" includes the impact of many aspects as pipeline conditions and maintenance, even gas theft, variations in temperature and pressure, billing cycle differences, and meter inaccuracies. A more accurate method consists in direct measurements of the leaks during transmission and distributions but in this case data availability is very limited. According to Burnham *et al.* [44] methane losses for leakage and venting during transmission and distribution phases account for around 2.75% (from 1.0 to 5.5%) of the overall natural gas produced. Howarth *et al.* [45] suggests comparable values: 1.4 to 3.6% expressed as percentage of methane produced over the lifecycle of a well.

Part of the losses that can be associated to gas transportation along pipelines are due to gas usage in the so-called gas compression stations. In such stations, part of the natural gas is used to feed compression systems in order to re-establish the pressure level needed to guarantee the proper gas flow in the pipeline. Similar considerations can be done for LNG. In this case, part of the natural gas is used during liquefaction, shipping and re-gasification phases.

When LNG is added to the mix of natural gas, three additional lifecycle stages are created: liquefaction, tanker transport, and regasification. In the liquefaction process, natural gas is cooled and pressurized to convert it to liquid form. LNG tankers transport this gas and, finally, regasification facilities are the last step LNG must pass through before going into the pipeline system. Tamura *et al.* [46] have reported emission factors for the liquefaction stage in the range of 1.32 to 3.67 g-C/MJ. In [47] the authors calculate emissions from tanker transport of LNG using a specific equation that is a function of tanker capacity, distance from each country and fuel consumption. Regasification emissions were reported by Tamura *et al.* to be 0.1 g-C/MJ [32]. Ruether *et al.* report an emission factor of 1.6 g-CO_2/MJ for this stage of the LNG lifecycle by assuming that 3% of the gas is used to run the regasification equipment [48].

6. Conclusions

The gas industry (extraction, transportation, storage and final usage) increased significantly in the last decades in both industrial and emerging countries, also thanks to the recent technological innovations, which made possible the exploitation of unconventional gas resources. For this reason, the most important international reports (IEA WEO, BP, Exxon) foresee a constant growth of gas demand till at least 2030–2040 ("Golden Age of Gas"), while correspondently coal and oil will slowly decrease and renewable energy sources will gain importance.

Some signals towards this direction are already present. In April 2015, traditionally the month when total electricity demand is lowest, U.S. generation of electricity fueled by natural gas exceeded coal-fired generation for the first time since the start of EIA's monthly generation data in 1973 [49].

As a matter of fact, there are many advantages in the use of natural gas. Among fossil fuels, it is the most environment-friendly: natural gas combustion generates no sulfurous oxides, no powders and the smallest amount of greenhouse gases (less than oil and even half of coal, given 1 kWh of electricity produced, but obviously more than renewable sources [50,51]). The increase in the use of gas can be positive for the global environment and can be related to the general trend of de-carbonation of the world energy supply.

International gas trade is increasing since natural gas is largely available—as it has recently been demonstrated by the Eni's discovery of one of the most largest natural gas field off Egyptian coast [52]—and currently even at low cost. The possibility to buy LNG via sea is in the long distance competitive towards the traditional pipes transportation, especially for Asian markets (for example Japan); furthermore, it gives the possibility to diversify the suppliers and to reduce the dependence from some specific countries and geopolitical areas.

The main concerns related to the world gas market—as the paper points out—are:

- the changing geopolitical scenario due to the role of some specific countries, such as the increasing internal production of the U.S. due to shale gas exploitation;

- the dependence of Europe on Russian gas (the European Commission published its energy security strategy seeking to ensure the energy stability) and the alternative projects to bring gas from Caspian, East Mediterranean, Middle East as well as LNG from various areas;
- the relations between Russia and China and the new role of Iran in the international scenarios, after the end of sanctions;
- the environmental issues due to unconventional gas extraction.

As a matter of fact, hydraulic fracturing associated with shale gas extraction consumes high quantities of water, may cause underground water contamination, methane fugitive emissions and even earthquakes have been blamed on shale gas extraction activities, as well as gas flaring and gas venting represent a further source of environmental pollution. These aspects still need accurate and thorough studies in order to verify the real impact of the new technologies. The future of gas—the so called "Golden Age", confirmed by the recent WEO 2015 [1], which states that gas is a "valid option" in the global process of de-carbonization of the World energy system—depends on the outcomes of these studies and also on how fast renewable energies technologies will be able to grow in the next decades.

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