

Natural gas: a bridge or a destination for a low carbon economy?

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Received date : 22/05/2025, Accepted date : 28/10/2025, Publication date: 05/12/2025

Abstract :

Natural gas, a clean substitute to oil and coal, has emerged as an energy source leading to the shift towards a low-carbon economy. By employing the descriptive and analytical method, this paper assesses the potential of natural gas in becoming a long-term objective in a sustainable energy future or if it is solely a transitional energy source. Accordingly, the present paper inspects the circumstances wherein natural gas could support long-term carbon reduction objectives. Although natural gas has instant emissions advantages, concerns arise with regard to its ecological footprint and compatibility with deep decarbonization pathways. Finally, the paper concludes with an evaluation of economic factors and policy implications that will determine if natural gas can evolve beyond a transitional fuel and assumes a foundational role in a low-carbon economy.

Keywords: natural gas, low carbon economy, energy transition

Jel Classification Codes: Q01, Q42

Introduction:

The present energy crisis is characterized by the aggravating consequences of climate change, a growth in global energy demand, and the depletion of oil reserves. Oil and other fossil fuels are finite resources. The upcoming decades will witness the peak of oil then the decline of world oil production. Oil prices will increase sharply when conventional oil production begins to decline unless a large quantity of alternative fuels becomes available (Howard Geller, 2002).

Geopolitical tensions have accelerated fossil fuels depletion, specifically oil. For instance, supply chains were disrupted by the Ukrainian conflict, which led to considerable price increases (Qi, 2023; Hertwich, 2023). Simultaneously, energy demand continues to increase because of industrial activities and population growth, further straining the limited resources.

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Additionally, there are economic and environmental risks presented by climate change worldwide. The United Nations in 2016 clarifies that the main source of climate change is energy use, causing around 60% of total global greenhouse gas emissions (Güney, 2019).

In 2017, an energy outlook was published by the International Energy Agency. It accommodated emissions reduction following the Paris Agreement concerning climate change, air quality improvement (solving a problem that caused the millions of premature deaths), and universal access to energy. In this “sustainable development scenario,” which does not necessitate a significant growth in energy-related investment contrasted with the baseline case, it is foreseen that global energy demand will remain on a rise, and the share of the global energy mix related to oil and gas will remain at 50% by 2040, depicting the central facilitator for universal energy access. CO₂ capture, utilization and storage, renewables, energy efficiency, and converting from coal to natural gas are the primary emission-reduction pathways for this energy shift. (Kamel Bennaceur, 2019).

Countries are shifting to low-carbon energy sources, such as renewable energies. Compared with crude oil or coal, natural gas has smaller carbon footprint; thus, it is a transition fuel to lower-carbon energy supplies (Holst, 2022).

It is increasingly pertinent to discuss the role of natural gas as a transition fuel to a low-carbon economy as a global effort to tackle the existing energy crisis. Natural gas is depicted as a "bridge fuel" because it is a transitional energy source that could assist in the change from carbon-intensive fossil fuels (coal and oil) to renewable energy. This characterization arises from the fact that natural gas combustion produces significantly lower quantities of CO₂ relative to coal, making it an appealing alternative to the short-term mitigation of greenhouse gas emissions (Shearer et al., 2014; X. Zhang et al., 2014). However, the implications of this shift are complex and multifaceted, bringing critical questions concerning the sustainability of depending on natural gas as a long-term solution. This is what we will try to analyse in this paper.

1. Natural Gas Potential Worldwide:

In Fredonia, United States (1821), inhabitants discovered gas bubbles in a creek floating to the surface, which prompted William Hart to dig and create the first natural gas well in North America earning him the title America's father of natural gas. A former railroad conductor in 1859 by the name Colonel Edwin Drake, (whose “Colonel” title is of an unknown origin yet impressive to the townspeople), dug the first well. He found crude oil and natural gas at 69 feet below the surface of the Earth. In contrast, recent natural gas discoveries occurred after searching for crude oil. However, gas was frequently an incidental finding because, as any gas containing in the reservoirs were tapped during the drilling operation, drillers were compelled to cease the drilling process by which gas is allowed to vent freely into the air. Following the 1970s oil shortages, natural gas was recognized as a necessary source of energy around world (Speight, 2019).

Compared to oil reserves, natural gas reserves are abundant and more widespread. By the end of 2000, the transition countries of the former Soviet Union had somewhat more proven gas reserves than Middle Eastern countries.

Additionally, over the past 25 years², proven natural gas reserves worldwide doubled owing to the increasing enhanced exploration and production techniques, discovery of new gas fields, and attraction towards natural gas (Howard Geller, 2002).

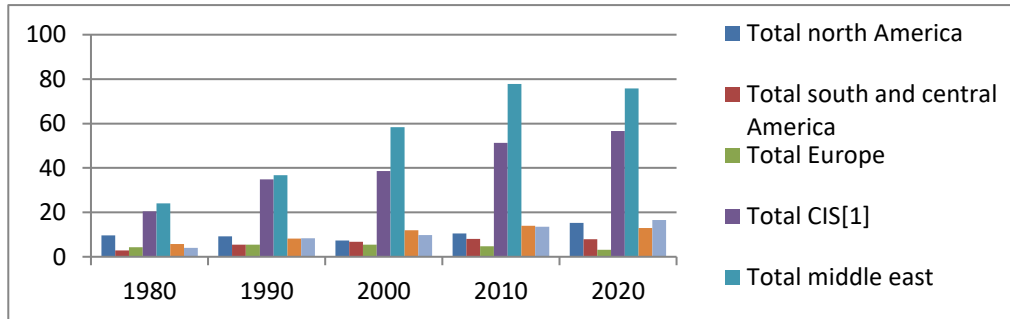
Despite a strong variation from year to year, since 1980 almost every year more natural gas reserves have been discovered than are consumed, so that despite the very strong growth in consumption, reserves are still increasing (Furfari, 2012).

Table 1. Proved Reserves of Natural Gas during (1980-2020)

Natural gas proved reserves (Trillion cubic metres)	1980	1990	2000	2010	2020	Share of total (%)	Ratio R/P
Total North America	9.6	9.2	7.3	10.5	15.2	8.1	13.7
Total South and Central America	2.8	5.5	6.8	8.1	7.9	4.2	51.7
Total Europe	4.3	5.5	5.4	4.7	3.2	1.7	14.5
Total CIS ³	20.5	34.9	38.6	51.3	56.6	30.1	70.5
Total Middle East	24.0	36.8	58.3	77.8	75.8	40.3	110.4
Total Africa	5.7	8.2	11.9	14.0	12.9	6.9	55.7
Total Asia Pacific	4.0	8.3	9.8	13.5	16.6	8.8	25.4
Total world	70.9	108.4	138.0	179.9	188.1	100	48.8

Source: (Energy Institute, 2024)

Fig 1. Proved reserves of natural gas during the period (1980-2020)



Source: Excel outputs based on the previous table

The statistics in the table reveal a persistent growth in global natural gas reserves between 1980 and 2020, as a result of recent discoveries of this resource. The Middle East and the CIS have the largest reserves globally, accounting for 40.3% and 30.1% of total global reserves in 2020.

2. The Contribution of Natural Gas in the Energy Mix:

Natural gas serves as a fundamental energy source because of its economic, environmental, and technical benefits and its convenience as a fuel with a high calorific content. Therefore, its production and consumption have advanced quickly since the start of the twenty-first century (Rahmane & Khouni, 2017).

² Almost from 1980.

³ The Commonwealth of Independent States

The reserves-to-production ratio (R/P ratio) is a key metric to comprehend the lifespan of an oil or gas reserve. The R/P ratio, expressed in years, provides the duration taken to generate the commercially extractible gas volumes or reserves prior to reaching the end of their economic life (The Commonwealth, 2023).

Table 1 illustrates that the natural gas reserve is sufficient for 49 years based on the 2020 statistics in case there are no new discoveries.

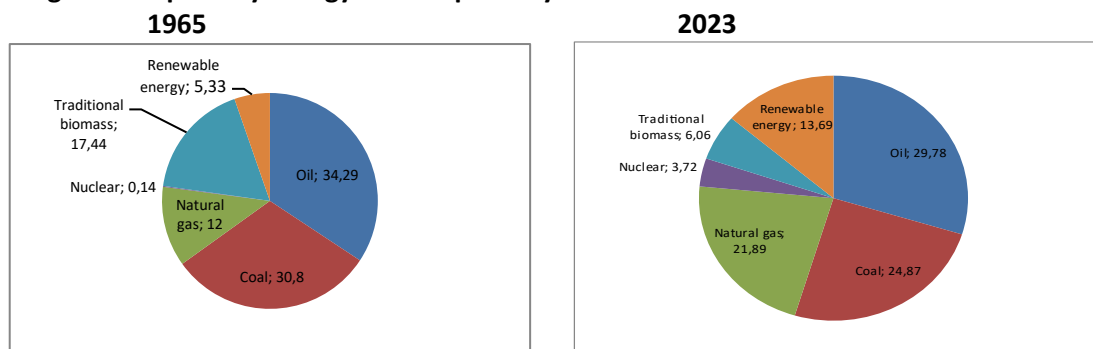
Global primary energy consumption has developed consistently, except for three periods marked by global recession episodes: 2020 (-4.3%), 2009 (-1.5%), and 1980-1982 (-0.6% annual average). These episodes were activated because of an oil production fall after the deepest economic recession in around a century caused by the COVID-19 pandemic; the global financial crisis caused by the housing market bubble; and the Iranian Revolution, respectively. In spite of the crisis episodes from 1965 to 2020, the annual rise of primary energy use was around 2.4%. In contrast, from 2021 to 2023, it totalled 2% because of the geopolitical tension between Russia and Ukraine.

Fossil fuels have been the basis of the global energy mix. From 1965 to 2000, fossil sources were the origin of around 90% of energy consumption whereas it reached around 86% on average from 2001 to 2020. 2020 marked a level of 83% concerning the share of fossil fuels, whereas hydroelectricity and renewable energies were approximately 13%. Among the causes for these 2020 figures are modifications in work practices and the decrease in mobility on a global scale (teleworking) because of COVID-19 (León & Di Scipio-Cimetta, 2022). Likewise, from 2021 to 2023 fossil fuels had 83% on average, whereas new renewable energies and hydroelectricity obtained 13.69%. Natural gas presented 12% from the total energy mix in 1965 and reached 21.9% in 2023 (Energy Institute, 2024; Ritchie et al., 2024).

Recently, according to the 2024 energy institute statistical review, natural gas production rose by 1.9% between 2013 and 2023, whereas oil and coal increased by 0.9% and 0.8%, respectively. Concerning consumption, natural gas consumption increased by 1.7% during the same period while oil and coal grew by the lower rates of 1.1% and 0.2%, respectively (Energy Institute, 2024).

In addition, coal, natural gas, and Oil contributed 27.8%, 20.9%, and 30.9% of the energy mix in 2013, respectively. In 2023, the contribution of coal and oil to the energy mix declined to 24.9% and 29.8% respectively, whereas natural gas rose by 1% during the mentioned period (Ritchie et al., 2024).

Fig 2. Total primary energy consumption by source in 1965 and 2023



Source: Excel outputs based on (Ritchie et al., 2024)

This highlights the significance of natural gas compared to other fossil energy sources, and its pivotal role as a source of energy in the future. This is highlighted through Fig. 2.

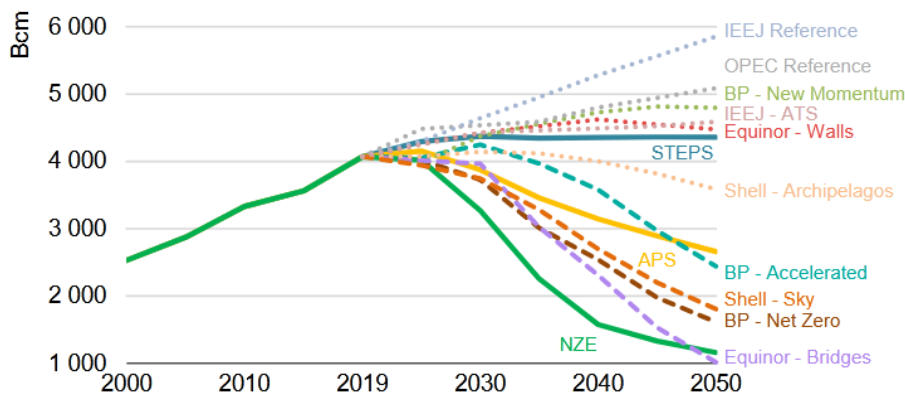
In contrast to other fossil fuels, natural gas consumption is developing globally because of its merits, and it is expected to remain on the rise for decades. It is expected to grow from 20% of global energy supply in 1997 to around 28% by 2050 in the Low Growth, Low Carbon Scenario developed by the International Institute for Applied Systems Analysis (IIASA) and the World Energy Council (WEC).

In the second half of the twenty-first century, the use of natural gas is expected to decrease in absolute and percentage terms in sustainable future scenarios such as the IIASA-WEC Low Growth, Low Carbon Scenario. Biomass, solar energy, and other renewable sources eventually substitute natural gas and other fossil fuels, becoming the primary forms of energy in these scenarios. Therefore, natural gas is perceived as a “bridging fuel” to assist the world in smoothly transitioning to renewable energy sources (Howard Geller, 2002).

A report was published by the IEA in 2021 named ‘Net Zero by 2050: A Roadmap for the Global Energy Sector’. However, much has changed since then despite the short time. Since the Covid-19 pandemic, the global economy has rebounded.

The first global energy crisis has seen world energy prices culminating in various markets, emphasizing energy security concerns. In spite of these unfavourable developments, the pathway detailed in the Net Zero Emissions by 2050 (NZE) Scenario remains narrow but still achievable (IEA, 2022).

Fig 3. The Future of Natural Gas Demand to 2050 Based on Many Scenarios



Source: (IEA, 2023)

Between 2021 and 2030, global natural gas demand, in the Stated Policies Scenario (STEPS), increases yearly at a 0.4% average rate, considerably less than 2010 and 2021 where the growth rate averaged 2.2%. In 2030, demand will reach 4400 bcm and maintain the same level up to 2050. In the Announced Pledges Scenario (APS), global natural gas demand peaks, and by 2030 it is around 10% below the levels of 2021. In 2050, demand becomes 40% under the 2021 levels. As for the Net Zero Emissions by 2050, natural gas demand drops lower and faster than

in the APS and STEPS, falling to 3300 bcm in 2030 and 1200 bcm in 2050 (IEA, 2023).

3. Natural gas as a transition fuel to a low carbon economy:

3.1 Low carbon economy:

Generally, an economy based on sustainable actions is named a low carbon economy (LCE), as it centred on reducing or isolating greenhouse gases (GHG) generated in the production chain, causing less environmental impact (Ambipar Group, 2022).

A decarbonisation process leads to a low carbon economy. It was officially recognized by the UK government in 2003. At first, it described an optimal scenario to reduce national CO₂ emissions to a low level, which continues to be used (Grainger & Smith, 2021).

A low carbon economy or a decarbonized economy is based on low carbon power sources with a minimum of greenhouse gas (GHG) emitted into the air, particularly carbon dioxide. GHG emissions caused by anthropogenic (human) activity represent the primary instigator of observed climate change since the mid-20th century.

Consistent emission of greenhouse gases may generate long-lasting changes globally, heightening the probability of irreversible, pervasive, and severe consequences for ecosystems and people (Popescu, 2022).

A low carbon economy can be reached using switching sustainable energy, a concept defined as a transition to a well-managed high-efficiency energy system to balance social and environmental costs, benefits, and risks, seen as sustainable. The switch can include the change from the utilization of fossil fuels to the exploitation of renewable energy sources in energy generation as well as the evolution from centralized to decentralized energy systems (Mohammad et al., 2021).

3.2 The role of natural gas as a bridge for a low carbon economy:

Presently and henceforward, geopolitical volatility and climate change are driving a new energy transition. Similar to previous transitions, the change is produced by certain events. In this case, taking action on climate change fulfil the goals of the Paris Agreement , which is anticipated to cause renewable energy, contributing a growing share of the global energy mix.

Analysts predict that hydrocarbon demand will peak between 2024 and 2035 and then decline. Demand for renewable energy like hydrogen, solar, and wind will increase over the same period. Gas and oil will not disappear completely, but hydrocarbons will progressively make way for renewables at the centre of the global energy system (KPMG, 2023.).

The scope of natural gas in the diminution of CO₂ emissions is pertinent because natural gas with a lower default carbon content of 15.3 Kg/GJ is cleaner than coking coal (25.8 Kg/GJ), non-coking coal (26.2 Kg/GJ), and crude oil (20 Kg/GJ) (Safari et al., 2019).

Due to possessing approximately half the CO₂ polluting effects vis-a-vis other fossil fuels, natural gas has been regarded as a transition fuel before renewable energy's technological viability can surpass its challenges to generate secure and sustained energy. In this context, a transition fuel means: a substitute low-carbon

fuel (natural gas) for higher content fossil fuels (oil and coal) to decrease CO₂ emissions in the approaching future (Gürsan & de Gooyert, 2021).

In addition, the combustion of natural gas creates fewer pollutants, including particulate matter and sulfur oxides, essential contributors to air quality problems (Toscano et al., 2016). These characteristic positions natural gas as a cleaner option that can efficiently displace harmful energy sources in various sectors, including transportation, electricity generation, and industrial applications (Le et al., 2019).

Furthermore, natural gas flexibility as an energy source strengthens its role in the shift. It can be employed in multiple forms, such as liquefied natural gas (LNG) and compressed natural gas (CNG), making it appropriate for diverse applications ranging from power generation to transportation (F. Zhang et al., 2021). The integration of natural gas into the energy mix can offset the intermittency affiliated with renewable energy sources like solar and wind energies, thereby providing a dependable backup when renewable output is low. This capability is essential for keeping grid stability as the share of renewables increases.

Natural gas has a key role in the short- to mid-term shift toward sustainable energy systems. Natural gas is a necessary transition fuel in the global energy transition, offering a lower-carbon alternative to fossil fuels like oil and coal. It serves as a bridge, facilitating the gradual transition towards renewable energy sources while preserving economic stability and energy security. Keeping natural gas open as an addition to renewable energy provides diversity in technology development and choice as well as innovation scope. A smooth, economically socially, and acceptable transition is crucial to prevent struggle with fossil-dependent countries.

4. The long-term viability of natural gas:

4.1 Challenges of natural gas in the short, medium and long-term:

4.1.1 Challenges of natural gas as a transition fuel:

▪ Methane emissions:

The possibility of natural gas as a transition fuel has controversy. Critics emphasize the environmental impact of methane emissions, which is a powerful greenhouse gas with a larger global warming potential than CO₂ (Alvarez et al., 2012). CH₄ is a more powerful greenhouse gas than CO₂, and it is one of the main contributors to greenhouse warming. The anthropogenic CH₄ emissions are responsible for more than half of the forcing of anthropogenic CO₂ worldwide. However, CH₄ only remains in the atmosphere for a relatively short time before oxidizing to form H₂O and CO₂. CO₂ stays in the air for hundreds or thousands of years (Hausfather, 2015).

The climate advantages of natural gas can be compromised if methane is leaked when extracting, transporting, and storing it (Zimmerle et al., 2015). Studies have revealed that improper management of methane emissions could make the overall greenhouse gas footprint of natural gas comparable to that of coal, which complicates its bridging role to a low-carbon future (Cathles, 2012).

▪ The delay to attain a low carbon economy:

Some researchers were concerned that the use of natural gas as a transition fuel might delay the attainment of a zero- or negative-carbon future. They contended that a renewable energy system for a zero-carbon future relies on the duration of the

transitional phase of natural gas. A more feasible option is leapfrogging to a renewable energy future using more innovation rather than employing natural gas as a transitional fuel. A sizable investment is imperative to build the infrastructure necessary in transporting natural gas. This investment can be implemented to other sustainable energy-related inventions if it is proven to be a short- to medium-term solution (Safari et al., 2019).

- **Natural gas crowd-out effect:**

The crowd-out effect is a noteworthy outcome of natural gas. Crowd-out occurs when investments are drawn from an emerging technology (renewables) by a bridging technology (natural gas). Because of the accompanying reinforcement of the fossil fuel infrastructure, investments in natural gas may prompt contributions in other fossil fuels and decrease investing in renewables by using crowd-out. If it indirectly extends the fossil fuel infrastructure, direct environmental rewards of gas can be nullified. In addition, if gas promotes other fossil fuels rather than substituting them, natural gas's role as a transition fuel can fail to help the debate on natural gas as a transition fuel; thus, we investigate its systemic impact on the transition of energy (Gürsan & de Gooyert, 2021).

4.2.1 Challenges to the Long-Term Viability of Natural Gas:

The long-term viability of natural gas as a principal energy source encounters several economic, environmental, and geopolitical challenges.

- **Economic Challenges:**

Volatility of its prices is a major economic challenge to the long-term viability of natural gas. It is influenced by competition from renewable energy sources, geopolitical tensions, and supply-demand dynamics. Işık indicates that fluctuations in natural gas prices can affect economic growth substantially, specifically in countries like Turkey where natural gas consumption and economic performance are connected (Işık, 2010). Moreover, the rise of renewable energy technologies has started to interfere with traditional energy markets, leading to heightened rivalry that could impair the economic viability of natural gas in the long-term. The demand for natural gas may decline, as renewable energy becomes more cost-effective, raising concerns regarding the long-term profitability of investments in natural gas infrastructure.

- **Environmental Concerns:**

In addition to economic factors, environmental concerns can be problematic to the feasibility of natural gas. Although natural gas is considered a cleaner option to oil and coal, its extraction and consumption contribute to greenhouse gas emissions. Brkić stated that in spite of having less pollution repercussions, natural gas is still a fossil fuel, and depending on it may impede the fight against global warming (Brkić, 2009). Additionally, the possibility of contaminating water and the environmental effects of hydraulic fracturing (fracking) have caused public worries about the sustainability of natural gas extraction methods (Vengosh et al., 2014). Vengosh et al. critically review the risks of unconventional shale gas development, underscoring the risk of water pollution, which could bring about public opposition stricter and rules (Vengosh et al., 2014). These environmental challenges postulate a re-evaluation of natural gas's role in the energy transition because relying on this resource may not suit long-term sustainability goals.

▪ **Geopolitical Factors:**

Geopolitical factors are essential to the future of natural gas. To serve their natural gas needs, many countries heavily rely on imports, exposing them to price volatility and supply disruptions. This reliance on imports can create instabilities, especially during geopolitical tensions, leading to concerns about energy security. As nations contend with these geopolitical realities, the long-term viability of natural gas as a stable energy source may be called into question.

The balance between renewable energy and natural gas will be critical in identifying the future energy landscape through the evolution of the market. Furthermore, shifting to a more globalized natural gas market has a set of challenges. The rising prevalence of short-term and spot trading of liquefied natural gas (LNG) has changed the dynamics of natural gas supply, doubting the value of long-term contracts (Xia et al., 2023). Since countries strive to mitigate reliance on an individual fuel and to vary their energy sources, traditional models of natural gas trade is required to accommodate a more competitive and fluctuating market environment. This adaptation could affect the long-term viability of natural gas, as countries may prioritize investments in renewable energy over traditional fossil fuels.

In summary, the natural gas feasibility in long-term is jeopardized by multiple economic, environmental, and geopolitical challenges. Natural gas as a transitional fuel is scrutinized because nations strive to satisfy their energy needs while addressing climate change.

Geopolitical dependencies, the volatility of natural gas prices, the evolving energy market landscape, and environmental risks of extraction methods altogether contribute to the ambiguity of the future of natural gas. It is essential for policy-makers and industry stakeholders to navigate these complexities to ensure that natural gas can sustainably influence the global energy transition.

4.2 Technological Innovations Enabling a Long-Term Role:

In 2024, the realm of natural gas technology continues to advance, displaying promising innovations that frame the world energy landscape. The ongoing commitment to efficiency and sustainability has sparked developments in natural gas technology, offering innovative opportunities for the future.

4.2.1 **Renewable Natural Gas (RNG):** RNG is a fuel derived from waste streams. Biogas is emitted when organic waste decomposes having 50%–60% methane. This biogas can be refined to expel impurities and intensify heating value. RNG may substitute for fossil natural gas in fuelling stations, storage tanks, and pipelines, or as a drop-in fuel demanding no engine modification to natural gas vehicles. Methane emissions are avoided by generation of RNG, which gives RNG a negative carbon intensity metric (grams CO₂ equivalent per megajoule of energy). RNG pathways that involve wastewater sludge, livestock waste, landfills, and food waste, have lower carbon intensities than fossil fuels. RNG is acquiring support as a sustainable substitute to traditional natural gas (Holst, 2022).

4.2.2 **Carbon Capture, Utilization, and Storage (CCUS):** CCUS involves capturing CO₂ from large point sources such as industrial facilities or a

power generation, which utilize fossil fuels or biomass as fuel. If it is not used on-site, the captured CO₂ is compressed and transported by rail, pipeline, truck, or ship to be employed in a range of applications, or injected into deep geological formations such as saline aquifers or spent oil and gas reservoirs (IEA, n.d.). CCUS technologies integration within natural gas facilities have developed significantly. Further improvements and applications of CCUS in natural gas plants are anticipated, contributing to reduced carbon footprints.

In addition to CCUS and RNG, there are other technologies (True Natural Gas Blog, 2024):

- 4.2.3 **Smart Methane Detection:** Smart sensors and monitoring systems seek to identify and alleviate methane leaks in natural gas pipelines and infrastructure swiftly. These technologies guarantee a proactive approach to decreasing methane emissions, mitigating environmental impact, and reinforcing safety.
- 4.2.4 **Energy Efficiency Solutions:** innovation is driven by the emphasis on enhancing energy efficiency within natural gas technologies. We expect to witness the emergence of smart technologies, heating systems, and appliances that are more efficient and that upgrade energy usage while reducing waste, following sustainability aims.
- 4.2.5 **Hydrogen Blending:** The concept of blending hydrogen with natural gas in pipelines is accelerating. This innovation enables a cleaner burning fuel mixture, downgrading emissions and developing the environmental credentials of natural gas. In 2024, developments in hydrogen blending technology are expected to be explored further, aiming for widespread adoption and adaptability.

Gas technologies are a key factor in supporting a sustainable energy transition. Creating more technologies in this sector is beneficial for human development and the global environment in three ways (International Gas Union, 2020):

- In the near-term, emissions would be reduced instantly after shifting to natural gas from oil or coal products, for both localized air pollutants and GHG emissions. Simultaneously, global access to clean, modern energy can be improved by gas technologies including for the world's poorest.
- In the medium-term, allowing distributed energy systems and raising energy consumption efficiency promotes structural transitions through gas technologies in the way energy is transferred and used. Natural gas can assist renewable power integration and decrease emissions and costs through the progressive advancement and deployment of highly efficient and low-cost innovations.
- Over the longer term, low- and zero-carbon gas technologies –including carbon capture, utilization, and storage (CCUS), hydrogen, and renewable gas– give an efficient and cost-effective pathway to drastically decrease GHG emissions. These technologies are applicable to sectors where emissions are pricy or difficult to moderate using other means. They can also exploit the existing gas infrastructure to mitigate capital investment.

4.3 Policy and regulatory frameworks for sustainable natural gas:

Natural gas sustainability efforts follow a set of pivotal regulatory approaches aiming to decrease emissions and encourage cleaner practices: emission targets, subsidy frameworks, and methane regulation. These policies collaborate to reduce the environmental effect of natural gas production, resulting in a more sustainable energy source.

4.3.1 **Emission targets:** Emission targets are foundational in regulating the sustainability of natural gas. The Global Methane Pledge (GMP), endorsed by 150 countries, seeks to mitigate methane emissions by 30% from 2020 levels in 2030. Canada, the European Union, and United States are creating ambitious objectives for methane reduction, with the EU utilizing methane intensity standards to imports to reduce emissions beyond its borders. There is a clear drive to alleviate emissions by pursuing both imported and domestic energy supplies to meet global sustainability benchmarks (IEA, 2024; IEA, Global Methane Tracker 2023, 2023; European Commission, 2024).

4.3.2 **Subsidy Frameworks and Financial Incentives:** Global attempts to minimize gas flaring in the natural gas sector and methane emissions are backed by regulatory policies and financial incentives. Reducing gas flaring and methane emissions is essential to achieving net-zero targets, particularly because gas and oil production is expected to rise until 2040. technology developments are making smaller projects more applicable, contributing to a 19% drop in global flaring since 2003 despite larger flaring reduction projects having the main focus. Methane mitigation is among the most effective ways to delay global warming. National oil companies, which produce about half of the world's gas and oil, are important to these efforts. At the 28th United Nations Climate Change Conference, or (COP28), over 50 companies, including many national oil companies, resolved to ambitious methane minimization objectives by signing a new decarbonization charter—the first pledge of its kind in this industry (World Bank Group, n.d; Cahill, 2024)

On the other hand, the European Union's strict methane standards for imports encourage global producers to follows EU emissions demands, creating a precedent that other major importers, such as Japan and South Korea, are contemplating through initiatives such as the CLEAN coalition (Cahill, 2024; (Systems Change Lab, n.d)

4.3.3 **Methane Regulation:** Methane, substantially more powerful than CO₂ in the short term, is a central focal point of present policies. The EU and U.S. have initiated strict regulations dictating constant supervision, reporting, and confirmation of methane emissions. For instance, regulations in Europe require methane intensity standards and flaring limitations, affecting both domestic production and imports. These regulative measures also include penalties for "super-emitter" events, which enables responding rapidly to large methane leaks, further decreasing emissions across the supply chain (European Commission, 2024; (US EPA, 2023).

4.4 Shift of natural gas from a bridge fuel to a long-term solution:

Early in the 2010s the natural gas community adopted an “advocacy narrative”: that the carbon reduction benefits of coal to gas switching in power generation (and oil to gas in other sectors), and the advantages of gas in backing up intermittent renewables, would ensure that gas remains not just a transition -but also potentially a destination- fuel for a low carbon economy. This narrative was most prominent in Europe, but also advanced globally, mainly by international (oil and) gas producers and exporters (Stern, 2020).

The change in perspective on natural gas from a temporary bridge fuel to a possible long-term energy solution reveals its vital role in balancing energy security and sustainability within the global energy transition. Traditionally viewed as a cleaner option to coal and oil, natural gas has reduced greenhouse gas (GHG) emissions and stabilized energy supplies when renewable sources are inadequate (Mohammad et al., 2021). Integrating it with renewable energy aids regions that lack developed renewable infrastructure, guaranteeing continuous power availability.

However, the narrative is changing due to geopolitical and environmental concerns. Leaked methane in the process of natural gas extraction and transportation challenges its clean energy status, causing demands for more stringent policies to minimize these emissions (Ogden et al., 2018). Additionally, recent energy emergencies have emphasized weaknesses associated with external natural gas supplies, urging countries to re-examine domestic natural gas investments to upgrade energy independence (Halser & Paraschiv, 2022). Its viability is also affected by economic considerations also, as fluctuations in natural gas expenses, driven by global market dynamics, can reduce its desirability compared to increasingly cost-effective renewables (Güney, 2019). Integrating hydrogen into existing gas infrastructure helps advance toward decarbonization, blending cleaner technology with existing resources. Therefore, while natural gas may be a transitional solution, its future role will depend on addressing environmental, economic, and geopolitical factors amidst the global drive for sustainability.

Conclusion:

In conclusion, natural gas is both necessary and complex to a low-carbon economy. Its ultimate status -as a destination or a bridge- relies on various intertwined factors. Natural gas has displayed significant potential across global energy markets. It makes for a reliable and comparatively cleaner option to more carbon-intensive fossil fuels, especially due to countries attempting to secure energy independence and diversify their energy mixes. As a transition fuel, it is shown to possess significant importance in promoting a gradual transition toward renewables, stabilizing energy systems and simultaneously decreasing greenhouse gas emissions. Nonetheless, multiple challenges must be handled to regard natural gas a viable long-term solution. These challenges include the economic volatility of natural gas markets, environmental concerns, and the geopolitical implications of relying on international gas supplies. Innovations in technology, such as hydrogen blending, carbon capture, utilization, and storage (CCUS), as well as stringent policies and regulations will be essential in minimizing those challenges and strengthening the sustainability profile of natural gas. Ultimately, whether natural gas functions as a permanent component or a stepping-stone of a low-carbon future will rely on the ability of the energy sector align with global sustainability goals.

References:

- Ambipar Group. (2022). *Low carbon economy: what is it? “zero-carbon” or “neutral carbon.”* (n.d.). Retrieved October 23, 2024, from <https://ambipar.com/ie/news/low-carbon-economy-what-is-it/>
- Alvarez, R. A., Pacala, S. W., Winebrake, J. J., Chameides, W. L., & Hamburg, S. P. (2012). Greater focus needed on methane leakage from natural gas infrastructure. *PNAS*, 109(17). <https://doi.org/10.1073/pnas.1202407109/-/DCSupplemental>
- Brkić, Dejan (2009). Are Fossil Fuels The Main Cause of Today's Global Warming? *Facta Universitatis, Series: Linguistics and Literature*. 6 (1). 29-38.
- Cahill, B. (2024). *National Oil Companies and Methane Reductions: How to Meet 2030 Goals*. Retrieved October 26, 2024, from <https://www.csis.org/analysis/national-oil-companies-and-methane-reductions-how-meet-2030-goals>
- Cathles, L. M. (2012). Assessing the greenhouse impact of natural gas. *Geochemistry, Geophysics, Geosystems*, 13(6). <https://doi.org/10.1029/2012GC004032>
- Energy Institute. (2024). *Statistical Review of World Energy*. Retrieved October 23, 2024, from <https://www.energyinst.org/statistical-review>
- European Commission. (2024). *New EU Methane Regulation to reduce harmful emissions from fossil fuels in Europe and abroad*. (n.d.). Retrieved October 26, 2024, from https://energy.ec.europa.eu/news/new-eu-methane-regulation-reduce-harmful-emissions-fossil-fuels-europe-and-abroad-2024-05-27_en
- Furfari, S. (2012). *Energy Politics and Geopolitics*. edition Technip. France. (in French)
- Grainger, A., & Smith, G. (2021). The role of low carbon and high carbon materials in carbon neutrality science and carbon economics. In *Current Opinion in Environmental Sustainability* (Vol. 49, pp. 164–189). Elsevier B.V. <https://doi.org/10.1016/j.cosust.2021.06.006>
- Güney, T. (2019). Renewable energy, non-renewable energy and sustainable development. *International Journal of Sustainable Development and World Ecology*, 26(5), 389–397. <https://doi.org/10.1080/13504509.2019.1595214>
- Gürsan, C., & de Gooyert, V. (2021). The systemic impact of a transition fuel: Does natural gas help or hinder the energy transition? In *Renewable and Sustainable Energy Reviews* (Vol. 138). Elsevier Ltd. <https://doi.org/10.1016/j.rser.2020.110552>
- Halser, C., & Paraschiv, F. (2022). Pathways to Overcoming Natural Gas Dependency on Russia—The German Case. *Energies*, 15(14). <https://doi.org/10.3390/en15144939>
- Hausfather, Z. (2015). Bounding the climate viability of natural gas as a bridge fuel to displace coal. *Energy Policy*, 86, 286–294. <https://doi.org/10.1016/j.enpol.2015.07.012>
- Holst, T. (2022). *Renewable Natural Gas: A Sustainable Approach to the Energy Transition*. Retrieved October 26, 2024, from <https://d36oiwf74r1rap.cloudfront.net/wp-content/uploads/Renewable-Energy-Jan2022.pdf>
- Howard Geller. (2002). *Energy revolution: policies for a sustainable future*. Island press.
- IEA. (n.d.). *Carbon Capture, Utilisation and Storage - Energy System*. Retrieved October 23, 2024, from <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage>
- IEA. (2022). *World Energy Outlook 2022*. Retrieved October 26, 2024, from <https://www.iea.org/reports/world-energy-outlook-2022>
- IEA. (2023). *Global Methane Tracker 2023, The case for methane policy and regulation*. Retrieved October 26, 2024, from <https://www.iea.org/reports/global-methane-tracker-2023/the-case-for-methane-policy-and-regulation>
- IEA. (2023). *Outlooks for gas markets and investment: a report for the G7*. Retrieved October 23, 2024, from <https://iea.blob.core.windows.net/assets/3e076ae9-9055-4af4-bba9-15ddaedcb703/Outlooksforgasmarketsandinvestment.pdf>
- IEA. (2024). *Global Methane Tracker 2024, Tracking pledges, targets and action*. Retrieved October 26, 2024, from <https://www.iea.org/reports/global-methane-tracker-2024/tracking-pledges-targets-and-action>
- International Gas Union. (2020). *Gas Technology and Innovation for a Sustainable Future*. Retrieved October 26, 2024, from <https://www.igu.org/resources/gas-technology-and-innovation-for-a-sustainable-future/>
- Işik, C. (2010). Natural gas consumption and economic growth in Turkey: A bound test approach. *Energy Systems*, 1(4), 441–456. <https://doi.org/10.1007/s12667-010-0018-1>
- Kamel Bennaceur. (2019). How the oil and gas industry is contributing to sustainability. *Journal of Petroleum Technologie*. 71 (03). 38–39. <https://doi.org/10.2118/0319-0038-JPT>
- KPMG. (2023). *The geopolitics of oil and gas*.
- Le, M. T., Nguyen, T. T., Tran, V. H., Nguyen, T. K. N., & Do, H. T. (2019). Can natural gas play an important role in the energy transition in Asia in the future? *Eurasian journal of business and management*, 7(4), 28–36. <https://doi.org/10.15604/ejbm.2019.07.04.004>
- León, M. G. De, & Di Scipio-Cimetta, S. (2022). The role of natural gas in today's energy transition. *DYNA (Colombia)*, 89(221), 92–100. <https://doi.org/10.15446/DYNA.V89N221.99347>
- Mohammad, N., Mohamad Ishak, W. W., Mustapa, S. I., & Ayodele, B. V. (2021). Natural Gas as a Key Alternative Energy Source in Sustainable Renewable Energy Transition: A Mini Review. In *Frontiers in Energy Research* (Vol. 9). Frontiers Media S.A. <https://doi.org/10.3389/fenrg.2021.625023>
- Ogden, J., Jaffe, A. M., Scheitrum, D., McDonald, Z., & Miller, M. (2018). Natural gas as a bridge to hydrogen transportation fuel: Insights from the literature. *Energy Policy*, 115, 317–329. <https://doi.org/10.1016/j.enpol.2017.12.049>
- Popescu, C. (Ed.). (2022). *Handbook of Research on Building Inclusive Global Knowledge Societies for Sustainable Development*. IGI Global. <https://doi.org/10.4018/978-1-6684-5109-0>

- Rahmane, A., & Khouni, R. Natural gas: a transitional energy towards a sustainable energy transition in Algeria. *Roa Iktissadia Review*, 7(2), 41-55. <https://www.asjp.cerist.dz/en/downArticle/126/7/2/46838>
- Ritchie, H., Rosado, P., & Roser, M. (2024). Energy Mix. *Our World in Data*. <https://ourworldindata.org/energy-mix>
- Safari, A., Das, N., Langhelle, O., Roy, J., & Assadi, M. (2019). Natural gas: A transition fuel for sustainable energy system transformation? *Energy Science and Engineering*, 7(4), 1075–1094. <https://doi.org/10.1002/ese3.380>
- Shearer, C., Bistline, J., Inman, M., & Davis, S. J. (2014). The effect of natural gas supply on US renewable energy and CO₂ emissions. *Environmental Research Letters*, 9(9). <https://doi.org/10.1088/1748-9326/9/9/094008>
- Speight, J. G. (2019). *Natural Gas: A Basic Handbook*. Elsevier. UK.
- Stern, J. (2020). The role of gases in the European energy transition. *Russian Journal of Economics*, 6(4), 390–405. <https://doi.org/10.32609/J.RUJE.6.55105>
- Systems Change Lab. (n.d.). *Eliminating Harmful Subsidies & Financing* | Retrieved October 26, 2024, from <https://systemschangelab.org/finance/eliminate-harmful-subsidies-and-investments>
- The Commonwealth. (2023). *Natural Gas Development in Low-Carbon Energy Transition*. Retrieved October 26, 2024, from <https://thecommonwealth.org/publications/natural-gas-development-low-carbon-energy-transition>
- Toscano, A., Bilotti, F., Asdrubali, F., Guattari, C., Evangelisti, L., & Basilicata, C. (2016). Recent trends in the world gas market: Economical, geopolitical and environmental aspects. *Sustainability (Switzerland)*, 8(2). <https://doi.org/10.3390/su8020154>
- True Natural Gas Blog. (2024). *Innovations in Natural Gas Technology: What to Expect in 2024*. Retrieved October 23, 2024, from <https://www.truenaturalgas.com/blog/post/innovations-in-natural-gas-technology-what-to-expect-in-20242>
- US EPA. (2023). *Biden-Harris Administration Finalizes Standards to Slash Methane Pollution, Combat Climate Change, Protect Health, and Bolster American Innovation*. Retrieved October 26, 2024, from <https://www.epa.gov/newsreleases/biden-harris-administration-finalizes-standards-slash-methane-pollution-combat-climate>
- Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. In *Environmental Science and Technology* (Vol. 48, Issue 15, pp. 8334–8348). American Chemical Society. <https://doi.org/10.1021/es405118y>
- World Bank Group. (n.d.). *Financing Solutions to Reduce Natural Gas Flaring and Methane Emissions*. Retrieved October 26, 2024, from <https://www.worldbank.org/en/programs/gasflaringreduction/publication/financing-solutions-to-reduce-natural-gas-flaring-and-methane-emissions>
- Xia, X., Wu, R., Liu, Y., Wu, J., & Lu, T. (2023). Value of long-term LNG contracts: A theoretical and empirical study. *Frontiers in Earth Science*, 10. <https://doi.org/10.3389/feart.2022.1058592>
- Zhang, F., Obeid, E., Bou Nader, W., Assaad, Z., Luo, X., & Zoughaib, A. (2021). *Well-to-Wheel analysis of natural gas fuel for hybrid truck applications* *Well-to-Wheel Analysis of Natural Gas Fuel for Hybrid Truck Applications Xiaobing Luo 5 (Corresponding Author)*. <https://doi.org/10.1016/j.enconman.2021.114271>
- Zhang, X., Myhrvold, N. P., & Caldeira, K. (2014). Key factors for assessing climate benefits of natural gas versus coal electricity generation. *Environmental Research Letters*, 9(11). <https://doi.org/10.1088/1748-9326/9/11/114022>
- Zimmerle, D. J., Williams, L. L., Vaughn, T. L., Quinn, C., Subramanian, R., Duggan, G. P., Willson, B., Opsomer, J. D., Marchese, A. J., Martinez, D. M., & Robinson, A. L. (2015). Methane Emissions from the Natural Gas Transmission and Storage System in the United States. *Environmental Science and Technology*, 49(15), 9374–9383. <https://doi.org/10.1021/acs.est.5b01669>