Reinventing the wheel?

Managing hydrogen import dependencies based on lessons from natural gas trade

(work in progress)

Abstract

Hydrogen is widely expected to become a globally traded commodity, and several countries are preparing to become importers or exporters. Considering similarities between natural gas and hydrogen in terms of transport and storage, a global hydrogen market is often expected to develop similar to the global natural gas market. However, little attention has been paid to what exactly these similarities are and what they can teach us about timing, sequence, and consequences of creating an international hydrogen market. To shed light on these questions, this paper examines the evolution of natural gas import dependencies in Belgium, drawing on a historical institutionalist-based framework. Similar to piped natural gas and LNG, Belgium needs to import a substantial part of its hydrogen demand. We review how the Belgian natural gas market evolved from the time the first natural gas molecules crossed the Dutch-Belgian border in 1966 until today, where Belgium like other European states is hit by a natural gas crisis. By mapping this evolution, we seek to identify tipping points, opportunities, and pitfalls that may be relevant for the development of a hydrogen market in Europe as a whole, and Belgium in particular. The paper attempts to provide insights into what to expect from the development of a regional or global hydrogen market in terms of timing, obstacles, vulnerabilities, etc., and may prevent to make the same or similar mistakes.

Keywords: hydrogen; hydrogen trade; natural gas trade; hydrogen value chains; natural gas value chains; import dependencies

Authors: Marie Dejonghe (marie.dejonghe@ugent.be), Thijs Van de Graaf (thijs.vandegraaf@ugent.be), Ronnie Belmans (ronnie.belmans@kuleuven.be)

Table of Contents

Abstract 0
1. Introduction 2
2. Similarities and differences between hydrogen and natural gas value chains 3
3. Analytical framework 4
4. The ancestor of natural gas in Belgium: town gas (1813-1965) 5
5. The development of the natural gas market in Belgium 6
5.1. Regional: Dutch gas (1965-1973) 6
5.2. International: Connecting gas-poor Europe with its gas-rich periphery (1973-1998) 8
5.3. Global: A liberalized European gas market connecting with the world (1998-2022) 11
5.4. Import dependencies: origins and consequences 13
5.4.1. Regional trade 13
5.4.2. International trade 14
5.4.3. Global trade 15
6. What to expect for hydrogen trade? 18
6.1. Drivers fueling the development of a hydrogen economy 18
6.2. Reinventing the wheel? 19
7. Conclusions 20
8. References 22

1. Introduction

Clean hydrogen[1] is expected to play a vital role in reaching the European climate goals, laid out in the European Green Deal announced in 2020. The European Commission's hydrogen strategy (European Commission, 2020) expects cross-border trade of these molecules to develop over the next few years and decades. Individual European member states like Belgium, the Netherlands, and Germany have drafted a national hydrogen strategy focusing on imports and international trade, while other EU member states like Portugal and Spain see opportunities to establish themselves as clean hydrogen exporters. Moreover, sourcing clean hydrogen or derivatives from outside of the EU has taken on additional urgency in the wake of Russia's invasion of Ukraine. Currently, the EU aims for 10 million tons of renewable hydrogen[2] imports by 2030 (European Commission, 2022)

There is still a lot of uncertainty regarding how quickly clean hydrogen value chains can scale up, the extent to which they could become an internationally traded commodity, and the broader energy security challenges that such trade would entail. These questions have predominantly been addressed by developing scenarios on the future of clean hydrogen demand, supply, and trade routes (e.g BNEF, 2020; Hydrogen Council, 2021; IEA, 2019, 2021; IRENA, 2022b). Often these scenarios are normative, in the sense that they start from the Paris climate goal of 1.5°C and then lay out hydrogen pathways to achieve that goal. In recent years, several studies have begun to analyze the broader (geo)political ramifications of hydrogen trade (Hausemann et al., 2021; IRENA, 2022a; Lebrouhi et al., 2022; Van de Graaf et al., 2020). However, these studies are often explorative, taking the form of thought exercises or horizon scans. Some have relied on various indices to try and position countries in the future landscape of hydrogen geopolitics (Pflugmann & Blasio, 2020), while others are based on expert surveys (IRENA, 2022a).

In this paper, we take a different approach to try and sketch a possible pathway for the development of international hydrogen markets and trade, and to examine the potential geopolitical consequences. Rather than developing scenarios or drawing inferences from various indices or expert opinions, we draw lessons for the future of hydrogen trade and geopolitics by looking at the historical evolution of international natural gas trade and related import dependencies. We consider natural gas a good point of reference because there are important similarities with hydrogen. Both are gasses, which can be used as feedstock and/or energy carriers. Long-distance transport calls for pipelines or ships, but that requires liquefication (LNG in the case of natural gas; ammonia, methanol, or other liquid hydrogen carriers in the case of hydrogen).

The central question of this paper is: which lessons can we draw from the historical development of the natural gas trade for the future of hydrogen trade? More specifically, we look at two broad aspects. First, we examine the timing, sequence, and geography of scaling up international gas trade and the underlying drivers. Second, we discuss the geopolitical ramifications (vulnerabilities or strengths) resulting from

[1] In this paper we use the technology neutral term "clean" hydrogen for hydrogen produced through electrolysis of water powered by renewable electricity and hydrogen produced through steam methane reforming with very high CO_2 caption rates and low methane emissions.

[2] The European Commission refers to renewable hydrogen as hydrogen produced trough electrolysis of water powered by renewable electricity. In its strategy the European commission considers only renewable hydrogen or hydrogen produced through biogas reforming as "clean" hydrogen.

growing natural gas import dependencies throughout different historical phases. Our analysis is based on a case study of Belgium, a large natural gas importer (both piped gas and LNG) located in Northwestern Europe that is actively exploring future hydrogen imports (Hydrogen Import Coalition, 2020; Ministerie van Energie België, 2021).

The remainder of the paper will continue as follows: first, we distinguish the differences or similarities between the natural gas and hydrogen value chain. Then we discuss the historical evolution of the natural gas market based on a historical institutionalist approach. The paper ends with an overview of what to expect for the hydrogen trade based on the natural gas trade. Our analysis is based on industrial data, document analysis, and four semi-structured interviews conducted with relevant stakeholders between March and May 2022. Given that the interviewees were ensured anonymity, they will only be discussed in a non-referable way.

2. Similarities and differences between hydrogen and natural gas value chains

Before discussing the development of natural gas import dependencies in Belgium, we identify the basic similarities and differences between natural gas and hydrogen value chains, on the production, transport, and consumption side. First, the supply side of the hydrogen value chain differs from natural gas. Hydrogen is not an extractive industry, but a conversion business. Technically, all countries are capable of producing electrolytic hydrogen. This stands in contrast to natural gas where in 2021, half of the natural gas reserves were concentrated in three countries (Russia, Iran, and Qatar) (BP, 2021). This has implications for energy dependencies. For example, by 2030 the European Commission foresees importing around half of its hydrogen demand (European Commission, 2022), while it was importing more than 80% of its natural gas demand in 2021 (Eurostat, 2022). In general, the future clean hydrogen market is therefore likely to be more decentralized than the current natural gas market.

Second, natural gas and hydrogen have similar transport methods: pipelines or shipping. According to IRENA (2022a), hydrogen can be transported by new pipelines in the gaseous form up to 4000 km to be cost-effective. When repurposed pipelines are used, the range increases up to 8000 km (IRENA, 2022a). For longer distances, hydrogen can be transported in liquid form or through hydrogen carriers like ammonia or methanol, where ammonia is the most cost-competitive carrier to transport hydrogen overseas (IRENA, 2022c). This distinction between gaseous and liquid hydrogen is similar to the division between natural gas and LNG.

Third, in terms of consumption, natural gas and hydrogen can be used as both energy carriers and feedstock. However, the demand pattern is expected to be slightly different: one-third of global natural gas final consumption is destined for the residential sector, leading to fluctuations in demand due to weather and seasonal conditions (IEA, 2020). Hydrogen is expected to be mostly consumed by the industrial and chemical sectors (Fils & Deutsch, 2021), sectors that have no seasonal fluctuations in their demand. There are possibilities for deploying clean hydrogen in the transport and power sectors as well, yet there is less agreement among different studies on how this would be translated in terms of volumes (Fils & Deutsch, 2021; IRENA, 2022b, 2022a).

Table 1: Differences between the natural gas and hydrogen value chain

	Natural gas	Hydrogen
UPSTREAM	Centralized suppliers: 50% of the reserves in 3 countries	Decentralized suppliers
MIDSTREAM	Transport by pipelines (gas) / shipping (liquid)	Transport by pipelines (gas) / shipping (liquid)
DOWNSTREAM	Natural gas as feedstock and energy carrier (1/3 for the residential sector)	Hydrogen as feedstock (oil refinery, ammonia, or steel production) Hydrogen as an energy carrier (fuel, energy storage)

3. Analytical framework

There is a long-standing tradition within International Relations (IR) to study political outcomes and change by placing them in their historical context (O. Fioretos, 2011; Hall & Taylor, 1996; Steinmo et al., 1992; Steinmo, 2008, 2015). Political events do not only happen in a historical context, they are also the result of historical processes. The value of a historical lens and the emphasis on timing and sequence and their interrelatedness with current political events are the focal points of historical institutionalism (HI). HI focuses on how institutions shape political behavior and how to understand institutional change (O. Fioretos, 2011; Steinmo et al., 1992; Steinmo, 2008). In this paper, we employ an HI approach to understand the development of the natural gas market. Institutions are broadly defined as "*formal or informal procedures, routines, norms and conventions embedded in the organizational structure of polity or political economy* (Hall & Taylor, 1996)". This broad definition allows to consider the natural gas trade as an "institution" and the evolution of trade patterns as a form of institutional change.

Table 2: Analytical framework

ANALYTICAL FRAMEWORK		
Drivers →	**Natural gas trade patterns** →	**Vulnerabilities**
- Path dependencies - Interests - Ideas - Exogenous shocks	- Regional - International - Global	- Herfindahl-Hirschman index - % of natural gas in the energy mix - Governance - Infrastructure

We identify four categories of drivers that fuel and influence the (institutional) changes in Belgium's natural gas import dependencies (see table 2). The first driver is *path dependency*. Once created, institutions are often difficult to change because of path dependency (O. Fioretos, 2011; Sorensen, 2015) whether it is due to lock-in effects, increasing returns, or positive feedback (Pierson 1997). If and how there is institutional change, is therefore highly influenced by the institutional path that already lies behind it. Next to path dependencies, public or private *interests* function as additional explanations for change. Interests are understood as the "*material interests of the principal actor*" (Hall, 1997). Policies or regulations can be based on the public interests of individuals or groups. However, regulation can also become the result of electoral interests (Hall, 1997), or industrial interests that employ state regulation to served their interests and result in 'regulatory capture' (Dal Bo, 2006; Stigler, 1971). Next to interests, there has been growing attention in the HI literature towards the explanatory value of *ideas* in understanding change (Finnemore & Farrell, 2017). Ideas play, once embedded, another important role in understanding how institutional change is possible (Lieberman, 2002; Steinmo, 2008, 2015). Finally, institutional change (or continuity) is not only the result of incremental processes. There are also external forces that have an impact on institutional changes. HI scholars define *exogenous shocks* as external critical moments or triggering points that had an impact on society as a whole. Those critical moments can be economic crises, political tensions, or conflicts.

These four categories of drivers have steered the development of the Belgian natural gas market towards four distinct periods determined by its geographic trade pattern. Each period entails import dependencies and therefore vulnerabilities in terms of security of supply or geopolitical ramifications. We measure the vulnerabilities coming from import dependencies with both qualitative and quantitative parameters. First, the *Herfindahl-Hirschman Index* (HHI) measures the size and concentration of suppliers within a market, in this case, the natural gas market. When there is only one supplier, the HHI is 1. The index decreases according to new suppliers that enter the market and takes on a value between 0 and 1. A second quantitative parameter is the *share of natural gas consumption in the total energy mix*. A lower share of natural gas in the energy mix may result in more resilience when supply disruptions occur compared to when there is a high share of natural gas in the energy mix. These quantitative parameters only partly explain how vulnerable the natural gas market is to disruptions. To mitigate vulnerabilities, *governance* plays a crucial role. Governance is defined as "*the government's ability to make and enforce rules, and to deliver services (…)"* (Fukuyama, 2013). This includes concluding contracts and introducing policy measures to mitigate geopolitical risk and prevent supply disruptions. Lastly, extensive *infrastructure* networks play important role in how to cope with supply disruptions or conflicts.

4. The ancestor of natural gas in Belgium: town gas (1813-1965)

Belgium has no indigenous natural gas reserves, but it has been a major coal producer. Before natural gas molecules were imported into Belgium, the gas consumption in Belgium was mostly coal gas, a byproduct of the heating of coal. This coal gas was a mixture of methane, hydrogen, nitrogen, carbon dioxide, and carbon monoxide and was already part of the Belgian energy mix since the 19^{th} century. The distribution and exploitation of coal gas fell under the responsibility of the British Imperial Continental Gas Association (ICGA). The distribution of coal gas was centered around large Belgian cities like Antwerp, Ghent, and Brussels, which led to a gradual change of name from coal gas to 'town gas' (Eandis, 2013). In 1929, the ICGA created the company Distrigas to connect its different gas distribution networks by one pipeline between Antwerp and the Borinage (a major coal-mining region). Distrigas had the responsibility to conclude contracts, supply the gas to the network, and distribute the town gas to its off-takers in industry and distribution companies (Brion et al., 1995; Distrigas, 2007).

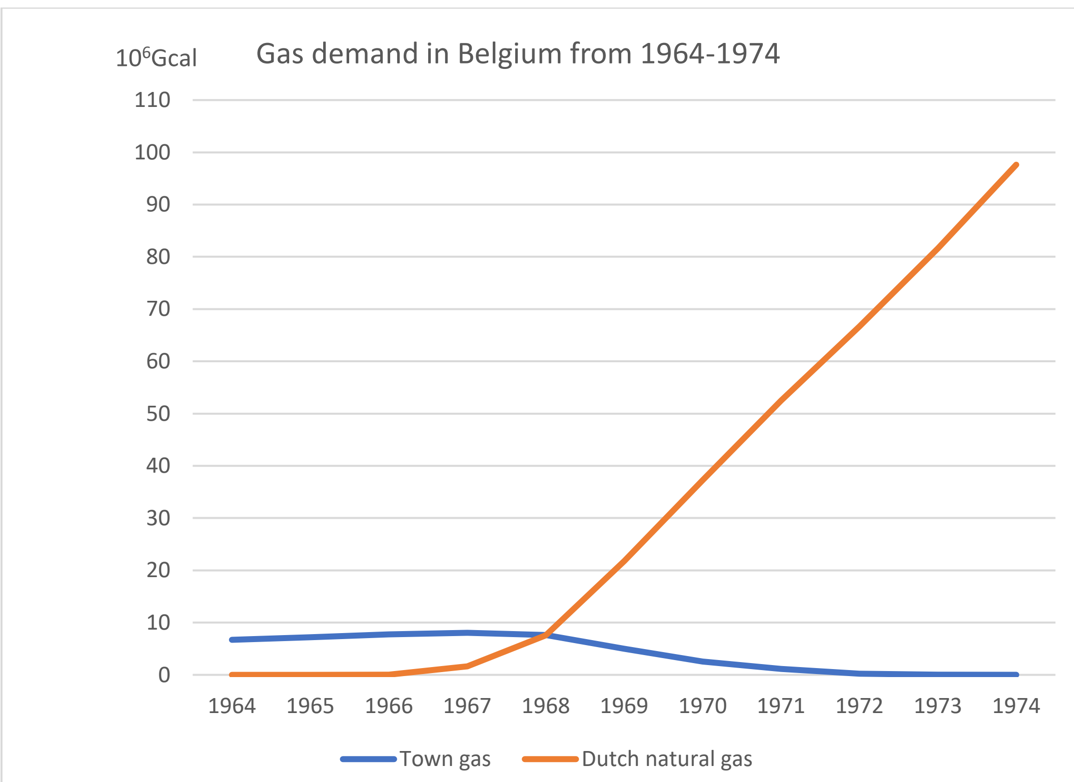
The consumption of town gas was limited and almost exclusively used for residential cooking purposes and installed in bourgeoisie families or hospitals (Eandis, 2013). The town gas industry was small because of the economic regression during the 1930s and was not expected to be able to compete with the electricity or coal industry. It was only with the discovery of large natural gas fields in Europe, that the industry saw extensive growth and that town gas was rapidly replaced by natural gas (Brion et al., 1995).

5. The development of the natural gas market in Belgium

5.1. Regional: Dutch gas (1965-1973)

Soon after the 1959 discovery of large natural gas fields in Groningen, the Netherlands began exploring the possibility of exports to neighboring countries (Nies, 2011). In 1965, the first natural gas contract was concluded between Distrigas and the Nederlandse Aardolie Maatschappij (NAM) (De Clercq, 1975; Nationale Bank van België, 1967). The initial contract was concluded for 20 years with 5 bcm of natural gas exported to Belgium each year, 2 bcm reserved for industry, and 3 bcm for household consumption (Nationale Bank van België, 1967). On the 10th of October 1966, the first molecules crossed the Dutch-Belgian border (De Clercq, 1975). The contract signed by Distrigas and NAM was a long-term contract with take-or-pay and destination clauses. The price of natural gas was based on the *replacement value price* of other competing fuels in the market, mostly crude oil or other petroleum products (Melling, 2010). Gas-to-gas competition was completely excluded (Correlje et al., 2003; Dickel et al., 2007; Gustafson, 2020). In the first ten months of 1967, 0.247 bcm of natural gas were imported into Belgium. This represented 15% of the annual gas consumption in Belgium at that time (Nationale Bank van België, 1968). In 1971 - after only 5 years- almost all the town gas consumption in Belgium was replaced by Dutch natural gas (see graph 1) (De Clercq, 1975; Eandis, 2013).

Graph 1: Gas demand in Belgium (1964-1974)

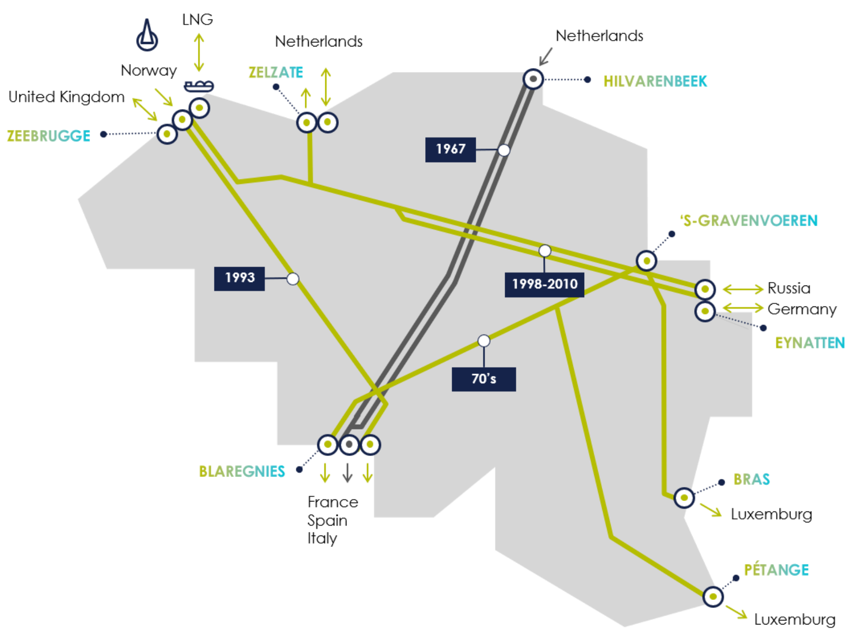


Source: Synergrid (no date available)

To limit investment risks and uncertainties about natural gas volumes and revenues, agreements on construction of pipelines were linked to natural gas supply contracts (*Interview #1*, personal communication, March 30, 2022). The link of natural gas deals with large infrastructure projects was common all over Europe and was called: 'gas for pipes' deals (Dickel et al., 2007; Högselius et al., 2013). The Dutch contracts of the 1960s became a model for other contracts that were negotiated at that time and are up until today a model for contracts between gas suppliers and their clients (Gustafson, 2020).

Dutch natural gas has a low-calorific value due to its high nitrogen and hydrogen concentration (Correlje et al., 2003). Since the Netherlands was the first and only supplier of natural gas in Belgium during the 1960s and 1970s, the appliances of town gas were adapted to the low-calorific Dutch gas and the first transmission pipeline was constructed in 1967 to specifically transport low-calorific gas from the northern to the southern part of Belgium. The households connected to this network consumed low-calorific gas while other pipelines and distribution networks were constructed later to transport high-calorific gas from other natural gas producers (Norway and Algeria). Because of this, Belgium has at present two separate transmission networks depending on the calorific value of the gas (see Figure 1) (*Interview #1*, personal communication, March 30, 2022).

Figure 1: Transmission network in Belgium (green is high calorific gas, grey is low calorific gas)

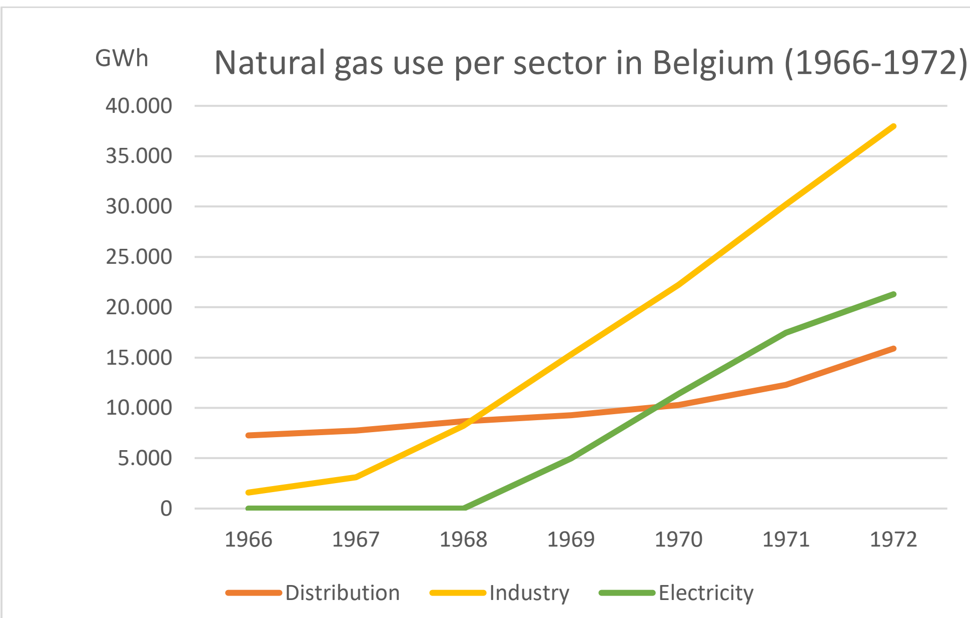


Source: Fluxys (2022)

The construction of transmission pipelines led to transit opportunities for Belgium. The pipeline from Hilvarenbeek (on the Dutch border) to Blaregnies (on the French border) was one of the first pipelines to transport Dutch natural gas through Belgium to France. Later in the 1970s, an extra transmission pipeline was constructed to transport natural gas from 's-Gravensvoeren (NL) to Blaregnies (FR), this time high-calorific gas from Norway. Today, the pipeline from 's-Gravensvoeren to Blaregnies, called the SEGEO pipeline, is used almost exclusively to transit natural gas to France or Luxembourg (FPS Economy, 2021).

The newly introduced Dutch natural gas had versatile applications: it could be used for industry (energy and non-energy use), residential heating and cooking, and power generation. In the early years, the Dutch gas was mainly consumed by households since they consumed town gas before and their appliances and the distribution network could be easily retrofitted to suite natural gas. Many households replaced coal with natural gas to fulfill their heating demands, which resulted in the introduction of central heating in many families (Eandis, 2013; Gustafson, 2020). Later, new distribution networks were constructed as well. Initially, natural gas demand increased only gradually, while the off-take of Dutch gas was fixed. Therefore, natural gas supplies exceeded demand. To compensate for the surpluses, Distrigas encouraged the industry to switch from oil or town gas to natural gas (see graph 2) (De Clercq, 1975). However, two-thirds of the natural gas consumption remained from households and was therefore variable due to seasonal fluctuations and peak hours. The regular offtake of Dutch gas and the lack of gas storage at that time made it difficult to take the volumes and use the gas consistently. Therefore, Distrigas concluded interruptible back-to-back contracts with the power generation sector to balance the irregular demand and the regular supply (De Clercq, 1975). Later, the contracts concluded with the Netherlands became more flexible and made it possible to adjust the imported volumes to the demand.

Graph 2: Natural gas consumption in Belgium (1966-1972)



Source: Synergrid (2022) (comment: from 1966-1973 there is also town gas included in these numbers)

5.2. International: Connecting gas-poor Europe with its gas-rich periphery (1973-1998)

In the late 1960s, more natural gas fields were discovered on and around the European continent. In the North Sea, the Norwegian Ekofisk field was discovered in 1969. Simultaneously, natural gas exports from the Soviet Union to Western Europe started in 1968, and infrastructure for LNG exports from Algeria was constructed after the discovery of the enormous Hassi R'Mel gas fields in 1956 (Gustafson, 2020). In 1973, a consortium of European companies[3] including Distrigas concluded a contract with the Phillips Group, an American petroleum company that had a concession for drilling the Ekofisk field in the North Sea (Conoco Phillips, 2017; Gustafson, 2020; Matlary, 1985). Norwegian gas arrived in Belgium in 1977 via a pipeline from Emden, Germany (Matlary, 1985).

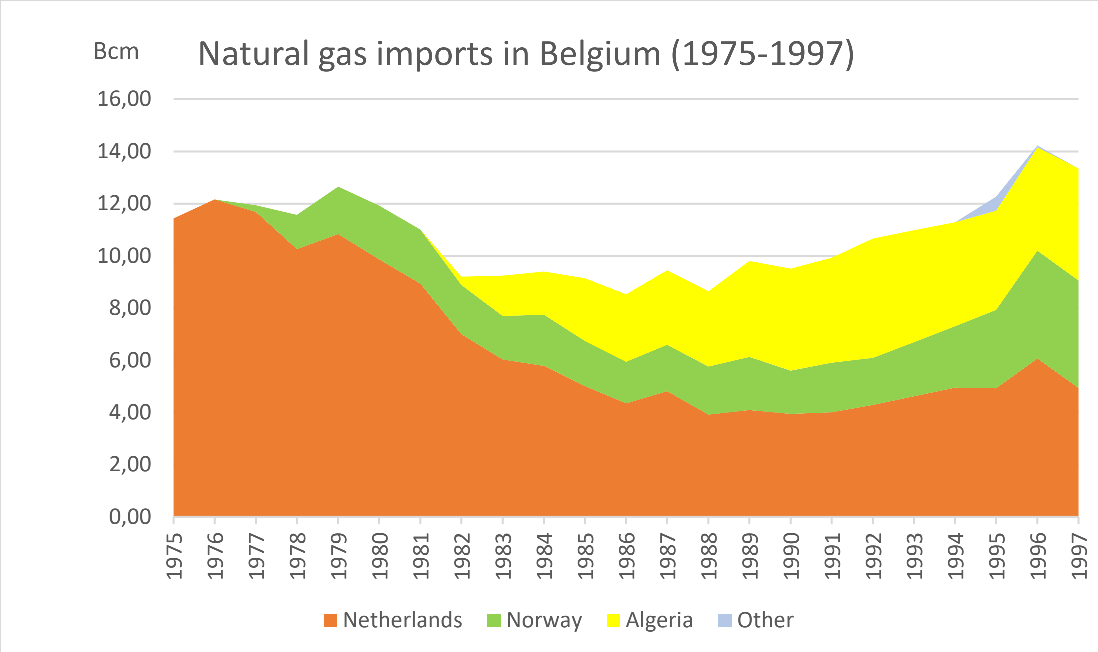
In 1972, another European consortium with seven partners (including Distrigas and Gas de France), called SAGAPE (Société d'Achat de Gaz Algérien Pour L'Europe), started negotiations to bring Algerian gas to the European continent but these negotiations failed (Verberckmoes, 1993). Later in 1975, Distrigas bilaterally negotiated a contract with Sonatrach, the Algerian national gas and oil company and both parties agreed to trade 100 bcm of natural gas over 20 years. But, because to the two oil shocks in the 1970s, Distrigas was not able to pay for the high price indexed to oil (Melling, 2010; Peter et al., 1995). Additionally, there was a decrease in natural gas demand because of energy saving measures, the further development of nuclear energy and new European rules restricting the use of natural gas in power generation. Distrigas could not follow the agreed contract and requested renegotiations (*Interview #4*, personal communication, May 19, 2022). It was only in 1982 that both parties could agree on a new contract and gas molecules could start to be transported to Belgium (via an LNG terminal in northern France) (Melling, 2010; Peter et al., 1995). Distrigas would take off lower natural gas volumes in return for a higher natural gas price, which led Sonatrach to renegotiate its other contracts as well, including that with ENI. As a consequence, the price of Algerian gas generally increased in the rest of Europe (*Interview #4*, personal communication, May 19, 2022).

Bringing Algerian gas to Belgium, in Northwestern Europe, is technically challenging. At that time, pipelines were only considered for natural gas exports to Italy. In 1977, ENI and Sonatrach commissioned a pipeline called the Transmed pipeline (Hayes, 2004). This pipeline became operational in 1983 but its limited capacity meant that northern Europe could not be serviced (*Interview #3*, personal communication, May 17, 2022). To receive Algerian LNG, a LNG terminal and regasification plants in were built in Zeebrugge starting from 1978 (Verberckmoes, 1993). In 1982, the first volumes of Algerian gas reached Belgium via France because the LNG terminal in Zeebrugge was not finalized yet. In 1987, when the construction of the LNG terminal was completed, the first LNG tanker arrived in Zeebrugge. This was the start of twenty years of Algerian gas exports to Belgium (see Graph 3) (Verberckmoes, 1993).

At present, LNG trade is perceived as a flexible way of complementing existing contractual volumes. This was not the case in the first decades. The investments in LNG infrastructure were enormous and only a fixed long-term agreement with large volumes would ensure the return on investment. Later, when LNG infrastructure costs were redeemed and a more liquid LNG market evolved, LNG received its more flexible status. But until then, LNG was similar to piped gas in terms of flexibility and contracts (*Interview #2*, personal communication, April 21, 2022). Hence, they were referred to as 'floating pipelines'.

[3] The European consortium consisted of the following companies: Ruhrgas from Germany, Distrigaz from Belgium, Gas de France from France, and Gasunie from the Netherlands

Graph 3: Natural gas imports in Belgium by supplier (1975-1997)

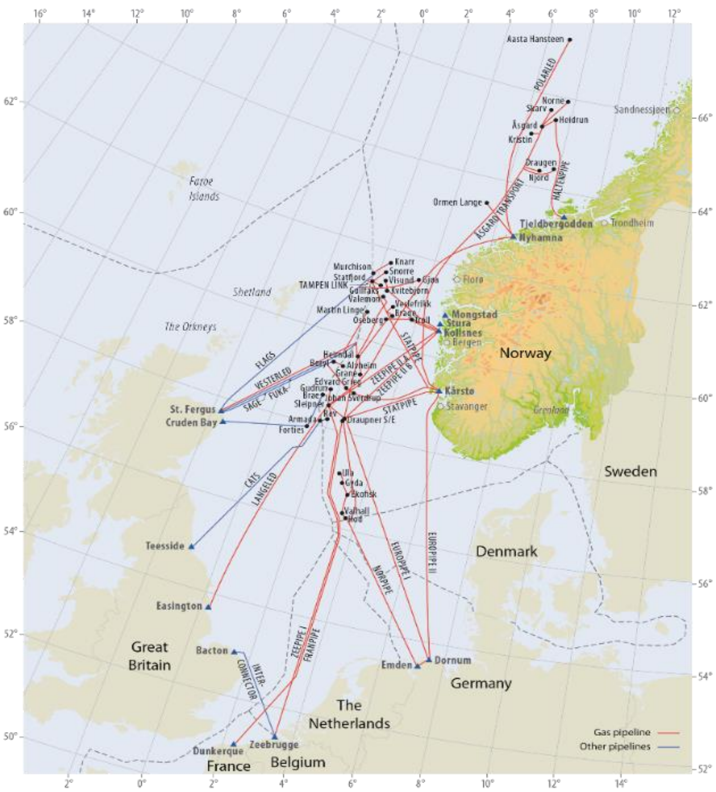


Source: Cedigaz and EUROSAT (2022)

In 1985, a high-calorific gas storage facility of 0.7 bcm was constructed in Loenhout. The facility functions to balance the seasonal demand in Belgium and was under the authority of Distrigas, now Fluxys (Preter, 2016). The Loenhout facility was built only in 1985 to balance the gas supply from the new suppliers since these contracts were less flexible than the contracts with the Netherlands. Natural gas producers can purchase storage capacity in Loenhout at a regulated tariff. Furthermore, the producer is obliged to "*use its reasonable endeavors"* to fill its storage up to 90% of its capacity by the first of November (Fluxys, 2014; *Interview #1*, personal communication, March 30, 2022)

The discovery of large gas fields in the North Sea shelf under the authority of Norway and the United Kingdom gave a boost to infrastructure projects (see figure 2). In 1993, the Zeepipe pipeline from the Norwegian Sleipner gas field to Zeebrugge was constructed. This was the first direct sea pipeline from the North Sea to Zeebrugge (De Tijd, 1988). A new domestic transmission pipeline was constructed and supplied Belgian end-users as well as transit to France (FPS Economy, 2021). In 1996, the construction of the Interconnector between the UK and Zeebrugge started (The Kingdom of Belgium & The Government of the United Kingdom of Great Britain and Northern Ireland, 1997). Natural gas could flow in both directions through the Interconnector, and therefore it was a suitable way to balance the natural gas volumes in the UK. Moreover, an extra pipeline the VTN/RTR was finalized in 1998 (see figure 1). This pipeline connected Zeebrugge with Germany and the Netherlands (Distrigas, 2007).

Figure 2: Pipeline network in the North Sea



Source: Norwegian Petroleum Directorate (2020)

The increase of natural gas suppliers and supply routes was essential for the further development of the natural gas trade in Belgium. During the 1990s, there was a civil war in Algeria. In 1992, president Boudiaf was killed and in 1994, there were difficulties with the renovation of liquefaction plants in Arzew. Distrigas experienced difficulties with its supply of LNG to Belgium (De Tijd, 1994; Van Hove, 1992) and in 1995 the gas deliveries were temporarily stalled (Belga, 1995). Therefore, Distrigas had to secure its supply by diversifying its trade partners in the short-term (De Tijd, 1994; Van Hove, 1992). In the late 1990s small volumes were bought from Saudi Arabia and Germany (Vermeire, 1996). At that time, imports from Algeria were considered more uncertain than imports from Russia (Stern & Rogers, 2017).

5.3. Global: A liberalized European gas market connecting with the world (1998-2022)

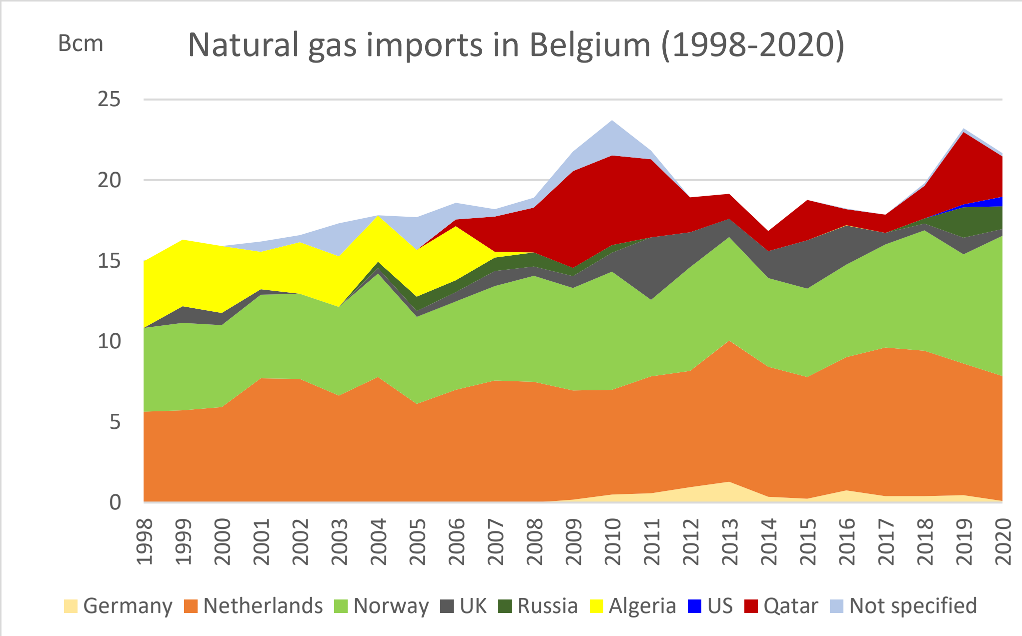
With the turn of the century, a lot has changed in the natural gas market in Europe. In 1998, the European Commission announced its Gas Directive concerning "*common rules for the internal market in natural gas"* (Directive 98/30/EC, 1998). The directive led to the split of Distrigas into Fluxys and Distrigas in 2001 where the "new" Distrigas focused on purchasing/trading natural gas, and Fluxys was responsible for the transmission and storage (Fluxys Belgium, 2001). Furthermore, the Commission for Electricity and Gas Regulation (CREG) was established to regulate the liberalized section of the market (IEA, 2001). Contracts concluded in consortia were opened up, and the different actors received their share in a new contract (*Interview #1*, personal communication, March 30, 2022). It was only in 2007 that the liberalization of the natural gas market in Belgium was finalized (Distrigas, 2007).

The liberalization of the natural gas market resulted in the creation of the physical Zeebrugge trading hub (ZEE) led by Huberator. Natural gas trading hubs were established to set reference prices and facilitate trading in a liquid market. This would accelerate the transition toward short-term contracts and increase the flexibility of the natural gas market, compared to the oil-indexed long-term contracts (Finon & Locatelli, 2002). The hub of Zeebrugge was ideally placed geographically to become a transit point between the UK, Norway, and the European continent. However, it was not until 2009 that the hub was mature and competitive with its Dutch and British equivalents. In 2012, Fluxys initiated the establishment of a virtual trading hub, the Zeebrugge Trading Point (ZTP) (Heather, 2012). All of this led to an increase in the spot trading of natural gas. In 1999 only 8% of the natural gas was purchased on the spot market and was expected to increase to no more than 15% (IEA, 2001). In 2020, almost half of the volumes consumed in Belgium were purchased on the spot market (CREG, 2021).

When spot trading became more mature, new dynamics between the spot market prices and oil-indexed natural gas prices emerged. When natural gas supply meets demand, the differences between oil-indexed and spot prices are manageable (Melling, 2010). In the last decade, supply exceeded demand and spot market prices were well below oil-indexed prices. This was mainly a result of the shale gas revolution in the United States and the further integration of LNG in the European natural gas market (Franza, 2018). The oil-indexed prices did not follow these market trends leading to a discrepancy between both pricing mechanisms. Natural gas customers sought to renegotiate their contracts and link the prices in their contracts to spot prices. Gradually, gas prices became determined by the market. However, the contractual changes are based on the reliance on the oversupply of natural gas. When the market tightens and natural gas becomes scarce, the formerly relatively stable long-term contracts become subject to the market with soaring prices as result (Franza, 2018; Melling, 2010). This happened in the second half of 2021, with skyrocketing natural gas prices in Europe, increasing even more since the invasion of Russia in Ukraine (McWilliams & Zachmann, 2022).

In the last two decades, Belgium received most of its natural gas volumes from more or less the same partners as it did in the 1990s (see graph 4). Norway and the Netherlands remained the most important partners, providing the bulk of imported gas molecules to Belgium. In 2007, the contract with Sonatrach ended, and these volumes were substituted by Qatar determined by a long-term contract concluded with RasGas II until 2027. These baseload volumes are further complemented with smaller and more flexible volumes from different partners around the globe (Trinidad and Tobago, Peru, Nigeria, Spain, Yemen, etc.) However, since 2013, gas production in Groningen is contested as a consequence of the earthquakes that hit the province. Public protests rose and the Dutch government agreed to reduce natural gas production to zero in the coming decade (Rijksoverheid Nederland, 2021). Therefore, the distribution network for low-calorific natural gas in Belgium has to be converted to networks fit for high-calorific natural gas (Gas verandert, 2017) and Belgium will have to search for new natural gas trading partners in the coming months and years to meet its domestic natural gas demand.

Graph 4: Natural gas imports in Belgium



Source: EUROSTAT (2022)

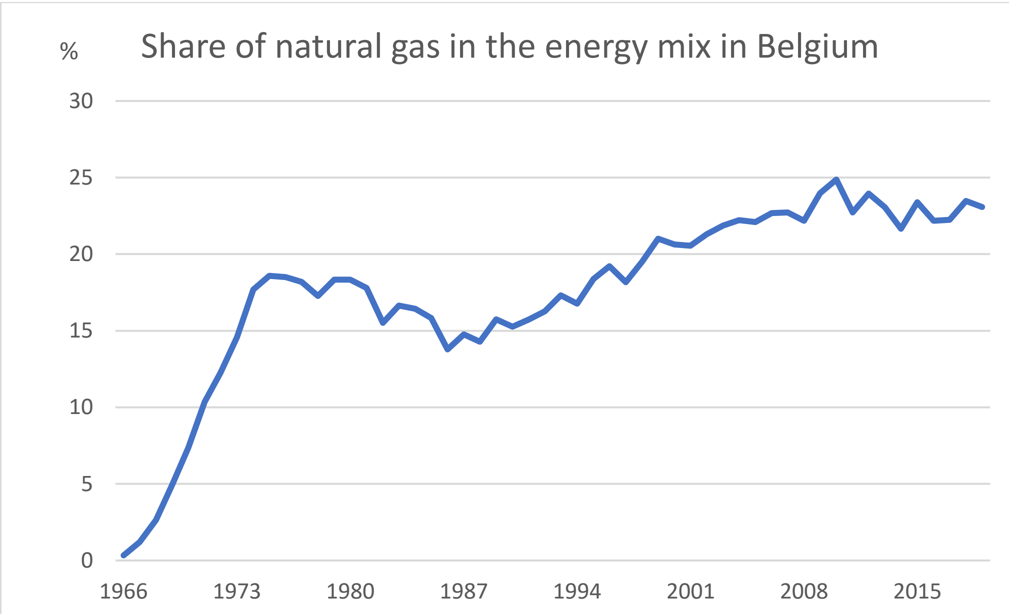
5.4. Import dependencies: origins and consequences

5.4.1. Regional trade

We define multiple drivers that initiated the natural gas trade in Belgium (see table 3). First, the natural gas trade in Belgium kicked off as a result of Distrigas' commercial interests. Buying Dutch gas and selling it to customers was a promising business opportunity for Distrigas to increase and secure its position in the energy market. In addition, Distrigas had experience dealing with gas. Distribution networks were already in place (for town gas) and only small adjustments were needed to refit them for natural gas. This can be interpreted as a path dependency: the presence of the town gas network and experience with handling gas made it easier for Distrigas to start importing natural gas. Further, the idea that natural gas was less polluting than town gas was introduced to the public, resulting in the increasing deployment of natural gas in residential appliances and improving the life quality of many households (Gustafson, 2020).

With the natural gas imports from the Netherlands, Belgium also became a transit country (apart from domestic natural gas consumption, Distrigas also traded natural gas to France or Germany). For about ten years the Netherlands was the only supplier of natural gas in Belgium and therefore the HHI was 1. Further, graph 5 shows that from 1967 until 1973 the share of natural gas in the Belgian energy mix increased to almost 18%. Belgium was, therefore, more vulnerable to the risks of a supply disruption. To manage this vulnerability, Distrigas concluded long-term contracts. However, the take or- pay-clause in the concluded contracts was a double-edged sword, resulting in a risk of (high) supplies to process, even when there was a low (or lower) demand. Flexibility in the contracts only partly solved the problem, and therefore demand-side policy measures were necessary to assure all the natural gas was processed. Since the natural gas volumes were fixed first, the consumption pattern of natural gas was adapted multiple times to comply with the supply. Another way to secure the natural gas supply was the development of a large and dense pipeline transport network in Belgium. Building further on the existing town gas network, Belgium rapidly took on the role of transit between its neighbors Germany, France, Luxembourg, and the Netherlands.

Graph 5: Share of natural gas in the energy mix in Belgium

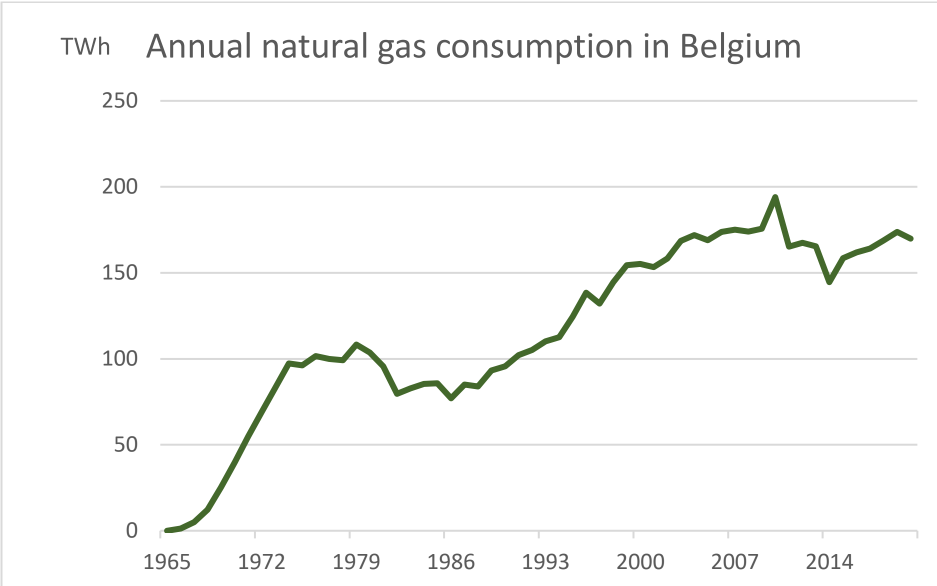


Source: Our world in Data (2022)

5.4.2. International trade

With the oil shock in 1973, the first exogenous shock hit the natural gas market. Ideas of natural gas scarcity dominated the public debate and diversification policies were introduced. Since Belgium had started importing natural gas a decade earlier and households switched to natural gas for their heating and cooking needs, strong demand for natural gas remained and it was therefore inevitable that Distrigas needed new suppliers. This path dependency steered a further integration of the natural gas market. New contracts with Norway and Algeria led to a geographic expansion of the natural gas trade leading to an international trade pattern. With more natural gas suppliers, the HHI decreased to 0,75 with gas imports from Norway in 1977 and to 0,39 when LNG was imported from Algeria in 1982. The decrease in the HHI went hand in hand with a decrease in the share of natural gas in the energy mix. Natural gas consumption decreased rapidly by 25% from 108 TWh in 1979 to 80 TWh in 1982. In 1986 natural gas consumption was only 77 TWh, which was the lowest point since the oil shock in 1973 (see Graph 6).

Graph 6: Annual natural gas consumption in Belgium



Source: Our world in data (2022)

The decrease in natural gas consumption is the result of energy-saving measures and the prohibition of using natural gas for power generation to guarantee the supply for households and industrial off-takers. However, there are also arguments that this was the result of the nuclear lobby, securing its market position by limiting the use of natural gas in the electricity sector (*Interview #4*, personal communication, May 19, 2022). Moreover, the long-term contracts and the expansion of pipelines between Belgium and its suppliers relatively secured the Belgian position in the natural gas market. This resulted in a more resilient position to potential natural gas supply disruptions. In addition, with the LNG terminal in Zeebrugge and the storage facility in Loenhout, Distrigas gained more bargaining power during contract negotiations with suppliers of piped gas. A striking example of Belgium's resilience is the short-term natural gas procurements of Saudi Arabia and Germany when the natural gas supply of Algeria was disrupted as a consequence of the civil war.

With the improved resilience of Belgium in the natural gas market, demand started to increase again. The ban on power generation of natural gas was lifted and the idea of natural gas as a clean fuel was raised. This must be seen in the light of the climate ambitions at that time and the establishment of the UNFCCC in Rio de Janeiro in 1992 (Szabo, 2021). Later in the 1990s, electricity generation plants were again fueled with natural gas as a consequence of the higher efficiency of the combined cycled gas turbine (CCGT) plants and their reduced emissions (Van Den Broek, 1995). Furthermore, those gas-fired power plants were less expensive than their nuclear equivalents and they were constructed more quickly than nuclear plants (Houben, 1994).

5.4.3. Global trade

By the turn of the century, the ideas of a liberalized natural gas market were introduced in Europe and an advanced pipeline network had evolved. The natural gas market became dominated by global trade which was based on a liquid market with long-term contracts that were complemented with flexible spot procurements and prices linked to the market. The global and liquid market that evolved was furthermore the result of an already extensive pipeline network and the LNG terminal in Zeebrugge. This path dependency made it for Belgium possible to keep its focal position. The HHI decreased to 0,3, which means a diversified supply of natural gas. However, the share of natural gas in the Belgian energy mix increased as well and is expected to increase even more with the electrification of the Belgian energy demand, the nuclear phase-out, and the European climate ambitions (Van Roost et al., 2020). A diversified supply remains therefore important to be able to manage supply disruptions. On top of that, the Dutch decision to terminate the exploration of natural gas in the Groningen province pushes Belgium to convert its low-calorific natural gas network to high-calorific natural gas on top of the search for other new supplies to compensate for the Dutch natural gas (Gas verandert, 2017).

Since 2021, after the COVID-19 pandemic, the whole natural gas market has been challenged. Natural gas spot prices suffer from skyrocketing prices, that affect other fuels and contract prices in return since half of the natural gas supply contracts have prices indexed to the spot market prices (CREG, 2021). In addition, natural gas reserves in Europe are depleting and the overall natural storage in Europe is low (Zeniewski, 2021). The Russian war in Ukraine since February 2022 has heralded even more a new era in the natural gas market. This exogenous shock introduced strong ideas within Europe that import dependencies entail high risks in terms of security of supply but also on the geopolitical position of countries. With the announced REPowerEU plan, the European Commission wants to phase out Russian natural gas and accelerate the roll-out of renewable energy. The natural gas demand eventually ought to be reduced and green alternatives, like clean hydrogen, may find their way into the energy mix (European Commission, 2022). The plan also includes regulation for minimum gas storage in Europe, diversification of natural gas suppliers, an acceleration of the transition away from fossil fuels, an External Energy Strategy, and an EU Energy platform, making voluntary joint procurements of natural gas or hydrogen possible. Regulation that has been suspended with the liberalization, like joint procurements in consortia, may be reintroduced.

In sum, during the first decades of the natural gas trade Belgium faced high risks of natural gas shortages in case of a disruption of the supply of its only supplier. Different governance mechanisms and the expansion of the natural gas infrastructure were initiated to cope with those vulnerabilities. It took almost two decades to develop a liquid market and make Belgium a resilient player in the natural gas market. With the arrival of the liberalized natural gas market, most of the governing mechanisms like long-term contracts and consortia were suspended and the market relied on the robust infrastructure and diversified flexible supply routes. When the natural gas market was hit with a new crisis starting in 2021, the same mechanisms were reintroduced to cope with the risk of supply disruptions and high gas prices (see table 3).

Table 3: origins and consequences of natural gas import dependencies

Origins and consequences of import dependencies of natural gas in Belgium			
Period	**Drivers**	**Natural gas trade patterns**	**Vulnerabilities**
1966-1972	**Path dependency**: the presence of town gas network, and experience with handling gas **Interests**: commercial interests of Distrigas **Ideas**: natural gas is less polluting than town gas	REGIONAL	**HHI**: 1 **Share of natural gas in energy mix**: 0-18% **Governance**: long-term contracts, take or pay **Infrastructure**: distribution network + transmission network (low-calorific gas)
1973-1997	**Exogenous shock**: Oil shock in 1973 and 1979 **Path dependency**: existing natural gas consumption in Belgium **Ideas**: natural gas as a transition fuel, CCGT is more efficient than coal-fired power plants, natural gas is scarce, and diversification of suppliers	INTERNATIONAL	**HHI**: 0,77 (Norway), 0,39 (Algeria) **Share of natural gas in energy mix:** 1970s 14%, 1980s 20% **Governance**: a ban on power generation with natural gas, energy-saving measures, concluding contracts in a consortium **Infrastructure**: LNG-terminal in Zeebrugge: bargaining power, Zeepipe, Interconnector, and Loenhout storage facility
1998-2021	**Path dependency**: the presence of an LNG terminal in Zeebrugge, and increasing electricity demand **Ideas**: Liberalization and the internal market in Europe, and natural gas as a transitional fuel	GLOBAL	**HHI**: 0,3 **Share of natural gas in the energy mix**: +/- 25% **Governance**: shift to spot market procurements, 50% of natural gas from long-term contracts **Infrastructure**: LNG terminal in Zeebrugge: flexible off-take, transform a low calorific network into a high calorific network, and low natural gas reserves in Europe
2022	**Exogenous shock**: Russian invasion in Ukraine **Ideas**: high risks connected to import dependencies	GEOPOLITICAL?	**Governance**: high natural gas prices and REPowerEU

6. What to expect for hydrogen trade?

Today, there is no cross-border hydrogen trade or a mature clean hydrogen market. Nevertheless, the European Commission envisages importing 10 million tons of renewable hydrogen by 2030 (European Commission, 2022). Hence, a hydrogen market needs to evolve. In this last section of the paper, we examine potential drivers that may fuel the development of the hydrogen market. Building on the similarities and differences mentioned in section 2 and the different categories of drivers that shaped the development of the natural gas market we explore what to expect for setting up hydrogen value chains in Belgium.

6.1. Drivers fueling the development of a hydrogen economy

In a future hydrogen market, exogenous shocks are not excluded, since clean hydrogen will be partly produced outside of Europe. These shocks can differ from shocks related to the natural gas market like the oil shocks in the 1970s or the Russian war in Ukraine, or in the form of the physical impact of climate change since the renewable hydrogen plants will be located in coastal regions that are prone to the effects of climate change (IRENA, 2022a).

The infrastructure path dependency is expected to play a similar role, since hydrogen has similar transport methods compared to natural gas, and the natural gas network can be repurposed. Moreover, In Belgium there is already a hydrogen transport network owned by Air Liquide, providing current industrial end-users with locally produced hydrogen. However, the network is rather small (Air Liquide, 2021). Policymakers in Europe opt for repurposing the existing natural gas transport network, as introduced by the European Hydrogen Backbone initiative. The initiative, existing of energy operators coming from different European states, aims to build a pan-European hydrogen network mostly based on repurposing existing pipelines and further integrating the network with new pipelines within Europe (European Hydrogen Backbone, 2022). However, according to Agora Energiewende (2021), industrial hydrogen demand will be centered around a few "no-regret" corridors in Europe and it would be therefore not necessary to create a pan-European hydrogen backbone (Agora Energiewende, 2021). In Belgium, Fluxys is preparing to adjust its natural gas transmission network to hydrogen and CO_2 streams (Fluxys, 2022). Moreover, Belgium has experience with the trade of (at present fossil fuel-based) methanol or ammonia. Therefore, the infrastructure for importing those chemical products is already in place as well as the know-how and a mature industrial demand.

Similar to natural gas, trading hydrogen serves industrial economic interests. Currently, there are dozens of hydrogen projects announced in Belgium and Europe. DEME and the Port of Antwerp have launched the project Hyport in the port of Duqm in Oman where they foresee an electrolyser capacity in a first phase of between 250 and 500 MW (DEME, 2022). There are also domestic initiatives like the Power-to-Methanol initiative in the Port of Antwerp introduced by a consortium including for example Engie, Port of Antwerp, Fluxys, and INEOS (Power to Methanol Antwerp, 2022). These two examples are only a few of many projects evolving around hydrogen, steering the development of the so-called hydrogen economy. The regulatory capture, using state regulation to serve industrial interests, may thus evolve when setting up hydrogen value chains.

Furthermore, the baseline of the whole clean hydrogen story remains the idea of reducing CO_2 emissions to reach climate neutrality. Clean hydrogen plays a vital role in the EU's strategy to become carbon neutral by 2050 and reach the European Climate ambitions (European Commission, 2020). Next, as a result of Russia's war in Ukraine, Europe experiences the negative consequences of its import dependencies. Therefore, the European Commission introduced policy measures to reduce not only the dependence on Russian gas but fossil fuels in general, to reinforce its resilience and strategic autonomy. Ideas of diversification and monitoring of the geopolitical implications of energy are translated into an EU External Energy Strategy which will play an important role in the hydrogen economy as well. The shift in the EU's stance toward import dependencies will undoubtedly have repercussions for setting up hydrogen value chains (European Commission, 2022).

6.2. Reinventing the wheel?

If a hydrogen market would evolve according to the pattern of the development of the natural gas market, the first decades would entail the most vulnerabilities. Clean hydrogen imports would come from a few if not one, suppliers, and the market will be fragmented and organized bilaterally. Moreover, Belgium's hydrogen demand is expected to increase depending on different scenario's to between 50TWh (FOD Economie, 2021) and 750TWh by 2050 (Hydrogen Import Coalition, 2020). A sharp increase in hydrogen demand combined with only a small amount of hydrogen suppliers causes a low resilience to cope with potential supply disruptions, as identified during the development of the natural gas market. However, since hydrogen can be domestically produced as well, the risks of supply disruptions can be partly mitigated by local production (IRENA, 2022a). Yet, the local production of hydrogen in Europe will be limited.

To resist and cope with the vulnerabilities of hydrogen import dependencies, the same ingredients that were employed in the natural gas market, can be useful for setting up hydrogen value chains. First, diversification measures on the supply side were essential to compensate for potential losses of natural gas volumes in the case of supply disruptions. The supply contracts with Norway and Algeria resulted in a diversified supply of natural gas and made Belgium more resilient. Since hydrogen production is possible all over the globe, the amount of partners to import hydrogen from is less concentrated than with natural gas, resulting in more potential trade partners and diversified supply routes.

Second, demand side policy measures were necessary to cope with the risks related to import dependencies. During the development of the natural gas trade in Belgium, demand priorities were adjusted multiple times and resulted even in European regulation to prohibit power generation with natural gas. Setting clear priorities for hydrogen demand will become therefore a key instrument to manage the risks of import dependencies. During the development of the natural gas trade, these priorities were set mostly as a reaction to certain vulnerabilities or shocks. In a future hydrogen market, it might be important to proactively set the priorities and anticipate the consequences of potential shocks, certainly when supply is limited and fragmented.

Third, different experts (IRENA, 2022a; Nuñez-Jimenez & Blasio, 2022; Roberts et al., 2021) expect the hydrogen market to be kicked off based on long-term contracts with take-or-pay clauses to mitigate investment risks, similar to the Dutch natural gas long-term contracts in the 1960s. Those contracts can secure supply in the first years when there is no liquid market yet. The natural gas supply contracts were mostly the result of negotiations in consortia. Through its REPowerEU plan, the European Commission introduced the European Energy platform to make joint procurements of hydrogen possible (European Commission, 2022). The German initiative H2Global similarly functions as an instrument to conclude long-term contracts with hydrogen suppliers based on an auction to set prices (H2Global, 2022). Long-term contracts have shown their benefits but also their weaknesses during the development of the natural gas market. Contractual agreed volumes are a tool to secure supply but may cause problems as well, when the volumes are not compatible with the demand, as was the case with Algerian LNG in the late 1970s.

Fourth, the role of infrastructure has been central during the development of the natural gas trade in Belgium. If Belgium would reuse its infrastructure network for hydrogen trade, it can build on its obtained resilience in the natural gas market. However, the adjustments to the current network cannot be compared to the adjustments that were needed in the 1960s to make the town gas network compatible with natural gas. There is a high risk of embrittlement of the steel of natural gas pipes since the chemical properties of hydrogen are different than those of natural gas. Hence, repurposing the natural gas pipelines is very technical and needs to be done case by case, which makes the process very capital intensive (IRENA, 2022c).

Additionally, hydrogen can be stored in similar geological structures as natural gas. The storage facility in Loenhout would therefore be suitable for hydrogen storage (Waterstofnet, 2021). However, almost four times more storage space is required to store the same amount of energy as natural gas (Cihlar et al., 2021). In addition, the question remains how hydrogen storage facilities would function in a hydrogen market. The facility in Loenhout has been constructed to meet fluctuations in demand. Yet, the demand for hydrogen is more constant than that for natural gas. In contrast to natural gas, electrolytic hydrogen supply is vulnerable to seasonal fluctuations since it is produced with renewable electricity from wind or solar power. There are therefore arguments to establish storage facilities in export countries instead of import countries to balance potential supply disruptions and respect the contractually agreed volumes. Nonetheless, hydrogen reserves in import countries have a strategic role to lower the import dependency rate and increase bargaining power (Crawford, 2020; IRENA, 2022a).

7. Conclusions

There is no doubt that clean hydrogen and its derivatives will play a vital role in achieving the European climate ambitions. In the coming years, different hydrogen value chain will be established connecting suppliers with their off-takers and import dependencies will evolve. For setting up these value chains, experts and policymakers often refer to the natural gas and LNG value chain. Based on this assumption, we examined in this paper the development of the natural gas value chain and its related import dependencies to explore pathways and stumble blocks connected to setting up hydrogen import value chains.

If a hydrogen market will be established in a similar way to natural gas, the energy security risks may be the highest in the first decades, since Belgium will be dependent on only a few (if not only one) supply countries for its hydrogen demand. Similar to natural gas, hydrogen demand is diverse, and different sectors will have a hydrogen demand to decarbonize their industry. It will be therefore crucial to comply with demand with supply to mitigate the risks of hydrogen shortages. During the first decades of natural gas trade, flexibility and agility of natural gas were possible, because priorities were put forward, long-term contracts were concluded and robust transport infrastructure was built. If the hydrogen market develops in a similar way to the natural gas market, the same instruments to mitigate the risks of import dependencies may be employed.

This paper has opened a door to more academic research regarding the interconnection between natural gas and hydrogen chains. We have shown the relevance of studying similarities and differences between natural gas and hydrogen and how they are translated into similar pathways and vulnerabilities. Therefore we assume that similar instruments and policy measures may find their way into the hydrogen market. There is thus no need to start from scratch when setting up hydrogen value chains in Belgium or Europe since a lot can be learned from the experiences of the natural gas market. There is no need to completely reinvent the wheel.

Acknowledgments:

With the financial support of the Energy Transition Fund

economie

8. References

Agora Energiewende. (2021). *No-regret hydrogen infrastructure for Europe*. https://www.agora-energiewende.de/en/press/news-archive/no-regret-hydrogen-infrastructure-for-europe/

Air Liquide. (2021, July 12). *Distributie*. Air Liquide Benelux. https://industrie.airliquide-benelux.com/belgie-nederland/distributie

Belga. (1995, July 1). Belgie koopt aardgas in Abu Dhabi. *Belga*.

BNEF. (2020). *Hydrogen Economy Outlook*.

BP. (2021). *Statistical Review of World Energy*. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Brion, R., Moreau, J.-L., & Tack, E. (1995). *Tractebel 1895-1995: Metamorfosen van een industriële groep*. Antwerpen : Mercatorfonds. http://lib.ugent.be/catalog/rug01:000350817

Cihlar, J., Mavins, D., & van der Leun, K. (2021). *Picturing the value of gas storage to the European hydrogen system*. Guidehouse.

Conoco Phillips. (2017). *40 Years with Gas from Ekofisk to Europe*. Conoco Phillips. https://www.conocophillips.no/news-media/story/40-years-with-gas-from-ekofisk-to-europe/

Correlje, A., Van der Linde, C., & Westerwoudt, T. (2003). *Natural Gas in the Netherlands From Cooperation to Competition?* Oranje-Nassau Groep. http://inis.iaea.org/search/search.aspx?orig_q=RN:34066235

Crawford, N. (2020). *Hydrogen: Strategic reserves*. International Institute for Strategic Studies. https://www.iiss.org/blogs/analysis/2021/12/hydrogen-strategic-reserves

CREG. (2021). *Studie over de prijzen op de Belgische aardgasmarkt in 2020*.

Dal Bo, E. (2006). Regulatory Capture: A Review. *Oxford Review of Economic Policy*, *22*(2), 203–225. https://doi.org/10.1093/oxrep/grj013

De Clercq, M. (1975). *ACTUELE EN TOEKOMSTIGE BEVOORRADING EN GEBRUIK VAN AARDGAS IN BELGIE*. Rijksuniversiteit Gent.

De Tijd. (1988, September 8). Distrigas en Statoil akkoord over terminal. *De Tijd*.

De Tijd. (1994, April 11). Distrigas heeft problemen bij aanvoer Algerijns aardgas. *De Tijd*.

DEME. (2022). *DEME and partners present HYPORT®Duqm, a large-scale green hydrogen project in Oman*. DEME-Group.Com. https://www.deme-group.com/news/deme-and-partners-present-hyportrduqm-large-scale-green-hydrogen-project-oman-1

Dickel, R., Gönül, G., Gould, T., Kanai, M., Konoplyanik, A., & Selivanova, Y. (2007). *Putting a price on energy: International Pricing Mechanisms for Oil and Gas*. Energy Charter Secretariat.

Directive 98/30/EC, CONSIL, EP, 204 OJ L (1998). http://data.europa.eu/eli/dir/1998/30/oj/eng

Distrigas. (2007). *Activiteitenverslag 2007*.

Eandis. (2013). *Aardgas van vroeger tot nu*.

European Commission. (2020). *A hydrogen strategy for a climate-neutral Europe*. https://www.eu2018.at/calendar-events/political-events/BMNT-

European Commission. (2022). *REPowerEU*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A108%3AFIN

European Hydrogen Backbone. (2022). *European Hydrogen Backbone*. https://ehb.eu/files/downloads/ehb-report-220428-17h00-interactive-1.pdf

Eurostat. (2022). *EU natural gas import dependency down to 83% in 2021*. https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220419-1

Fils, G., & Deutsch, M. (2021). *12 Insights on Hydrogen*. Agora Energiewende. www.agora-industry.de

Finnemore, M., & Farrell, H. (2017). Global Institutions without a Global State. In K. O. Fioretos (Ed.), *International Politics and Institutions in Time*.

Finon, D., & Locatelli, C. (2002). *The liberalisation of the European gas market and its consequences for Russia*. 15.

Fioretos, O. (2011). *Historical Institutionalism in International Relations*. 45.

Fluxys. (2014). *Storage facility of Loenhout*.

Fluxys. (2022). *Bouwen aan de waterstof- en CO2-infrastructuur voor België*. https://www.fluxys.com/nl/energy-transition/hydrogen-carbon-infrastructure

Fluxys Belgium. (2001). *Director's report*.

FOD Economie. (2021). *De rol van gasvormige energiedragers in een klimaatneutraal België*.

FPS Economy. (2021). *International gas trade in Belgium: Determining the origins and destination of imports and exports, and eliminating transit from annual data*. 12.

Franza, L. (2018, May 17). *Gas market liberalisation: Does Europe really want it?* Www.Euractiv.Com. https://www.euractiv.com/section/energy/opinion/gas-market-liberalisation-does-europe-really-want-it/

Fukuyama, F. (2013). What Is Governance? *Governance*, *26*(3), 347–368. https://doi.org/10.1111/gove.12035

Gas verandert. (2017). *Arm gas wordt rijk gas*. https://www.gasverandert.be/nl

Gustafson, Thane. (2020). *The bridge natural gas in a redivided Europe*.

H2Global. (2022). *The H2Global Mechanism*. https://h2-global.de/project/h2g-mechanism

Hall, P. A. (1997). The Role of Interests, Institutions, and Ideas in Comparative Politival Economy of the Industrialized Nations. In M. I. Lichbach & A. S. Zuckerman (Eds.), *Comparative Politics: Rationality, Culture, and Structure*.

Hall, P. A., & Taylor, R. C. R. (1996). Political Science and the Three New Institutionalisms. *Political Studies*, *44*(5), 936–957. https://doi.org/10.1111/j.1467-9248.1996.tb00343.x

Hausemann, N., Weber, K., & Block, J. (2021). The Geopolitics of Hydrogen: Old Dependencies in a New Energy Market. In *Eurosolar Times*.

Hayes, M. H. (2004). *Algerian Gas to Europe: The Transmed Pipeline and Early Spanish Gas Import Projects*.

Heather, P. (2012). *Continental European Gas Hubs: Are they fit for purpose?* Oxford Institute for Energy Studies. https://doi.org/10.26889/9781907555510

Högselius, P., Åberg, A., & Kaijser, A. (2013). Natural gas in cold war Europe: The making of a critical infrastructure. In *The Making of Europe's Critical Infrastructure: Common Connections and Shared Vulnerabilities*. https://doi.org/10.1057/9781137358738_2

Houben, Gert. (1994, June 8). Nieuw plan van-producenten van elektriciteit. *Het Belang van Limburg*.

Hydrogen Council. (2021). *Hydrogen for Net Zero*.

Hydrogen Import Coalition. (2020). *Shipping sun and wind to Belgium is key in climate neutral economy*. https://www.waterstofnet.eu/_asset/_public/H2Importcoalitie/Waterstofimportcoalitie.pdf

IEA. (2001). *Energy Policies of IEA Countries: Belgium*.

IEA. (2019). *The Future of Hydrogen*. International Energy Agency.

IEA. (2020). *Final consumption – Key World Energy Statistics 2020*. IEA. https://www.iea.org/reports/key-world-energy-statistics-2020/final-consumption

IEA. (2021). *Global Hydrogen Review 2021*. OECD. https://doi.org/10.1787/39351842-en

Interview #1. (2022, March 30). [Personal communication].

Interview #2. (2022, April 21). [Personal communication].

Interview #3. (2022, May 17). [Personal communication].

Interview #4. (2022, May 19). [Personal communication].

IRENA. (2022a). *Geopolitics of the energy transformation: The hydrogen factor.* https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jan/IRENA_Geopolitics_Hydrogen_2022.pdf

IRENA. (2022b). *Global Hydrogen Trade to Meet the 1.5°C Climate Goal Part I: Trade Outlook for 2050 and Way Forward*. https://www.irena.org/publications/2022/Jul/Global-Hydrogen-Trade-Outlook

IRENA. (2022c). *Global hydrogen trade to meet the 1.5°C climate goal: Part II – Technology review of hydrogen carriers*. International Renewable Energy Agency.

Lebrouhi, B. E., Djoupo, J. J., Lamrani, B., Benabdelaziz, K., & Kousksou, T. (2022). Global hydrogen development—A technological and geopolitical overview. *International Journal of Hydrogen Energy*. https://doi.org/10.1016/j.ijhydene.2021.12.076

Lieberman, R. C. (2002). Ideas, Institutions, and Political Order: Explaining Political Change. *The American Political Science Review*, *96*(4), 697–712.

Matlary, J. H. (1985). Perspectives on the Role of Norwegian Gas. *Norwegian Institute of International Affairs*.

McWilliams, B., & Zachmann, G. (2022). *The European Union demand response to high natural gas prices*. https://www.bruegel.org/2022/04/the-european-union-demand-response-to-high-natural-gas-prices/

Melling, A. J. (2010). *Natural Gas Pricing and Its Future: Europe as the Battleground*. Carnegie Endowment for International Peace. www.Carnegie.ru

Ministerie van Energie België. (2021). *Belgische Federale Waterstofstrategie*. https://economie.fgov.be/sites/default/files/Files/Energy/waterstof-visie-en-strategie.pdf

Nationale Bank van België. (1967). *Nationale Bank van België Verslag 1966*.

Nationale Bank van België. (1968). *Nationale Bank van België Verslag 1967*.

Nies, S. (2011). *OIL AND GAS DELIVERY TO EUROPE: An overview of Existing and Planned Infrastructure*. IFRI.

Nuñez-Jimenez, A., & Blasio, N. D. (2022). The Future of Renewable Hydrogen in the European Union. *European Union*, 86.

Peter, Wolfgang., Kuyper, J.-Q. de., & Candolle, B. de. (1995). *Arbitration and renegotiation of international investment agreements*. Kluwer Law International. https://books.google.com/books/about/Arbitration_and_Renegotiation_of_Interna.html?hl=nl&id=g3XhTx1NTvIC

Pflugmann, F., & Blasio, N. D. (2020). The geopolitics of renewable hydrogen in low-carbon energy markets. *Geopolitics, History, and International Relations*, *12*(1), 9–44. https://doi.org/10.22381/GHIR12120201

Power to Methanol Antwerp. (2022). *CONCEPT*. Power to Methanol Antwerp. https://powertomethanolantwerp.com/concept/

Preter, R. D. (2016). *De onzichtbare hand boven België. Een economische geschiedenis.: Invloed van liberalisering, globalisering en europeanisering*. Maklu.

Rijksoverheid Nederland. (2021, March 8). *Wetsvoorstel 'Wat Na Nul' in internetconsultatie* [Nieuwsbericht]. Ministerie van Algemene Zaken. https://www.rijksoverheid.nl/actueel/nieuws/2021/03/08/wetsvoorstel-wat-na-nul-in-internetconsultatie

Roberts, D., Deasley, S., Wood, C., & Brown, A. (2021). *Making Early Hydrogen Projects Investable*. Frontier Economics.

Sorensen, A. (2015). Taking path dependence seriously: An historical institutionalist research agenda in planning history. *Planning Perspectives*, *30*(1), 17–38. https://doi.org/10.1080/02665433.2013.874299

Steinmo, S. (2008). Historical institutionalism. In D. Della Porta & M. Keating (Eds.), *Approaches and Methodologies in the Social Sciences* (1st ed., pp. 118–138). Cambridge University Press. https://doi.org/10.1017/CBO9780511801938.008

Steinmo, S. (2015). Institutionalism. In J. D. Wright (Ed.), *International Encyclopedia of the Social & Behavioral Sciences (Second Edition)* (pp. 181–185). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.93055-1

Steinmo, S., Thelen, K., & Longstreth, F. (Eds.). (1992). *Structuring Politics: Historical Institutionalism in Comparative Analysis* (1st ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511528125

Stern, J., & Rogers, H. (2017). The evolution of European gas pricing mechanisms. In *The European Gas Markets: Challenges and Opportunities* (pp. 359–392). Springer International Publishing. https://doi.org/10.1007/978-3-319-55801-1_15

Stigler, G. J. (1971). The Theory of Economic Regulation. *The Bell Journal of Economics and Management Science*, *2*(1), 3–21. JSTOR. https://doi.org/10.2307/3003160

Szabo, J. (2021). Natural Gas' Changing Discourse in European Decarbonisation. In M. Mišík & N. Kujundžić (Eds.), *Energy Humanities. Current State and Future Directions* (pp. 67–88). Springer International Publishing. https://doi.org/10.1007/978-3-030-57480-2_5

The Kingdom of Belgium & The Government of the United Kingdom of Great Britain and Northern Ireland. (1997). *Agreement relating to the transmission of natural gas through a pipeline between the Kingdom of Belgium and the United Kingdom of Great Britain and Northern Ireland*.

Van de Graaf, T., Overland, I., Scholten, D., & Westphal, K. (2020). The new oil? The geopolitics and international governance of hydrogen. *Energy Research and Social Science*, *70*. https://doi.org/10.1016/j.erss.2020.101667

Van Den Broek, Guy. (1995, January 25). Siemens ziet STEG centrales met 60 % rendement. *De Tijd*.

Van Hove, L. (1992, September 12). Aardgasbevoorrading: Te veel eieren in de verkeerde mand? *De Tijd*.

Van Roost, J., Van Nuffel, L., Vingerhoets, P., d'Haeseleer, W., De Maré, C., Deschuyteneer, T., Vancaeyzele, V., & Van Gijzeghem, F. (2020). *De rol van gas in de Belgische energietransitie: Aardgas en waterstof*. KVAB Press.

Verberckmoes, S. (1993). *Distrigas voert groot deel aardgas in via Zeebrugge*. https://www.nt.nl/archief/1993/07/24/distrigas-voert-groot-deel-aardgas-in-via-zeebrugge/

Vermeire, J. (1996). Zeebrugge as a hub for gas flows in north west Europe. *ONS Conference*.

Waterstofnet. (2021). *Welke toepassingen kent waterstof?* https://www.waterstofnet.eu/nl/waterstof/welke-toepassingen-kent-waterstof

Zeniewski, P. (2021, October 22). *Despite short-term pain, the EU's liberalised gas markets have brought long-term financial gains*. IEA. https://www.iea.org/commentaries/despite-short-term-pain-the-eu-s-liberalised-gas-markets-have-brought-long-term-financial-gains