# NATURAL GAS SUPPLY CHAIN IN THE FORM OF LNG - POLISH AND EUROPEAN MARKETS

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**Abstract**

Natural gas production in Europe does not meet the demand for this raw material. The solution is the import of raw materials, and LNG, i.e. liquefied natural gas, is becoming increasingly popular. The LNG supply chain includes natural gas production, liquefaction, and then transport to the unloading terminal, where it is regasified and sent to the final recipient. There are many import terminals in Europe and their number is constantly growing, which shows the increased demand for a different source of raw material than pipelines. The aim of the article is to present the extraction, consumption and import of natural gas in the Polish and Europe, as well as the presentation of the LNG supply chain and a discussion of the import terminals located in European countries.

**Keywords:** natural gas, fuel consumption and extraction, LNG, supply chain, LNG import terminals, energy policy

## Introduction

Natural gas is a fuel used in many sectors of the economy, from its basic use in households to its use in industry and services. Due to the large energy gain arising from its combustion, this raw material is used to produce energy (Kalisz et al. 2010: 28). Based on data from 2018 it can be concluded that Poland depends on natural gas supplies from outside the country to meet the requirements of demand for this raw material. This results in the implementation of import solutions, including import of natural gas in the form of LNG (Liquefied Natural Gas) (Ministry of Energy 2019: 28).

## Share of natural gas in the Polish and European markets

Natural gas is present in Poland in several areas. The main one is the region of the Polish Lowlands. In addition, deposits are located in the foothills and the Carpathians, as well as in the Polish Exclusive Economic Zone (Polish EEZ). In 2018, the state of recoverable natural gas resources amounted to 142.16 billion $m^3$, which represents an increase of 22.97 billion $m^3$ compared to the previous year (Szulficki et al. 2019: 11-14). The extraction of raw material from documented deposits with different ways of obtaining it is presented in Table 1.

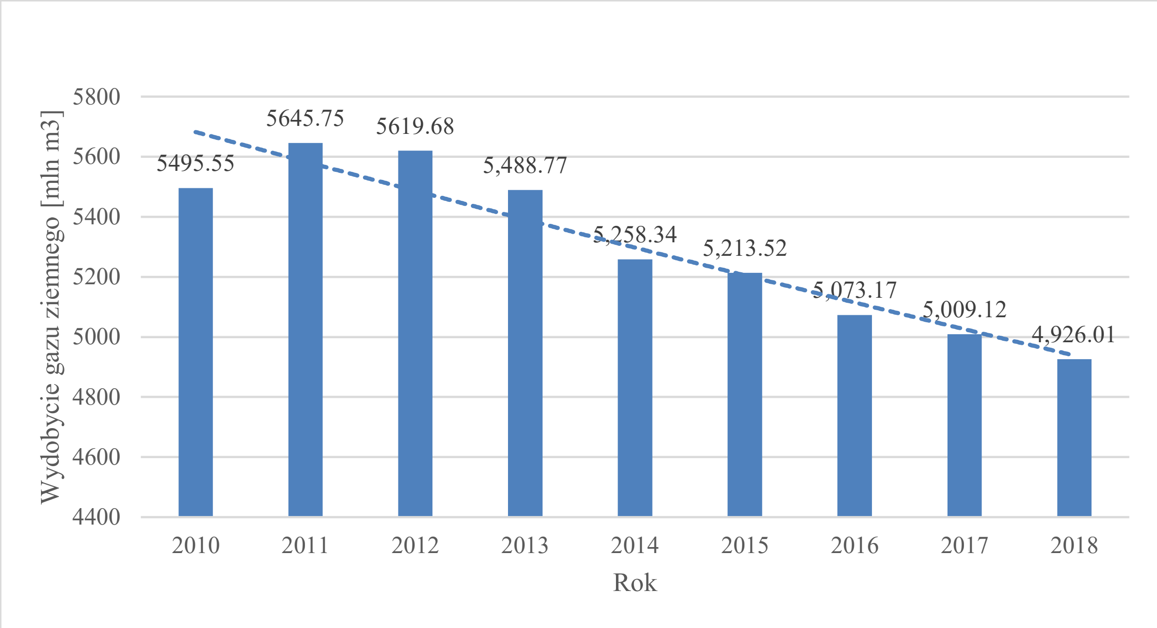
**Table 1. Natural gas production in Poland [million $m^3$]**

| Description | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| **TOTAL** | **5495.55** | **5645.75** | **5619.68** | **5 488.77** | **5 258.34** | **5 213.52** | **5 073.17** | **5 009.12** | **4 926.01** |
| from gas reserves | 4911.79 | 5073.99 | 5024.53 | 4 746.87 | 4 501.85 | 4 455.91 | 4 278.98 | 4 192.69 | 4 073.93 |
| from crude oil reserves | 176.78 | 177.43 | 186.07 | 737.44 | 365.72 | 367.14 | 381.28 | 385.30 | 425.00 |
| from condensate reserves | 406.98 | 394.33 | 409.08 | 4.46 | 390.77 | 390.47 | 412.91 | 431.13 | 427.08 |

*Source: Own elaboration based on: Szulficki et al. 2011: 16; Szulficki et al. 2012: 16; Szulficki et al. 2013: 16; Szulficki et al. 2014: 14; Szulficki et al. 2015: 14; Szulficki et al. 2016: 14; Szulficki et al. 2017: 14; Szulficki et al. 2018: 14; Szulficki et al. 2019: 14.*

Starting from 2011, there has been a decline in natural gas production in Poland, with no decrease in its use. This drop is shown in Chart 1.

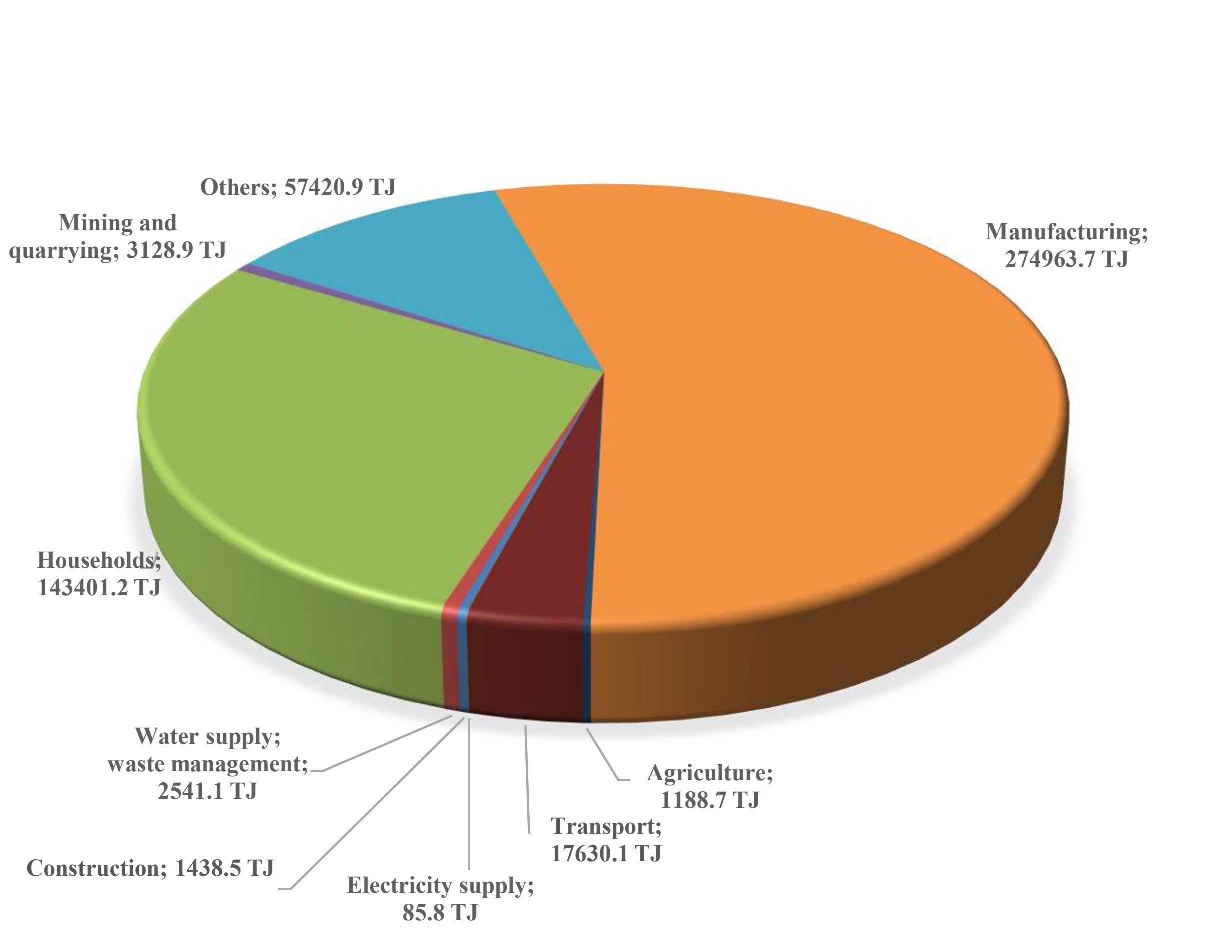
**Chart 1. Natural gas production in Poland over the years [million $m^3$]**




*Source: Own elaboration based on: Szulficki et al. 2011: 16; Szulficki et al. 2012: 16; Szulficki et al. 2013: 16; Szulficki et al. 2014: 14; Szulficki et al. 2015: 14; Szulficki et al. 2016: 14; Szulficki et al. 2017: 14; Szulficki et al. 2018: 14; Szulficki et al. 2019: 14.*

Data from 2017, from the Central Statistical Office, show the direct consumption of energy in Poland. It increased by 2.7% compared to the previous year. Among all energy carriers, high-methane natural gas significantly increased its share in the energy market, and its highest consumption was observed in industrial processing and households (Central Statistical Office 2018: 34). The consumption of natural gas by economic sector is shown in Chart 2.

**Figure 2. Direct consumption of natural gas in Poland in 2017**




*Source: Own elaboration based on: Central Statistical Office 2018.*

Turning to the situation in Europe, the production of natural gas depends on the geographical conditions of each country. Referring to data published by BP, the highest output in 2018 was achieved by Norway (120.6 bcm), while the lowest natural gas output was obtained by Poland (4.0 bcm) (Dudley 2019:32). When analysing annual production, it should be concluded that total gas production in Europe has been declining since 2010. The annual production data are summarised in Table 2.

In 2017, the annual calorific value of natural gas in Europe reached 18556.16 thousand terajoules, which is higher than the value obtained in 2016 (17821.27 thousand terajoules). The upward trend has been continuing since 2014 (Eurostat 2019). Meanwhile, the 2018 report shows that Europe is responsible for 6.5% of the world's natural gas production, with only 2.0% of the world's proven reserves (Dudley 2019: 32). The annual net calorific value of natural gas is shown in Chart 3.

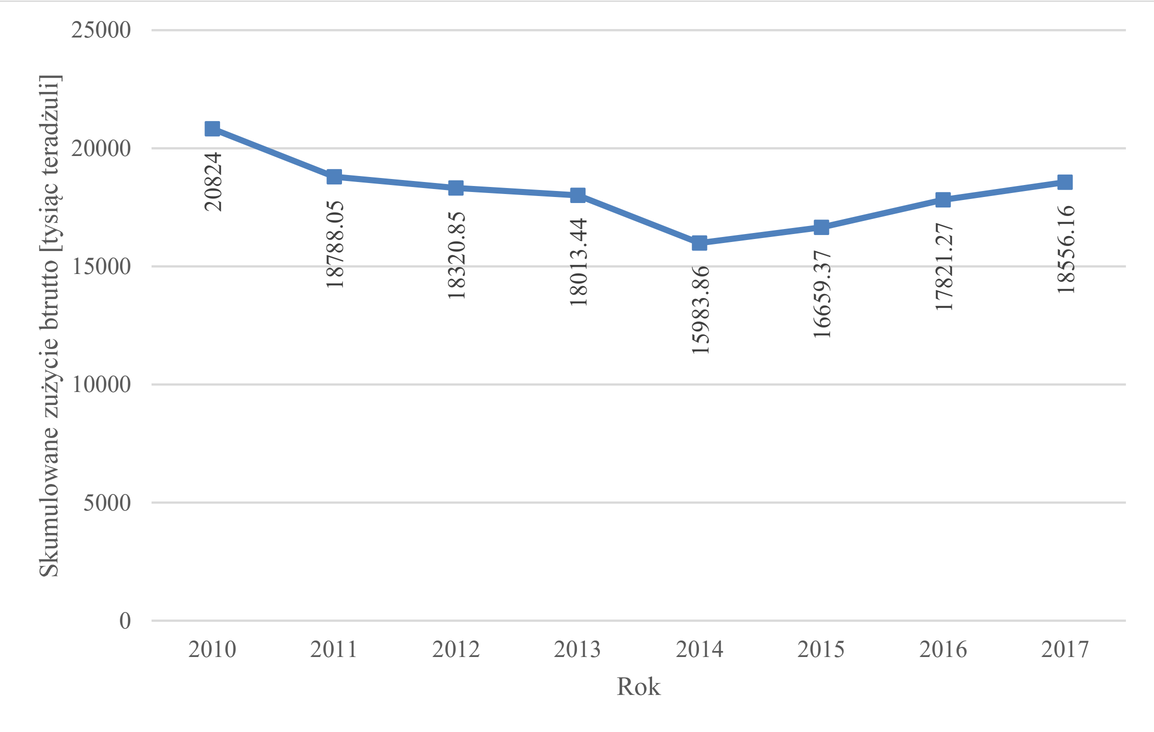
**Table 2. Annual production of natural gas in Europe [bcm]**

| Country | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Denmark | 8.5 | 6.9 | 6.0 | 5.0 | 4.8 | 4.8 | 4.7 | 5.1 | 4.3 |
| Germany | 11.1 | 10.5 | 9.5 | 8.6 | 8.1 | 7.5 | 6.9 | 6.4 | 5.5 |
| Italy | 8.0 | 8.0 | 8.2 | 7.4 | 6.8 | 6.4 | 5.5 | 5.3 | 5.2 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Netherlands | 75.3 | 69.5 | 68.4 | 72.4 | 60.4 | 45.9 | 44.3 | 38.6 | 32.3 |
| Norway | 106.4 | 100.5 | 113.9 | 107.9 | 108 | 116.2 | 115.9 | 123.2 | 120.6 |
| Poland | 4.3 | 4.5 | 4.5 | 4.4 | 4.3 | 4.3 | 4.1 | 4.0 | 4.0 |
| Romania | 10 | 10.1 | 10.1 | 10.0 | 10.2 | 10.2 | 9.1 | 9.9 | 9.5 |
| Ukraine | 19.4 | 19.5 | 19.4 | 20.2 | 20.2 | 18.8 | 19 | 19.4 | 19.9 |
| United Kingdom | 57.9 | 46.1 | 39.2 | 37.0 | 37.4 | 40.7 | 41.7 | 41.9 | 40.6 |
| Other Europe | 9.7 | 9.9 | 8.9 | 7.8 | 7.2 | 6.8 | 9.2 | 9.5 | 8.7 |
| **Total Europe** | **310.6** | **285.5** | **288.1** | **280.7** | **267.4** | **261.6** | **260.4** | **263.3** | **250.6** |

*Source: Dudley 2019:32.*

**Chart 3. Annual calorific value of natural gas in the European Union**




*Source: Own calculations based on: Eurostat 2019.*

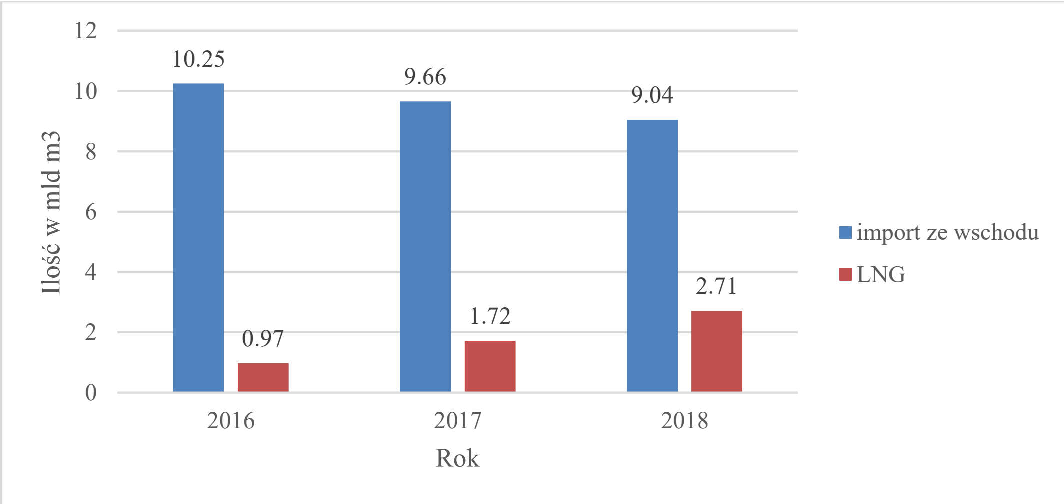
Europe is not rich in gas deposits; this is also the case in Poland. To a large extent, Polish natural gas production does not satisfy the consumption of the resource. This results in the import of material, which reached 77.77% of the total energy needs of the country satisfied by imports from other countries in 2017. The European Union has achieved a slightly lower rate with 74.32% in 2017 (Eurostat 2019a).

Import in the case of Polish demand for gas is unavoidable. According to the PGNiG's data, domestic production has reached 3.8 bcm, which constitutes about 22% of the source of gas supply. The remaining part, i.e. 13.5 bcm, is imported from Poland. Polish imports of natural gas include pipeline supplies from Russia and LNG to the President Lech Kaczyński LNG Terminal in Świnoujście (PGNiG 2019).

Thanks to the construction of the LNG terminal in Poland, the possibility of receiving natural gas in the form of LNG has been gained. LNG (*Liquefied Natural Gas*) is natural gas that is liquefied after being subjected to prior inspection and then in liquid form at the appropriate temperature, stored and transported. The great advantage of liquefying it is that in the liquid state it only takes up 1/600th of the volume that would be required for natural gas at standard temperature and normal pressure. It is a relatively non-toxic substance, because when released into the environment it does not cause poisoning, but as natural gas it is combustible, so it is subject to the same dangers as in any other industrial activity (Łaciak et al. 2012: 430).

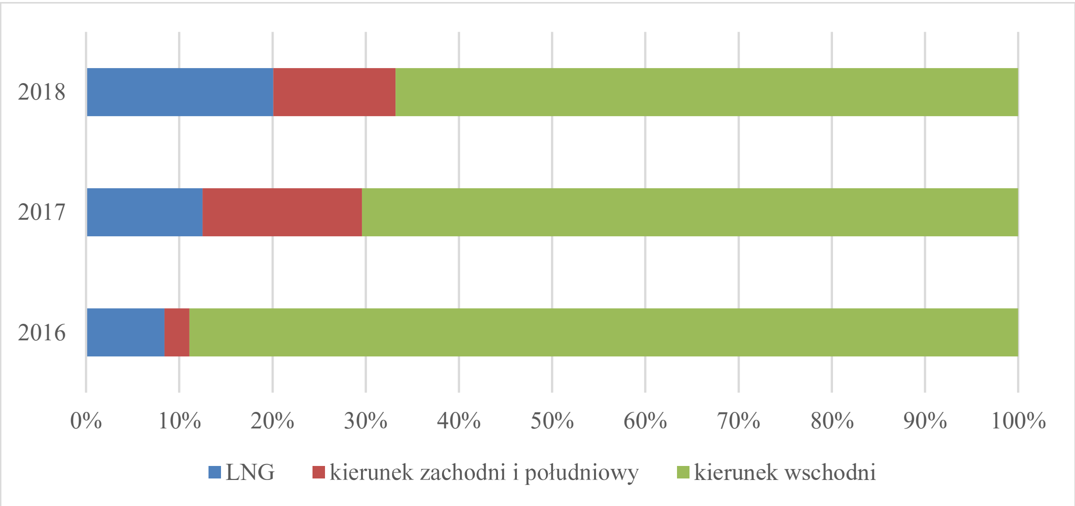
The LNG terminal has been in operation since 2016, reaching in 2018 over 20% share in the import structure. Since then, supplies from the East have been reduced – from 88.9% to 66.8%, but they cannot be completely excluded, as under the Yamal contract PGNiG undertook to pay Gazprom for 85% of the contractual value of gas until 2022. This is an unfavourable system, among other things due to the quality of supplies and the cost of raw materials, which is why it was decided to build a portfolio of safe supplies based on LNG and gas supplies from the Baltic Pipe gas pipeline (PGNiG 2019). Information on imports of natural gas from Gazprom and LNG and the percentage share in the PGNiG import structure is presented in Chart 4 and Chart 5.

**Chart 4. Quantity of imported natural gas to Poland [bcm]**




*Source: PGNiG 2019, http://pgnig.pl/aktualnosci/-/news-list/id/pgnig-2018-kolejny-rok-mniejszego-importu-gazu-z-rosji-i-wiekszego-importu-lng/newsGroupId/10184 (access: 17.10.2019 r.).*

**Chart 5. Percentage share in the structure of natural gas imports in Poland [%]**




*Source: PGNiG 2019, http://pgnig.pl/aktualnosci/-/news-list/id/pgnig-2018-kolejny-rok-mniejszego-importu-gazu-z-rosji-i-wiekszego-importu-lng/newsGroupId/10184 (access: 17.10.2019 r.).*

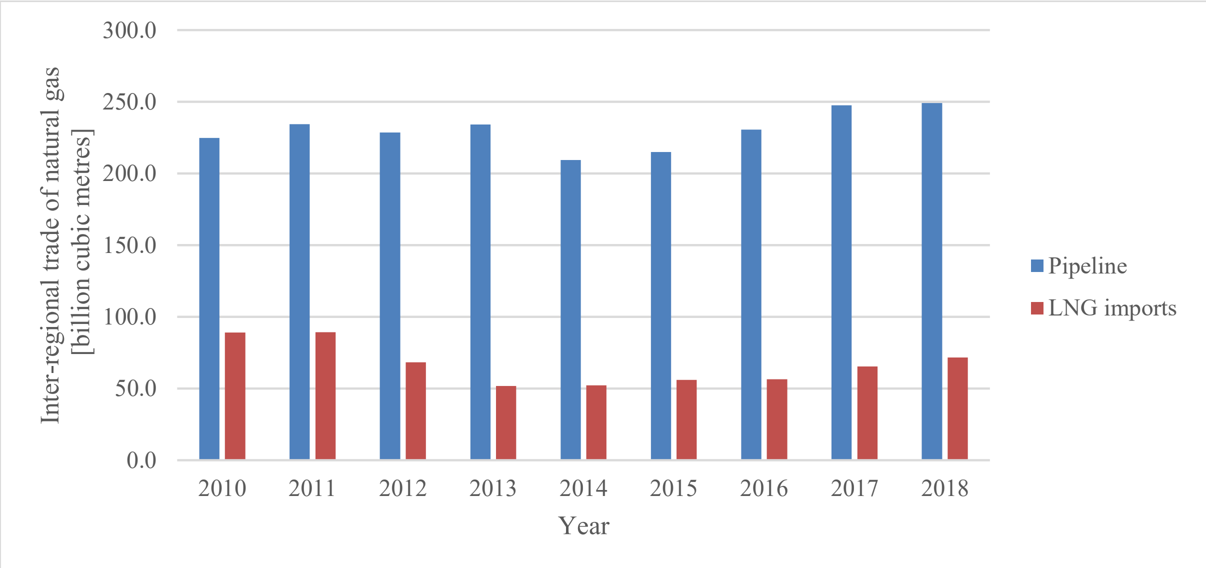
Natural gas imports to Europe were as follows: in 2018 European countries imported 320.6 bcm of natural gas to meet their energy needs, 7.9 bcm more than in the previous year. Although supplies from the pipeline continued to dominate the energy market, the share of LNG was gradually increasing. In 2018, European countries imported most LNG from Qatar, i.e. 22.6 bcm, Nigeria (12.5 bcm) and Algeria (12.4 bcm) (Dudley 2019:38-40). Natural gas imports to European countries, by type of supply, are presented in Table 3 and Chart 6.

**Table 3. Natural gas imports to European countries [bcm]**

| | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Type of gas supply | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Pipeline | 224.8 | 234.4 | 228.5 | 234.1 | 209.4 | 214.9 | 230.5 | 247.5 | 249.1 |
| LNG imports | 89.1 | 89.2 | 68.2 | 51.8 | 52.1 | 56.0 | 56.5 | 65.3 | 71.5 |
| **Total imports** | **313.9** | **323.6** | **296.7** | **285.8** | **261.4** | **271.0** | **287.0** | **312.7** | **320.6** |

*Source: Dudley 2019:38.*

**Chart 6. Types of natural gas supply by year**




*Source: Own elaboration based on: Dudley 2019:38.*

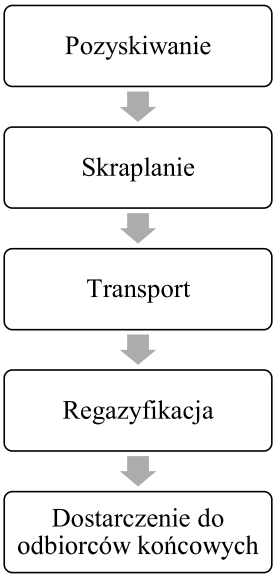
### Natural gas flow in the form of LNG from producer to consumer

The European market depends on external sources of natural gas. The consequence of this is the development of solutions that can effectively supply raw material shortages. One of these is LNG, which currently accounts for 22% of the supply market share. The LNG market is very volatile and the gas valuation itself depends on many elements which ultimately shape the offer and make it attractive for both the exporter and the importer (Zajdel, Ruszel 2015: 95).

The transport of natural gas in the form of LNG is based on five pillars: acquisition of the raw material, liquefaction, transport, regasification and transmission of gas to end users. Each element of the supply chain has subordinate technologies that generate costs that significantly affect the final assessment of the profitability of the investment. Awareness of the relationship between the links allows downtime in the process to be eliminated at the lowest possible cost (Zajdel, Ruszel 2015: 96). Figure 1 shows a graphical representation of the LNG supply chain links.

The first link in the LNG supply chain is the acquisition or production of natural gas, preceded by appropriate exploration and appraisal works (Zajdel, Ruszel 2015: 96). The scale of the project is variable and can be determined by such factors as the size of the extraction area, the amount of geological work (seismic and drilling), the amount of extraction and the type of gas produced (Zaleska-Bartosz, Klimek 2011: 724). Sources of gas may be either onshore or offshore, which means that the location and way of obtaining gas may vary (Zajdel, Ruszel 2015: 96-97). Natural gas can be extracted directly from gas sources or as a by-product of oil or coal (Wielgosz 2014: 100). The activities belonging to this element of the chain also include the supply of natural gas to the export terminal, where, after transporting the raw material, it is subjected to subsequent measures (Zajdel, Ruszel 2015: 97).

**Figure 1. LNG Supply Chain**




*Source: Own elaboration based on: Zajdel, Ruszel 2015:97.*

When considering the extraction of natural gas for transformation into LNG in the context of imports into Europe, the fields in the leading export countries should be specified. In Qatar, the Northern Field contains the largest deposits of natural gas in the world; after extraction, the raw material is transported through a pipeline network to the terminal at Ras Laffan (Oil & Gas 360 2017). There are many mining sites in the United States, mainly in Texas, Pennsylvania, Oklahoma, Louisiana and Ohio. The largest shale gas production is from Marcellus Shale, located in Pennsylvania, West Virginia, Ohio and New York. The Permian Basin (Texas and New Mexico) and Utica Shale (Ohio, Pennsylvania and West Virginia) also have high yields. There is also offshore production in the USA, located in the Gulf of Mexico (EIA 2018).

Natural gas is transported from the place of its acquisition to the LNG transmission terminal equipped with liquefaction facilities (Zaleska-Bartosz, Klimek 2011: 725). The next link in the supply chain is primarily the production of LNG from natural gas through liquefaction. Liquefaction is the change in the state of aggregation from the gas phase to the liquid phase, under appropriate environmental conditions, e.g. a change in pressure or temperature. The main component of natural gas is methane, but apart from this there are also other hydrocarbons (ethane, propane) and nitrogen, oxygen, carbon dioxide and sulphur. To prevent the production of undesirable products from the liquefaction process, natural gas must be purified, above all from water and carbon dioxide. This minimises the risk of solid particles that would be formed when the gas is cooled down to approx. -160°C. The result of elimination of unnecessary chemical compounds is the purity of LNG – contamination constitutes about 5% of its composition, the remaining 95% is methane. There are three methods of liquefaction used (Polskie LNG 2019):

- a classic cascade cycle, in which natural gas, purified from unnecessary chemical compounds, is cooled in three cooling cycles, using propane, ethane and methane in turn; a relatively energy-efficient method, although it requires many installations and additional raw materials, e.g. pure propane and ethane,
- a cascade cycle with mixed refrigerant, i.e. a modified classic cycle using one compressor and one refrigerant (hydrocarbon mixture); more energy-intensive than the classic cycle, but fewer installations are required, resulting in lower costs,
- a turboexpander expansion cycle in which a device called a turboexpander expands part of the gas which is then cooled to a very low temperature and treated as a cooling medium for the next gas batch; this method does not require a great deal of investment but consumes a lot of energy in operation.

The liquefied natural gas is then stored in appropriate conditions. Due to the very low temperature, storage tanks must have a very special construction, including suitable metal, polymeric, insulating materials and a system of detailed inspections. Tanks can be divided into three categories, i.e. (Łaciak et al. 2012: 431):

- ground tanks, including:
  - a steel tank without an external protective casing (*Single Containment Tank*),
  - a steel tank with additional concrete protective casing (*Double Containment Tank*),
  - steel tank with external (sealed) concrete jacket (*Full Containment Tank*),
- tanks partly in the ground,
- underground tanks.

The last activity within the second link of the supply chain is loading the LNG onto special means of transport, i.e. methane carriers (Zaleska-Bartosz, Klimek 2011: 724).

Qatar is the largest exporter of LNG in the world. Following the merger of Qatargas and Rasgas, Qatar Petroleum was founded to operate a total of 14 liquefaction plants, making it the world's largest such organisation. Foreign partners, including Exxon Mobil and Royal Dutch Shell, are also involved. In addition, the Qatar government owns LNG tankers, as well as shares in terminals and participation in global gas producers, including Shell and the BG Group (Woźniak 2018: 16). The subsidiary Ras Laffan Liquefied Natural Gas Company Limited operates two LNG liquefaction facilities with a total production of 6.6 MTPA (million tonnes per annum), while generating by-products from the process. The entire terminal also has all the necessary systems and extensive external infrastructure (Qatargas 2019).

The United States has a significant share in the LNG market. Initially, their LNG concept was based on the creation of a large number of import terminals. After the so-called shale revolution, during which the documented natural gas reserves increased and its extraction increased, the import terminals were transformed into liquefaction terminals. As a consequence, the share of the LNG export market increased (Janusz et al. 2017: 30-31). The Sabine Pass LNG terminal, located in Cameron Parish, is operated by Sabine Pass Liquefaction, owned by

Cheniere Partners. It has 6 natural gas liquefaction plants, each with a capacity of approximately 4.5 MTPA. It is fully equipped with an export terminal, 5 tanks and 2 docks, and is connected to the Creole Trail Pipeline. This terminal, unlike the basic solutions, apart from liquefying gas to LNG, also has the possibility to sell unprocessed natural gas, which increases its number of customers (Cheniere 2019).

The essence of LNG trade is its ability to be transported over long distances without linear transmission infrastructure, i.e. gas pipelines. Transport, the third link in the supply chain, is connected with other infrastructure, including loading and unloading terminals as well as the facilities located there and the fleet of vessels, i.e. LNG tankers (Rosłonek 2016: 88-89). These ships have double hulls to prevent gas leakage and puncture in case of collision with another vessel (Łaciak 2011: 510). The raw material is transported by sea and placed in special cryogenic tanks, isolated from external factors, with an overpressure of the gas phase of 0.5 bar (Rosłonek 2016: 88-89).

The tanks used in transport are divided into three types (Łaciak 2011: 510):

- spherical tanks which are not part of the hull of the ship but are fixed to special fittings inside the hull; the inner liner is made of aluminium or aluminium alloy; the tank is heat insulated and the upper surface is provided with a protective casing; the space between the tank and the casing is monitored for methane; tanks of this type are easier to repair and considered safe, but their shape does not allow the entire volume of hull to be filled with raw material,
- membrane tanks, i.e. the ship's hold, are covered with thermal insulation from the inside, and from the cargo side with e.g. high-alloy steel sheet, glass fibre structure or aluminum foil layers, and the space between them is monitored for methane content; the advantage of this solution is the use of hull volume to the maximum, however, in case of damage, it is extremely difficult to locate the failure and quickly repair,
- tanks based on Japanese technologies, i.e. IHI (designed by Ishikawajima-Harima Heavy Industries), CS1 (Combined System Number One).

During transport, a number of measurements are made in order to detect inconsistencies. In the cargo chamber, the pressure of the gas phase above the liquid, the temperature of the LNG, and the temperature of the gas phase are tested, and also the quantity of liquid is controlled before and after unloading (Rosłonek 2016: 91).

Research shows that the transport of LNG is more cost-effective compared to the transport of an equivalent amount of natural gas through a subsea gas pipeline of more than 1,300 km, as well as compared to the transport through a land gas pipeline of more than 4,000 km. The entire LNG supply chain is economically viable if it is transported over long distances (Rosłonek 2016: 88).

Upon arrival at the destination, the next link in the process – regasification – takes place. This is preceded by unloading, i.e. pumping the LNG from the tanks located on the methane carriers to the tanks of the unloading terminal by means of pumps located on the tankers. These pumps are divided into two types: larger, pumping LNG and smaller, which maintain a low temperature inside the tank. The loading capacity of a typical methane carrier is about 130,000 $m^3$. In addition to the long time needed for the transmission of raw materials, a huge amount of energy is required. Part of the energy is converted into heat and affects the LNG, increasing its tank temperature by approximately 0.5 °C. In order to prevent temperature changes during pumping into the receiving terminal's storage tanks, the system of insulated pipes must be cooled down beforehand. It is also important heed the pressure in the tanker's tank – by pumping out huge amounts of liquefied gas in a short time, the pressure increases. In order to keep the pressure constant, methane is injected which, in combination with gas evaporated during the journey, prevents the formation of an adverse local vacuum. Then, the gas is transported to storage tanks located at the terminal, which have the same structure and fall into the same categories as the tanks used for storing the raw material before the transport process (Łaciak et al. 2012: 431-433).

LNG re-gasification takes place in the unloading terminal. This process consists in restoring the gas from the liquid form to the original gas form by heating it. The regasification method depends on the location and availability of fuel or heating medium. Liquefied natural gas evaporators can be divided into (Polskie LNG 2019a):

- evaporators used to heat the raw material to a temperature equal to or greater than the ambient temperature, including:
  - evaporators heated with sea water or by hand (*Open Rack Vaporizers – ORV*), which, after being filtered and checked, flows in pipes around LNG panels to release heat; after the process, the water is discharged into the sea/river,
  - evaporators heated by air, using the heat of atmospheric air,
- evaporators with direct heating to a temperature higher than the ambient temperature:
  - fire heating by means of gas burners,
  - electric heating, by means of special electrical installations,
- evaporators with indirect heating to a temperature higher than the ambient temperature, where a heating medium, e.g. water, is used:
  - steam heating,
  - water heating with submerged gas heaters (*Submerged Combustion Vaporiser – SCV*),
  - heating with heat carriers, e.g. isopentane.

Regasification is followed by quality control of the obtained gas and determination of its composition. This serves to specify the amount of LNG energy in the cargo settlement process. These measurements are made only on land, i.e. in the terminal area, not on ships, due to the continuous supervision of measurement and analytical equipment, i.e. gas chromatographs. The gas subject to checking is transferred to the transmission system (Rosłonek 2016: 92-93).

The largest import terminal in Europe is located in the Isle of Grain in the UK. It has 1 million $m^3$ of tank space, is capable of receiving 15 MTPA of raw material and has the necessary infrastructure for regasification, including 2 cryogenic lines and 2 jetties (GrainLNG 2019). Regasification takes place through evaporators with a heating medium, i.e. heating with water and submerged gas burners (*Submerged Combustion Vaporizers – SCV*s), enabling regasification at the level of 645 GWh/d (GrainLNG 2019a).

The Polish LNG terminal in Świnoujście has the possibility of in-process storage of raw material in tanks with the total capacity of 320,000 $m^3$. The terminal has a regasification installation with a technical capacity of 162.75 GWh/d, enabling the maximum capacity of 5 bcm of natural gas per year (in its natural state) to be reached, which is sufficient to satisfy 1/3 of the needs of the Polish economy. Regasification takes place by heating the liquefied material in SCVs – in order to evaporate the liquefied gas, water heated by waste gas is used, which then gives heat to the submerged pipes through which the liquefied natural gas flows. In addition, the terminal is under construction, which includes additional regasification facilities, another tank, a transshipment facility for rail and additional ship quays (Polskie LNG 2019b; Polskie LNG 2019c; SWI 2019; Polskie LNG 2019d).

The last stage of the supply chain is the supply of natural gas to final customers. These may include both households and companies (Polskie LNG 2019e). Directly from the import terminal, the raw material may be transferred by means of a gas connection pipeline to the transmission network (Gaz-System 2015). LNG transport in liquefied or regasified form may be carried out with the use of road tankers. When transporting raw material in liquefied form, tanks with cryogenic tanks are used to preserve its properties. Transport infrastructure capacity provides flexibility of supply and the absence of location limitations, and is not linked with high costs (Motowidlak 2014). Natural gas obtained from LNG, due to its purity, is also used as fuel for motor vehicles and power plants – exhaust gases generated in the processes have lower toxic components (Polskie LNG 2019e).

Poland belongs to the North-South Corridor project. By means of a pipeline network, the LNG import terminal in Świnoujście and the Baltic Pipe gas pipeline will be connected with an LNG import terminal located in Croatia. The connection will run through southern Poland, the Czech Republic, Slovakia and Hungary. The corridor is to consist of gas interconnections and national gas pipeline networks already in place. The benefits for the states will include integration of the gas market, increased security of supply and access to new sources of supply in countries without access to the sea (Gaz-System 2016).

**LNG terminals in Europe**

The gas policies of individual European countries vary significantly. However, they have one thing in common – the inability to obtain natural gas in order to fully satisfy their demand. For this reason, gas is obtained from external sources, through pipelines and by supplying liquefied gas in the form of LNG.

There are 35 LNG import terminals in Europe, including 4 Floating Storage Regasification Units (FSRUs). Most of them, six, are located in Spain. Their total capacity is 62 bcm/year. The United Kingdom has four terminals (including one located in the dependent British territory of Gibraltar). The British Isles host the largest import terminals in Europe – the Isle of Grain LNG Terminal, a single terminal with annual capacity of 19.5 bcm/year and two terminals in Milford Haven: the smaller Milford Haven – Dragon LNG terminal and Milford Haven – South Hook LNG terminal, whose total capacity is 28.6 bcm/year. The United Kingdom, with an annual capacity of 48 bcm/year, achieves takes second place on the European scale. The third country with a very high throughput is France, whose four import terminals generate a throughput of 34.25 bcm/year (Gas Infrastructure Europe (GIE) 2019). Both the abovementioned terminals and other terminals in Europe differ in their capacity to accommodate methane carriers, i.e. their capacity. All the import terminals located in Europe are shown in Table 4.

**Table 4. Import terminals in Europe**

| Country | Terminal Name | Operating Company | Year of opening | Maximum hourly throughput [$m^3/h$] | Annual nominal throughput [bcm/year] | LNG storage capacity LNG [$m^3$] | Number of tanks | Maximum LNG ship size serviced [$m^3$] |
|---|---|---|---|---|---|---|---|---|
| Belgium | Zeebrugge LNG Terminal | Fluxys Belgium SA | 1987 | 1 700 000 | 9.00 | 386 000 | 4 | 266 000 |
| Finland | Tahkoluoto/Pori | Gasum Oy | 2016 | - | 0.10 | 28 500 | 1 | 20 000 |
| | Tornio Manga (Roytta) | Manga LNG Oy | 2018 | - | 0.40 | 50 000 | 1 | - |
| France | Dunkerque LNG Terminal | Dunkerque LNG SAS | 2016 | 1 900 000 | 13.00 | 600 000 | 3 | 267 000 |
| | Fos-Tonkin LNG Terminal | Elengy SA | 1972 | 620 000 | 3.00 | 80 000 | 1 | 75 000 |
| | Fos Cavaou LNG Terminal | Fosmax LNG | 2010 | 1 160 000 | 8.25 | 330 000 | 3 | 267 000 |
| | Montoir-de-Bretagne LNG Terminal | Elengy SA | 1980 | 1 600 000 | 10.00 | 360 000 | 3 | 267 000 |
| Greece | Revithoussa LNG Terminal | DESFA S.A. | 2000 | 798 000 | 7.00 | 225 000 | 3 | 260 000 |
| Spain | Barcelona LNG Terminal | Enagás, S.A. | 1968 | 1 950 000 | 17.10 | 760 000 | 6 | 266 000 |
| | Bilbao LNG Terminal | Bahía de Bizkaia Gas S.L. (BBG) | 2003 | 1 000 000 | 8.80 | 450 000 | 3 | 270 000 |
| | Cartagena LNG Terminal | Enagás, S.A. | 1989 | 1 350 000 | 11.80 | 587 000 | 5 | 266 000 |
| | Huelva LNG Terminal | Enagás, S.A. | 1988 | 1 350 000 | 11.80 | 619 500 | 5 | 173 400 |
| | Mugardos LNG Terminal | REGANOSA | 2007 | 412 800 | 3.60 | 300 000 | 2 | 266 000 |
| | Sagunto LNG Terminal | Planta de Regasificación de Sagunto S.A.(Saggas) | 2006 | 1 000 000 | 8.80 | 600 000 | 4 | 265 000 |
| Netherlands | Gate terminal Rotterdam | Gate Terminal B.V. | 2011 | 1 650 000 | 12.00 | 540 000 | 3 | 266 000 |
| Lithuania | FSRU Independence | KN (JSC Klaipėdos nafta) | 2014 | 460 000 | 4.00 | 170 000 | 4 | 160 000 |
| Malta | Malta Delimara LNG terminal | Enemalta Corporation | 2017 | 89 000 | 0.70 | 125 000 | 5 | - |
| Norway | Øra LNG, Fredrikstad | Gasum Oy | 2011 | - | 0.10 | 5 900 | 9 | - |
| | Mosjoen | Gasnor AS | 2007 | - | - | 6 500 | 5 | - |
| Poland | Świnoujście LNG Terminal | Polskie LNG S.A. | 2016 | 656 000 | 5.00 | 320 000 | 2 | 216 000 |
| Portugal | Sines LNG Terminal | REN Atlântico, S.A. | 2004 | 1 350 000 | 7.60 | 390 000 | 3 | 216 000 |
| Russia | FSRU Kaliningrad | Gazprom PJSC | 2019 | 450 000 | 3.70 | 174 000 | - | - |
| Sweden | Lysekil | Gasnor AS | 2014 | - | 0.30 | 30 000 | 1 | - |
| | Nynäshamn | AGA Industrigaser | 2011 | - | 0.30 | 20 000 | 1 | 15 000 |
| Turkey | Aliaga Izmir LNG terminal | EGE GAZ A.S. | 2006 | 680 000 | 6.00 | 280 000 | 2 | 265 000 |
| | Aliaga Etki LNG terminal Neptune | Etki Liman İşletmeleri A.Ş. | 2016 | 600 000 | 5.00 | 145 000 | 4 | - |
| | FSRU Iskendurun (Dörtyol) | BOTAŞ Petroleum Pipeline Company | 2019 | 830 000 | 7.30 | 263 000 | - | - |
| | Marmara Ereglisi LNG terminal | BOTAŞ Petroleum Pipeline Company | 1994 | 685 000 | 6.20 | 255 000 | 3 | 130 000 |
| UK | Gibraltar | Gasnor AS/ Royal Dutch Shell | 2011 | - | 0.20 | 5 000 | 5 | - |
| | Isle of Grain LNG Terminal | National Grid PLC | 2005 | 2 650 000 | 19.50 | 1 000 000 | 8 | 266 000 |
| | Milford Haven - Dragon LNG terminal | Dragon LNG | 2009 | 1 140 000 | 7.60 | 320 000 | 2 | 217 000 |
| | Milford Haven - South Hook LNG terminal | South Hook LNG Terminal Company Ltd | 2009 | 2 440 000 | 21.00 | 775 000 | 5 | 265 000 |
| Italy | FSRU OLT Offshore LNG Toscana | Olt Offshore LNG Toscana SpA | 2013 | 592 465 | 3.75 | 137 500 | 4 | 180 000 |
| | Panigaglia LNG Terminal | Snam SPA | 1971 | 427 000 | 3.40 | 100 000 | 2 | 70 000 |
| | Porto Levante LNG Terminal | Terminale GNL Adriatico S.r.l. | 2009 | 1 038 857 | 7.58 | 250 000 | 2 | 180 000 |

*Source: Own elaboration based on: Gas Infrastructure Europe (GIE) 2019.*

The potential of LNG and the possibility of becoming independent from gas supplies through the pipeline network are recognised by more and more European countries. Many existing terminals are being extended – as is the case with the Polish LNG terminal in Świnoujście – or are currently under construction. There are plans to build 19 terminals located in various parts of Europe, including Poland – in 2025 it is planned to locate a floating terminal in Gdańsk Bay (FSRU Polish Baltic Sea Coast) (Gas Infrastructure Europe (GIE) 2019). Import terminals which are under construction in 2019, together with the e xpected date of their completion, are presented in Table 5.

**Table 5. LNG import terminals under construction in Europe**

| Country | Terminal name | Company operating terminal | Planned year of opening | Planned maximum hourly efficiency [$m^3/h$] | Planned annual nominal efficiency [bcm/rok] | Storage capacity for storing LNG LNG [$m^3$] | Number of tanks [items] |
|---|---|---|---|---|---|---|---|
| Croatia | Krk Island LNG terminal, Omišal | LNG Croatia LLC | 2021 | 300 000 | 2,60 | 140 000 | 2 |
| Finland | Hamina | Haminan Energia, Alexela Varahalduse AS | 2020 | - | - | 30 000 | 1 |
| Spain | Gijón (Musel) LNG Terminal | Enagás, S.A. | finished, no authorisation | 800 000 | 7,00 | 300 000 | 2 |
| | Gran Canaria (Arinaga) LNG terminal | Gascan | 2027 | 150 000 | 1,30 | 150 000 | 1 |
| | Tenerife (Arico-Granadilla) LNG terminal | Gascan | 2021 | 150 000 | 1,30 | 150 000 | 1 |
| Italy | Oristano - Santa Giusta | HIGAS | 2020 | - | - | 9 000 | 6 |
| | Ravenna | PIR-Petrolifera Italo Rumena group/Edison | 2021 | - | - | 20 000 | 2 |

*Source: Own elaboration based on: Gas Infrastructure Europe (GIE) 2019.*

Norway and the European part of Russia are the only European countries with export terminals. The amount of exported LNG is not large, but it is absorbed entirely by the market, which shows the market interest in natural gas in this form (Gas Infrastructure Europe (GIE) 2019). The export terminals are shown in Table 6.

**Table 6. LNG exports from European countries**

| Country | Terminal name | Operating company | Year of opening | Quantity of exported LNG [t/year] |
|---|---|---|---|---|
| Norway | Kollsnes 1 | Gasnor AS | 2003 | 40 000 |
| | Kollsnes 2 | Gasnor AS | 2007 | 80 000 |
| | Risavika (Stavanger) | Gasum Oy | 2011 | 300 000 |
| | Snøhvit, Hammerfest | Equinor ASA | 2007 | 4 300 000 |
| | Snurrevarden (Karmøy) | Gasnor AS | 2003 | 20 000 |
| | Tjelbergodden | AGA Industrigaser | 1997 | 10 000 |
| Russia | Cryostar Vysotsk | Novatek OAO | 2019 | 660 000 |

*Source: Own elaboration based on: Gas Infrastructure Europe (GIE) 2019.*

The aim of many European countries is now to expand the gas infrastructure, which will increase Europe's energy security. The possibility to become at least partly independent from Russian pipeline supplies is an important argument in the negotiations on natural gas supply contracts, in particular as regards price reductions. In the event of any armed conflict in Europe or in the territory of an exporting country, the existence of LNG terminals ensures the continuity of gas supplies (Ruszel 2014: 54-57). Furthermore, it should be noted that the construction and planning of new import terminals is part of Europe's energy policy. Qatar is currently the world's largest LNG exporter. In the context of European supply, the United States, which has a significant share, is important. If Australia opens up to the European market, which currently exports raw materials only to the Asian market, the frequency and quantity of deliveries could increase significantly. In addition, the emergence of an additional competitor on the market could lead to a reduction in LNG prices (Dudley 2019: 40).

**Summary**

Natural gas, extracted from deposits in Poland and other European countries, is not able to satisfy the demand for this raw material. The solution is to obtain it from external sources, both through pipelines and in the form of LNG. The potential of LNG has also been noticed by Poland, which, within a few years of the opening of the LNG import terminal, increased its share in the structure of natural gas imports to approx. 22%.

The LNG supply chain includes its change of state – from the gas phase to the liquid phase in the process of liquefaction and return from liquid to gaseous form in the process of regasification. These links in the chain require extensive infrastructure, including one of the process methods (depending on the type of terminal) and specialized tanks, tailored to the storage of goods in the specified conditions. The transport between the terminals requires special tankers, i.e. methane carriers, which apart from special tanks also have a control system and pumps, which enable pumping out the LNG, while maintaining appropriate external factors. Due to the low temperature of the cooled LNG, any aberration would result in a change of state of aggregation and an increase in pressure, resulting in destruction.

There are currently 35 LNG import terminals in operation in Europe, and a dozen or so more are currently under construction or planned. Many of the existing ones are being extended, including the Polish terminal in Świnoujście. Spain has the largest number of import terminals; however, the largest terminals are located in Great Britain. Analysing import data, it should be noted that there is an upward trend that affects the creation or planning of new terminals in Europe, especially in countries that have not previously used this raw material, e.g. Croatia. Although Europe has no significant gas reserves, there are also export terminals on its territory, located in Norway and the European part of Russia.

European countries have seen in LNG the possibility of becoming independent of unfavourable natural gas supplies from Russia, and of ensuring their energy security in the event of armed conflicts. Moreover, if competition in the supply market increases, they will be able to choose the most advantageous offers for them and thus be able to negotiate prices. At the same time, countries with import terminals may act as intermediaries and gain from further transmission of raw materials to countries which do not have the possibility to receive LNG by sea.

Looking ahead, we can assume that natural gas obtained from LNG will be a very popular, if not the most popular, primary energy carrier. Its success can be attributed to its purity, i.e. low content of unnecessary chemical compounds, which translates into their low percentage in exhaust fumes. New methods of acquisition also allow us to confirm our belief that fears about the rapid depletion of resources are unfounded.

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