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# QUALITY ANALYSIS IN THE SUPPLY CHAIN OF TRANSPORTED LNG

*Karolina Czerwińska, Andrzej Pacana*

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## **Abstract**

The natural gas market has changed over the last few years. The approach to commercial relations hitherto was conditioned by the method of supply of this raw material, which was mainly carried out using gas pipelines. Taking into account the fact that natural gas has a six hundred times higher energy density in the form of LNG than in uncompressed form, it is economically justified to transport the resource by more than just traditional gas pipelines. Maritime transport of LNG has become an alternative means of delivering volumes to areas with insufficient gas resources. The article presents general methods of settlement and quality control of LNG in marine loading and receiving terminals. The types of measurements used in LNG settlements carried out on ships and on land are analysed. The aim of the paper was to analyse the way of ensuring and supervising the quality of LNG transported to the ship and to design an assessment form and monitor the stability of the quality level of LNG supplies with the use of a single measurement control card. It is proposed to use a two-track numerical stabilisation control card for single measurements and a mobile range IX – MR (Xi – MR).

**Keywords:** supply chain, natural gas, liquefied natural gas (LNG), quality control

## **Introduction**

One of the components of the energy transformation is a gradual shift away from the use of traditional energy carriers, i.e. crude oil, in sea and land transport towards alternative fuels, among which a significant potential is connected with popularisation of the use of vehicles powered by LNG (liquefied natural gas). Nevertheless, the energy transformation within the transport sector determines the need for state investment in many areas which are seemingly not related to each other and require a specific policy for each of them. The areas mentioned above should include the following: systemic-market, legal, economic, technological and infrastructural. In addition to the above, the social sphere should be placed, within which transformations are much slower and are a resultant of changes introduced in other areas. In each of these areas, there is a series of barriers and risks that could slow down the processes mentioned, which stem from the specific nature of liquefied cold gas supplies (Brodacki 2017: 4). Therefore, the quality of transported LNG plays an important role.

Product quality is defined as the degree of compliance with specified requirements or benchmarks (Lisiecka 2002: 106; Hamrol 2002: 267-269). The quoted definition finds its application in the area of fuel quality, in the context of controls carried out at individual links on the logistics transport and distribution chain. The objective of the inspection is to ensure an appropriate level of quality of the set of features important from the point of view of functionality and environmental protection, as well as the life and durability of internal combustion engines (Ryczyński 2011: 260; Ryczyński 2012: 262).

The subject of this paper is the analysis of quality management in the supply chain of transported liquefied natural gas (LNG). The analysis of this issue will be based on a multifaceted

analysis of the logistics supply chain of LNG and accounting measurements (transferred energy) of LNG. The aim of the article was to analyse the way of ensuring and supervising the quality of transported LNG and to present a draft form of assessment and monitoring the stability of the quality level of LNG supplies with the use of a single measurement control card. The information from the proposed single measurement control card will protect against unloading LNG of low energy value into the storage tanks of the terminals.

### **Forms of processing and characteristics of natural gas**

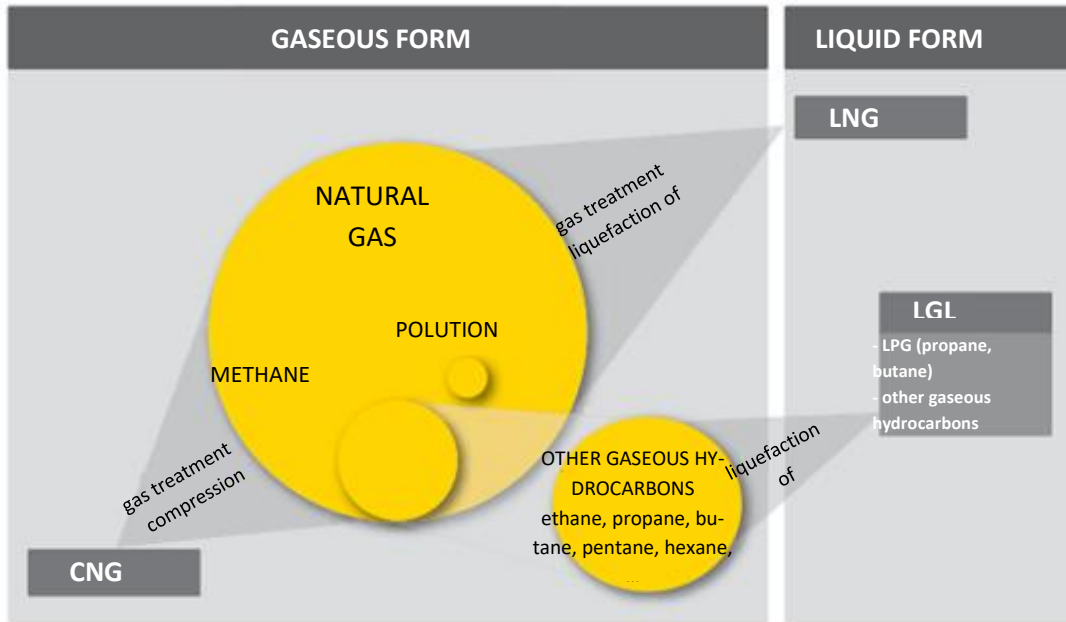
Natural gas produced from conventional and unconventional deposits or extracted from crude oil mainly consists of methane –  $\text{CH}_4$  (85-95% depending on the deposit). Natural gas may also contain other hydrocarbons such as: propane –  $\text{C}_3\text{H}_{10}$ , ethane –  $\text{C}_2\text{H}_6$ , butane –  $\text{C}_4\text{H}_{10}$ , isobutane –  $\text{C}_4\text{H}_8$ , pentane –  $\text{C}_5\text{H}_{12}$  and other elements not used in industry – impurities (e.g. oxygen, hydrogen, carbon dioxide, helium, nitrogen, steam). It may also locally contain ingredients such as mercury (Tałach and Rudkowski, 2012: 284-287 and Woroch Klonowski, 2006: 30-31). Cold gas can be transported more cost-effectively through compression or liquefaction. Both methods make it possible to increase the energy density of cold gas by reducing the volume. The process of liquefaction of natural gas requires thorough drying and purification of the gas. Appropriately prepared natural gas is liquefied and in a liquid state at a temperature of approx.  $-162^\circ\text{C}$  (depending on the composition in the range  $-166^\circ\text{C}$  -  $157^\circ\text{C}$ ) is ready for storage and transport. LNG occupies only 1/600 of the volume required for a comparable – primary – natural gas quantity at room temperature under normal pressure (Łaciak and Nagy 2010: 707; Molenda 1993; Zaleska - Bartosz and Klimek 2011: 724). By reducing the volume, LNG reaches a significant energy density per  $1\text{ m}^3$  (expressed in  $\text{GJ/m}^3$ ).

The following products are obtained by changing the state of concentration of natural gas and its components:

- NGL (natural gas liquids) – heavier hydrocarbon molecules (propane and butane) present in the liquid state are evaporated at the pressure prevailing on the earth's surface. The most popular product produced by NGL is LPG (liquefied petroleum gas) composed of propane, butane or their mixture, which at a pressure of a few atmospheres is a liquid.
- CNG (compressed natural gas) – is a compressed natural gas that is the result of more than two hundred times the compression of natural gas (after the removal of pollutants).

A diagram of the transformation of natural gas to LNG, NGL and CNG is shown in Figure 1.

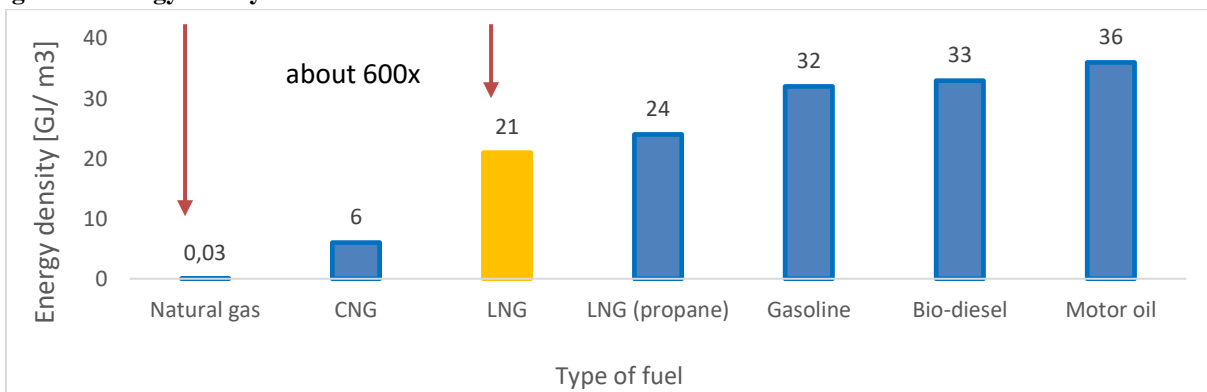
**Figure 1. Basic forms of natural gas processing and its components**



Source: [www.uniongas.com](http://www.uniongas.com) (access: 01.11.2019)

Given the fact that natural gas has a six hundred times higher energy density in the form of LNG ( $21 \text{ GJ/m}^3$ ) than in uncompressed form ( $0.03 \text{ GJ/m}^3$ ), the transport of natural gas is economically justified not only by traditional (onshore or offshore) pipelines but also by other means. For this reason, the maritime transport of LNG has over time become an alternative means of supplying natural gas volumes to areas with insufficient gas resources. The energy density of LNG per  $1 \text{ m}^3$  is also over three times higher than the energy density of CNG ( $6 \text{ GJ/m}^3$ ), but it should be remembered that it is about 1/3 lower in relation to traditional fuels – petrol or diesel (with energy densities of  $32$  and  $36 \text{ GJ/m}^3$  respectively). Figure 2 shows the energy densities of individual fuels.

**Figure 2. Energy sensity**

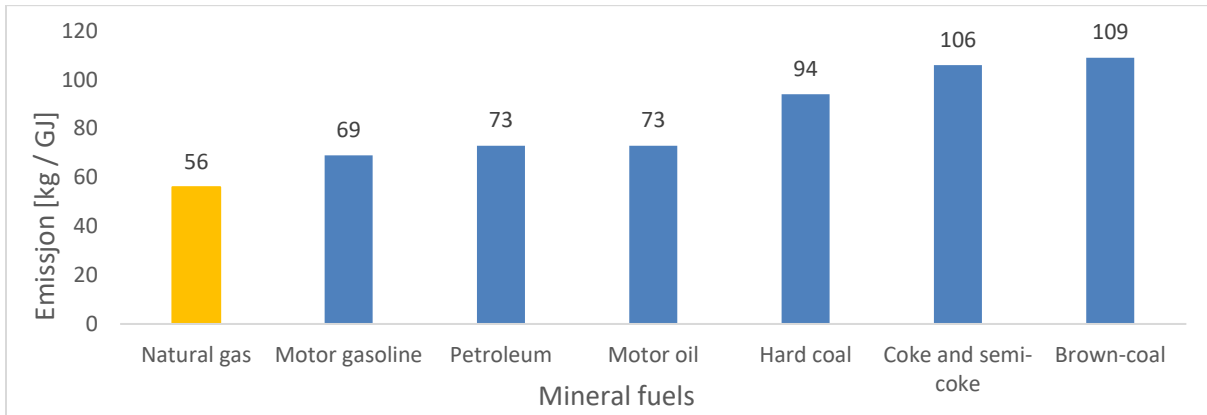


Source: [www.igg.pl](http://www.igg.pl) (access: 01.11.2019)

LNG is a much more environmentally friendly fuel than other fossil fuels. The carbon dioxide emission factor per unit of energy is equal to  $56 \text{ kg CO}_2/\text{GJ}$ , which means that the combustion

of natural gas emits almost 50% less CO<sub>2</sub> than the combustion of fossil fuels (coal and lignite), whose emission factors are 94 and 109 kg CO<sub>2</sub>/GJ respectively. Natural gas is also considerably more environmentally friendly as compared to liquid fuels (petrol and diesel), whose benchmarks are 69 and 73 kgCO<sub>2</sub>/GJ. These characteristics make the use of LNG for energy purposes more attractive, mainly in countries that are trying to reduce their greenhouse gas emissions. Figure 3 presents emission factors of selected types of fossil fuels.

**Figure 3. Energy sensity flues**



Source: Own calculations based on the data available: Calorific values (TOC) and CO<sub>2</sub> emission factors (EC) in 2016 to be reported under the Emission Allowance Trading Scheme for 2019, Warsaw 2018.

### LNG logistical supply chain

A supply chain is defined as a set of a specified number of units working together in an integrated way to deliver the right product to the right place, at the right time, at the right quality and at the lowest cost (Adamczewski 2001: 22). The supply chain includes integration that goes beyond a single company's area, because the supply chain is understood as the cooperating mining, processing, trade, logistics and other service companies that are involved in improving the flow of products, funds and information (Witkowski 2003: 15-20). Thus, the supply chain connects and refers to the participants in the process of bringing the finished product to the market.

The LNG supply chain can be described as a network of cooperating licensed companies engaged in the production of natural gas from onshore and offshore fields, as well as joint ventures using LNG production terminals (liquefying natural gas) and shipowners owning various types of specialised LNG vessels, LNG terminal receiving companies (regasification terminals) and end customers who buy natural gas, i.e. companies from different sectors of the economy and households. The main objective of the chain is to develop an adequate flow of natural gas from the extraction area to the customer while ensuring maximum efficiency from the perspective of the producer and end user.

In order to permit the free supply of natural gas, it has become necessary to supply, by sea, natural gas volumes to areas where there are insufficient natural gas resources. LNG import with the use of specialised ships (gas carriers) is a transport technology used in many countries. Liquefied natural gas trade began in 1965, when the first fixed route for LNG supplies from the Arzew

terminal (Algeria) to Canvey Island (Great Britain) (Filin and Zakrzewski 2006: 848; Dobrowolski and Kolodziejczak 2009: 10) was launched.

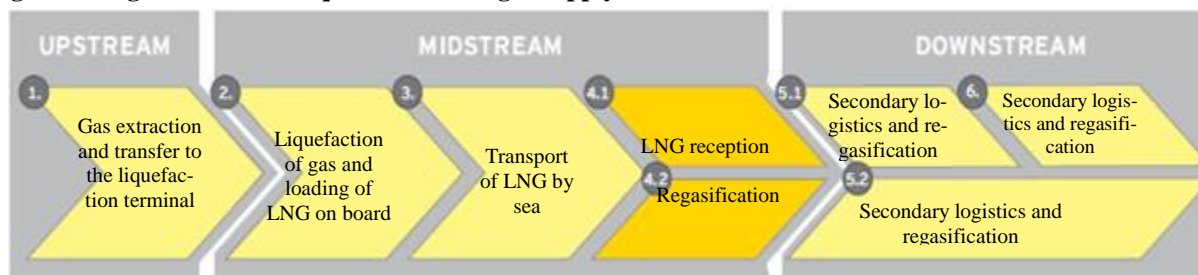
Maritime transport facilitates the import of LNG from various sources located in different parts of the world, which is a kind of guarantee of security of supply, despite the higher costs for land transport by pipeline for closer sources of supply. The condition for this type of supply is to have a maritime fleet with parameters adjusted to the sailing conditions prevailing in various parts of the world and LNG receiving terminals (Ficoń and Sokołowski 2012: 404-405).

The international transport of liquefied natural gas is carried out in accordance with the following steps:

1. Natural gas is usually supplied via pipelines from the field to liquefying installations, i.e. loading terminals also known as export or liquefaction terminals.
2. In export terminals, the process of liquefaction of gas is carried out and it is compressed onto ships or stored in tanks. LNG carrier ships (methane carriers) can accommodate from several tens of thousands to about 250 thousand m<sup>3</sup> of LNG (currently there are methane carriers under construction with a capacity exceeding 250 thousand m<sup>3</sup> of LNG).
3. LNG is delivered by sea in methane carriers to reception facilities – regasification terminals.
4. After the cargo has been delivered by sea to the receiving installation:
  - 4.1. Pressurising the LNG from the methane carrier ships to the shore and storing usually a small part of it in an unchanged form;
  - 4.2. the regasification process (change in the state of concentration from liquid to gas by increasing the temperature and volume of the natural gas) to which most of the transported liquid fuel is subject;
5. Liquefied natural gas can be transported further, e.g. by smaller methane carriers (so-called secondary logistics) or tankers. Secondary logistics usually concerns a small amount of volumes received at the terminal.
6. After regasification, liquefied natural gas is injected into the gas pipeline network or distributed to end users.

A simplified diagram of the flow of liquefied natural gas is shown in Figure 4.

**Figure 4. Logistics chain of liquefied natural gas supply**



Source: Own calculations based on the data available: "Wpływ terminalu LNG na rozwój społeczno-gospodarczy w Polsce i w województwie zachodniopomorskim". Ernst & Young Global Ltd. Warszawa 2013.

Due to the complexity of the LNG supply process, it is important to ensure that the process is carried out correctly in order not to lose the quality of liquid gas at any of the stages presented.



An adequate level of quality in the natural gas supply chain is ensured by the right infrastructure, which guarantees the smooth execution of all logistics processes. The physical flow of natural gas at all stages of the supply chain is most dependent on this (Ficoń and Sokołowski 2012: 403-404; Chłopińska and Nowakowska 2017: 1353; Łaciak 2011: 508; Łaciak, et. al. 2012: 430).

Export (liquefying) and import (regasification) terminals are a strategic element of LNG distribution logistics. The basic task of regasification terminals (such a terminal is located e.g. in Świnoujście) is to receive liquefied natural gas and then regasify it and inject it into the transmission network. Taking into account the functional solutions applied, it is possible to separate several types of LNG terminals (Analysis of costs and benefits of regional liquefied natural gas solution in the East Baltic area, including proposal for location and technical options under the Baltic Energy Market Interconnection Plan, Booz&Co, 2012):

- The onshore terminal – LNG is pumped from methane carriers to tanks located on land in close proximity to the port. Liquid gas is regasified in onshore installations and injected into the gas system.
- Maritime gravity terminal – the terminal together with regasification installations is located on an artificially created island. LNG is delivered to the terminal, regasified and injected into the onshore transmission network using an underwater gas pipeline.
- Regasification methane carrier – methane carriers transporting liquid gas may be equipped with regasification installations. Upon arrival of the methane carrier at the destination port, the LNG is regasified directly on board the vessel and injected into the onshore transmission network using an underwater gas pipeline.
- Maritime storage and regasification terminal – the terminal takes the form of a floating platform or a vessel equipped with LNG tanks and regasification infrastructure. The terminal can be permanently or temporarily immobilised at a specific point in the sea near the shore. Liquefied gas from methane carriers is pumped to the terminal, where it is regasified. The resulting gas is injected into the onshore transmission network via an underwater gas pipeline.

Some of the LNG can also be stored in cryogenic tanks – LNG storage facilities.

### **Settlement measurements of LNG – transferred energy**

The accounting of liquefied natural gas cargoes transported by sea has been carried out for a long time worldwide and expressed in units of energy. The accounting system functioning in unloading terminals is based on measurements of many components of values, on the basis of which the final value of energy "stored" in the unloaded quantity of transported LNG is calculated. The measurement idea is based on a precise assessment of the effective volume of the tested LNG batch and the determination of its calorific value. The product of both cases is the target energy value (Rosłonek 2015: 123).

Some of the measurements are made on the ship and these include (Rosłonek 2016: 91):

- measurement of LNG level in the cargo chamber of the gas carrier, carried out both before and after the start of the unloading process,

- measurement of the pressure of the gas phase located above the liquid in the cargo compartment of the LNG carrier,
- measurement of the temperature of the LNG in the carrier cargo compartment,
- measurement of the temperature of the gas phase above the liquid in the carrier cargo compartment,

Outside the ship, the chemical analysis of the transported LNG within the quality range of C<sub>1</sub>-C<sub>6+</sub>, N<sub>2</sub> and CO<sub>2</sub> is performed. Although in practice, in cargoes of liquid gas transported by sea, hydrocarbon components reaching more than C<sub>4</sub> do not occur, similarly to carbon dioxide. LNG quality control is the only "measurement" performed on land at a part of the terminal (Rosłonek 2016: 91).

On the basis of these measurements it becomes possible to calculate (GIIGNL 2015):

- the quantity of liquid gas in each cargo chamber of a gas carrier as the difference in height of the LNG liquid in the vessel's chamber before and after the unloading. In order to properly classify the height of the LNG column to its volume in the cargo chamber, so-called ship correction tables are used, taking into account its specificity – the list along the main axis of the hull (LIST) and the difference in draught of the bow and stern resulting from the momentary re-ballasting of the ship (TRIM), as well as from all kinds of tables concerning temperature correction coefficients affecting the thermocryogenic expansion/shrinkage of steel elements and the displacement of floating elements in the liquefied gas.
- calculation of the volume of BOG (Boil Off Gas – gas vapour transferred from onshore tanks to the gas tanker chambers when discharging the liquefied LNG) filling the space in the cargo chamber when the liquefied gas is discharged into the onshore terminal tanks – the volume of BOG introduced and the volume of LNG discharged should be equal,
- LNG density calculation is performed according to the algorithm ISO 6578,
- the calculation of the gross calorific value of the gas filling the gas carrier (BOG) chamber is performed according to the ISO 6976 algorithm,
- calculation of the gross calorific value of LNG according to the algorithm in ISO 6578,
- calculation of the final energy value of the unloaded batch.

During the unloading of LNG from the gas carrier to the tanks located at the receiving terminal, the total energy of LNG treated as fuel is calculated according to equation (1). In the case of loading onto a ship at the loading terminal, the formula (2) (GIIGNL 2015) is used to calculate the total energy. A diagram of the determination of the transferred LNG energy is shown in Figure 5.

$$E = V_{LNG} \cdot D_{LNG} \cdot GCV_{LNG} - E_{Gas\ displaced} - E_{Gas\ to\ ER} \quad (1)$$

$$E = V_{LNG} \cdot D_{LNG} \cdot GCV_{LNG} - E_{Gas\ displaced} + E_{Gas\ to\ ER} \quad (2)$$

where:

E – total 'net' energy reduced by that part of the energy 'transferred' in the form of BOG (E<sub>Gas displaced</sub>) from the terminal tanks to the cargo chambers of the liquefied natural gas carrier during the unloading of the LNG – or alternatively complementarily reduced by E<sub>Gas to ER</sub>,

V<sub>LNG</sub> – the volume of liquid gas discharged or transferred [m<sup>3</sup>],

$D_{LNG}$  – the density of the LNG [kg/m<sup>3</sup>],

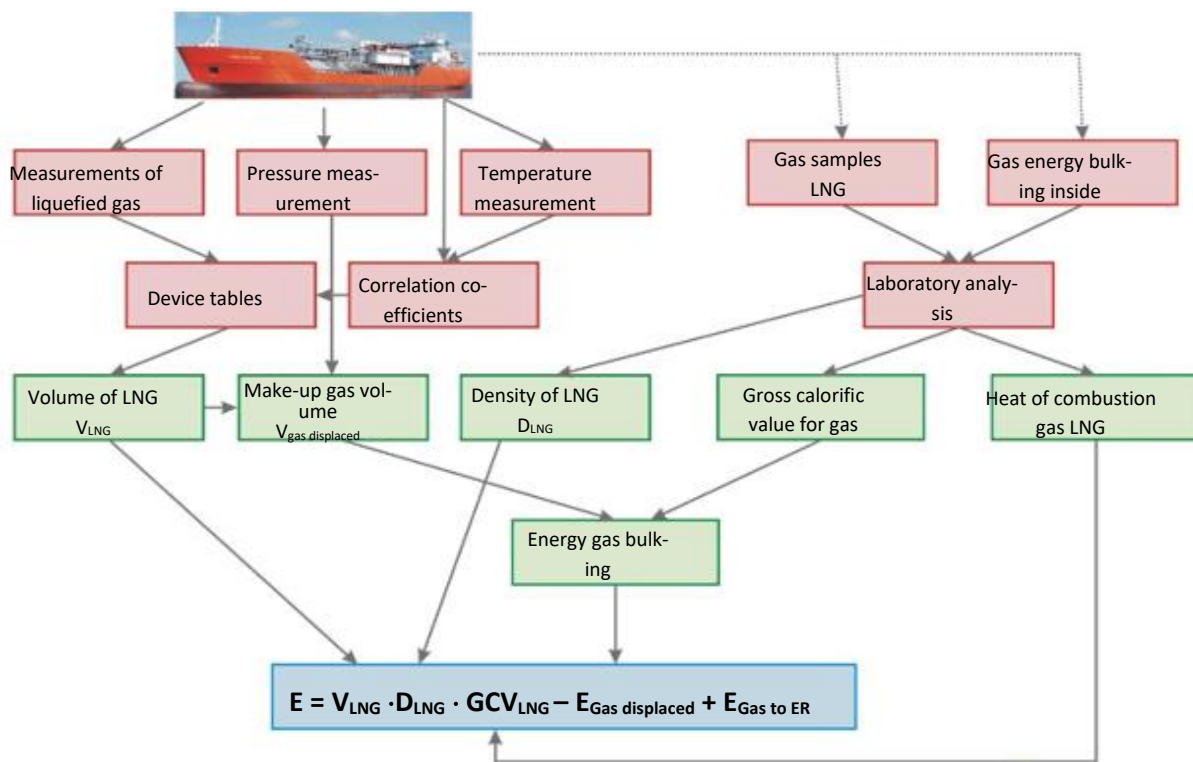
$GCV_{LNG}$  – the gross calorific value of liquefied natural gas in relation to the mass unit of the liquid (often referred to as GCV) [MJ/kg],

$E_{Gas\ displaced}$  – BOG energy [usually MMBTU],

$E_{Gas\ to\ ER}$  – energy consumed for the potential LNG supply of engines or motors on board the vessel for the operation of various systems on board (most often during loading/unloading  $E_{Gas\ to\ ER} = 0$ ) [usually MMBTU].

In international trade in liquid gas, the most frequently used unit of account is the British heat unit – MMBTU (million British thermal units, 1 MMBTU = 106 BTU), but it is not an SI unit. The BTU value indicates the amount of energy needed to increase the temperature of one pound of water by one degree Fahrenheit. Due to the imprecise nature of the definition of this unit and due to the change in the specific heat value of water at different temperatures, the energy value oscillates between 1054 J and 1059 J (i.e. from about  $2.92 \cdot 10^{-4}$  kWh to about  $2.94 \cdot 10^{-4}$  kWh) (Nerc-Pełka 2009: 138-139).

**Figure 5. Scheme determination of the LNG energy transferred**



Source: Own calculations based on the data available: GIIGNL 2015

The BOG energy value represents a small part of the total "net" energy, so it is often assumed in the calculations that the BOG vapours are pure methane, which is additionally treated as a perfect gas. The compressibility parameter for BOG vapours should not be taken into account in this determination. This is justified because, as mentioned above, the BOG energy is a relatively small element in equation (1) and the vapour pressure of the BOG slightly exceeds the atmospheric pressure. On a large number of unloading terminals, the  $E_{Gas\ displaced}$  segment is not calculated, but

a constant value, e.g. 0.3% (GIIGNL 2015). The simplifications presented do not contribute to any material error, but merely facilitate the practical use of equation (1).

In practice, all calculations performed during LNG unloading are usually performed twice – on the ship and at the receiving terminal, by CTMS (custody transfer measurement system).

### **Quality control of transported LNG**

In order to determine the value of LNG energy in the settlement process of the load (delivered and unloaded in the receiving terminal), it is necessary to precisely define its composition. Ongoing analyses of the quality of the liquid gas are carried out on the basis of which it is possible to calculate the density of the LNG and any calorific values. As in the case of natural gas quality control in line infrastructure, gas chromatography (Roslonek et al. 2005: 7-8) is used for quality control in offshore LNG terminals. Considering the need to ensure constant measurement and analytical supervision over gas chromatographs, these devices are located exclusively on land (within the terminals). During the unloading of LNG, liquid samples are taken and directly regasified. A representative evaporated LNG sample is analysed for content. Analyses within the terminals are performed using process gas chromatographs on-line or in stationary laboratories (Roslonek 2016: 93).

### **Proposal to use control cards to monitor the transferred LNG energy**

The multithreaded nature and complexity of the problems to be solved by the various organisations present in the LNG supply chain make it necessary to select appropriate methods in the decision-making support process, on strategic and operational grounds. The Statistical Process Control (SPC) is a possible proposal for a method to support the quality assurance of transported liquid gas and at the same time to improve the quality of the organisation's operations.

Due to the growing emphasis on quality (TQM) in all types of organisations, it seems obvious that SPC should be applied to non-production processes. SPC has been used, among other places, in supply systems (Zurier 1989), transport systems, service systems (Mundy et al. 1986) and in the fuel and energy industry (Lager 1999; Thomson et al. 2000; Braga et al. 2013). The wide range of SPC applications is due to the fact that in any larger system, whether it is a district heating/cogeneration, electricity or gas system, variability will occur sooner or later, making a statistical approach to prevent process deregulation desirable (Saluga et al. 2017: 27-28). Control cards are an easy to use and relatively effective tool to prevent this problem.

Process control cards are among the oldest tools for statistical quality control (Mazur and Gołaś 2010: 60). With the help of control cards, it is possible to track the status of selected characteristics on the basis of samples (taken at specified intervals), while an excessive level of deviation of the values of controlled characteristics signals the presence of special disturbances, which must be eliminated by corrective actions. In view of the fact that there are deviations in each actual process, it is necessary to define the tolerances for the lower and upper control limits, which are indicated on the control charts as a line. If the values of the characteristics of the subsequent samples taken from the stream of product to be tested are within the specified control lines (GLK and DLK), then the process can be considered stable and running properly (Myszewski 2009: 129-

130). Process deregulation occurs when one of the border (control) or warning lines has been crossed.

In contrast to 100% or even step control, most of the control cards are designed for multi-part samples, which makes them cheaper, faster and very effective with the use of appropriate methodology. Diagnostics of several or even a dozen elementary samples is basically the only solution in the case of destructive testing. However, the control cards are not devoid of imperfections. In addition to the need to use an adequate methodology, special attention should be paid to the skilful selection of the control card and the randomness of sampling. It should also be noted whether there was no correlation between the properties of goods in the tested sample (Szymaszal et al. 2006:367; Bartkowiak 2011: 63-64). These shortcomings should be highlighted in particular in processes other than typical production processes. This is the case, for example, with measurements of liquefied natural gas, specifically one of the components of the LNG volume coefficient – temperature, since the temperature of liquid gas in one sample area depends on the temperature in the neighbouring area. A particular application of the SPC could take place in the area of pumping LNG to the tanker. It seems advisable to monitor the flow of gas. This objective is economically justifiable. Pumping poor quality LNG into the tanker and only then performing the current quality control, even repeated at the customer's, will not protect against technical, organisational and economic consequences. Due to the specific nature of the LNG transport process to the terminal, an appropriate control card was selected for the analysis of the stability of the quality of liquid gas supplies for continuous processes and low variability between subsequent samples. It was a two-track numerical control card for stabilisation of single measurements and moving range IX - MR (Xi - MR). On this card, position measurements are monitored by single measurements of a selected feature, and the so-called moving ranges (MR), which are the absolute value of the difference between two consecutive measurements, are used as a measure of variability. On the IX – MR card, the average value of moving spreads is the starting point for determining the control position of the limits in the card. The draft form for assessing the stability of the quality level of LNG supply is presented in Figure 6.

The chart of the card shows five lines::

- Upper control line (GLK),
- Central line (LC),
- Lower control line (DLK) – if its value does not appear in the chart of moving ranges, it is assumed to be equal to 0.

Sometimes, after some time of using the card, the following warning lines are added: upper warning line for track value IX (GLOIX), lower warning line for track value IX (DLO), upper warning line for track value MR (GLOMR). Their values are determined from formulae analogous to control lines but taking into account indicators selected from tables depending on the situation.

The value of the control card line is calculated as follows:  
For track values of individual measurements (IX):

- Calculation of average sample values:

$$\bar{x} = \frac{\sum x}{n} \quad (3)$$

- Calculation of the central line value (LC) for the single measurement value track (IX):

$$LC = \bar{x} = \frac{\sum x_i}{n} \quad (4)$$

- Calculation of the moving range mean value from single measurements:

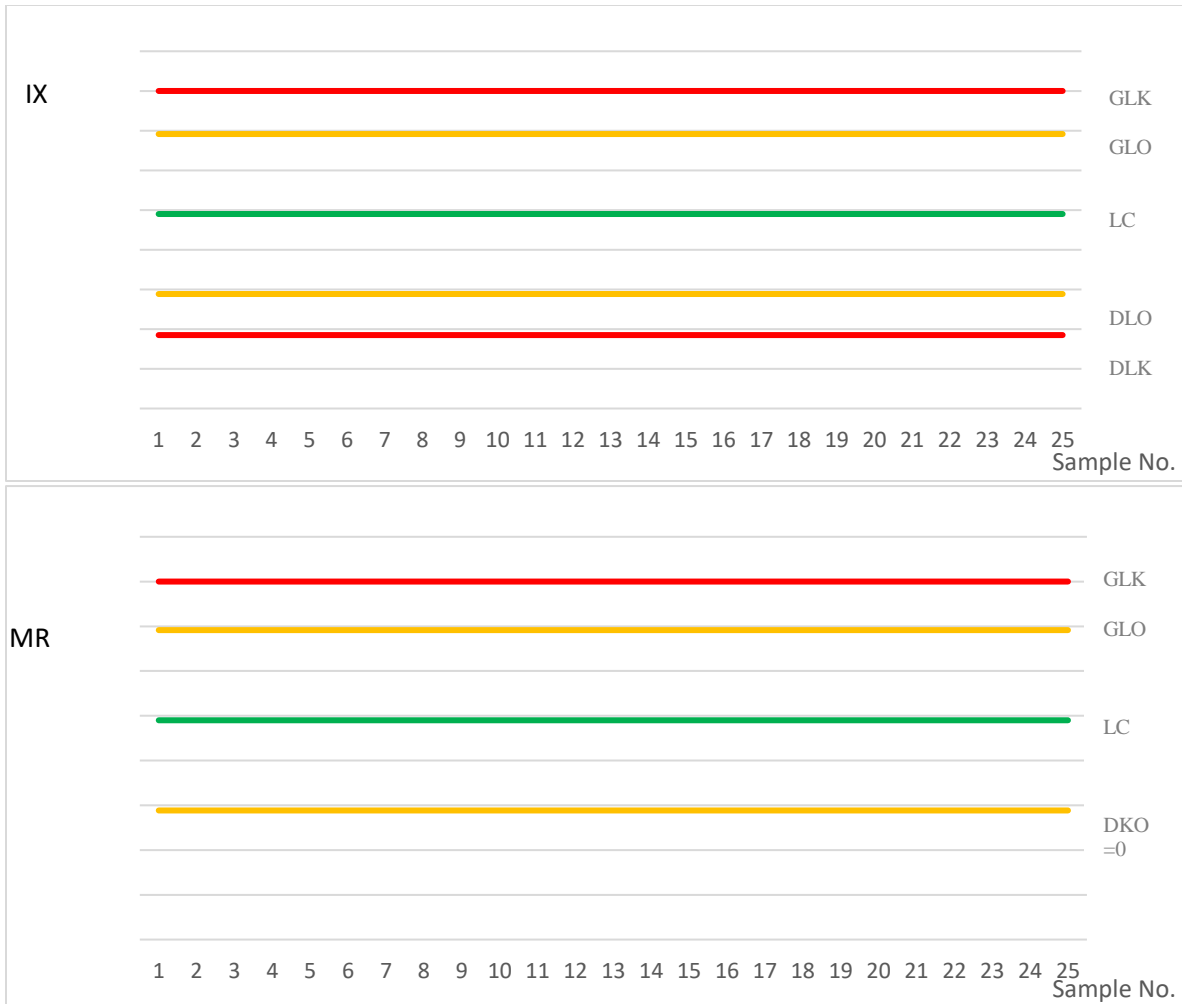
$$C\overline{MR} = \frac{\sum MR}{n-1} \quad (5)$$

$$DLK = \bar{x} - 2,66 \cdot \overline{MR} \quad (7)$$

$A_3$  for e.g. two-element samples (individual measurements) equals 2.66.

**Figure 6. Draft of a charter of control IX – MR**

Company logo			CONTROL CARD IX - MR								Date of issue:		
Terminal:			Control card number:					Period between samples:					
Ship:			Gas carrier unloading chamber number:						The number of samples:				
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13
1													
2													
3													
4													
<b>Sum</b>													
$\bar{x}$													
<b>R</b>													
Sample No.	14	15	16	17	18	19	20	21	22	23	24	25	26
1													
2													
3													
4													
<b>Sum</b>													
$\bar{x}$													
<b>R</b>													



Source: Own calculations

For the MR movable range tracks:

- The moving range is calculated as the absolute difference between the measurements of the values of adjacent samples.
- Calculation of the centreline value (LC) for the path of moving ranges (already calculated value):

$$LC = \overline{MR} = \frac{\sum MR}{n-1} \quad (8)$$

- Calculation of the upper (GLK) and lower (DLK) control lines for the single measurement value track (IX)

$$GLK = 3,27 \cdot \overline{MR} \quad (9)$$

$$DLK = 0 \quad (10)$$

$D_4$  for two-element samples (individual measurements) equals 3.27.

The formulae for this card use the designations:

$x_i$ - the  $i$ th value of the feature,

n- number of measurements,

MR- mobile range calculated from the formula:

$$MR = |x_i - x_{i-1}| \quad (11)$$

$\overline{MR}$ - average value of the mobile range.

The analysis of control grids is limited to determining, on the basis of the results obtained (shape of the diagrams drawn up), whether there are grounds for considering the monitored process as maladjusted. If there are no indications to that effect, the process should be considered as correct and no corrective actions should be taken. However, when there are signals, intervention is needed. Possible signals are described in the PN-ISO 8258 standard. The classic signal forcing an intervention is the crossing of a control line. Nevertheless, other signals are also used for analysis, e.g. trends (7 consecutive values of increasing or decreasing character) or runs (7 consecutive values on one side of the central line).

The use of control cards makes it possible to improve the quality level with relatively low costs (much lower than e.g. modernisation of the machine park). The most important benefits of using control cards are (Montgomery 1997: 227; Demski 2009: 48-49):

- Prevention of problems – the use of control cards makes it easier to detect trends and changes in the process, which makes it possible to detect disturbing changes in the process before it starts producing non-compliant products (in our case LNG with inappropriate parameters).
- Avoidance of unnecessary corrections – control cards make it easier to distinguish random changes from changes to which eliminable causes can be attributed,
- Determination of the average value of the quality indicators of the product (LNG) and the range of variability, so that it is possible, for example, to determine the expected fraction of non-compliant product or to choose a better way of securing the cargo.

For the unloading of liquid gas, monitoring of the quality of the unloaded LNG (analysis of the results obtained from the samples within the control chart charts) will make it possible to stop the unloading in case of a diagnosis of inadequate LNG quality to avoid problems and unnecessary costs. The information from the proposed single measurement control card will protect against unloading LNG of low energy value into the storage tanks of the terminals.

An additional advantage of using the proposed control card is that it is easy to use and understand. The proposed form is a tool that enables the analysis and monitoring of the LNG quality level at the unloading point.

### Summary

The belief in the good quality of liquid gas determines whether the customer is satisfied and loyal. The most important criterion in this respect is confidence in the level of quality offered. Measures and systems to ensure the safety and security of both LNG installations and transport are constantly being improved. The constant development of technologies (terminals, storage tanks, methane carriers, monitoring devices, etc.) contributes to raising high standards in LNG operation.



Recently, Poland has joined the group of countries and companies that participate in the global trade in liquefied gas supplied by sea transport. The rules of LNG settlement in offshore terminals differ from those used for settlement of gases in linear infrastructure. Therefore, the article presents general methods of accounting and quality control of liquid gas in offshore terminals. In addition, the types of measurements used in LNG settlements carried out both on land and on ships were analysed. The aim of the article was to analyse the way of ensuring and supervising the quality level of transported LNG and to present a draft form of assessment and monitoring of the stability of the quality level of LNG supplies with the use of a single measurement control card.

The proposed solution for monitoring the level of quality of LNG received by terminal storage will allow, in the case of obtaining results exceeding control lines or a series of disturbing results indicating inadequate LNG quality, unloading to be stopped in order to avoid technical problems and often significant costs. The information from the proposed single measurement control card will be able to protect against unloading LNG of low energy value into the storage tanks of the terminals.

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

*Paulina Zwolenik*

## 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<sup>3</sup>, which represents an increase of 22.97 billion m<sup>3</sup> 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.

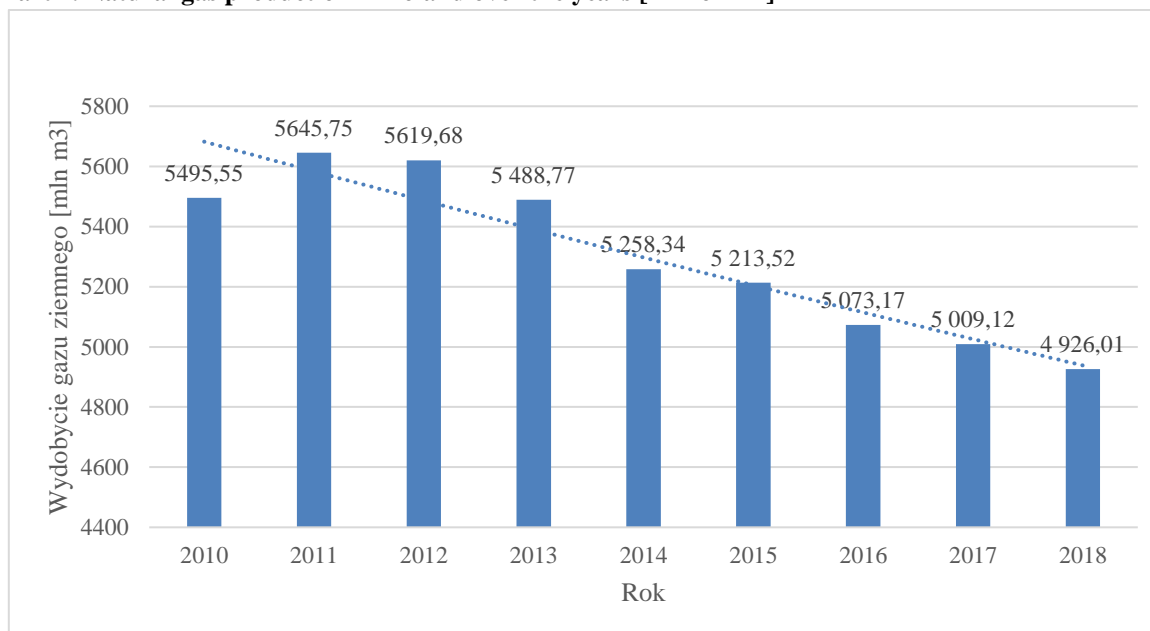
**Table 1. Natural gas production in Poland [million m<sup>3</sup>]**

Description	Year								
	2010	2011	2012	2013	2014	2015	2016	2017	2018
<b>TOTAL</b>	<b>5495.55</b>	<b>5645.75</b>	<b>5619.68</b>	<b>5 488.77</b>	<b>5 258.34</b>	<b>5 213.52</b>	<b>5 073.17</b>	<b>5 009.12</b>	<b>4 926.01</b>
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.

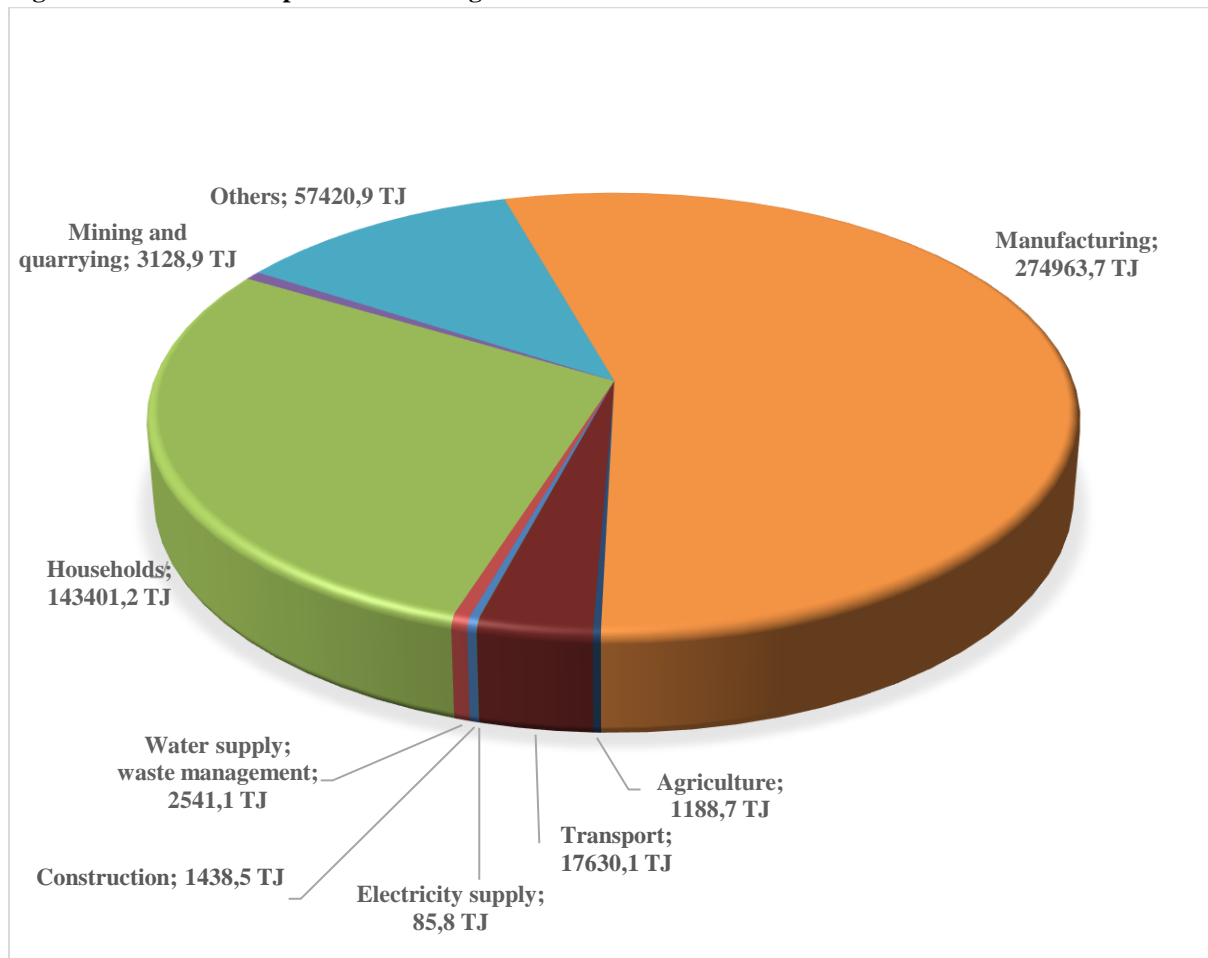
**Chart 1. Natural gas production in Poland over the years [million m<sup>3</sup>]**



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.

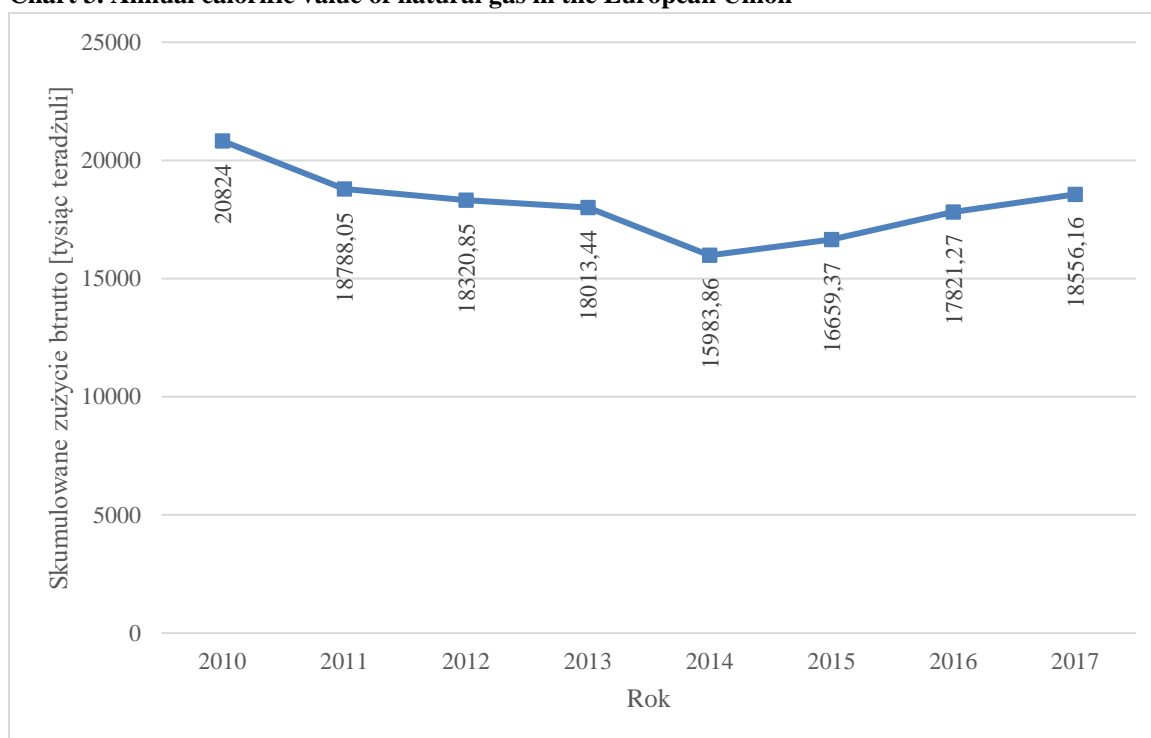
**Table 2. Annual production of natural gas in Europe [bcm]**

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
<b>Total Europe</b>	<b>310.6</b>	<b>285.5</b>	<b>288.1</b>	<b>280.7</b>	<b>267.4</b>	<b>261.6</b>	<b>260.4</b>	<b>263.3</b>	<b>250.6</b>

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).

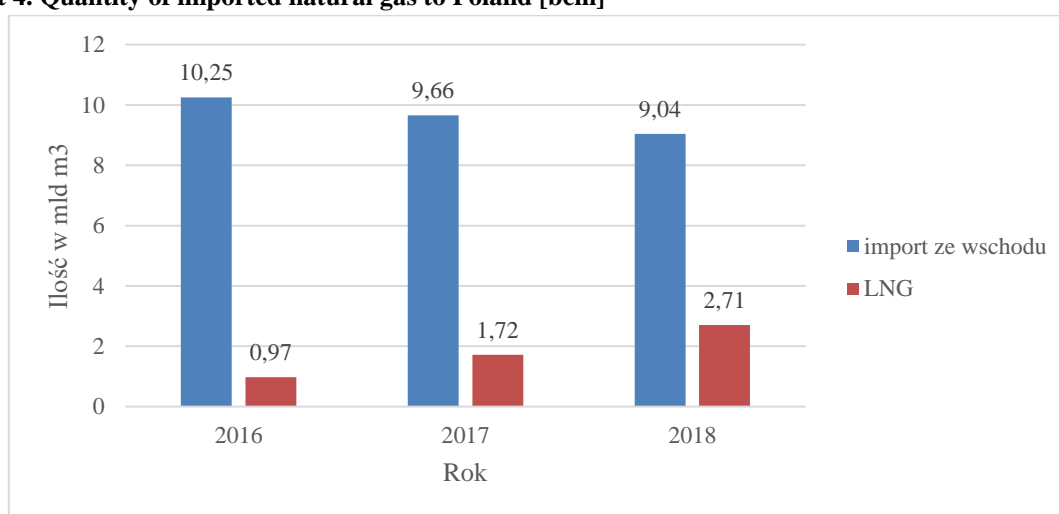
Import in the case of Polish demand for gas is unavoidable. According to the PGNiG's data, domestic production has reached 3.8 bcm, which constitutes about 22% of the source of gas supply. The remaining part, i.e. 13.5 bcm, is imported from Poland. Polish imports of natural gas include pipeline supplies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

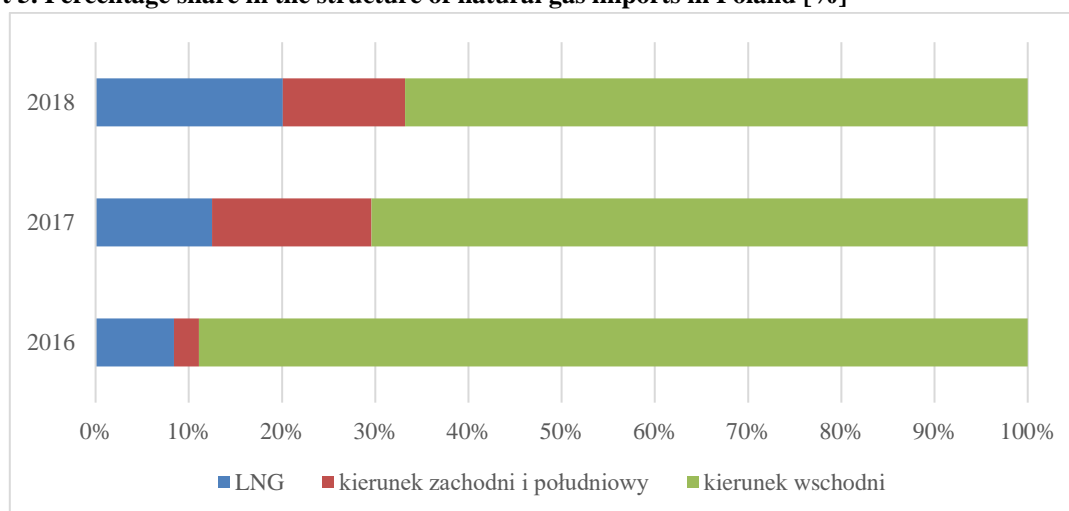
The LNG terminal has been in operation since 2016, reaching in 2018 over 20% share in the import structure. Since then, supplies from the East have been reduced – from 88.9% to 66.8%, but they cannot be completely excluded, as under the Yamal contract PGNiG undertook to pay Gazprom for 85% of the contractual 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.).



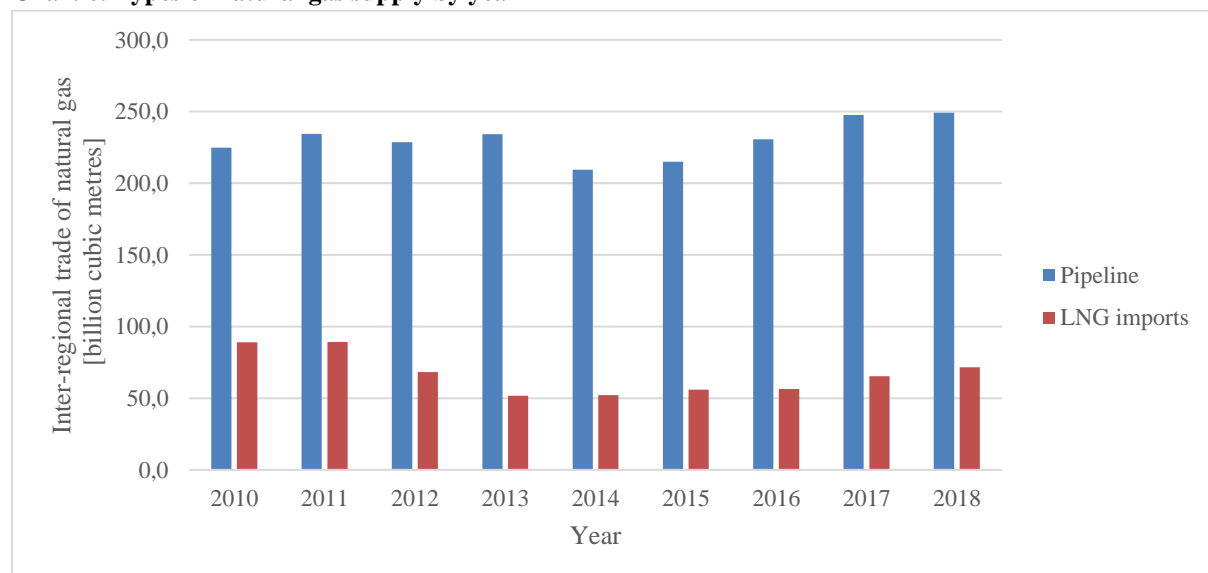
Natural gas imports to Europe were as follows: in 2018 European countries imported 320.6 bcm of natural gas to meet their energy needs, 7.9 bcm more than in the previous year. Although supplies from the pipeline continued to dominate the energy market, the share of LNG was gradually increasing. In 2018, 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	
<b>Total imports</b>	<b>313.9</b>	<b>323.6</b>	<b>296.7</b>	<b>285.8</b>	<b>261.4</b>	<b>271.0</b>	<b>287.0</b>	<b>312.7</b>	<b>320.6</b>	

Source: Dudley 2019:38.

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



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

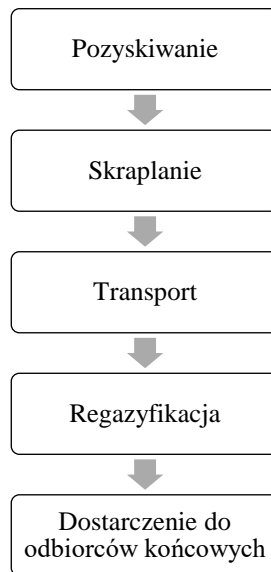
### Natural gas flow in the form of LNG from producer to consumer

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 on-shore 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

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water and carbon dioxide. This minimises the risk of solid particles that would be formed when the gas is cooled down to approx.  $-160^{\circ}\text{C}$ . 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 aluminium 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<sup>3</sup>. 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 (Roślonek 2016: 92-93).

The largest import terminal in Europe is located in the Isle of Grain in the UK. It has 1 million m<sup>3</sup> 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 – SCVs*), 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<sup>3</sup>. 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 <sup>3</sup> /h]	Annual nominal throughput [bcm/year]	LNG storage capacity LNG [m <sup>3</sup> ]	Number of tanks	Maximum LNG ship size serviced [m <sup>3</sup> ]
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 Atlántico, 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 Industriegaser	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 Iskenderun (Dörtüyl)	BOTAŞ Petroleum Pipeline Company	2019	830 000	7.30	263 000	-	-
	Marmara Ereğlisi 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 expected 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 <sup>3</sup> /h]	Planned annual nominal efficiency [bcm/rok]	Storage capacity for storing LNG [m <sup>3</sup> ]	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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# OPPORTUNITIES AND THREATS FOR THE INTRODUCTION OF NUCLEAR POWER IN POLAND

*Paulina Potyrańska*

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## **Abstract**

The goal of the study is to show the potential for nuclear power development in Poland. SWOT and PEEST analyses were used, which in a multifaceted way showed the opportunities and threats of investment in this project. Based on the draft document Energy Policy of Poland until 2040 (PEP2040), the plans and actions aimed at the construction of the first Polish nuclear power plant are presented. The review of the operating costs of a nuclear power plant has made it possible to analyse the efficiency of nuclear investment by comparing the expected costs with the achievable results. It has been shown that obtaining energy from uranium will contribute to the country's energy security, competitiveness of the economy, and improvement in air quality in the long term. Diversification of energy sources will allow Poland to become more energy independent and adapt its energy sector to climate challenges.

**Keywords:** nuclear power engineering, first nuclear power plant in Poland, energy security, diversification of energy sources, Polish energy policy

## **Introduction**

Electricity is seen by many as one of the elementary goods. It is therefore difficult to imagine functioning without access to it, especially in industrialised countries, which include Poland. In the 1950s, the first nuclear power plants were commissioned: Obninsk (1954, USSR) and Calder Hall (1956, UK), which initiated the energy revolution. Worldwide, nuclear power plants are located in more than 30 countries – in the European Union (EU) 14 countries alone use nuclear power, which accounts for half of all EU member states. Poland is one of the few developed countries in Europe where no nuclear power plant operates.

Restrictions on access to fossil fuels (which include coal, oil and natural gas), insufficiently developed renewable energy sources, climate change caused by excessive environmental pollution and progressive global warming of the planet, growing demand for electricity – these are just a few of the problems that Poland is currently struggling with. In order to solve these difficulties, diversification of energy sources is necessary. This is possible, inter alia, through the construction of a nuclear power plant, from which energy would be obtained as a result of nuclear reactions (nuclear fission or fusion). The development of nuclear energy will allow Poland to become more energy-independent. Moreover, it would make it possible to achieve all the objectives of the national energy policy:

- energy security;
- energy competitiveness and efficiency;
- limited impact of power engineering on the environment.

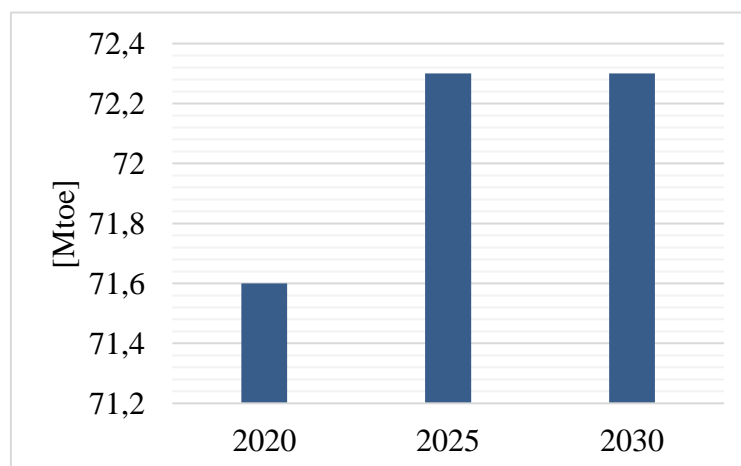
## Interest in nuclear energy in Poland

For years, the subject of nuclear power development in Poland has been the subject of intense public discussion. The first plans and talks began in 1956, when the Office of the Government Plenipotentiary for the Use of Nuclear Energy was established on 6 July to coordinate organisational and administrative work in the field of nuclear science and technology. It was composed of 40 members and its term of office lasted 2 years. In 1973 this office was transformed into the Atomic Energy Office, which worked until 1980. In 1972, it was decided that the first nuclear power plant in Poland would be located in Żarnowiec. In 1975, the Government Presidium issued a decision no. 20/75 of 14 February on the directions of using nuclear energy in the national economy, according to which the power plant in Żarnowiec was to be commissioned in 1983, but two years after this decision the date was postponed to 1985. At that time, a decision was also made to locate another power plant in Klempicz. Despite the advancement of the construction work in 1990, the work was interrupted. One of the reasons for this was the concern about the safety of the power plant caused by the Chernobyl disaster. This event slowed down the development of nuclear power in Poland for many years. It was only in 2005 that a document entitled "Energy Policy of Poland until 2025" considered the possibility of building nuclear power plants in Poland. In 2009, the Council of Ministers published the document entitled "Energy Policy of Poland until 2030", which provided for the construction of a power plant. According to this document, it would be opened in 2024. On 28 January 2014, it was decided to adopt the Polish Nuclear Energy Programme (PNEP). The main tasks of the PNEP include defining the objectives for the implementation of nuclear energy in Poland.

## Poland's energy policy

As a result of economic growth, development of new technologies and changes in the lifestyle of citizens, the demand for energy is growing (Figure 1.). In order to ensure the satisfaction of the growing demand, it is necessary to diversify the energy sources, as well as to reduce the emission of air pollutants (above all CO<sub>2</sub>); therefore Poland should develop low-emission energy sources (renewable energy sources (RES) and nuclear energy).

**Figure 1. Projections of the structure of final energy demand in Poland in 2020-2030, in millions of tonnes of oil equivalent [Mtoe]**



Source: Own study based on the document *Forecast of demand for fuels and energy up to 2050*, Agencja Rynku Energii S.A.

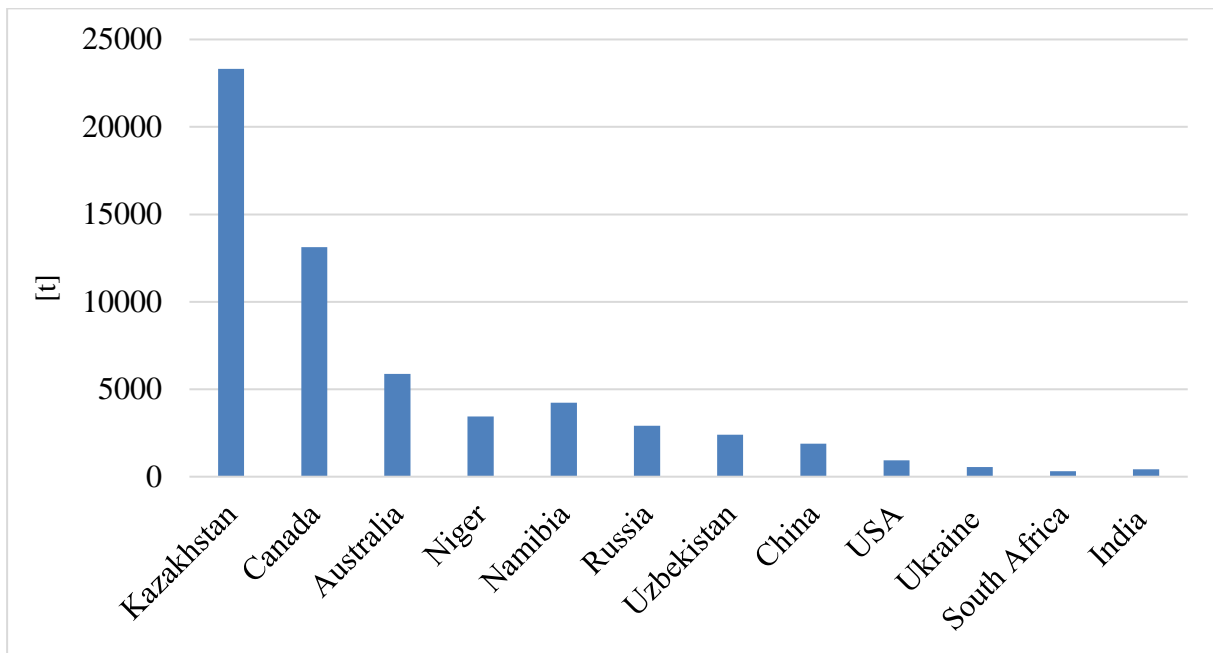
On 23 November 2018, the Ministry of Energy published a draft document entitled "Energy Policy of Poland until 2040" (PEP2040), which developed eight energy policy orientations, including the implementation of nuclear energy as the fifth. Its aim is to reduce the emissions of the energy sector and to make the system safe to operate. The commissioning of the first nuclear unit of the power plant, with a capacity of 1-1.5 GW, dates to 2033. By 2043, another five nuclear units with a total capacity of approximately 6-9 GW are planned to be opened. In order to efficiently implement the project, it is necessary to ensure and improve formal, legal and financial conditions for the construction and operation of the first Polish nuclear power plant, including the integration of part of the administrative proceedings, enabling simultaneous application for permits, and making the procedures for the participation in the contract more flexible. Another element of the fifth direction is the qualification of appropriate staff and the launch of research and development potential to provide a technical support tool for supervision units (State Atomic Energy Agency, Office of Technical Inspection). Requirements and action paths will be included in the Human Resources Development Programme for Nuclear Power. The last issue addressed in PEP2040 is the disposal of low and intermediate level waste to be collected at the national radioactive waste disposal site, but this will not be sufficient, and therefore there are plans to open a new disposal site for low and intermediate level waste in 2027.

According to PEP2040, the choice of location is determined by the availability of cooling water and the possibility of capacity evacuation and other capacity withdrawals in individual parts of the country. Taking into account the above factors, the location of the nuclear power plant on the Polish coast – Kopalino or Żarnowiec, as well as in central Poland – in the vicinity of Bełchatów is being considered. In accordance with PEP2040, the Polish Ministry of Energy will take the final decision on the location of the first unit of the power plant in 2020.

### **Diversification of uranium supply sources**

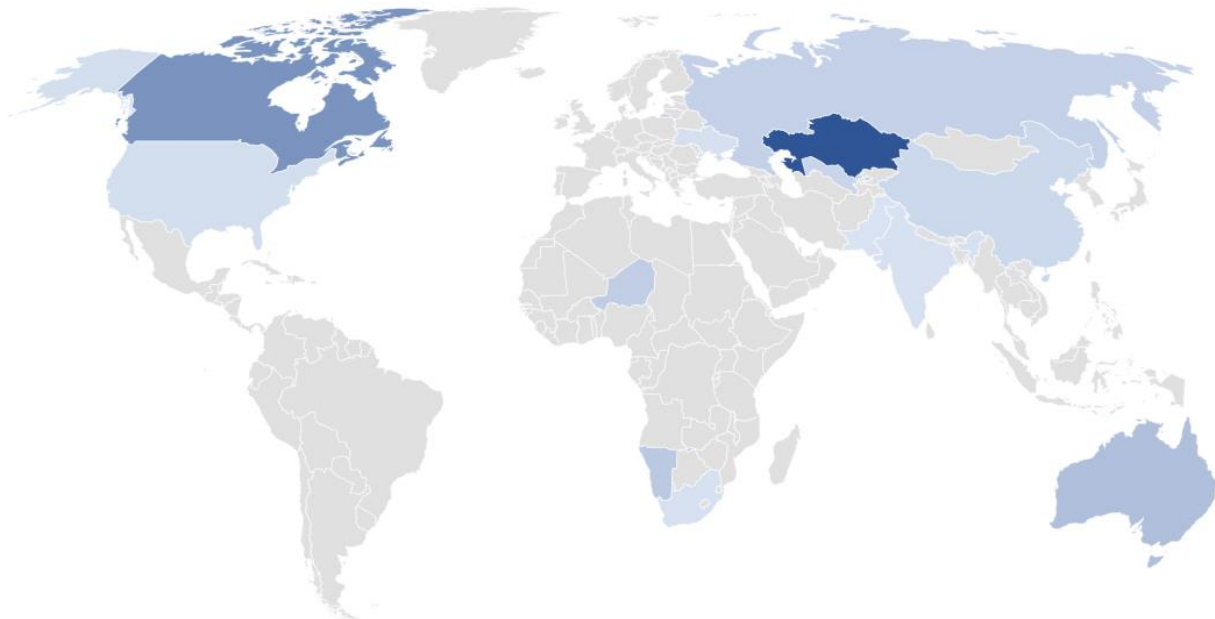
Poland only has resources of poor ores, therefore it is not possible to cover the demand for uranium from conventional and unconventional deposits (e.g. from ashes) in the context of the construction of a nuclear power plant. As a result, Poland will be obliged to obtain this element in another way, namely to import it from other countries. Australia, Kazakhstan, Russia and Canada have the largest deposits of uranium, and with the currently discovered deposits, developed technology and demand for the element, uranium should be sufficient for more than 100 years. The largest uranium producers are Kazakhstan, Canada, Australia, Niger, Namibia, Russia, Uzbekistan and China (Figure 2., Map 1.).

**Figure 2. World uranium production in 2017, tonnes [t]**



Source: Own study based on <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx> (access: 10.07.2019)

**Map 1. Uranium mining in 2017**



Source: Own study based on <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx> (access: 10.07.2019)

Potential contractors for a nuclear power plant in Poland include the United States (USA) and South Korea. During the I Polish-Korean Nuclear Forum, organised by the Polish Ministry of Energy and the Embassy of South Korea in Poland on 20 September 2018 in Warsaw, talks among representatives of nuclear energy companies on business cooperation took place. Korean concern Doosan Heavy Industries&Construction, which manufactured the most important parts of the AP1000 reactors by Westinghouse, proposed the transfer of production



technology. In November 2018, U.S. Energy Secretary Rick Perry announced that the Americans were ready to sell the technology and build a nuclear power plant, as well as to share in the costs. On 8 November 2018, the Joint Declaration of the US Department of Energy and the Polish Ministry of Energy on enhanced cooperation in the field of energy security concerning, among others, security of gas supply, nuclear energy and cyber-security was signed. On 12 June 2019, Piotr Naimski, Government Plenipotentiary for Strategic Energy Infrastructure, and Rick Perry, US Secretary of Energy, signed a Memorandum of Understanding (MoU) on cooperation in the field of civil nuclear energy. The agreement is an expression of both parties' willingness to cooperate in the fifth direction of the draft Polish Energy Policy until 2040 (PEP2040). The American candidate is Westinghouse, which has produced over 440 nuclear reactors, including four AP1000 reactors in China. According to PEP2040, the final selection of the technology and the general contractor for the first Polish nuclear power plant will take place in 2021.

### **Energy security and nuclear energy**

A modern energy policy for the country should place emphasis on ensuring energy security, defined as the state of the economy allowing the prospective demand of consumers for fuels and energy in a technically and economically justified manner to be covered, while maintaining the requirements of environmental protection (Energy Law 1997, Journal of Laws No. 54, item 348, p. 10). Management of the country's energy security is connected with three aspects: energy, economic and ecological.

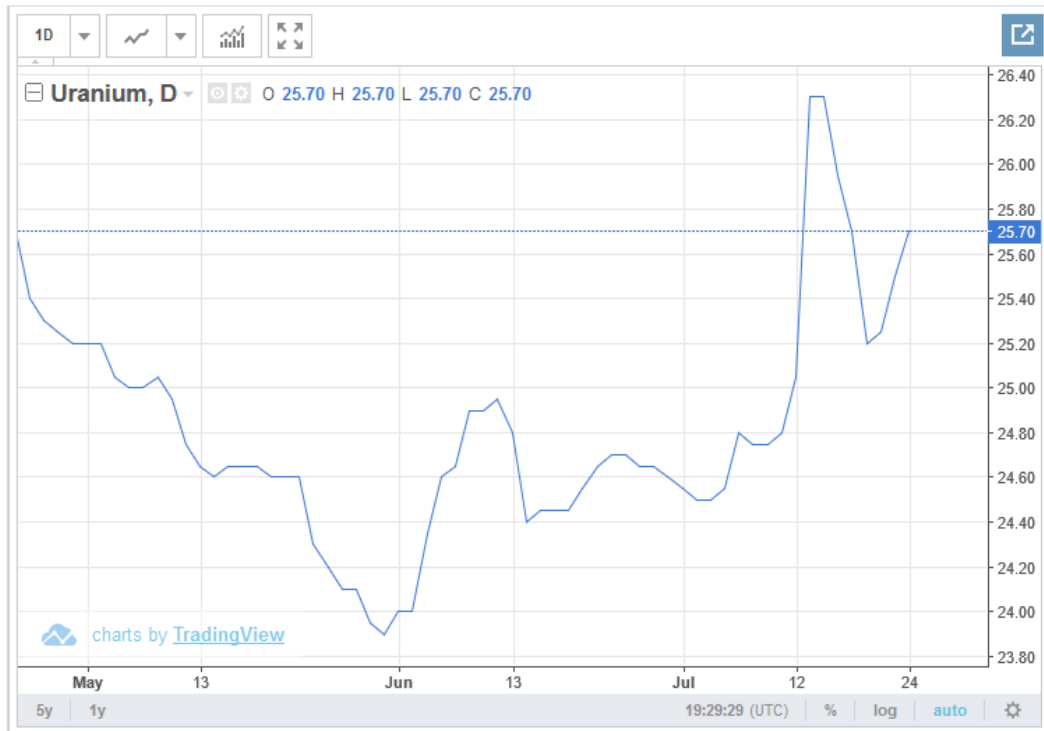
The energy aspect is related to balancing the demand and supply side and ensuring the reliability of the system. Maintaining the energy balance means guaranteeing an adequate amount of energy raw materials so as to be ready to meet the needs of useful energy consumers at any time. Ensuring the reliability of the system concerns the ability to deliver the required quantities and standards of power. The economic aspect refers to ensuring that demand for usable energy is met at socially acceptable prices, which are set in contracts/tariffs. The environmental aspect concerns the observance of the binding principles of environmental protection, which means that the energy sector should not contribute, among other things, to the degradation of the natural environment and to the creation of irreversible states. This is primarily related to investment in clean energy technologies: renewable energy sources (RES) and nuclear energy.

Nuclear energy is part of all aspects of energy security:

- I. A nuclear power plant in Poland will ensure that the energy balance is maintained, as it will diversify the energy sector, which will result in less dependence on fossil fuels (to the greatest extent on coal) and on the state of the weather (in the case of renewable energy sources, including wind power plants). In the long term, coal, oil and natural gas will be insufficient to produce electricity because, given the increasing demand for energy and limited access to these raw materials, they will not be able to meet demand at some point in the future and, as a consequence, the energy balance will be interrupted. The balance between diversified energy sources affects the increase in the country's energy security. Uranium deposits are located in politically stable countries, making the supply of this fuel less endangered and systematic. In addition, uranium is a raw material that is easy to transport and store.

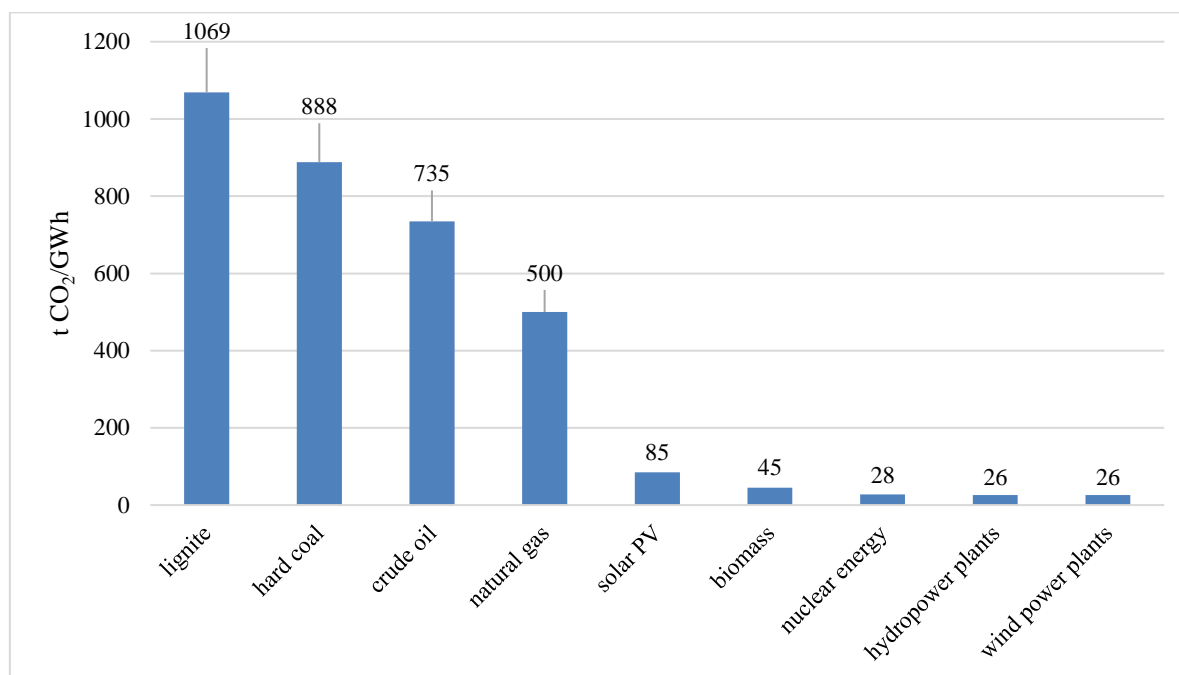
- II. As shown in the chart below (Figure 3.), the price of a pound of uranium ranges from USD 23.9 to USD 26.3, nuclear reactors are cheap to operate, and the price of electricity is almost insensitive to fluctuations in uranium prices (this is due to the relatively small amount of fuel used to produce energy). In addition, contracts with uranium suppliers are mostly long-term, which is a long-term guarantee of access to fuel.

**Figure 3. Evolution of the price of the uranium per pound [in USD], from May 24 to July 24 2019**



Source: <https://tradingeconomics.com/commodity/uranium> (access: 24.07.2019)

- III. In Poland, radioactive waste due to the activity of radioactive elements is divided into three groups: highly active, medium active and low active. Each of these groups requires different treatment for transport, disposal and storage. The disposal of radioactive waste takes place in specially designated areas at the National Radioactive Waste Repository (an additional repository is planned to be opened in 2027). Another issue is the concern about a major accident at a nuclear power plant and radioactive contamination. These are justified (Chernobyl (1986) and Fukushima (2011)); however, the power plants currently under construction are equipped with modern protection systems, and moreover, the previous failures were caused mainly by human error or natural disasters, and not by technological defects. Nuclear energy is low-emission energy, emitting an average of 28 tonnes of CO<sub>2</sub>/GWh (Figure 4.), which contributes to improving air quality; however, the discharge of cooling water from reactors results in thermal pollution, and there is also a risk of radioactive contamination of waters. In terms of the overall picture, nuclear power plants are one of the most environmentally friendly ways of generating energy and meet the requirements of the environmental aspect of energy security.

**Figure 4. Average greenhouse gas emission intensity, by energy source [tons CO<sub>2</sub>/GWh]**

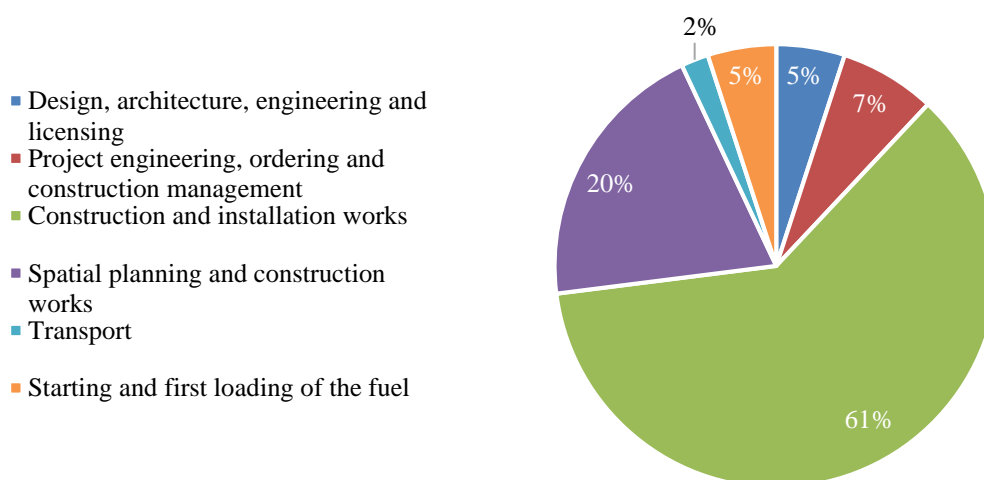
Source: Own study based on *Nuclear Power Engineering in the face of global challenges of energy security and non-proliferation regime in the era of climate change*, Młynarski T., Wydawnictwo Uniwersytetu Jagiellońskiego Kraków 2016. p.185

### Analysis of the operating costs of a nuclear power plant

Nuclear power generation costs include:

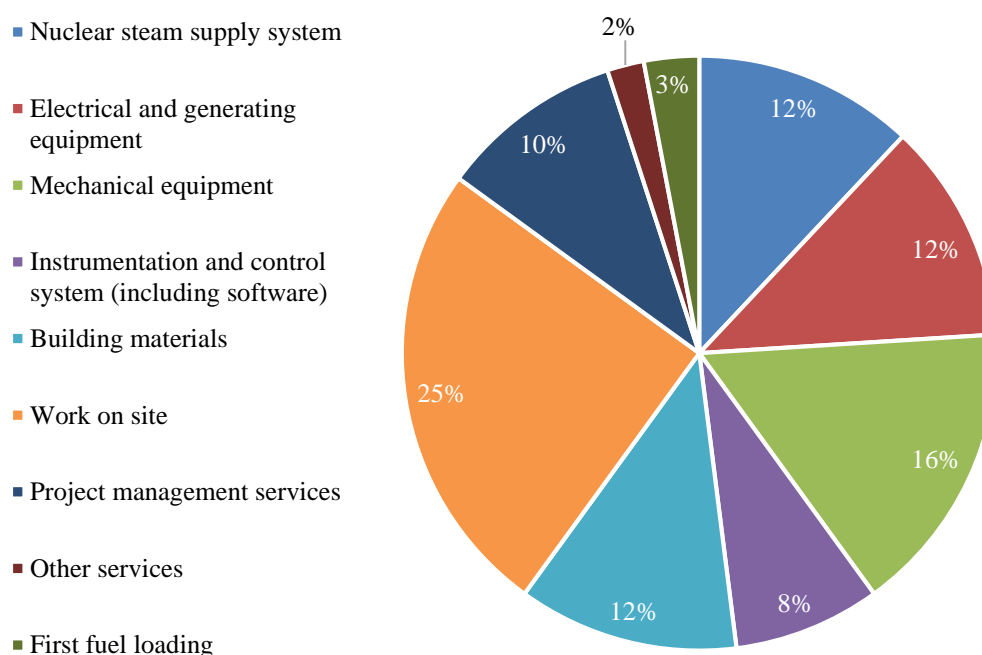
#### 1. Internal costs:

- Investment costs – represent more than 50% of the cost of energy generation (Pach-Gurgul 2015: 257). They are divided by activity (Figure 5) and in terms of labour, goods and materials (Figure 6);

**Figure 5. Investment costs by activity**

Source: Own study based on *The World Nuclear Supply Chain: Outlook 2035*, 2016.

**Figure 6. Investment costs in terms of labour, goods and materials**



Source: Own study based on *The World Nuclear Supply Chain: Outlook 2035, 2016*.

- O&M costs include maintenance and repairs. They constitute about 18% of the costs of energy generation (Pach-Gurgul 2015: 257);
- Decommissioning costs – represent about 4% of the costs of energy generation (Pach-Gurgul 2015: 257);
- Fuel cycle costs – include uranium prices, conversion, enrichment, fuel fabrication and waste disposal. They account for about 20% of the costs of energy generation (Pach-Gurgul 2015: 257).

## 2. External costs:

- Grid costs (related to transmission and distribution of energy);
- Social costs and environmental losses (including health funds);
- Costs incurred for environmental protection (e.g. fees for CO<sub>2</sub> emissions);
- Taxes;
- Costs incurred for security of energy supply;
- Costs incurred to ensure social acceptance.

The largest group of costs are investment costs, which are higher than in the case of a coal or gas-fired power plant. In addition, these costs are difficult to estimate, which increases the investment risk. The construction time of a nuclear power plant is longer and its operation carries the risk of high social costs and environmental losses in the event of a reactor accident. The fuel cycle costs are relatively low (reactor power generation requires little fuel; reactors are cheap to operate) and stable, and would therefore ensure the competitiveness of the economy. Charges for CO<sub>2</sub> emissions are much lower compared to other conventional energy sources.

Given the overall cost of a nuclear power plant, it is the cheapest low carbon energy source in the world, as high investment costs are offset by low fuel cycle costs.

### Analysis of the potential for development of nuclear energy

The SWOT analysis consists in comparing the strengths, weaknesses, opportunities and threats of a given project (Table 1.).

**Table 1. SWOT analysis of the introduction of nuclear power in Poland**

Strengths	Weaknesses
<ul style="list-style-type: none"> <li>– Investment in nuclear energy is in line with the objectives of the national energy policy and the EU climate and energy package.</li> <li>– Achievement of the environmental effect (in the case of nuclear power – avoided emissions).</li> <li>– Adapting the production process to a changing climate (low carbon energy source).</li> <li>– Electricity prices are insensitive to fluctuations in uranium prices and reactors are cheap to operate.</li> <li>– Once in operation, a nuclear power plant can run continuously for about 60 years.</li> </ul>	<ul style="list-style-type: none"> <li>– High investment costs accounting for over 50% of all costs.</li> <li>– Thermal water pollution caused by the release of cooling water.</li> <li>– Long construction time of the power plant.</li> <li>– Need for disposal and storage of radioactive waste.</li> <li>– No domestic uranium deposits.</li> <li>– External costs are difficult to quantify.</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>– Securing the expected increase in demand for final energy.</li> <li>– Long-term guarantee of uranium supplies (resources will last for more than 100 years).</li> <li>– Development of national research and development facilities.</li> <li>– Increase in local employment (new jobs).</li> <li>– Diversification of the national energy sector.</li> <li>– Continued development of the nuclear power industry.</li> </ul>	<ul style="list-style-type: none"> <li>– Risk of terrorist threat.</li> <li>– Strong lobby for the development of renewable energy sources (RES).</li> <li>– Negative public perception of nuclear energy (concerns about accidents and radioactive contamination).</li> <li>– Risk of using nuclear energy for military purposes (dual use technology).</li> </ul>

Source: Own elaboration

The PEEST analysis, otherwise known as general ambient segmentation, is based on the analysis of political, environmental, economic, socio-cultural and technological factors (Table 2.).

**Table 2. PEEST analysis of the introduction of nuclear power in Poland**

<p>Political factors</p>	<ul style="list-style-type: none"> <li>– Inevitability of improving energy security and diversification of energy sources.</li> <li>– Implementation of nuclear energy with the fifth direction of the Polish Energy Policy until 2040.</li> <li>– The reduction of CO<sub>2</sub> emissions required by the European Union (EU).</li> <li>– Limited impact of energy on the environment as a goal of the national energy policy.</li> </ul>
<p>Environmental factors</p>	<ul style="list-style-type: none"> <li>– Nuclear power is a low-carbon energy source (28 tonnes of CO<sub>2</sub>/GWh).</li> <li>– As a result of the release of cooling water, thermal pollution occurs.</li> <li>– Risk of radioactive contamination of humans and the environment as a result of accidents.</li> <li>– Nuclear power plants generate large quantities of radioactive waste.</li> </ul>
<p>Economic factors</p>	<ul style="list-style-type: none"> <li>– High investment costs of building a nuclear power plant.</li> <li>– Economic development and projected increase in energy demand.</li> <li>– Limited access to depleted fossil fuel resources.</li> <li>– Risk of high social costs and environmental losses.</li> <li>– A stable global uranium market.</li> <li>– Decrease in unemployment due to the creation of new jobs in the construction and operation of the nuclear power plant.</li> <li>– Gross domestic product (GDP) growth.</li> <li>– Costs incurred for the education of the staff.</li> </ul>
<p>Socio-cultural factors</p>	<ul style="list-style-type: none"> <li>– Negative attitude of society and ecologists.</li> <li>– Lack of public education on the benefits of nuclear energy, as well as in the field of energy (identifying nuclear energy with nuclear weapons).</li> <li>– Concerns about reactor failure.</li> <li>– Insufficient number of qualified people to work at the power plant (need for training).</li> </ul>

Technological factors	<ul style="list-style-type: none"> <li>– The technologies used to build power stations are now modern, but in 60 years' time they will be out-dated.</li> <li>– Long-term construction process of the power plant.</li> <li>– Insufficiently developed transmission grid.</li> </ul>
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Source: Own elaboration

## Summary

As a result of climate change caused by excessive human activity, the projected increase in demand for final energy and the inevitable depletion of fossil fuel resources, diversification of energy sources is justified and advisable. It creates an opportunity for the development of nuclear power, which will contribute to the implementation of all the objectives of Poland's energy policy:

- energy security, which includes ensuring that the energy balance is maintained, cheap and stable supplies of uranium, and electricity prices that are not sensitive to fluctuations in uranium prices.
- competitiveness and energy efficiency, understood as the reduction in the use of fossil fuels to produce electricity by starting production at a nuclear power plant.
- limited impact of the energy sector on the environment resulting from low emission of the energy source emitting 28 t CO<sub>2</sub>/GWh.

Investment in nuclear energy could be an excellent complement to renewable energy sources (RES), especially given the dependence of RES on weather conditions. Undoubtedly, the best scenario for the Polish energy sector of the future is to obtain energy from renewable sources and nuclear power plants, as they are the answer to climate challenges.

The SWOT and PEEST analyses carried out allow us to conclude that there are prospects for nuclear power development in Poland. The political, economic and environmental environment is characterised by favourable strategic conditions, which may change the attitude of society and lead to a positive assessment of its potential. The multidimensional and multi-faceted approach makes it possible to come to the conclusion that the inclusion of nuclear energy in the Polish energy sector is the right thing to do.

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# MANAGING CONFIDENTIAL INFORMATION ON PETROLEUM PROJECTS IN THE CASE OF THIRD PARTIES

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## **Abstract**

In each business, certain confidentiality provisions are concluded. In the oil and gas business, information is a matter of importance. Therefore, it is routine in the petroleum industry to sign confidentiality clauses or confidentiality agreements. Also in many cases, the confidential information needs to be disclosed to certain third parties, either for completing the project or due to regulations. Hence, apparently, there would be a conflict between the confidentiality obligations and such disclosures to third parties. In this study, we analyse the risks and effects of the authorised disclosure of confidential information to third parties. The research hypothesis is that in the mentioned relations there is not enough coherence and accordance that can completely manage the safety of disclosed information. The main source of our research is Lex Petrolea (legal and contractual norms accepted internationally by governments and companies that are active in the petroleum industry).

**Keywords:** confidentiality, non-disclosure, petroleum contract, NOC, IOC, third party, transparency

## **Introduction**

The protection of confidential information is an important component of many transactions in the oil and gas industry. In this industry, all of the related information, including contractual, financial, fiscal, economic, environmental and technical information, is absolutely crucial and valuable. (Hardwicke-Brown, 1996: 356) Such data are inevitably disclosed between the parties to a petroleum contract. Therefore, they agree upon a confidentiality clause or non-disclosure agreement to bind themselves to keep the information obtained secret and not to use it in a way that is not related to the project.

Petroleum contracts are complex and usually involve different considerations which engage the third party in the project. As an example, considerations relating to the financing of the project will engage a bank or a financier with confidential information, as they need to know the characteristics of the project which they are going to invest in. (Myers, 1984: 127) Another similar case is the insurance clause. With regard to the insurance clause in a petroleum contract, the second party to the petroleum contract, presumably an international oil company (IOC), usually needs to buy insurance coverage for the risks associated with the project. When an insurance company insures the risks, it must identify and also quantify risks in the project. Thus all of the related information should be revealed to the insurance company. (Park, 1996: 131) In addition to this, some information needs to be disclosed to public authorities or, in the case of dispute resolution, the information will be disclosed to third parties involved in the relevant process. Therefore, the general challenge here is how the parties to the main contract are supposed to protect the confidential information despite disclosing it to others.

Perhaps the simplest answer is that the confidentiality clause/agreement usually has determined exceptions that allow for the revealing of certain information to certain persons such

as public organisations, subcontractors, insurance companies, etc. But what is the guarantee of the safety of information after it has been disclosed to third parties?

An international upstream contract is usually maintained between two main parties; a company or a set of companies, jointly as in a JV, which represents a host state as the first party. Since in most cases it is a National Oil Company NOC that has such a role, it is more convenient to use this term throughout this study as we recall the first party as (NOC). Although sometimes it may not be an NOC by exact definition.<sup>1</sup> The second party is a company or a set of companies, jointly as in a JV, which act as a contractor or an investor. Since it is usually an international oil company (IOC) that does this job, we use this term to refer to the second party to the contract. Although sometimes it may not be necessarily an IOC by its exact definition, we use this term because it is more convenient to use and transmits the meaning. In both cases, it would not make a significant difference to the results of our analyses if the first party wasn't exactly an NOC or the second party an IOC. The third-party would be different types of individuals and companies ranging from public persons to private persons. The main issue here is, how will the obligations be enforced and what would be the remedy especially in the case of the third parties?

It is assumed that in relation to third parties, confidentiality provisions have deficiencies that leave the risks threatening confidentiality of the information unmanaged while it has been disclosed to the third parties. Also, it should be mentioned that our analyses are general and we are not concerned with a certain type of petroleum contract in a certain region or certain period of time, as confidentiality provisions (whether as a confidentiality clause or a non-disclosure agreement) are almost the same (in essence) in different types of petroleum contracts. Nevertheless, in our analysis, we have brought examples from confidentiality clauses in different types of upstream petroleum contracts for better clarification.

Our methodology, in its general form, is based on *Lex Petrolea*. *Lex Petrolea* comprises the international norms of oil and gas law, which are accepted and applied by the host states and multinational companies investing in this industry. This concept first appeared in the arbitration award between the government of Kuwait and American Independent Oil Co (AMI-NOIL) in 1982, on the issue of determining proper compensation for the expropriation of the assets by the government of Kuwait. (Talus, *et al.*, 2012: 181) Later the academics and commentators in this field generalised the doctrine of *lex Petrolea* to other areas of oil and gas law such as contracts and regulations. (Martin, 2012, Wawryk, 2015) Therefore, sources in different jurisdictions are not that divergent and *lex Petrolea* is held as the criterion which has helped countries and companies to apply an integrated approach toward different issues. Thus in our research, it is the main source. Also, according to this we provide our study with examples from different upstream contracts in different countries. Therefore, in the first section, we discuss and describe the current characteristics of the confidentiality provisions in the context of *Lex Petrolea* then based on the characteristics of such provisions in the petroleum industry, we analyse the risks threatening the confidentiality of the information while the information has been submitted to the different types of third parties. The risk elements in this concern are abusing the confidential information or disclosure of that information to unauthorised persons, which

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<sup>1</sup> also the first party could be an authoritative body like ministry of energy of the host state. In such cases the contract would be an administrative contract and thus it would be out of our topic.

may result in severe economic loss, especially in the case when a rival that has a direct interest in such data obtains them. In the second section, we will apply a variety of risk management methods ranging from avoidance and prevention methods, retention methods and transfer methods like an indemnification clause.

### **Confidentiality provisions in petroleum projects**

Confidentiality provisions in petroleum projects could mean either a confidentiality clause within petroleum contracts or a separate confidentiality/non-disclosure agreement, or both. Essentially, there is not a significant difference between a confidentiality clause and a confidentiality agreement. In other words, both of them set the same obligations. The only possible difference perhaps is that a confidentiality agreement has more details. Therefore, in this section we describe confidentiality terms in the format of a confidentiality agreement as this will be more comprehensive, meanwhile highlighting the confidentiality strategies in petroleum contracts.

Confidentiality agreements or non-disclosure agreements are contracts entered into by two or more parties in which some or all of the parties agree that certain types of information that pass from one party to the other or that are created by one of the parties will remain confidential. (Radack, 1994: 68)

Confidentiality agreements in different industries are relatively similar. Although there may be different strategies in negotiating them and adjusting them to special characteristics and needs in each business, they all share the same general framework of clauses. (Derman, 1992) Exchanging confidential information between companies in the petroleum industry is inevitable, either to complete a project or to attract companies to work with each other in a project. (Martin, 2004a: 281) Companies usually attempt to protect their shared intellectual property by including confidentiality provisions in their contracts or relations. (Smith, 2000: 36)

#### ***Describing the information and data subject to confidentiality***

Currently, based on the obligation of the parties to transparency standards there are two major approaches toward drafting confidentiality agreements; 1) narrow interpretation of confidential information 2) wide interpretation of confidential information. In the petroleum industry, the principle is to be transparent. Thus, confidentiality has a narrow and objective realm. Nonetheless, some host states may apply a wide interpretation of confidential information due to some national interests, although this is usually due to governmental corruption. (McPherson, Charles, 2015: 60)

From the perspective of the confider and confidant to a confidentiality agreement, confidential information will tend to be divergent. Typically, the confidant tends to apply the narrow interpretation of confidential information with the clarity of exact information subject to the confidentiality agreement. On the other hand, a wide and subjective interpretation of confidential information is in favour of the confider. Therefore, in most of the petroleum contracts, both sides of the contract are obliged to hold confidentiality to maintain the balance between themselves by sharing the risks and benefits of confidential information. For example, in the eleventh section of the contract between Albanian NOC (Albpetrol) and Stream oil & gas Ltd, for Delvina block, we read that although the information obtained during the project belongs to the Albanian NOC, the contractor also has an interest in such information. Thus, both sides are

obliged to keep the confidentiality of the information before each other. There is similar content in the model gas service contract of Iraq (2009) in article 33.5. Nonetheless, in some countries, such as Iran, based on the current draft of IPC contracts (new Iranian petroleum contracts), the contractor has no right to the information obtained during the project and subsequently; it is only the contractor which is obliged to keep the confidentiality of the information.

In the petroleum industry, generally, all data obtained during operations describing the hydrocarbon, geological and geophysical data, logs and analyses, pressure trends, estimates of the reserves in place, commercial, technical information are valuable and subject to confidentiality provisions. This type of information is widely accepted to be subject to confidentiality. However, other categories of information – such as contractual clauses, legal information and rights, and obligations of parties to the contract – are not assumed to be confidential in many oil-producing contracts. (Rosenblum, Maples, 2009: 24)

Therefore, the less confidential information, the greater the advantage for the IOCs. On the other hand, for host states, it is better to impose more restrictions to make sure that all of the information obtained in their project and reservoir is safe and will not be disclosed or used against their benefits or without their permission.

### ***Obligations of the confidant***

Generally, a confidant is obliged in two types of obligations; the first main obligation is not to disclose the information. The second main obligation is not to use information in a way that is not associated with the project.

More objectively, the confidant is prohibited from the sale, trade, publishing, disclosure or reproduction of the confidential data to the third party or out of the relevant project.

In oil and gas projects, confidentiality obligations are manifested in two ways; either as a confidentiality clause within the main contract between parties to a petroleum contract, or as an independent confidentiality agreement. Although the usual practice is to apply only a confidentiality clause within petroleum contracts in a way that the confidentiality clause itself covers all the confidentiality provisions. Some jurisdictions also apply non-disclosure contracts in addition to the confidentiality clause. Iran and Libya currently use this method. In this method, the confidentiality clause sets the general frame of the confidentiality provisions whereas the non-disclosure agreement concerns such provisions in a detailed manner.

### ***Exceptions for disclosing of information in specific cases***

For some regulatory issues, and also for getting the project completed, the confidant is usually exempted from confidentiality requirements in certain relevant cases. (Martin, 2004b: 286)

Exceptions can be categorised into four types;

- Exceptions the parties agree upon. Disclosures to third parties like insurance companies and financiers are the main examples.
- Exceptions which the authority bodies impose, e.g. for auditing, fiscal, social and environmental matters (in general, transparency necessities). (Mainhardt-Gibbs, 2007)
- Exceptions imposed due to fiduciary duties in the case of JVs or JOAs. Meaning if there is another company involved in the venture or operation, it has the right to know the required information of the project which is investing in it. (Bean, 1993: 75-89)

- Exceptions due to the procedures of dispute resolution. Whether by litigation, arbitration or other ADR<sup>2</sup> methods, some necessary information which may be confidential need to be disclosed. (Brown, 2000: 971 , Hardwicke-Brown, 1996: 357)

### ***Warranties of the obligations***

A combination of a wide range of remedies can be applied in a confidentiality agreement including:

- Setting liquidated damages
- Accounting of benefits earned by the confidant by unauthorised use or disclosure of the confidential information
- Injunctive relief, either an interim or permanent injunction.
- Order for delivery up and destruction of materials that the confidant has obtained through the breach of confidence or unauthorised use. (Hardwicke-Brown, 1996: 376)

If the confidentiality agreement is silent about the remedy for the breach or the contractual remedy is insufficient, it will be provided or supplemented through common law (or the related rules of governing law to the agreement) and equitable principles. (Hardwicke-Brown, 1996: 379) Remedies provided by these means can include compensation for damages, injunctive relief, and also an order to destroy materials.

The most important issue surrounding breach of confidentiality in the petroleum industry is proving that the breach has actually occurred. This is especially true regarding the obligation not to use confidential information for other purposes. Since it is nonconcrete to prove that the confidant has used confidential information for another project, the confider faces a difficult situation in proving the breach. It seems that a good way of solving the problem in such cases is to include a clause in the confidentiality agreement which exempts the confider from having to prove such abstract and psychological cases of the confidentiality obligation being breached. Also, there may be another remedy provided not by the confidentiality agreement but the main petroleum contract itself. If the breach of confidentiality obligations is considered a ‘material breach’ under the contract or by court or arbitration verdict, the confider has the right to terminate the contract as a remedy for material breach. (Rosenblum,Maples, 2009: 29 , Stannard,Capper, 2014)

### ***Termination of the agreement***

A confidentiality agreement may provide that the confidant’s obligations will survive for a limited period. This usually depends on the nature of the deal. For example, if it is about closing a proposed acquisition transaction with the confidant, its obligations under the confidentiality agreement will terminate on the closing. (Hardwicke-Brown, 1996: 384)

The confidant typically prefers the termination to be limited and accurate while the confider might be willing to enjoy perpetual and subjective confidentiality rights. Nonetheless, if the parties have not determined when the agreement will end, it is not necessarily perpetual. In this case, it seems the relevant customs and practices known will supplement the agreement.

In the petroleum industry, there is no standard time when a confidentiality agreement ends. It may be different ranging from termination of the main petroleum contract to perpetuity

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<sup>2</sup> Alternative Dispute Resolution

of the confidentiality obligations. In the model gas service contract of Iraq, Article 33.3 determines that the confidentiality obligations end three years after the termination of the main contract. In Cambodia's production sharing contract (PSC) model, the term for the confidentiality obligation is two years after the termination of the main contract. And in the Kurdistan region's PSC model, confidentiality obligations end at the same time that the main contract reaches the termination point. In Pakistan's concession model, article 11.2, confidentiality obligations are perpetual. The same provision has been applied in Kuwait's model of technical assistant contracts.

The time variations might reflect a difference in the competitiveness of a country's petroleum industry, different philosophies about the disclosure of information, or some other variables. (Rosenblum,Maples, 2009: 25). Nonetheless, it is reasonable that the information stays confidential during the operation of the oilfield and information concerning the project and reservoir still matters.

### **Analysing confidentiality regarding third parties**

As has been explained in the previous sections, disclosure of confidential information is authorised in exceptional cases. According to the exceptions, there will be three different categories of third parties:

- Third parties who are involved in a petroleum project and receive information based on the parties' agreement.
- Public third parties who receive information based on regulations.
- Third parties who receive information during the dispute resolution process.

Based on the rule of privity of contracts (Rosenblum,Maples, 2009),(Stone, Devenney, 2017: 158) the confidentiality agreement does not impose any obligation on third parties. Therefore, it is crucial to research the risks threatening the confidentiality of the information and legal and contractual tools to secure the information while at the disposal of third parties. In this section, we are going to analyse this issue accordingly.

#### ***Private third parties***

Third parties under this category share three characteristics. Firstly, all of them receive information based on the agreement between the confider and confidant. Secondly, it is necessary for the completion of the project to share certain information with them. Thirdly, their relationship with either confider or confidant is based on private law or commercial law tools such as a contract. Insurance companies, financiers, subcontractors or companies participating in the operation or venture are examples of this category.

Although these third parties are not directly obligated under the confidentiality agreement between the NOC and IOC, they are obliged to keep the received information confidential generally due to either a separate confidentiality agreement/clause or regulations and customs derived by the principle of good faith. (Fontaine, De Ly, 2006: 179) For example, insurance companies are obliged to maintain client confidentiality, based on their own internal statutory or consumer rights regulations. (Merkin, Steele, 2013: 77) Moreover, in each case, there is also a confidentiality clause embedded in their contract, which forms their own private/commercial relationship with either the IOC or NOC. Hence, such third parties take the duty of confidentiality, but originating from laws and customs it is very general and needs circumstances to be

proved before a dispute resolution body, which will be harder than the situation when there is a direct contractual relationship between the main confider and the third party. It is usually the IOC that deals directly with the third parties and contractual confidentiality leverages are at its disposal. Thus if the third parties disclose or use the confider's information in an unauthorised way, the NOC has no direct contractual leverage against the third party. This is the main confidentiality risk an NOC takes in this category of third parties.

In the case of the first risk, the best way to manage the risk is to share it with the IOC. For that purpose, an NOC should share the ownership of the confidential rights with the IOC or give it benefits such as the right to use the knowledge obtained in other projects (with the NOC's permission). Thus, the IOC will maintain the confidentiality of the information more carefully, as its own benefits are involved. If an NOC does not prefer this method, it can manage the risk by including an indemnification clause in the confidentiality agreement between the first confider (here an NOC) and the confidant (an IOC) where the risk will be managed. Since the indemnification clause passes the burden of loss and risk to the indemnifier (Hutchens, 1992: 269), in this case, the confidant will be responsible for violation of information confidentiality by third parties. The confidant's responsibility will be to stop the violation of the confidentiality and pay the relevant damages to the confider.

The confidant can also pass the risk to the third party. However, it should be noticed that some third parties, such as insurance companies, do not accept indirect losses. In such cases good faith and fair dealing obligations can help, at least, to make the third party do its best to secure the confidentiality of the information. (Adler, Mann, 1994: 33), (ICC, 2006: 12)

The other risk is that the confidentiality clause between the confidant and the third party may have lower standards and recognise different definitions than the confidentiality terms between the NOC and IOC. Hence, it will not cover the confider's information properly. If the two sets of the confidentiality terms have different standards, this may result in some risks. For example, if the definition of the confidential information in the second confidentiality agreement/clause does not overlap with the first confidentiality agreement, it will leave some information unprotected. Or, if the term of the agreements is different, there will be a problem. Meaning that if the second agreement terminates before the first, the third party is no longer to keep the information confidential, while the first confidentiality agreement still holds confidentiality.

To manage this risk, two methods are possible. One is to make sure that the confidential information in the main confidentiality agreement is recognised as confidential between the confidant and the third party too. This can be actualised by dropping a line in the confidentiality clause between the confidant and the third party that they agree to also recognise all the confidential information between the first confider and confidant as confidential too. Another way is to oblige the confidant in the main confidentiality agreement to keep the same margins of confidentiality with the third party. This method is currently more common in most petroleum contracts. For example, in Iraq's gas service contract model, article 33.1, it has been determined that confidential information can be disclosed to third parties (in authorised cases) provided that they adhere to the same confidentiality provisions as this contract.



### ***Public third parties***

In each petroleum project, there is some information that needs to be disclosed to the authorities, public entities, or even non-governmental organisations (NGOs). The challenge in this phase is how this information is going to be safe. Do the public entities have a duty of maintaining the confidentiality of such information? To know the answer, one should first analyse the relationship between confidentiality obligations and transparency necessities. In other words, we need to know which is the principle and which is the exception from the principle. Considering each of these concepts as the principle and the other as an exception to the principle is relative and depends on the main philosophical background and theories shaping a legal regime. Transparency regulations originate in the area of public law, while confidentiality obligations are based on the theory of contract and thus come from private law. Legal theories which give superiority to public law will recognise transparency as the principle and confidentiality as the exception to the principle of transparency. On the other hand, legal theories prioritising private law will act vice versa. (Maddahinasab, 2018) Hence, depending on the background in each legal regime, the answer varies. Nonetheless, we can consider solely the petroleum industry and the trends within this business or so-called *lex petrolea*, to see how the issue has been dealt with.

Being a natural resource that creates high revenue flows, the petroleum industry has made a proper atmosphere for corruption for both governments and private corporations. Challenges like fair and efficient systems for licensing, contracting, revenue collection, auditing, local content, and public spending, as well as the environmental and social impacts of the industry, are also causes which have given rise to a common conclusion that transparency is a necessary factor in this industry. (Short, 2014: 8) Thus it can be said that the trends in the petroleum industry are inclined toward considering transparency as the principle and confidentiality as the exception to the principle. (McPherson, Charles P, 2014),(Gault, 2014) In recent years, implementation of the Extractive Industries Transparency Initiative (EITI) standards by many countries in their petroleum industries has fortified the role of transparency more than before. According to the EITI's standards, members are encouraged to report information concerning the revenues from the sale of natural resources and make such information publicly accessible. (Poretti, 2015) In addition to these non-mandatory standards, in many countries there are mandatory requirements and regulations which promote transparency, such as the USA's Freedom of Information Act. Under these standards and regulations, not only do public entities not have any obligation to maintain the confidentiality of the information which companies report to them, but rather they must make such information publicly accessible. Therefore, the type of information which needs to be reported to the public entities cannot be confidential. Thus, if the parties have agreed to keep such information confidential, it will be an invalid agreement due to being against these regulations or public order. However, it should be noticed that freedom of information acts usually determine which kind of information is not subject to transparency. For example, in the USA's freedom of information act, trade secrets and technical information are excepted from being disclosed. (McCARTHY, Kornmeier, 1980: 58) In other words, the type of information which is private can be confidential and subsequently there is no need for it to be disclosed to the authorities. The problem emerges, however, when the regulations are not comprehensive in recognising this kind of information. And since

such information is considered as exceptions to the principle of transparency, it is construed narrowly. Hence, only the information which has been stipulated in the regulations is entitled to be confidential and the remainder is subject to transparency regardless of being inherently private or not.

Therefore, the main risk in this section would be the probability of deficiency in the regulations and standards concerning transparency norms. The parties to the contract can manage this risk, to some extent, by opting for a governing law which is more effective for them. Usually, however, they must adhere to the host state's legal system. Since NOCs are related to host governments, in this case, it can be said that the IOCs' information is at risk. Considering this, in the case that the regulations are not efficient enough, the parties to the confidentiality agreement/clause can negotiate to provide a remedy for the IOC's loss, in the event in which its confidential information of a private and privileged nature has been made public due to such regulations. In order to manage this risk properly, they should identify exactly the type of information that has not been recognised in the transparency regulations and they also need to determine, in the contract, under which circumstances the IOC is entitled to compensation.

### ***Dispute resolution process***

In the case of dispute resolution, there are two options for the parties to petroleum contracts; litigation or arbitration (and alternative dispute resolutions). In each case, they may need to disclose some confidential information, which is required for the judges or arbitrators to settle the dispute. If they choose litigation, it is interpreted that they have withdrawn from their confidentiality rights, as the courts are public and disclosing confidential information to them is the same as the parties making the information public themselves. So obviously it is better to choose arbitration if they want to keep the confidentiality of the information. But is the arbitration mechanism enough to secure the confidentiality of the information?

Confidentiality has been stated as a key feature of why businesses choose arbitration rather than litigation. In a survey of US/European users of international commercial arbitration conducted in 1992 for the LCIA by the London Business School, confidentiality was listed as the most important benefit of arbitration. (Bagner, 2001) In another survey conducted by the School of international arbitration at Queen Mary University in London, 84 percent of those surveyed admitted to choosing arbitration at least in part because of its confidentiality. (Gerbay, 2012) But is confidentiality actually a feature of arbitration?

The reason that arbitration looks confidential is its private nature. As mentioned before, litigation is a public dispute resolution method. Hence using litigation is concomitant with the withdrawal of confidentiality rights. On the other hand, arbitration is private and, by using it, parties do not put confidential information in the public domain. Thus, it sounds like the arbitration method features confidentiality. However, this does not necessarily mean that arbitration is actually confidential. In past decades, the privacy of arbitration had the same meaning as being confidential. (Bagner, 2001: 243) But recently these two notions, despite being correlated, have been distinguished from each other and have been defined separately. Current development defines the privacy of arbitration as being self-contained between the parties to the dispute, but this does not necessarily mean that it is confidential. (Noussia, 2010: 25) In many jurisdictions, the arbitration mechanism does not guarantee the secrecy of any disclosed information. Thus, third party participants in the arbitration process who have not agreed to any

confidentiality agreement or rules remain free from confidentiality obligations. (Schmitz, 2005: 1211) Third parties in an international arbitration process include arbitrators, witnesses, and experts. With respect to arbitrators, it is accepted that arbitrators have an ethical duty to maintain confidentiality, and that the remainder of the third parties are not bound by any such duty. In other words, in both cases, there is no legal guarantee for safeguarding confidential information which has been disclosed to them. (Buys, 2003: 124)

Although it is still possible in some jurisdictions<sup>3</sup> or arbitration centres<sup>4</sup> that third participants involved in the arbitration process (or other ADR mechanisms) be obliged to keep confidentiality of information (Reuben, 2005: 1261, Trakman, 2014: 6-8), it is safer to have them agree to confidentiality in order to manage the risks in this case. The parties to arbitration may provide for confidentiality and non-disclosure by incorporating a confidentiality clause into their arbitration agreement, or through a distinct confidentiality agreement. (Trakman, 2014: 3) In this way, the parties can turn the arbitrators' ethical duty into a binding legal duty to maintain confidentiality. In the case of other third parties involved in the process of dispute settlement, such as experts and witnesses, having them sign a confidentiality agreement in each case will cause inconveniences in the process of dispute resolution. Therefore, for the sake of having an efficiently fast process of dispute settlement, it is better to distinguish between those who receive more important information and those who receive less. And then the parties can agree on only having a confidentiality agreement with those who have received crucial confidential information. Hence, if signing a confidentiality agreement with each third party would cause inconvenience in the dispute resolution process, they can skip those who have access to less important information which will not form a serious risk.

Regarding other dispute resolution methods known as alternative dispute resolution (ADR), the confidentiality risks regarding third parties and the relevant solution are the same as in the case of arbitration. However, in the case of mediation, the duty of confidentiality has been more accepted, and it is usual in mediation agreements to provide confidentiality obligations. (Trakman, 2014: 8)

## **Conclusion**

In the relationship between an NOC and an IOC and third parties, it is usually the NOC which is more exposed to the risk of disclosure of their confidential information. This is because the NOC must disclose more information, such as geographical information, information on the reservoir's hydrocarbon characteristics, and so forth. Also most of the time, the NOC is recognised as the owner of the information obtained during the petroleum project. However, the IOC also must disclose some important information. For example, in the case of transferring technologies to the host state. Or in some cases, such as concession information obtained during the project belonging to the IOC, the NOC or owner will become aware of such information due to inspections or reporting duties from the IOC. On the other hand, exceptionally, to facilitate project completion or to comply with relevant regulations, the confidential information must be

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<sup>3</sup> For example under the laws of the United Kingdom, parties to arbitration are forced to rely on confidential rules that are implied into their agreement by operation of the common law. Although these implied rules are grounded in conceptions of privilege and privacy, not confidentiality.

<sup>4</sup> For example, London Court of International Arbitration (LCIA) in article 30.1 of its governing rules, American Arbitration Association (AAA) in its amended rules have provided specifically for confidentiality.

disclosed to specific organs or bodies such as the tax bureau, social and environmental organs, subcontractors and financiers, or any other persons who participate in the project. Therefore, in the confidentiality agreement, such disclosures are exceptionally authorised.

When the NOC/IOC discloses the information in the authorised cases (e.g. to an insurance company), some confidentiality provisions should be provided to protect the safety and proper use of the information. Hence, some specific confidentiality agreements or clauses may occur between the IOC and the private third parties. In this study, we analysed the relationships between these two sets of confidentiality provisions and concluded that if the confidentiality provisions between the NOC/IOC and the third parties are general in nature and have less strict provisions and lighter obligations on the third party than the main confidentiality provisions between NOC and IOC, the third parties will be less bound to confidentiality obligations, which is recognised by the NOC and IOC. Therefore, the subsequent confidentiality provisions should conform and overlap with the original confidentiality provisions between the NOC and IOC. If there is not enough harmony between these two sets of confidentiality provisions, some of the confidential information may be exposed to the risk of disclosure or used against the benefits of the confider. The elementary method to manage this risk is that the NOC and IOC oblige themselves to set the same confidentiality standards with the third parties. This method is currently used in some petroleum contracts. Also, we concluded that using an indemnification clause as a method of transferring risk management can guarantee the main confider's confidentiality rights in the case in which the third party is only related to the confidant.

In the case of public third parties, we concluded that transparency in the context of petroleum law is superior, and that applying confidentiality to information is exceptional. Therefore, confidentiality rights are construed narrowly and this may be risky, specifically, when the parties to the contract have no choice other than to adhere to a specific legal system which is deficient in regard to recognising the type of information which is exempted from transparency regulations. In this case, the IOC would be more vulnerable. Thus, considering the circumstances in the confidentiality agreement which provide compensation for the IOC's loss, in this case, the risk can be managed.

Regarding the third parties who are involved in an arbitration process and receive confidential information, we concluded that they are not necessarily obliged to keep confidentiality duties unless they have agreed to a confidentiality agreement. Thus, the best method to manage this risk is avoidance, by binding any receiver of the confidential information, including arbitrators, experts, witnesses, and lawyers, to proper confidentiality provisions.

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# ENERGY POLICY OF LIECHTENSTEIN

*Anna Kucharska*

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## Abstract

Liechtenstein is the fourth smallest country in Europe, which determines the low economic importance of this country on the international arena. Therefore, Liechtenstein is usually overlooked in the analysis of economic policies in various countries, including the energy sector. However, the analysis of such a small country brings a valuable complement to researches on potential and challenges with regard to the implementation of energy transformation policy especially taking into account the countries with poor capabilities. It should be emphasised that due to difficult geographical conditions and strong external influences, deepened analysis of the process of formulating energy policy in Liechtenstein should arouse the interest of those countries that suffer geographical disadvantages to strengthen their energy security.

**Keywords:** energy policy, energy transition, Liechtenstein, energy security

## Introduction

Liechtenstein is the fourth smallest country in Europe in terms of surface area, with 160 km<sup>2</sup> (Liechtenstein in Zahlen 2018: 4). Due to its small size, which largely determines its economic importance on the international scene, Liechtenstein is generally disregarded in considerations of the economic policy aspects of various countries, including the power generation sector. There are no studies on Liechtenstein in the scientific literature. Only reports describing selected issues concerning the power generation sector of this country can be found, e.g. the UN Liechtenstein National Climate Report 2005 (Liechtenstein National Climate Report), the VP Bank energy report (Energiebericht 2017), and government documents, which include energy strategies, reports by the Liechtenstein Statistical Office, or government programmes. Nevertheless, the value of an analysis of such a small state is a valuable addition to research into the potential and challenges, but also into the capabilities of individual countries with regard to the implementation of energy transformation policies.

**Map 1. Geographic situation of Liechtenstein in Europe**



Source: <https://www.1843magazine.com/travel/liechtenstein-the-magic-princedom> (access: 31.7.2019).

The aim of this paper is to analyse the formulation of energy policy in Liechtenstein with a view to ensuring national energy security, based on the characteristics of the existing geographical, political and economic opportunities of the country. For this reason, the main part of the paper is divided into three parts, the first of which deals with legal and institutional issues, the second with the economic dimension of energy policy, and the last with social issues. The topics discussed in the paper are based primarily on government documents defining national priorities for the development of the power generation sector and the geopolitical situation of Liechtenstein with particular emphasis on relations with neighbouring countries – Switzerland and Austria.

It should be stressed that due to difficult geographical conditions and strong external influences, the examination of the process of formulating power generation policy in this country should be of particular interest to those countries which are themselves disadvantaged in order to strengthen their energy security, taking into account all the necessary elements to ensure it. However, before discussing Liechtenstein's energy policy, the definition of basic concepts in the form in which they will be used for further analysis should first be clarified.

### ***Definition of a State's energy security***

The definition of energy security reveals differences in the elements it focuses on – some researchers highlight aspects related to security of supply, such as the availability of energy or its price, while others highlight issues related to the impact on economic and social welfare (Choong 2015: 1078).

According to the most common definition, energy security means the ability of the national economy to cover the current and future supply of energy to domestic consumers at socially acceptable prices, while maintaining political independence (Młynarski 2013: 23-24) and environmental and climate protection.

The International Energy Agency defines energy security as the uninterrupted availability of energy sources at an affordable price. At the same time, it points out that this concept has many dimensions. For example, in the long term, it refers primarily to investments in securing energy supplies in line with economic development and environmental sustainability needs (Energy Supply Security: 13). It is therefore recognised that energy security is a chain of inter-related values and economic and political factors (Młynarski 2013: 23-24), which shows the complexity of this concept. Actions to ensure energy security relate to a wide variety of areas affecting sustainable development policies, economic policies, power generation markets, socio-economic changes or technological development (Cziomer, Lasoń 2008: 18). Therefore, energy security has a raw material and product, infrastructural, political, international and human capital dimension (in terms of availability of qualified personnel) (Bojańczyk 2014: 144).

In terms of the subject matter, energy security is an element of the state's national security. It also refers to international security as an element of foreign policy, which is based on the most important interests of the state. It follows from this that the State is the main actor in energy security. However, it operates alongside other participants in the energy security system, such as power generation corporations and end consumers (Młynarski 2013: 23).

Energy security is a component of raw material security because it is based on traditional raw materials: coal and lignite, crude oil, natural gas and uranium. With regard to the latest energy production and storage technologies, raw materials such as lithium, cobalt, magnesium,



silicon, etc. are also becoming crucial. Energy security also refers to economic security, because the area of power generation directly affects the efficiency and competitiveness of the economy (Młynarski 2013: 23-24). Therefore, the task of the state energy policy is to coordinate all these dimensions of security as important elements for the undisturbed functioning of the modern state.

### ***The modern concept of energy policy***

In the definitional sense, the concept of energy policy arises from the definition of raw material, energy and environmental security and the concept of sustainable development. Therefore, the aim of energy policy is to determine the state's activity, which is necessary to secure the current and future needs for raw materials, ensuring sustainable and balanced economic development, based on policies that include such activities as diversification of energy supply sources, creation of reserves of raw materials, limiting the accessibility of foreign entities to the domestic energy market and concluding international agreements (Młynarski 2013: 24).

The power generation transformation policy is a detailed specification of the energy policy, and at the same time a guideline for its development and objectives. A narrow and most basic definition of energy transformation means changing the current energy model, which is based on non-renewable energy sources in the form of fossil fuels, to an energy system based on renewable energy sources (Ruszel, Młynarski, Szurlej 2017: 29). The energy transformation policy is strongly based on technological factors, but changes in the economic and social fields are also an important element (Schneidewind, Augenstein, Scheck 2010-2012: 122-123). This is because the subject of the energy transformation is a complex one and relates to many fields and areas far beyond the energy sector. For this reason, four dimensions are mentioned that define the areas of change in the energy transformation process: technological, economic, institutional and sociological (cultural) (Schneidewind, Augenstein, Scheck 2010-2012: 122-123).

Energy transformation is directly identified with the uptake of low or zero carbon energy sources, which are based on appropriate efficient and energy saving energy generation technologies. The elements promoting the development of RES include advanced technologies, increased economic competitiveness, political support, and the education of society. The benefits of the development of renewable sources include reducing the negative environmental impact of the traditional energy sector, supporting the diversification of energy supply, and increasing the energy independence of states. In addition, these activities are combined with the development of the idea of energy saving, which at the same time should be accompanied by an increase in energy efficiency in various industrial and service sectors through such activities as insulation and thermal modernisation, energy efficient lighting, and cogeneration and energy recovery in industrial processes (Ruszel, Młynarski, Szurlej 2017: 29-30).

Society is one of the main pillars of the energy transformation as its initiator and recipient – depending on the perspective adopted. Society, as the payer, bears most of the costs of financing public programmes and investments. Some of the changes can be implemented through social commitment, e.g. electromobility or energy saving. Hence, the importance of educating the society and shaping citizens' awareness of energy issues (Ruszel, Młynarski, Szurlej 2017: 31-32) is emphasized in state energy strategies and programme documents. One

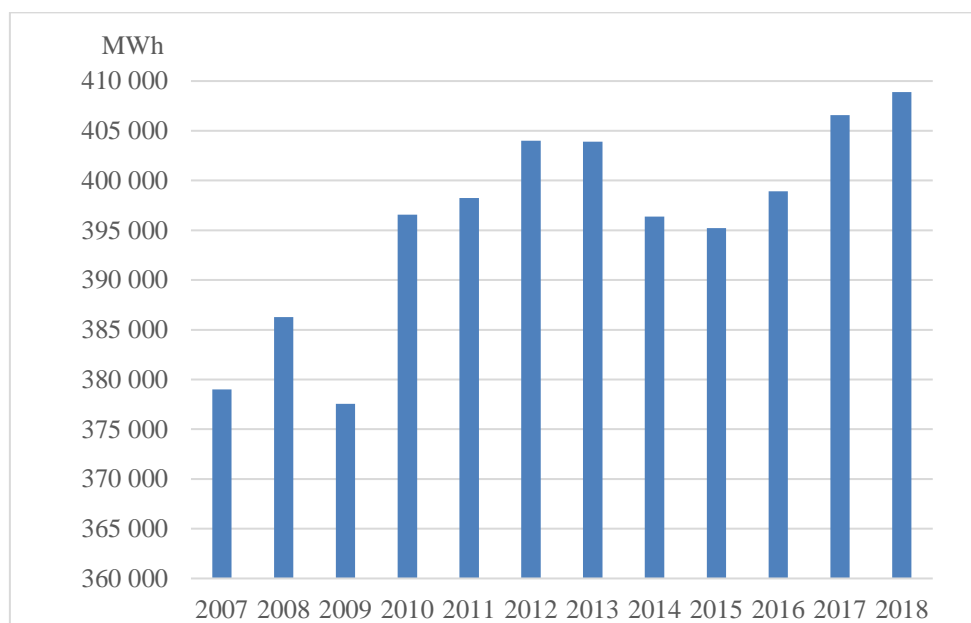
of the challenges in relation to society is consumer activation. The social base is strongly linked to the development and diffusion of new technologies, because on the one hand they enable citizens to raise quality of life, and on the other hand they determine the demand for them and the need to disseminate them. Thanks to the technologies, it was possible to create a new dimension of power generation, defined as prosumer energy. This concept was introduced by Alvin Toffler in his book *The Third Wave* in the 1980s (Toffler 1980: 264-270). The basic definition defines a prosumer as both a producer and a consumer, not only of energy, but of every good (Mirowski, Sornek 2015: 73-81). Prosumer power generation assumes that the hitherto passive consumer will join the production system by generating energy for his own use in a home microinstallation, and any surpluses may be transferred to the grid (Słupik 2014: 129). The role of the state in the context of prosumer power generation is primarily to educate society, promote certain values related to environmental protection, support civic movements focused on caring for the environment, and stimulate civic activity in this field through various incentives, such as subsidies.

### **Liechtenstein's energy policy**

#### ***The structure of Liechtenstein's energy balance***

Energy consumption in Liechtenstein is high – it is almost twice as high as the European average *per capita* (Energy consumption..., <https://www.worlddata.info/europe/liechtenstein/energy-consumption.php>, access: 1.12.2019) – and in 2018 amounted to 1,210,461 MWh and thus the energy consumption decreased by 2.5% compared to 2017. According to data from the Liechtenstein Statistical Office, the largest share of consumption in 2018 was in electricity with a share of 33.8% (Energiestatistik 2018 Liechtenstein, 2019: 6). This information is a little unclear, because the electricity itself also had to be generated from something in the first place. In statistical terms, however, this data should be understood as electricity imported in the form of a finished product into Liechtenstein (Energiestatistik 2018 Liechtenstein, 2019: 15 ). The dominant supplier for Liechtenstein is Switzerland (98% of electricity imports), which in turn produces most of its imported energy from nuclear power plants (Energiestrategie 2020, 2012: 7). The second largest energy carrier in terms of share in consumption is natural gas (20.4%), followed by diesel (12.2%) and heating oil (9.1%) (Energiestatistik 2018 Liechtenstein, 2019: 6).

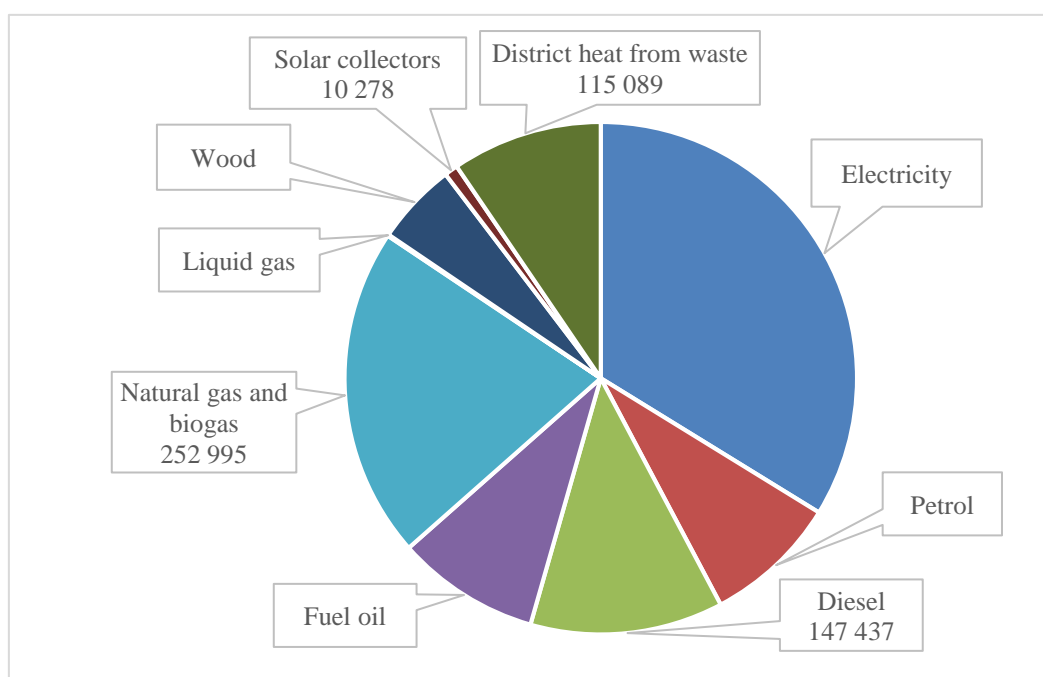
**Graph 1. Electricity consumption in Liechtenstein from 2007 to 2018 [MWh]**



Source: compiled on the basis of: *Energiestatistik 2017 Liechtenstein*, publ. Amt für Statistik, p. 18, *Energiestatistik 2018 Liechtenstein*, publ. Amt für Statistik, state as of July 2019, p. 7.

The share of Liechtenstein’s own energy production in total energy production is low and amounted to 13% in 2018 (12.6% in 2016 and 12.3% in 2017 (*Energiestatistik 2017 Liechtenstein*, 2018: 9)), but electricity production alone has decreased by 5% compared to 2017 (*Energiestatistik 2018 Liechtenstein*, 2019: 6). Domestic electricity sources include hydro-power, cogeneration units for natural gas, and photovoltaics (*Energiestatistik 2017 Liechtenstein*, 2018: 9).

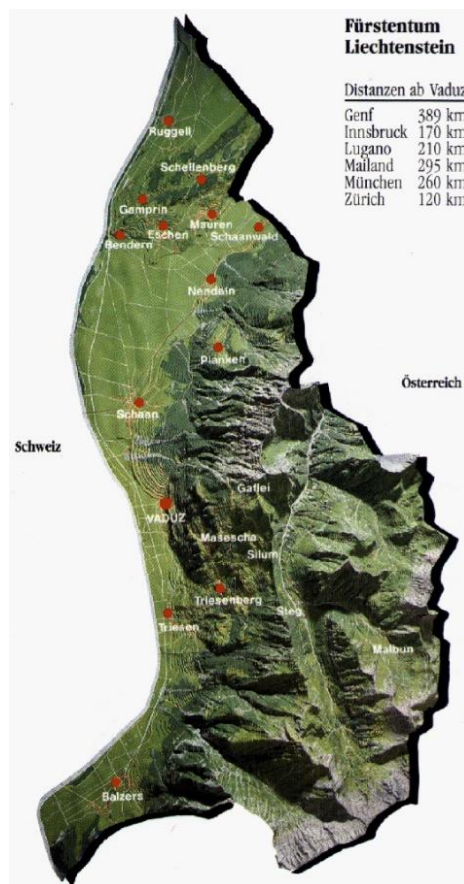
**Graph 2. Overall energy consumption in Liechtenstein in 2018 [MWh]**



Source: compiled on the basis of: *Energiestatistik 2018 Liechtenstein*, publ. Amt für Statistik, state as of July 2019, p. 8.

Liechtenstein is therefore in a very difficult position when it comes to energy self-sufficiency. It does not have its own energy resources, which makes it completely dependent on imports or RES. Renewable energy sources require a lot of space, which this country does not have. In addition, 15% of Liechtenstein's surface area is mountainous, i.e. not usable areas (Droege, Genske 2013: 9) and unusable for renewable installations. In addition, Switzerland, the main exporter of energy to Liechtenstein, has decided to stop producing energy from nuclear power plants, which have hitherto provided it with enough energy to export. Although this will be done gradually over a broad time horizon, Liechtenstein has now been put in a position where the future of its security of energy supply is uncertain.

Map 2. Topographical map of Liechtenstein



Source: <http://www.map-library.com/map-library/maps-of-europe/maps-of-liechtenstein/>, (access: 31.7.2019).

Observation of Liechtenstein's energy policy shows that the European Union and Switzerland have the greatest influence. Nuclear power plants can be identified as the main reason why Liechtenstein has a special partnership with Switzerland. As mentioned above, electricity imported by Liechtenstein comes mainly (although not exclusively) from this source (Liechtenstein, <http://de.atomkraftwerkeplag.wikia.com/wiki/Liechtenstein>, access: 31.7.2019). Neighbouring Austria does not have nuclear power (although it is also an importer) and does not have a source of electricity that is at the same time stable in terms of production and sufficient capacity for export. It is therefore interesting in this context to see the decision taken in Switzerland to phase out nuclear power generation altogether.

However, it can be seen that the Swiss decision is generally accepted in Liechtenstein, for several reasons. First of all, Liechtenstein is one of the countries dominated by anti-nuclear

sentiments. In the first decade of the 21st century, it was planned to build a nuclear power plant in Liechtenstein in order to increase national energy independence and guarantee a secure and stable energy supply. However, numerous social protests were raised against the construction plans, the force of which was strengthened after the nuclear power plant accident in Fukushima in 2011 (Liechtenstein: "Das AKW kommt", <https://www.vol.at/liechtenstein-das-akw-kommt/1358032>, access: 31.7.2019). As a result, Liechtenstein has joined the anti-atomic trend, as has Switzerland. Secondly, Switzerland's plan to phase out nuclear energy includes a long-term perspective, until 2034 at this point in time. Liechtenstein therefore considers that it still has time to prepare its energy system for the changes. According to studies carried out by a group of researchers at the University of Liechtenstein, the country is able to reduce its dependence on imports from today's 90% to 50% by 2040, and to achieve energy independence in the next two generations, i.e. by 2070 (Droege, Genske 2013: 5). The last reason is that Liechtenstein relies on the extensive development of renewable energy sources, energy saving and energy efficiency, as well as the further development of transnational transmission networks and the interconnection of energy markets. All these elements are intended, in accordance with the strategy papers, to guarantee the security of Liechtenstein's energy supply in the future.

With regard to Liechtenstein's relations with the European Union, they have been shaped as in the case of Switzerland, i.e. in a natural way due to its location in the central part of Europe, but also due to the similarity of approach to energy, climate and environmental policy, which Liechtenstein places great emphasis on. By signing the agreement on the European Economic Area, Liechtenstein was incorporated into the internal market of the European Union, creating a common area of free movement of goods, services, capital and people, taking into account uniform rules on competition and prohibited state aid. At the same time, a field of cooperation in the field of consumer protection, environment, health and education was opened (So wird EU-Recht zu EWR-Recht, <http://eealaw.efta.int/de/>, access: 31.7.2019). For this reason, the European Union's energy policy is a real factor influencing this area in Liechtenstein.

### ***The legal and institutional dimension of Liechtenstein's energy policy***

Against the backdrop of Europe, Liechtenstein is one of the countries that paid attention to the importance of the energy sector at an early stage. This has been reflected in historically passed legislation. The crisis of the 1970s contributed to the adoption of the first Energy Regulation in Liechtenstein in 1979 as a complement to building regulations. This ordinance regulated issues related to the heating of buildings and the type of heating installations, and its aim was to reduce energy consumption for heating buildings, which at that time represented half of all energy used by the state (Biedermann: Energie, <https://historisches-lexikon.li/Energie>, access: 31.7.2019).

The framework for energy policy-making in Liechtenstein began to take shape in the 1990s, as in most Western European countries. In 1996, the *Energy Saving Act* was adopted in Liechtenstein, the main objective of which was to promote alternative forms of energy production, in particular solar energy. In 1998, Liechtenstein became a signatory to the Kyoto Protocol, which resulted in a commitment to reduce carbon dioxide emissions by 92% by 2012 compared to 1990 levels. The *Energy Concept in Liechtenstein 2013*, adopted in 2004 and the *Energy Efficiency and Renewable Energy Act 2008* (Biedermann: Energie, [68](https://historisches-</a></p></div><div data-bbox=)

lexikon.li/Energie, access: 31.7.2019) were to help achieve this goal. Both documents set out the scope of appropriate measures required for energy saving and support for renewable energy sources (Biedermann: Energie, <https://historisches-lexikon.li/Energie>, access: 31.7.2019).

The *Liechtenstein Energy Concept 2013* stressed in particular the need for the technological development of the energy sector to ensure security of energy supply without the need to expand access to raw materials for future energy production. At the same time, technological innovations in the energy sector were intended in the *Energy Concept...* to support climate protection by reducing harmful emissions from the combustion of fossil fuels. The document stresses the need for rational energy production and extending it to renewable sources (Energiekonzept Liechtenstein 2013 der Regierung des Fürstentums Liechtenstein, [http://cdn1.vol.at/2009/06/sm\\_fl\\_energie.pdf](http://cdn1.vol.at/2009/06/sm_fl_energie.pdf), access: 31.7.2019). The *Energy Concept...* had the following objectives:

- reduction of carbon dioxide emissions by 10% by 2010 compared to 1990 levels;
- increasing the share of RES in total energy consumption to 10% by 2013, mainly through the use of domestic biomass, biofuels and solar energy, whose share in energy production in the next decade was planned to triple;
- reduction of energy losses both in transmission (through modernisation of infrastructure and buildings) and in its production, through the construction of cogeneration (blocks for the production of electricity and heat);
- stepping up information policy and public incentives (Energiekonzept Liechtenstein 2013 der Regierung des Fürstentums Liechtenstein, [http://cdn1.vol.at/2009/06/sm\\_fl\\_energie.pdf](http://cdn1.vol.at/2009/06/sm_fl_energie.pdf), access: 31.7.2019).

The document also provided for appropriate financial resources to support the actions and objectives outlined. Interestingly, the *Concept...* also assumed a greater use of wood and wood processing waste (e.g. sawdust) for heating purposes, considering this energy source to be carbon-neutral and taking into account the national potential (Energiekonzept Liechtenstein 2013 der Regierung des Fürstentums Liechtenstein, [http://cdn1.vol.at/2009/06/sm\\_fl\\_energie.pdf](http://cdn1.vol.at/2009/06/sm_fl_energie.pdf), access: 31.7.2019).

The *Act on Support for Energy Efficiency and Renewable Energy*, adopted in 2008, regulated issues related to the provision of financing for the improvement of energy efficiency and the strengthening of the use of RES, while maintaining the objectives related to environmental protection. The Act directly referred to Directive 2004/8/EG of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market (LGBI-Nr. 2008/116: 1).

In accordance with Article 22 of the *Energy Efficiency and Renewable Energy Act*, an Energy Office was established, which is an advisory body to the National Economy Office (*Amt für Volkswirtschaft*, acting under the Ministry of Infrastructure, Economy and Sport – *Ministerium für Infrastruktur, Wirtschaft und Sport* (Ministerium für Infrastruktur, Wirtschaft und Sport, <https://www.regierung.li/ministerien/ministerium-fuer-infrastruktur-wirtschaft-und-sport/amtsstellen>, access: 31.7.2019) in the field of energy policy. Its job covers:

- advising private entities, municipalities and institutions on issues related to energy policy and possibilities of support;
- development and implementation of concepts resulting from the national energy policy;
- preparation of a plan for financial support for measures to implement energy objectives;

- issuing construction certificates in accordance with the Swiss Minergie<sup>5</sup> standards;
- develop an Energy Action Plan in line with EEA objectives (Energiefachstelle im Amt für Volkswirtschaft, <https://www.energiebuendel.li/Akteure/Energiefachstelle.aspx>, access: 31.7.2019).

Article 20 of the Act establishes the Energy Commission as an advisory body to the government and defines its tasks and powers (LGBI-Nr. 2008/116: 1). In addition to the Energy Commission, there are currently two specialised committees to advise the government. The tasks of these bodies are defined as follows:

1. Energy Commission – advises the government on all matters concerning energy policy. It monitors the process of implementation of the energy policy and technological development of this sector, as well as supervising ongoing activities related to the implementation of the provisions of the Energy Efficiency Act. In addition, it is responsible for providing and developing financial support for the construction of demonstration plants. The Power Generation Committee conducts campaigns to disseminate energy information and raise public awareness on these issues, in particular with regard to the use of energy-efficient lighting and household appliances.
2. The Energy Market Supervision Commission – is one of the governmental regulatory authorities. The scope of its activities is limited to issues related to energy market supervision in accordance with national and international regulations on the subject. In accordance with its respective competences, the Commission provides advice to the government, in particular on matters relating to electricity and natural gas market law.
3. Board of Appeal in Administrative Matters – an appeal body in matters of management and decisions concerning construction, road and rail transport, electronic communication, housing, environmental protection, agriculture, etc. (Auszug aus dem Staatskalender des Fürstentums Liechtenstein, <https://www.energiebuendel.li/Akteure/Kommissionen.aspx>, access: 31.7.2019).

In May 2012 the *Energy Strategy 2020* was adopted in Liechtenstein, which outlined the objectives of the national energy policy and the transformation of the sector. The *Energy Strategy 2020* replaced the previous *Energy Concept 2013* and constituted its superstructure (Energiesstrategie 2020, <https://www.energiebuendel.li/EnergiepolitikFL/Energiesstrategie2020.aspx>, access: 31.7.2019). The newly adopted *Strategy...* set four basic objectives, including security of energy supply, economic profitability of energy production, as well as maintaining it at a level favourable to consumers, not hindering social development and environmental protection (Energiesstrategie Liechtenstein 2020, 2012: 12-15). Apart from these objectives, the objectives directly from EU documents concerning the increase of energy efficiency by 20%, as well as the increase of RES share in electricity generation by 20% and the reduction of carbon dioxide emissions by 20% by 2020 compared to 1990 levels were also accepted (Energiesstrategie 2020, <https://www.energiebuendel.li/EnergiepolitikFL/Energiesstrategie2020.aspx>, access: 31.7.2019).

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<sup>5</sup> Minergie includes a set of standards for low energy consumption, ecological and energy-efficient buildings, recognised in Switzerland and Liechtenstein.

The strategy paper presented for the first time data on the level of energy consumption in particular sectors. On this basis, the success of the action groups has been identified, including concrete measures aimed at directly achieving the objectives set out in the *Strategy...* by 2020. These include the building sector, the transport sector, the energy efficiency area, electricity generation, education for raising energy awareness, and laying the foundations for appropriate national energy policy planning, in particular to identify areas for improvement. The *Strategy...* embraces a variety of methods for achieving the objectives set and implementing specific measures on a voluntary basis. In order to create incentives to increase motivation to act, the *Strategy...* foresees the creation of appropriate financial support and emphasises better access to information and education (Energiestrategie 2020, <https://www.energiebuendel.li/EnergiepolitikFL/Energiestrategie2020.aspx>, access: 31.7.2019).

The current actions based on the assumptions of the *Energy Strategy 2020* are evaluated satisfactorily. Thanks to the financial means for the support of RES and energy efficiency, it was possible to save about 6 million litres of heating oil and reduce carbon dioxide emissions by about 12 thousand tonnes. In terms of photovoltaic development, 285 Wp (i.e. peak capacity) per capita were installed in Liechtenstein by the end of 2012, making Liechtenstein the world's second largest producer of photovoltaic services per capita. These installations provide electricity for 3,000 households (Energiepolitische Ziele in Liechtenstein, <https://www.energiebuendel.li/EnergiepolitikFL.aspx>, access: 31.7.2019). According to the French RES development ranking, in mid-2015 Liechtenstein was already the world's first in terms of the number of photovoltaic installations per capita (Renewables 2016 Global Status Report: 212).

The Liechtenstein Energy Union (German: *Energiebündel Liechtenstein*) was established with the main task of creating a platform bringing together all participants in the energy area in order to achieve a level of cooperation for them, as well as to highlight the presence of each of them. The Liechtenstein Energy Union constitutes a response to the European debate on energy and climate challenges and supports national energy policymaking, referring to the energy policy of the European Union and neighbouring Switzerland. The Liechtenstein Energy Union considers it necessary to take measures to reduce energy consumption through the efficient production and use of energy. As well as increasing activity to improve the security of energy supply, which is to be supported by the development of renewable energy sources (Akteure im Energiebereich, <https://www.energiebuendel.li/Akteure.aspx>, access: 31.7.2019).



**Table 1. Legal regulations concerning energy policy in Liechtenstein**

Regulatory area	Legal act	Legal act in original
Support for the energy transition	Law of 24 April 2008 on the Support of the Energy Efficiency and Renewable Energies	Gesetz vom 24. April 2008 über die Förderung der Energieeffizienz und der erneuerbaren Energien (Energieeffizienzgesetz; EEG)
Support for the energy transition	Regulation of 27 May 2008 on Support of the Energy Efficiency and Renewable Energies	Verordnung vom 27. Mai 2008 über die Förderung der Energieeffizienz und der erneuerbaren Energien (Energieeffizienzverordnung; EEV)
Construction law	Construction Law of 11 December 2008	Baugesetz (BauG) vom 11. Dezember 2008
Construction law	Building Regulation of 22 September 2007	Bauverordnung (BauV) vom 22. September 2009
Construction law	Energy Ordinance of 21 August 2007	Energieverordnung (EnV) vom 21. August 2007
Construction law	Law of 23 May 2007 on the energy performance certificate for buildings	Gesetz vom 23. Mai 2007 betreffend den Ausweis über die Gesamtenergieeffizienz von Gebäuden (Energieausweisgesetz, EnAG)

Source: *Energiebündel Liechtenstein*, <https://www.energiebuen-del.li/EnergiepolitikFL/RechtGrundlagen.aspx>, (access: 31.7.2019).

### ***Economic dimension of Liechtenstein's energy policy***

In its strategy paper on energy policy, Liechtenstein draws attention to the growing global demand for energy, which goes hand in hand with the use of fossil fuels. Today, global energy production is based on non-renewable, coal, hydrogen or nuclear energy raw materials. Therefore, in relation to the policy of energy sector transformation, which is gaining increasing popularity in the world, the key challenge of the 21st century is to break the global trend in which the traditional energy system is based on hydrocarbons and coal and to switch the entire economy to renewable energy sources (Energiestrategie Liechtenstein 2020, 2012: 53). For this reason, more and more emphasis is placed on the nature of the energy sector, which corresponds to the pro-environmental policy. Thus, the importance of the origin and method of energy production is growing, which is reflected in the structure of the domestic energy mix and the form of production abroad (due to imports) (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 37).

In its energy policy, Liechtenstein has adopted three pillars to ensure that energy consumption and its consequences in terms of reducing existing natural resources, emissions of environmentally and climate-damaging gases and dependence on locally unavailable energy sources are as little harmful to the economy and society as possible. These three key elements are: increased energy efficiency, increased use of renewable energy sources and measures to reduce energy consumption as well as energy-related products and services (in line with the principle of *sufficiency*). The first two pillars, energy efficiency and increasing RES production, are strongly popularised and usually treated as key elements for solutions to energy policy challenges across Europe. The reason for this is the fact that increasing energy efficiency and enhancing the use of RES is not in principle related to the reduction of the level of comfort (in terms of industrial production dimension and quality of life of the society). In practice, both these areas require concrete action, including careful analysis of the economic, social and technical feasibility of their implementation. Liechtenstein assesses its potential very positively in all these areas and assumes that it is possible to implement these tasks in conjunction with the implementation of economic objectives and the maintenance of social acceptance for them. This assessment is based, inter alia, on studies published in the report *Renewable Sources of Liechtenstein* (German: *Erneuerbares Liechtenstein*), which show that by 2070 full self-sufficiency of the country based on RES is possible with simultaneous minimisation of greenhouse gas emissions, if the previous efforts in this aspect are maintained with a focus on the energy policy objectives adopted (Energierstrategie Liechtenstein 2020, 2012: 53).

The Liechtenstein energy economy is growing in importance, in particular in the field of renewable energy sources, the consulting industry for the optimisation of energy processes, and also energy supply. The energy sector in turn is influenced by the recommendations stemming directly from the Liechtenstein energy strategy and the accompanying debates, which refer to past energy policy making plans. For this reason, Liechtenstein places emphasis on the monitoring and control of the currently implemented measures so that the effects of the strategic document can be coordinated on an ongoing basis (Energierstrategie Liechtenstein 2020. Rück- und..., 2017: 37). For this reason, in the first half of 2017 an evaluation document for the *Energy Strategy 2020* was prepared. The evaluation document entitled *Energy Strategy Liechtenstein 2020. Retrospection and perspectives for the future in the medium term* (German *Energierstrategie Liechtenstein 2020. Rück- und Ausblick zur Halbzeit*) was developed in the middle of the outlined time horizon of the *Energy Strategy 2020*. The evaluation document emphasises that nowadays important economic elements of the planned actions are often omitted when making decisions concerning the energy sector. The basic errors made in the strategic planning process included, first of all, the omission of external costs of maintaining power installations in readiness to provide services and costs related to the operation of infrastructure and energy consumption. Secondly, it was pointed out that investment decisions were often based on too short a time horizon, which meant that in the assumed period it was not possible to fully realise all the planned measures within their full implementation cycle. This made it necessary to take a decision – based on environmental criteria and economic benefits – on which of the planned tasks could not be carried out. Hence, the evaluation document advised that at the stage of investment planning, costs should be included in the full life cycles of the implemented processes. An additional difficulty in this respect is the worldwide trend of rising energy prices (Energierstrategie Liechtenstein 2020. Rück- und..., 2017: 13-14).

By demonstrating in government documents the awareness of the challenges posed by the energy transformation, Liechtenstein assesses current trends in the energy sector as an opportunity for its economy, provided that the actions taken are based on a well-established analysis of economic benefits. Liechtenstein is in a good starting position for the implementation of the energy transformation policy. This is possible, *inter alia*, thanks to the potential of high-tech companies or developed educational institutions, which in the wave of the global trend of changes in the energy sector have a chance to increase their benefits (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 13-14). The energy transformation requires the cooperation of both science and industry in the development and implementation of technological innovations. Meanwhile, Liechtenstein is a highly industrialised country with a particular focus on high-tech industry (Liechtenstein - the business location, 2017: 2), hence the importance of energy as a factor building the competitiveness of the national economy is strongly emphasised in its strategy document. It assesses that this aspect is dominated by the continued availability of energy in the form of certain supplies, which should be accompanied by competitive prices, taking into account the situation on foreign markets (due to the interdependence of markets). In this respect, a special role is played by power generators and distributors, which in the case of Liechtenstein are two State-owned companies: Liechtenstein Power Stations (German: *Liechtensteinischen Kraftwerke* – LKW) and Liechtenstein Gas Supply Company (German: *Liechtensteinische Gasversorgung* – LGV). These companies play an important role in Liechtenstein's energy policy, *inter alia* by contributing to the definition of general principles and guidelines for future energy supplies (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 37) and the framework conditions for an action strategy for the future development of energy policy (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 37).

### ***The social dimension of Liechtenstein's energy policy***

Economic development, employment, and social development are strongly interlinked. The projections for economic development in Liechtenstein were presented in the Strittmatter Partner AG survey, based, among others, on the values of the Liechtenstein Statistical Office, and assume a progressive growth, and the individual scenarios differ only in the expression of its degree (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 52). Such prospects are a positive stimulus for the power generation sector, which, particularly with regard to the concept of energy transition, requires numerous and costly investments. Of course, state subsidies are important in order to stimulate investments in measures aimed at the practical implementation of national energy and climate policy. In this respect, Liechtenstein has developed a support programme for each of the eleven municipalities with a view to achieving climate objectives, including in particular financial assistance to reduce energy demand and increase the use of RES (Die 11 Gemeinden in Liechtenstein, <https://www.energiebuendel.li/Akteure/Gemeinden.aspx>, access: 31.7.2019). It should be remembered, and this is also pointed out in Liechtenstein's energy strategy, that social and economic development determines the exponential growth of energy consumption. In order to break this link between energy development and consumption, efforts are needed to carry out comprehensive tasks in all the social and economic areas that affect the energy sector. This aspect is a central challenge for the future energy policy of Liechtenstein (Energiestrategie Liechtenstein 2020, 2012: 52).

With reference to the challenge outlined above, Liechtenstein has directly taken over from the Swiss Energy Strategy 2050 the concept of "Society 2000-Watt", which focuses primarily on strengthening actions in the field of energy efficiency and RES (Energiestrategie Liechtenstein 2020, 2012: 53). This concept is a vision of long-term development for a climate-neutral, energy-efficient and equitable energy distribution society. Building a "2000-Watt Society" has three long-term objectives:

- reduction of energy demand to 2000 watts of continuous power per capita;
- reducing greenhouse gas emissions to 1 tonne of CO<sub>2</sub> eq per capita;
- justice in energy consumption.

In the light of these objectives, the concept aims to ensure the long-term sustainable use of energy and the equitable distribution of available resources, which, in line with the ambition of the creators of the "2000-Watt Society", should cover all regions of the world. The central point is the reduction of the share of fossil fuels through the increase of energy efficiency in all areas of energy consumption, with simultaneous development of RES as substitutes for fossil fuels. In Switzerland, pilot projects are being carried out to implement this concept in the form of "Energy Cities". (including Zürich, Basel and Buchs) (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 16). These measures not only serve the objectives of the process of shaping a specific model of society, but are also part of the construction sector, which in Liechtenstein has a strong emphasis on the implementation of energy objectives due to its high potential for improvement. One of the concepts for the development in this area was the elaboration of an "Energy City" certificate, which status can be obtained by individual cities or municipalities meeting the objectives set out in the *Energy Strategy 2020*. These objectives include long-term implementation of tasks such as support for the construction of RES installations, development of environmentally friendly transport and efficient use of energy sources (of any origin). The certificate is issued by the independent Association of "Energy Cities", which carries out an evaluation every four years, which may extend the validity of the certificate or withdraw it (EnergieLand Liechtenstein, <https://www.energiebuendel.li/EnergiestadtLabel.aspx>, access: 31.7.2019).

The specificity of this country is the labour force, more than half of which are workers living abroad, mainly Swiss (55.1%) and Austrians (40.8%). In 2017, 19,398 employees lived permanently in Liechtenstein and 21,299 employees commuted from abroad to work (Liechtenstein in Zahlen 2019, 2019: 26-28). This fact has certain consequences: Liechtenstein must remain an attractive economy in order to secure workers. For this reason, it places emphasis on environmentally friendly energy production, but only if it takes place under economically advantageous conditions (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 13-14). In view of the generally accepted definitions of energy security, which include an element of economic efficiency in energy production, it should be stressed that this is a question of the degree of social and economic burden that may be incurred in a given country. This burden in Germany is far beyond what Liechtenstein can afford, as it emphasises in its strategic documents. Therefore, the *Energy Strategy 2020* adopted in Liechtenstein outlines general assumptions and objectives, but their achievement will depend to a large extent on how much the citizens, entrepreneurs and the state budget cope with the financial burden of the energy transformation (Energiestrategie Liechtenstein 2020. Rück- und..., 2017: 13-14).

Liechtenstein, like many other European countries, has difficulty in accelerating the development of electromobility. The *Energy Strategy 2020* set the goal of increasing the number of newly registered electric vehicles to 1,250 between 2012 and 2015, whereas in that period there were only 400. The evaluation document for the *Strategy...* pointed out that the estimates for the development of electromobility in Liechtenstein were overestimated. Hence, its originally planned development was reduced to 20% of its baseline level. Such a revision of the *Energy Strategy 2020* has led to a similar need to adjust energy efficiency and greenhouse gas emissions targets for 2020 (Energierstrategie Liechtenstein 2020. Rück- und..., 2017: 30), given the importance of transport for all these elements. The realism of the objectives based on practical experience has changed expectations for the development of electromobility in Liechtenstein. It is now assumed that there will be further technical progress in the field of electric vehicles and batteries, but significant development of electromobility will start in 2025. In order to support it, a programme has been initiated in Liechtenstein for the extension of charging stations for electric vehicles, in particular fast charging stations. In June 2016, the Energy Committee adopted the objective of building at least one publicly accessible fast-charging station in each municipality, with state funding of 20% of the investment (with a maximum of CHF 10,000). The subsidy is conditional on the guarantee that the station will be supplied with ecologically produced electricity (Schnellladestation/Elektromobilität, <https://www.energiebuen-del.li/ElektroGasMobilit%C3%A4t/Schnellladestation.aspx>, access 31.7.2019).

### **Summary and conclusions**

The analysis of actual activities undertaken so far in the field of the energy transformation shows a strong correlation of geographical conditions, which unequivocally determine the shape of energy policy and the transformation of the sector in this country.

This is important for the energy transformation policy, because as a result of the formation of energy, environmental and climate awareness, the social needs on which consumer decisions are based are unified. On the one hand, this justifies active measures in power generation policy and, on the other, the potential to implement various tasks, develop innovative solutions and develop technologies that will secure, reduce and appropriately shape this demand.

The following important aspects of the energy transformation policy can be deduced from the analysis of programmes and activities undertaken within the framework of cooperation between the DACH countries:

- strong emphasis is placed on technological development and innovation, which stimulate the economy and help to build the competitiveness and economic strength of the state on a macro scale;
- the latest technologies, which are still under development, are issues with particular potential not only in terms of predictable applications and improvements in the power generation sector and beyond, but above all in terms of building a leading position in the international arena;
- dissemination of knowledge and interest of citizens in environmental issues (grass-roots work) is a core activity for the social energy transformation.

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