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CONSTENTS

Design of a Subscription Based Community Solar Energy System for the Business Community of the "Back Gate", Alex Ekwueme Federal University Ndufu-Alike, Ikwo, Ebonyi State, Nigeria

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Abstract: This study presents a model design of a subscription based community solar energy for the business community of the "Back gate", Alex Ekwueme Federal University Ndufu-Alike Ikwo. The business community is largely dependent on the use of fossil fuel generators due to the absence of connection to the Nigeria national electricity grid. The extensive use of the fossil fuel is not only associated with environmental pollution and global warming but its reserve is also finite, non-renewable and expensive. This study presents the use of solar energy to supply the electrical energy need of twenty (20) business premises at the study location. The design was carried out according to the daily electrical load profile of the community, taking into consideration the solar irradiation data of the location, the geographical location and the weather condition. The sizing of each of the system components and the economic analysis of the system in terms of the life cycle cost and electricity unit cost was also taken into consideration. The subscription based community solar with smart meter control gives energy access at reduce cost, the total unit of consumption, unit balance and other energy status per time. The unit cost of electricity using the model design was determined as #0.078/kWh which is cheaper with real time energy costing via a smart meter thereby encouraging the usage of the energy system as an efficient system with enhanced energy accessibility, real time energy services, climate change adaption by reduction of greenhouse gas emission, clean energy development plans/implementation within the community and an investment platform for would-be investors and philanthropist.

Key words: Community solar energy, charge controller, inverter, battery, Smart meter, Photovoltaic array

1.0. Introduction

Ndufu-Alike community in Ikwo local government area of Ebonyi state, Nigeria is largely dependent on fossil fuel generators for their electrical energy need due to unavailability or inadequacy of electric power supply within the community. Behind the Alex Ekwueme Federal University Ndufu-Alike (Figures.1 and 2) is a business community at the location popularly called the "back gate" which are largely involved in typesetting, printing, photocopying, binding, scanning and lamination of students assignments, projects and other documents. Their extensive use of fossil fuel is not only associated with environmental pollution and global warming but its reserve is also finite and non-renewable (Sagar, 2005; Fashina, 2019). The imbalance between energy demand and supply in electrical energy has necessitated the proliferation of these generators (especially "I better pass my neighbor generators" as used and called in Nigeria) which are dependent on fossil fuel, gasoline and diesel for operation. This alarming mass dependence on it exposes communities or persons around the location to the emission of greenhouse gases and air pollution.

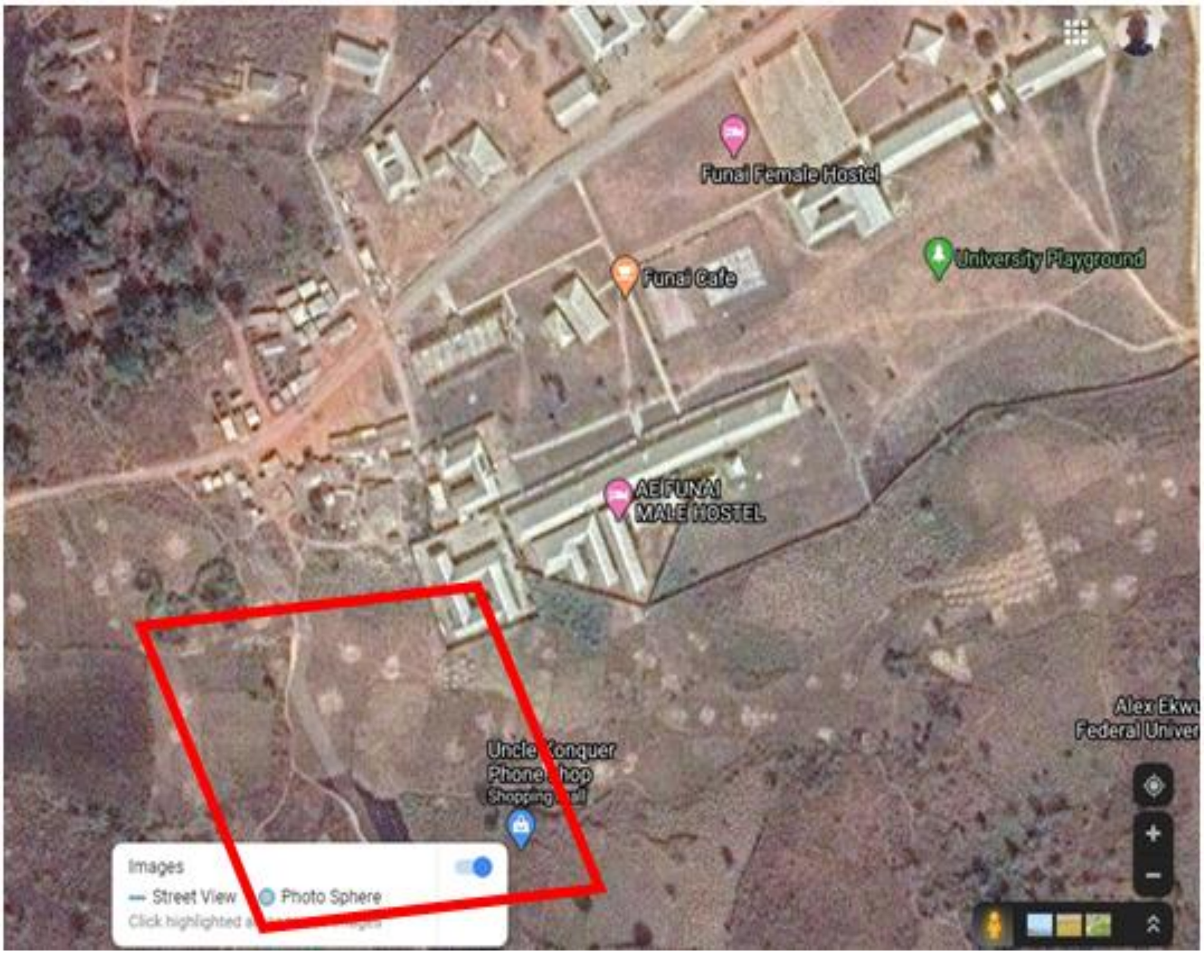

Figure 1: Google Map showing the study location described by the red polygon

Among the existing clean and renewable energy sources, solar energy is one of the most promising as the other sources are limited in their applications due to geographical conditioning, among other factors. The study location has evidently proven to be viable for solar energy installation as seen from the solar irradiation data of the location and the recent commissioning of a 2.8MW off grid solar hybrid power plant at Alex Ekwueme Federal University Ndufu-Alike Ikwo (FUNAI), Ebonyi State on August 2, 2019 by the Federal government of Nigeria (https://rea.gov.ng/osinbajo-inaugurates-2-8mw-solar-power-plant-funai/) which is only limited to the University campus. Solar energy technology also called the photovoltaic (PV) system has been characterized as eco-friendly, abundantly available with no geographical restrictions and is based on the photovoltaic phenomenon (Saleh *et al.*, 2015).

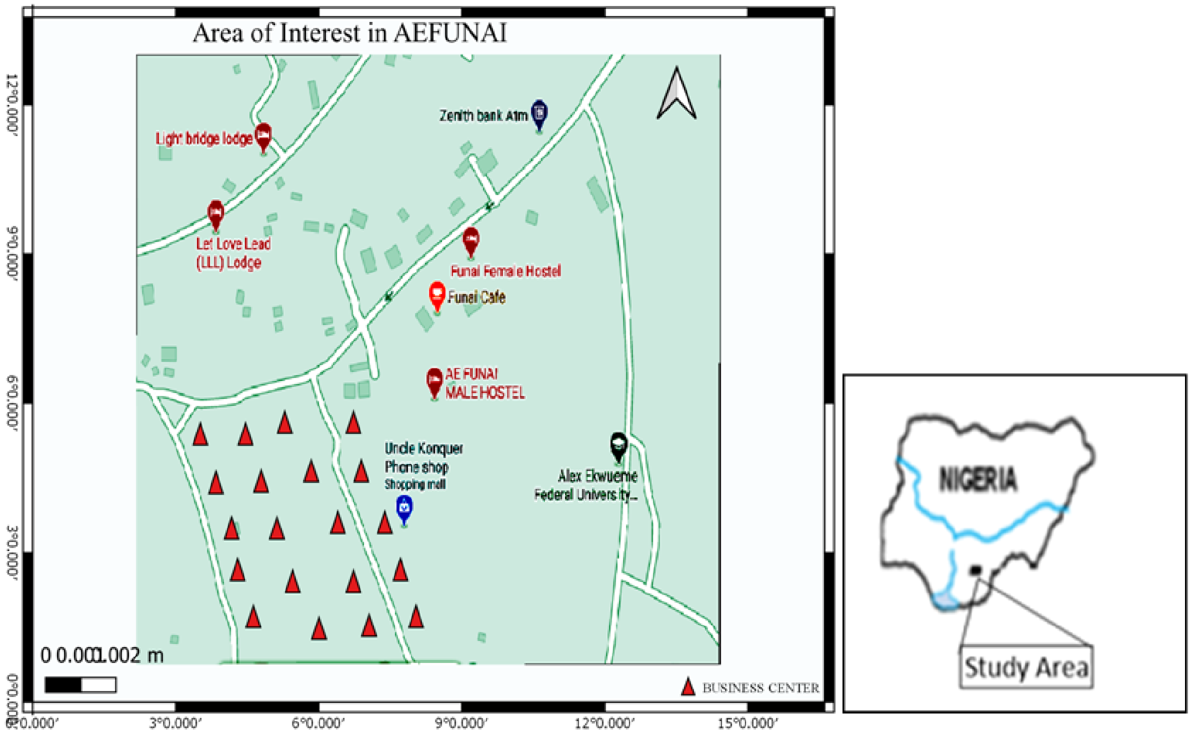

Figure 2: Location map of AEFUNAI showing 20 selected business centres at the “back gate”

The PV system consists of an arrangement of solar arrays which encompasses the ensemble of solar panel to absorb and convert sunlight into electricity, a solar inverter to change the electric current from direct current (DC) to alternating current (AC), installations cables, batteries for storage of surplus energy for use at night and the solar charge controller also called an integrated battery solution for providing regulated DC output as well as monitoring of battery voltage among other components of the systems (Guda and Aliyu, 2015).

PV system ranges from roof top mounted, ground mounted and wall mounted to building integrated system with capacities from a few to several thousand watts to large power stations megawatts generation. PV systems have no moving parts and such do not produce noise. It is highly module in nature, reliable, pollution free, requires little or no maintenance cost and can be easily installed at a choice location. Though the output from PV generator is zero at night, the incorporation of battery ensures that the PV generator charges the battery during the day while the battery serves as the power source at night so as to mitigate the issue of PV intermittency hence enhancing reliability (Hasan *et al*., 2016).

Many electricity end users are not able to implement individual solar energy installations due to financial or technical reasons. Although there are reports on PV system design, these reports are limited to standalone PV system for a single residential building (Abu-Jasser, 2010; Guda and Aliyu, 2015; Hasan *et al.*, 2016), local government offices (Johnson and Ogunseye, 2017), Laboratories (Saleh *et al.*, 2015; Mahmood, 2019) and Hybrid off-grid solar system (Chukwuemeka and Felix, 2018). The concept of community solar for energy accessibility is rarely reported. A community solar energy system is a mini solar plant whose electricity is shared by more than one property, building, shop or business premises. It is often ground mounted solar photovoltaic energy arrays which are smaller in installation size and power output than the utility scale solar PV systems but significantly larger than most individual roof top installations (Markvart *et al.,* 2006). The primary purpose of community solar is to allow members of a community the opportunity to share the benefits of solar power even if they cannot or prefer not to install solar panels on their property. Homes and businesses, even if shaded by trees, receive a bill credit as if the panels were on their own roof using "virtual net metering" or smart energy meter which cost less than they would ordinarily pay to their utility provider. The solar garden allows people to go solar even if they do not own property or roof top, thereby making it an attractive option for renters or those who live in shared building. The community solar has two modes of participation namely the ownership and the subscription mode/model of participation (Joshi and Yenneti, 2020).

The ownership model allows participants to own some of the panels or a share in the solar energy installation project such that they benefit from all the power produced by their share of the solar panels or in the installed solar energy system. In such a model, an individual can purchase enough share to meet the individual's annual or monthly energy requirement or electricity use such that a matching proportion of the installed system's actual output is credited through the individual's electricity bill or through some other form of arrangement with the solar energy system or project administrator.

The subscription model which is the model adopted in this study allows participants to become subscribers and pay a lower price for the electricity sourced from the community solar farm without owning the panels or paying for the installation. A third party or a utility company could develop and own the project and then extend an opportunity to the public to participate using smart meter so as to enhance real time energy consumption and costing (Chan *et al.*, 2017). A pictorial diagram of a typical solar garden and array concept is shown in figure 3, figure 4 shows an offsite shared solar while figure 5 shows how a solar garden works.

Figure 3: A solar garden array (https://www.sunshinecoast.evolutionsolar.com.au)

Figure 4: Community solar energy concept (https://www.energy.gov/eere/solar/community-and-shared-solar)

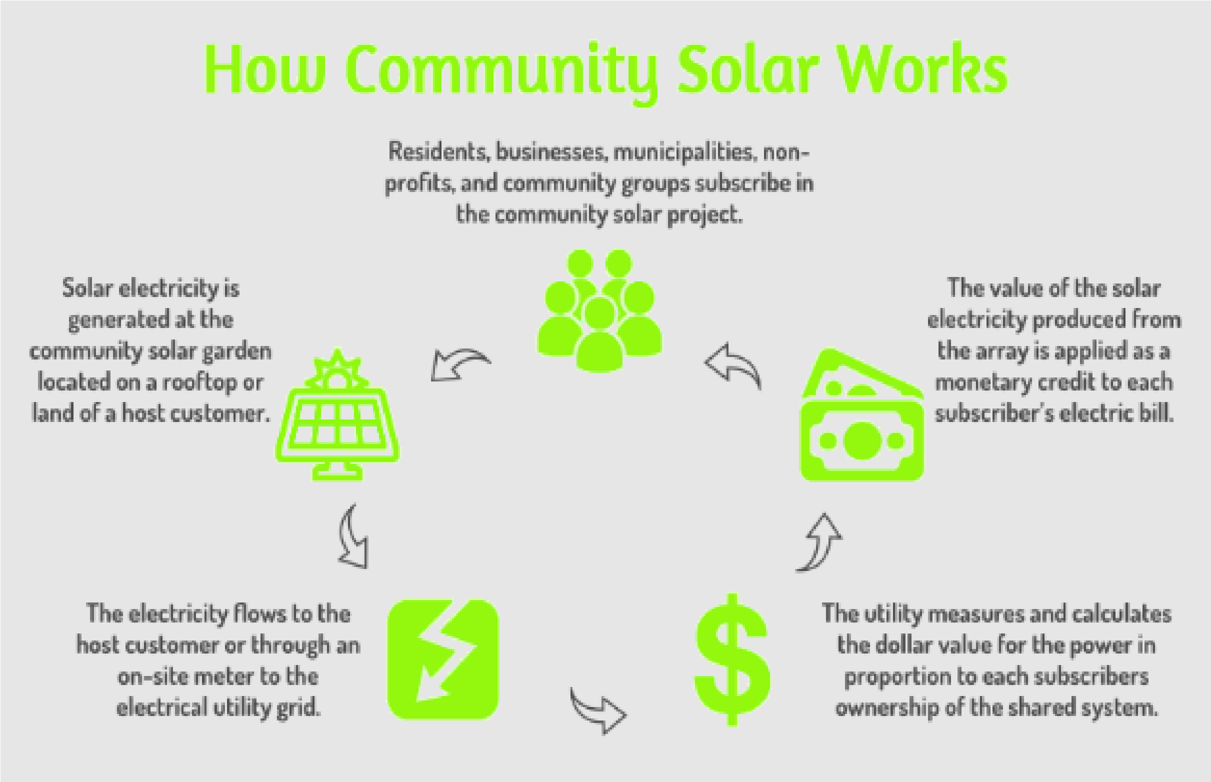

Figure 5: How solar garden works (https://www.sunshinecoast.evolutionsolar.com.au)

This study proposes a model which can be built upon for enhancing energy accessibility in a poor energy state of Nigeria, energy investment, renewable energy policy platform, climate change adaptation by adoption of renewable energy over fossil fuel generators and real time energy costing using a community solar concept with smart energy metering for the "back gate" small scale business community of Alex Ekwueme Federal University Ndufu-Alike, Ikwo-Ebonyi state as a prototype/model. The study also shows that although, the initial investment/installation cost of solar energy system might be high its long time gain is enormous as given by the economic analysis thereby encouraging the participation of individuals, cooperate bodies and possible integration of the solar energy system into the Nigeria National grid given its outlined potentials as a way out to the nation's energy crisis.

2.0. Solar garden design Considerations/sizing

A basic block diagram of the solar energy generation is shown in figure 6 consisting of solar PV array, Charge controller, inverter, Battery and AC/DC loads.

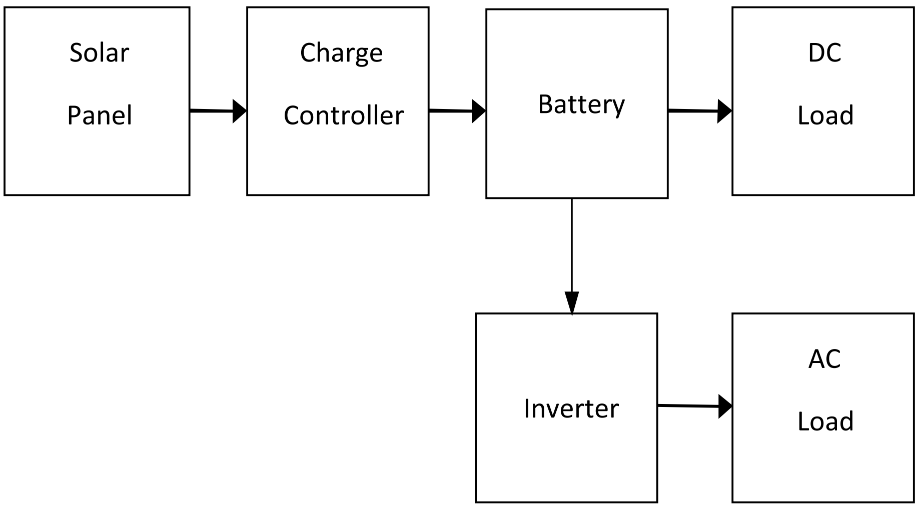

Figure 6: Basic block diagram for a solar system

The PV system design is essential for determining the voltage, current and power capacity of the system components for participating residential load profile balance/requirement. A local survey and energy auditing was carried out to determine the basic gadgets/appliances and their power consumption used by the business premises. It was discovered that the business premises largely use Photocopying machines, Laminating machines, Scanning machines, Laptops/Desktops, electric fans and phone charging points. A total of twenty shops (20) majorly involved in these appliances usage were selected. The basic power consumption of each of these appliances was selected after which the average of the range of power consumption by the appliances and average number of each of the items in a given shop was taken for the calculation of the energy profile and other system considerations. A usage period of 7:30am to 6:30 pm (11 hours) West African time was considered since it is the active period of the students' availability on campus for academic activities by which the students also visit the business community. The average sun hours per day was estimated as five (5) hours. The loads are the power consuming units of the PV system which could be resistive or inductive loads. Each of the block items are discussed below taking into consideration energy demand, materials required/availability, cost consideration and efficiency factors.

2.1. Consumer energy demand (CED)/Residential load profile

The consumer energy demand (CED) which is the sum total of the energy demand by the chosen loads was calculated to determine the choice of other solar system design parameters taking into cognisance the duration of usage of loads, given the power requirement of the load as shown in table 1.The consumer energy demand for a given load which was used to obtain table 1 is expressed by equation 1 (Okwu *et al*., 2017):

$$CED = Q \times P \times T \qquad (1)$$

Where Q= Quantity of the load, T= Duration of usage of the load per day in hour (H) and P= Power rating of the load.

Table 1: Consumer energy demand

S/N	Load	Quantity Q	Power rating per unit P (Watt)	Total power rating (W)	Usage/Duration T (H) per day	CED (WH)
1	Photocopier	20	725	14500	6	87000
2	Laminating Machine	20	30	600	3	1800
3	Scanner	20	12	240	3	720
4	Printer	20	523	10460	6	62760
5	Laptop	20	83	1660	11	18260
6	Desktop	60	310	18600	11	204600
7	Electric Fan	20	80	1600	11	17600
8	Lighting bulb (Compact fluorescent lamp)	20	10	200	1	200
9	Cell phone charging	80	2.5	200	11	2200
Total consumer energy demand (CED)						=395140WH

Source: Survey of selected equipment and energy demand/audit of case study location

2.2. The Solar panel

For the community solar comprising of twenty (20) business premises as a model, the panel requirement was based on the total consumer energy demand (CED) as calculated in table 1. Although different types of solar panels exist with varying efficiency, for design involving interconnections of solar panels, panels of the same make or type is of optimum importance for required efficiency. For the model design in this study a choice of monocrystalline solar panels with a rated efficiency of 80 % was made. The solar panel was selected taking into cognisance factors which affect the efficiency of solar panel such as resistance, reflection, recombination and non-usable energy since only 20% of the about 1000W, 1 m^2 of solar energy radiated by the sun can be harnessed using solar panel which can be mounted on a roof top or a chosen site with provision for free movement in between the arrays for inspection.

A solar module: AE EXTREME 320P6-72 was selected for the design/ PV array sizing with specifications of: Rated voltage of one module $(V_{rm}) = V_{mp} = 36.75V$, rated current of one module$(I_{rm}) = I_{mp} = 8.71A$, Short circuit current $(I_{sc}) = 9.28\ A$,
Power rating of module $= 320W$; dc voltage of the system/system voltage $(V_{dc}) = 96V$. Other parameters for the PV array sizing are: Average sun hours per day $(T_{sh}) = 5\ Hours$
Average daily energy demand $(E_d) = 395140\ watt - hours$

The required daily average energy demand (E_{rd}) is obtained by dividing the daily average energy demand by the product of the efficiency of all the basic system components which is given by equation 2 (El Shenwy et al., 2017):

$$E_{rd} = \frac{E_d}{ŋ_b ŋ_i ŋ_c} \quad (2)$$

Where $ŋ_b$=Battery efficiency=0.90;
$ŋ_i$=Inverter efficiency=0.97
$ŋ_c$=Charge controller efficiency=0.98

$$E_{rd} = \frac{395140}{0.90 \times 0.97 \times 0.98}$$

$$E_{rd} = 461860.35kWh/day$$

The average peak power $P_{av,peak} = \frac{E_{rd}}{T_{sh}} = \frac{461860.35}{5}$

$$= 92372.07w$$

The total dc current of the system is given by equation 3 (Chukwuemeka and Felix, 2018) while equation 4 and 5 (Mahmood, 2019) gives the number of modules to be connected in series and in parallel respectively.

$$I_{dc} = \frac{P_{av,peak}}{V_{dc}} \quad (3)$$

$$= \frac{92372.07}{96} = 962.21\ A$$

Number of modules in series $N_{sm} = \frac{V_{dc}}{V_{rm}}$ (4)

$$= \frac{96}{36.75} = 2.61$$

$$\cong 3 \text{ modules}$$

Number of modules in parallel $N_{pm} = \frac{I_{dc}}{I_{rm}}$ (5)

$$= \frac{962.21}{8.71} = 110.47$$

$$\cong 110$$

Approximately three (3) modules are needed in series while one hundred and ten (110) modules are needed in parallel. The total number of modules (N_{tm}) that forms the array was determine by multiplying the number of parallel modules by the series modules to give the total required number of modules as 330 using equation 6 (Btineth and Dalahal, 2012):

$$N_{tm} = N_{sm} \times N_{pm} \quad (6)$$
$$= 3 \times 110$$
$$=330 \text{ modules}$$

The distance (D) of separation between the panel and the battery was limited to 10 m in order to reduce the voltage drop along the cable from the solar panel since the solar panels are often mounted at some distance away from the battery in order to achieve maximum energy thus causing a distance of separation.

2.3. Solar charge controller

The standard practice of sizing the charge controller is to ensure that it is able to withstand the product of the total short circuit current of the solar array. The required charge controller current (I_{rcc}) is given by equation 7 (Btineth and Dalahal, 2012) :

$$I_{rcc} = I_{sc}^{m} \times N_{pm} \times F_{safe} \quad (7)$$

The safe factor (F_{safe}) has a value of 1.25, whileI_{sc}^{m} is the short circuit current of the selected module with a value of 9.28 A. Using the number of parallel modules (N_{pm}) as 110 as calculated in equation 6:

$$I_{rcc} = I_{sc}^{m} \times N_{pm} \times F_{safe} \quad (8)$$
$$= 9.28 \times 110 \times 1.25$$
$$= 1276\ A$$

Selecting a charge controller, I-Panda MPPT Solar converter (System voltage 96V/192V/216V/240V/384V automatic recognition, Rated current: 50A; 60A; 70A; 80A) with preferred $V_{cc} = 96V\ and\ \ I_{cc} = 80A$;

Number of charge controllers $N_{cc} = \frac{I_{rcc}}{I_{cc}} = \frac{1276}{80} = 15.95$

$$\cong 16$$

As such sixteen charge controllers of 80A each will be suitable and hence were preferred for the design.

2.4. Battery, Battery connection and battery capacity calculation/Sizing

A deep cycle battery was preferred which is also the most recommended battery for a solar PV design with an advantage of many times of recharging cycles after discharge. The estimated energy storage (E_{est}) is determined using equation 9 (Hasan *et al.*, 2016);

$$E_{est} = E_d \times D_{aut} \quad (9)$$

Where E_d is the average daily energy demand of the participating business premises which was calculated as 395140 watt-hours. D_{aut} is the number of autonomous days and was taken to be 3days. Substituting into equation 9:

$$E_{st} = 395140 \times 3 = 1185420Wh$$

Selecting a deep cycle VRLA/SMF Luminous battery with specification C_b (Capacity of a single battery in Ah) = 250 Ah, V_b (Rated dc voltage of one battery) =12V and D_{disch} (Maximum depth of discharge also called depth of discharge DOD) =80%. The safe energy storage (E_{safe}) by the battery was calculated using equation 10 while the total battery capacity (C_{tb}) calculated using equation 11 (Hasan *et al*., 2016):

$$E_{safe} = \frac{E_{est}}{D_{disch}} = \frac{1185420Wh}{0.8} = 1481775Wh \quad (10)$$

The total capacity of the battery bank in ampere hours (C_{tb}) is determined by dividing the safe energy storage by the rated dc voltage of one battery V_b as follows:

$$C_{tb} = \frac{E_{safe}}{V_b} = \frac{1481775Wh}{12} = 123481.25\ Ah \quad (11)$$

The total number of batteries (N_{tb}) is obtained by dividing the total capacity of the battery bank by the capacity of one of the selected batteries and is given by equation 12:

$$N_{tb} = \frac{C_{tb}}{C_b} = \frac{123481.25Ah}{250\ Ah} = 494 \quad (12)$$

The number of batteries in series (N_{Sb}) was determined using equation 13 (Pal *et al*., 2015):

$$N_{sb} = \frac{V_{dc}}{V_b} \quad (13)$$

$$= \frac{96}{12} = 8 \text{ Batteries}$$

Number of parallel battery strings was determined using equation 14 (Abu-Jasser, 2010):

$$N_{pb} = \frac{N_{tb}}{N_{Sb}} \quad (14)$$

$$= \frac{494}{8} = 61.75$$

$$\cong 62 \text{ Batteries}$$

The required total number of batteries (N_{rtb}) was determined using equation 15 after calculating the number of batteries in series and parallel.

$$N_{rtb} = N_{Sb} \times N_{pb} \quad (15)$$

$$N_{rtb} = 8 \times 62 = 496 \text{ Batteries}$$

Four hundred and ninety six, 12V batteries with capacities of 250 Ah each is preferred to give the total capacity of 123500 Ah. Battery of same capacitance of 250 Ah each were selected for connection in order to ensure optimum performance. Although the energy usage period is largely within the day time, 7:30am to 6:30pm there will still be need for energy storage for off-peak usage due to variation in solar irradiation with changing weather conditions.

2.5. Inverter rating

An inverter is rated by its output power (P_{kva}) and DC input voltage (V_{dc}). The inverter was designed to have a power rating that is equal to 125% of the sum of the power of all loads running simultaneously (inductive and non-inductive appliances) and 3.5 times the sum of the power of all inductive appliances. The total power consumed by the defined loads is expected to have same nominal voltage of the battery bank that is charged by the solar PV module. Thus the inverter power (P_{inv}) was determined using equation 16 (Saleh *et al*., 2015) :

$$P_{inv} = 1.25\ (P_{sum} + 3.5P_{ind}) \quad (16)$$

Where P_{inv} = Power of the inverter

P_{sum} =Power of all loads running simultaneously (Resistive loads +Inductive loads) =48060 W

P_{ind}= Power of all inductive loads with large surge current=27400W

$$P_{inv} = 1.25\ (48060 + 3.5 \times 27400)$$

$$P_{inv} = 179950W = 179.95kW$$

The power rating of an inverter is related to the real power that is delivered by the output of the inverter and is given by the equation 17 (Saleh *et al.*, 2015):

$$Power\ factor\ (PF) = \frac{Deliverable\ real\ power}{Power\ rating\ of\ the\ inverter\ (P_{KVA})} \quad (17)$$

The real power is the power consumed for work on load while the PF is generally taken as 0.8.

$$0.8 = \frac{179.95kW}{P_{KVA}}$$

$$P_{KVA} = 143.96kVA$$

The standby mode power consumption which is the power consume by the system when it is not delivering power to the load was taken into consideration. It is usually 5VA per hour. Assuming the system runs for 24 hours, then the standby mode power consumption will be 120VA.Thus the rating of the inverter preferred for the design is 150 kVA.

2.6. Cable sizing

Two types of cables consisting of the inverter to distribution board (DB) system (AC current) of the individual residence and the PV array to battery bank (DC current) through charge controller was considered which is calculated thus: The PV array to battery bank through the charge controller' is obtained using the relation

$I_{cab} = I_{rcc} = I_{sc}^{m} \times N_{pm} \times F_{safe}$ Where each parameter has the same meaning and value. $I_{cab} = 9.28 \times 110 \times 1.25 = 1276A$

Hence a $3 \times 35\ mm^2$ insulated flexible copper cable was selected. For the inverter to distribution board system of each of the business premises/shop, the cable is based on the maximum continuous input current which is obtained from equation 17 (Saleh *et al*., 2015) as:

$$I_{oi} = \frac{P_i}{V_{oi} \times PF} \quad (17)$$

Where V_{oi} = Output AC voltage of inverter, I_{oi} = Current at inverter output

$$= \frac{179950W}{240 \times 0.8} = 937.23\ A$$

For each residence, I_{oi} = 46.86 A. Hence a $3 \times 10\ mm^2$ insulated flexible copper cable was selected.

2.7. Smart metering

A smart meter was employed in the model design to provide a means of energy control and real time energy consumption costing using telecommunication for the automated transmission of data to facilitate energy costing and energy consumption evaluation. The smart meter will give information on energy unit consumed, energy unit remaining, and other energy status at a given point in time using the short message service (SMS). The smart meter design for the energy consumption by the participating business premises consists of a Global System for Mobile Communications (GSM) modem, a microcontroller, a liquid crystal display, a Relay, output load, Analogue to digital converter (ADC) and power supply. While an embedded “C” language program consisting of attention (AT) command string/set was selected for installation as the communication gate way for exchange of instructions/data after conversion of the source code to Hex file for interpretation or use by the microcontroller which is shown in form of a block diagram in figure 7.

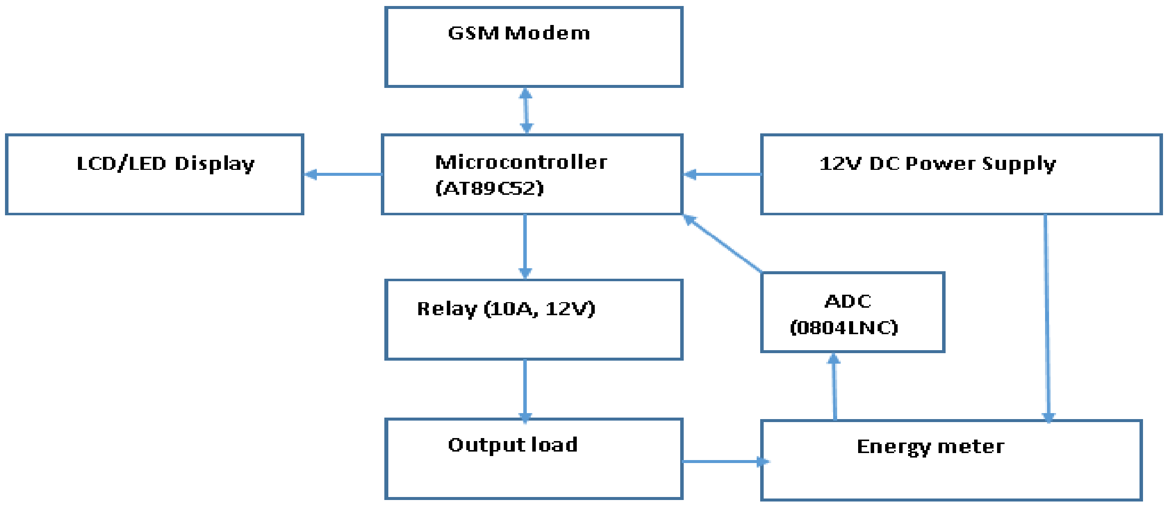

Figure 7: Block diagram of the smart energy meter

The entire system is powered by a 12V dc power supply unit. The microcontroller receives input from the GSM unit and sends it to trigger ON or OFF the relay. The relay receives the signal and either switches ON or OFF the energy supply to the participating shops or business premises. The microcontroller also receives signals from the phone and triggers the relay accordingly. At the interface between the smart energy meter and the microcontroller is the analogue to digital converter which receives analogue signals from the meter, converts to digital signal/equivalence in the form of unit of energy consumption, energy unit balance, low unit alert and other energy status as the case may be for processing by the microcontroller and further display by the liguid crystal display. A control centre will be in charge of the data base of each subscriber’s data such as name, phone number, shop number, SIM ID and energy consumption records where amount of energy unit paid for, unit used and energy unit balance will be used to update the individual subscriber’s data base for energy evaluation, planning, maintenance and management per time. As the energy is consumed by the loads in the individual participating residence, the smart meter sends units consumed to the prepared card which converts the unit consumed into expenditure (E) at every given instant after which it subtracts it from the recharged/subscribed unit amount (R_A) to obtain a balance (B) which is mathematically given by equation 18 (Joy, 2006) as:

$$R_A - E = B \tag{18}$$

The expenditure is calculated from the relation $E = N_A + C_C$, the current charge $C_C = E_C \times E_N \times M_F$ while the energy charged per kWh $E_C = L_R - P_R$. Where

L_R =Last system reading, E_C=Energy consumed, E_N=Energy charged per kWh

M_F=Multiplier factor, N_A=Net arrears, R_A=Recharged amount or subscribed unit amount

P_R=Present reading

2.8. Safety and protective devices

A fuse would be installed in series with each of the string to protect the modules and conduction from excess current and also to isolate faulty strings so as to enhance continuous energy supply. A lightning arrestor is recommended for installation to divert any surge which could be caused by lightning strike given the outdoor instalment. Selected earthly standards for the model design are BS6651, BS7430 and BS7671. DC disconnector at the DC side are also recommended as isolation devices to allow easy disconnection of the solar energy source in the event of system maintenance or fault.

2.9. Summary of PV model system components

A summary of the designed, selected or preferred components of the PV system comprising of the solar module, batteries, charge controller, cables, metering/control and safety/protection devices is shown in table 2 in terms of component model, power rating, voltage and current.

Table 2: Summary of PV model system components

S/N	Component	Quantity	Model	Power rating (W/Ah)	Voltage (V)	Current (A)
1	Solar module	330	AE EXTREME 320P6-72	320 W	36.75	8.71
2	Battery (Optional)	496	LUMINOUS VRLA/SMF Deep cycle Battery	250 Ah	12	-
3	Inverter	06	LUMINOUS 25kVA/240V	20000 W	360 Vdc/240Vac	66A dc/66A ac
4	Charge controller	16	I-Panda 240v/60A MPPT Solar controller	Not applicable	96	80
5	Cables	As required	Array to Battery Inverter to DB	3×35 and $3\times 10mm^2$	Insulated copper cable & flexible copper	
6	Smart energy meter	21	Not applicable	Not applicable	Not applicable	Not applicable
7	Protective/Safety devices	As required	Not applicable	Not applicable	Not applicable	Not applicable

Source: Theoretical analysis with the use of computational models/formulas and market/product survey for components specifications

3.0. Economic/investment cost analysis

A summary of the components cost of the modelled solar energy system is shown in table 3.

S/N	Component	Quantity	Unit cost (₦)	Total cost (₦)
1	PV Module	330	75000	24750000

2	Charge controller	16	240000	2640000
3	Battery	496	130000	64480000
4	Inverter	06	1500000	9000000
5	Cables (PV to battery & Inverter to Distribution board)	560 yards each	1000 per yard 1050 per yard	560000 588000
6	Smart meter	21	30000	630000
7	Design,Labour, installation/control cost	Not applicable		1500000
Total				(₦) 104148000.00K

Source: Theoretical analysis with the use of computational models/formulas and market/product survey for components specifications

The life cycle cost (LC_C) analysis is used to evaluate the behaviour of the proposed energy system. The life cycle cost analysis covers initial capital cost of components purchase and installation stage, operation and maintenance stage and the replacement stage. The operation and maintenance costs (OM_C) include annual periodic expenses for system management, site supervision and maintenance. The LC_C analysis takes into cognisance the longest life cycle of all system components. The storage batteries in the PV system are expected to be replaced every 5-10 years according to the battery type and operating conditions. The life cycle of the luminous battery proposed is 10 years while that of the PV modules is 25 years. The possible escalation trend in the overall costs of the system called inflation (i) and the possible decrease in the components cost with future mass production called the discounts (d) were considered for future estimation. The annual operation and maintenance cost is 2% of the PV initial cost (Shenawy, 2017) while the inflation rate (i) and the discount rate (d) was considered as 5 and 10% respectively. The annual OM_c cost was calculated using equation 14;

$$OM_c = 2\%\ PV_c \times \left(\frac{1+i}{1+d}\right)\left|\frac{1-\left(\frac{1+i}{1+d}\right)^{25}}{1-\left(\frac{1+i}{1+d}\right)}\right| \quad (14)$$

$$OM_c = 2/100 \times 24750000 \times \left(\frac{1+0.05}{1+0.1}\right)\left|\frac{1-\left(\frac{1+0.05}{1+0.1}\right)^{25}}{1-\left(\frac{1+0.05}{1+0.1}\right)}\right|$$

$$= ₦\,6804000.00$$

The battery replacement costs are usually calculated for the first time after 10 years and for second replacement after 20 years since the battery life is considered as 10 years. This is calculated using equation 15 (Mahmood, 2019):

$$B_{C1} = BC\left[\frac{1+i}{1+d}\right]^{10} \quad (15a)$$

$$B_{C2} = BC\left[\frac{1+i}{1+d}\right]^{20} \quad (15b)$$

Where BC, the storage battery cost is ₦ 64480000.

$$B_{C1} = 64480000\left[\frac{1+0.05}{1+0.1}\right]^{10}$$

$$= ₦\,38688000.00$$

$$B_{C1} = 38688000\left[\frac{1+0.05}{1+0.1}\right]^{20}$$

= ₦ 13927680.00

The system's life cycle cost was calculated using equation 16 (Shenawy *et al.*, 2017) by adding PV_c, B_{C1} (Battery cost), B_{C2} (Battery replacement), Inverter cost (Inv_c), Controller cost (C_C), Installation cost (I_C), Operation and maintenance cost (OM_c).

$$LC_C = PV_C + B_C + B_{C1} + B_{C2} + Inv_C + I_C + OM_C \quad (16)$$

= 24750000+64480000+38688000+13927680+9000000

+2640000+6804000

= ₦ 160289680

The annual life cycle cost (ALC_C) was estimated using equation 17 (Shenawy *et al.*, 2017).

$$ALC_C = LC_C\left[\frac{1-\left(\frac{1+i}{1+d}\right)}{1-\left(\frac{1+i}{1+d}\right)^{25}}\right]$$

$$ALC_C = 160289680\left[\frac{1-\left(\frac{1+0.05}{1+0.1}\right)}{1-\left(\frac{1+0.05}{1+0.1}\right)^{25}}\right]$$

= 11220277.60 K

The unit electrical cost (U_C) in ₦ /kWh can be estimated from the annual life cycle cost and the annual energy generation by the system using equation 18 (Mahmood, 2019);

$$U_C = \frac{ALC_C}{365 \times E_L} \quad (18)$$

$$= \frac{11220277.60}{365 \times 395140}$$

= ₦ 0.078/kWh

This is the unit cost of the installed system over 20 years of operation. A charge of ₦ 0.078/kWh is far cheaper than the present ₦ 30.93/kWh currently charged by the privatised Nigerian Power holding company called the Enugu Electricity Distribution Company (EEDC) in charge of Ebonyi state and is cheaper than the cost of using fossil fuel generator which is presently dispensed at ₦150.00k per litre in Nigeria.

3.0. Conclusion and recommendation

The community solar energy system which forms a mini electrical energy grid can be set up by a community/group of persons or an individual to open it up for subscribers with control using smart meter for energy pricing thereby reducing cost of an individual setting up the system especially for the low income earners, increasing energy accessibility/availability especially for low income earners even in cities, rural dwellers, small scale firms/industries and hence the enhancement of climate change adaptation through the reduction of carbon emission/greenhouse gases. Community solar concept has proven to be a fast growing approach to photovoltaic energy generation, transmission/utilisation. Given the pollution free nature, sustainability, reduced cost, reduction on fossil fuel reliance and other economic benefits of solar energy it becomes essential in contributing to the national energy mix and a promising alternative energy to households, firms and industries that depend on electrical energy for operation. Solar PV system with 330 modules have been estimated from the design to meet the energy demand of 20 selected small scale business/shops located at the "back gate" Alex Ekwueme Federal University Ndufu-Alike considered with a total appliances maximum daily energy demand of 48060W. Amidst the initial cost of installation of the system, its consistency, toughness, environmental friendliness and ease of maintenance makes the system worthy of consideration as it is beneficial for long-term energy investment since the payback period is less than 10 years while the life expectancy of the system is above 25 years. Also with the advent/improvement in technology for the production of PV component materials especially the solar module the initial cost of installation is expected to decrease, thereby reducing the payback period.

Having examined the potentials of solar energy using the community solar energy design concepts. It is recommended as a way of energy policy making that:

i. solar energy be integrated into the Nigerian national energy mix as a way out to the Nigeria energy poverty
ii. the establishment of local or indigenous industries for solar energy conversion technologies and application be encouraged by the government and other energy policy makers at all levels
iii. individuals and cooperate bodies be encouraged to generate solar power vai the community solar for onward integration to the national grid
iv. a national research and development fund on solar energy technology be created

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Pomeranian Voivodship – Present State, Opportunities Coming From Diversification the Directions of Energy Supplies and Perspectives for the Clean Energy Development

Tomasz Chyła

Abstract: The article presents the current state of the domestic power industry, with special emphasis on gas in the energy portfolio, analysing the process of becoming independent from natural gas supplies from Russia. The second part of the publication presents the author's reflections on the energetics industry in the Pomeranian Voivodeship, the development of innovative power engineering branches and the perspectives of turning away from high-emission fossil fuels. The author puts particular attention to the planned development of the offshore wind energy sector in the Pomeranian Voivodeship, which will be a driving force for the region's economy.

Key words: decarbonisation, Offshore Wind Energy, Pomeranian Voivodeship

1.0 Introduction

The article is an attempt to analyze the current situation in regional energy market in Pomeranian Voivodeship and to describe the perspectives for that market, showing the trends and taking into consideration observed innovative approach of companies and local government institutions. The main problem of this study is contained in the question: How the local decision makers and industry representatives should act during "clean energy revolution" to become a national leader in the use of renewable energy sources? The main problem will be solved by extraction of the following specific problems:

- What the energy revolution looks like in Poland?
- What is a current state of energy market in Pomeranian Voivodeship especially when it comes to achieving energy self-sufficiency?
- What are the innovative investments in the area of energetics in analyzed region?

The basic research method to solve the above problems is the analysis of the subject literature and specialist press. The article will be divided into 4 main substantive parts: present status of energy management in Poland, role of Pomerania in modern usage and diversification of natural gas sources, analysis of energy independence and use of renewable energy sources (RES) in the Pomeranian Voivodeship and finally a summary.

Energy Management in Poland

In 2006, the installation of the LNG terminal was recognized by the Polish Prime Minister and the Council of Ministers as a strategic investment for Republic of Poland. Nine years after this decision, the first cryogenic tanker arrived at the terminal built at a cost of PLN 3.6 billion, and in 2018 the volume of transshipment reached a planned value of 5 billion cubic meters of natural gas, which covered about 28% of the country's annual demand (about 18 billion cubic meters a year).

The terminal was the first such large investment to make Poland independent from the supplies of this raw material from the Russian Federation, which in time perspective started the trend of diversification the supply directions of this strategic fuel. In 2022, when the "Yamal contract" (31.12.2022) for the delivery of natural gas by the Yamal gas pipeline will expire, the “Baltic Pipe” is planned to be put into operation (01.10.2022). That strategic investment will allow the transfer of up to 10 billion cubic meters of gas per year from the north-west direction (including 25% of the gas extracted by Polish Oil and Gas Company (PGNiG) from concessions on the Norwegian Continental Shelf). Combined with domestic extraction at a projected level of 4,5 billion cubic meters per annum and augmentation in the regasification capacity of the LNG terminal in Świnoujście up to 7.5 billion cubic meters per year (planned in 2021 thanks to additional regasification installation) and in 2023 ultimately up to 10 billion m^3 thanks to third LNG process storage tank, LNG-to-Rail transshipment installation and the second jetty. Those two investments called “Northern Gate will have an excellent impact on improving the energy security of the country” (Miętkiewicz 2019: 57), moreover will give us the possibility of re-exporting the surplus (about 3.5 – 6.0 billion cubic meters with the estimated annual demand level of 18.5 billion cubic meters) to neighboring states (also dependent on supplies from the East).

The process of making independence from Russian’s gas supplies shows the trend of replacing hard coal and lignite (which share in Polish energy mix according to data from 2019 of Polish Energy Networks is respectively 49.3% and 26,1%) (PSE 2019) by a cleaner fossil fuel such as natural gas. Polish energy, which has been for a years based mainly on coal-fired power plants, in the last decade has been undergoing a transition which consist in the substitution of high-emission fuels by renewable energy sources (wind, solar, riverine and geothermal energy), and natural gas, which is a much more environmentally friendly energy carrier (its combustion emits about 40% less carbon-dioxide compared to coal, emissions of nitrogen compounds are also lower, and the emissions of sulfur and dust compounds are almost zero). Turning away from coal (of which deposits in Poland according to data obtained from the National Geological Institute, in 2016 amounted to about 58.6 billion tons for coal, and for lignite – about 23.5 billion tons, for annual consumption approx. 36 million tons for coal (2019) and for lignite - 61 million tons (2017)), strongly correspond to accepted in 2018 the European Union's strategic vision for 2050 (UE 2018) to achieve zero emissions by 2050. Although the Polish side has not declared its commitment to this goal by 2050, decarbonization is an inevitable process, which is the main objective of the "European Green Deal", i.e., a new Economic Development Strategy for the European Union published in December 2019 resulting from the United Nations Framework Convention on Climate Change (COP21) signed in April 2016 and called the "Paris Agreement".

Natural Gas in Pomerania Voivodeship

The decarbonization trend implies a number of investments that are in the planning, execution or operational phases. In addition to the elements mentioned in the article to expand the receiving potential of natural gas supplies by sea called the North Gate, the project of the

FSRU (Floating Storage Regasification Unit) terminal on the Gulf of Gdansk is being considered. In September 2020, a letter of intent was signed, which brings the construction program of a floating LNG terminal with a throughput of 4.5 billion m3 per year closer to the implementation. This will facilitate development process for the LNG market in our part of Europe and will also strengthen Poland's energy security. The location of the FSRU unit in the Gulf of Gdansk will increase the importance of this part of the coast on the economic map of the Baltic Sea i.e. through the possibility of direct bunkering the LNG vessels. Moreover "small scale" LNG terminal with a gas power plant which is planned (2028), at the end of the Gdynia Outer Port (External Port) will also make way to bunker the ships. The project of Port Gdynia assume also the construction of a barge adapted to bunkering other vessels with LNG (PORT 2020)Access to low-CO2 fuel for the marine fleet will have a positive impact on the environment. This is important in connection to the changes taking place in the maritime transportation market. From 2015, only ships using marine fuel with a maximum of 0.1% Sulphur content are allowed to sail in the Baltic and North Seas, in addition to the "Sulphur Directive" in the Nitrogen Emission Control Area (NECA) which include Baltic Sea starting from 2021 the newly built ships will need to meet stricter Tier III NOx standard. Technologies that reduce NOx emissions as required by MARPOL (The International Convention for Prevention of Maritime Pollution For Ships) include selective catalytic reduction (SCR) systems, exhaust gas recirculation (EGR) and the usage of alternative fuels such as LNG (GOV 2019),which seems to be the most economically justifiable alternative in the context of newly built units when raw material prices fall down in global markets. Example of a French CMA CGM shipping company, whose newest container ship, the "Jacques Saade" (ULCV - Ultra Large Container Vessel) powered by liquefied natural gas, has a payload of TEU 23 000 (PM 2020), clearly shows the direction of maritime transportation. Moreover, it indicates that the LNG terminal is highly demand even in the context of augmentation in the level of trans-shipment of ports: Gdansk (Deep Water Container Terminal) and Gdynia (External Port – completion planned in 2028). In addition, the potential of the ports and shipyards (esp. built in 2009 by Remontowa Shipbuilding LNG carrier "Coral Methane") of the Gdańsk Bay indicates that construction of small cryogenic LNG tankers should be a concept worthy of consideration.

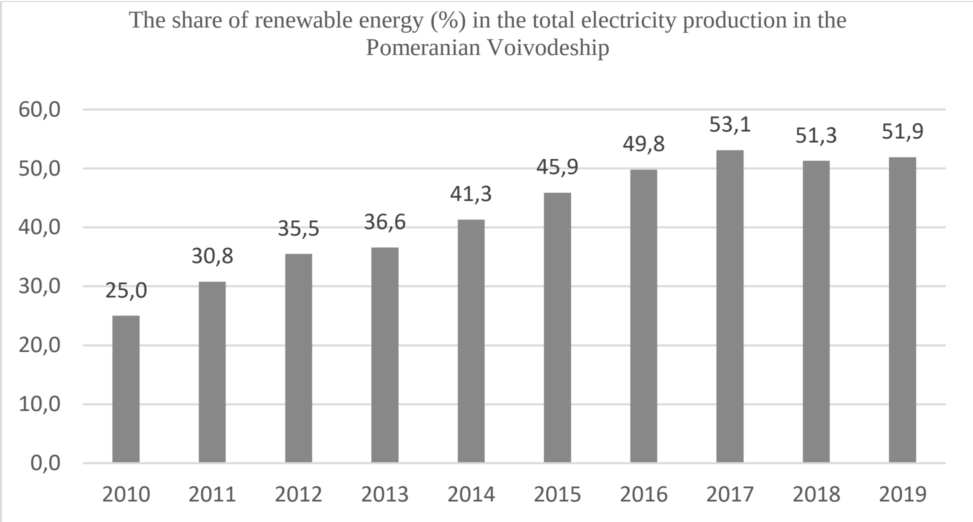
Constantly increasing import of gas impact on the decisions to create modern and "clean" plants producing electricity from natural gas. Testament to that is a fact of signing by the biggest Polish companies: PKN ORLEN, LOTOS and ENERGA a letter of intent in November this year (2020) on the construction of a gas and steam power plant in Gdańsk. The investment is preplanned to be ready by July 2026(LOTOS 2020).

Another example of usage of natural gas in the power industry of the Pomeranian Voivodeship is the city of Władysławowo, which is connected by an offshore pipeline with the Baltic Beta oil rig, and in the unique in European scale CHP (Combined heat and power) plant which use waste gas (byproduct) from the B3 and B8 field to cover its entire demand for electricity and heat of the region.

Analysis Of Energy Independence And Use Of Res In The Pomeranian Voivodeship

On the territory of the Pomeranian Voivodeship (which in 2019 was the 4th among the provinces in respect of usage of renewable energy sources. for electricity production - 51.9%, in comparison to the average for Poland - 15.5%) (GUS 2020), there are a number of investments related to the renewable and low-carbon energy market, which will be elaborated in the following part of the article. The process of increasing contribution of renewable energy in Pomeranian energy mix is shown on figure 1.

Figure 1 Share of renewable energy in total electricity production in the Pomeranian Voivodeship over the last 10 years.



Own study: based on GUS (Central Statistical Office) data "Pomeranian Voivodeship in numbers 2020"

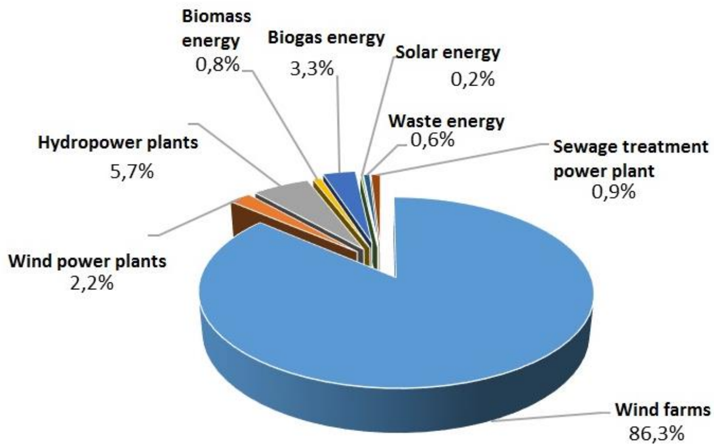
According to the draft "Polish Nuclear Energy Programme" updated in 2020, the most advantageous locations in the context of the future localization of the nuclear power plant are:

- coastal locations – Lubiatowo-Kopalino and Żarnowiec, for this placement environmental and localization research are the most advanced. They are supported among others by significant electricity demand in vicinity and the lack of large, available generation sources in the area, access to cooling water and the possibility of transporting oversized loads by the sea;
- locations currently used by baseload power plants, among others Bełchatów and Pątnów due to the developed transmission net, transport and other infrastructure, the location in the center of Poland and the fact that the construction of nuclear power plant in these areas after halt of the operated power plants will allow to maintain jobs.

[...] Considering the state of progress of the work and other conditions, the site of the construction of the first nuclear power plant will be selected from the coastal locations" (BIP 2020). According to the above document, the first of the planned 2 nuclear power plants will start producing electricity in 2033.

On the territory of the Pomeranian Voivodeship, which according to the data contained in the document published in 2018 entitled "Report on the energy sector and peri-energy services in the Pomeranian Voivodeship taking into account the prospects for the development of technology" - the production of electricity from renewable sources takes place in various sources and includes: 41 wind farms and 36 wind power plants with a total capacity of about 815 MW [...] (DRG 2020) , which represented about 12% of all electricity production in Poland using wind energy.

Figure 2 Renewable electricity generation in the Pomeranian Voivodeship in 2017.



Own study: based on GUS (Central Statistical Office) data

In the context of electricity production in the Pomeranian Voivodeship, which is not self-sufficiency in electricity generation, producing 52% of its own demand, wind, which is the largest energy potential of the region, generates 88,5% of the total generated electricity from renewable sources, which show figure 2. Despite the high participation rate of wind power plants, the Act on investments in wind power plants from May 2016 (so-called Distance Act), stopped the development of this energy sector in Poland. Changes planned by the Ministry of Development by the end of 2020 (including the liberalization of the 10H rule) might reverse this unfavorable trend. The planned amendments are also intended to apply to the mentioned above Distance Act, which requires the minimum distance of wind power plants to be set at ten times the total height of the installation (aforementioned 10H rule) and selected forms of nature protection.

In contrast to, in the opinion of the author, temporary stagnation in the development of onshore wind energy, is the launch and entry into the demonstration phase in September 2020 of the first Battery Energy Storage System (BESS), which is devoted to storage of energy produced mainly from RES by usage of specially developed batteries located in vicinity of the wind farm in Bystra near Gdańsk. The main objective of this investment is to improve safety of the electricity grid, by balancing shortages or excess energy produced that accompany the generation of energy by wind turbines. It should be mentioned that this is not the only one investment in Gdańsk Pomerania, in 2016 an energy storage facility with a maximum power of 0.75 MW and a capacity of 1.5 MWh in the vicinity of Puck was built.

A certain innovation on the national scale is a plan to use offshore wind energy. Citing research of the International Energy Agency, offshore windmills can operate (produce energy) at full power by 30 to even more than 50% per year unlike the land windmills which use full power by 23-40% of the operating time. In addition, the construction of windmills at sea is not accompanied by social protests and the Baltic Sea due to wind conditions, low salinity (corrosion aspect) and moderate depths (economic and technical factor), is an ideal basin for this type of investment.

According to the assumptions contained in the Polish Energetics Policy 2040 (PEP2040) and adopted in 27.11.2020 law about the promotion of electricity generation in offshore wind farms (so-called offshore law), offshore wind power will be implemented from 2025 and installed capacity will reach: around 5.9 GW in 2030 and about 8-11 GW in 2040. It is assumed that the first Wind Power Plant (WPP) will be built by 2024 and the closest to the implementation process is WPP Baltica-1 (owned by PGE – Polish Energetics Group), which in June 2020 received technical conditions for connection to the transmission network for power up to 896 MW. In 2021, an environmental decision is likely to be issued, which will bring closer a building permission. Except reduction of CO2 emissions, offshore wind power plants will contribute to the economic development of the Pomeranian Voivodeship. The development of this industry can be a flywheel for the economy. The shipbuilding industry and ports will be the entities that will be mostly activated in this process, this will be a huge opportunity for the Tricity (which has the best facilities for this), but also for the whole province. The Polish Wind Energy Association estimates that more than 70 sectors of the economy can participate in profit making, and more than 100 Polish entities can be involved in the process of preparation, construction, and operation of wind farms in the Polish Sea Areas. An undoubted asset of the region is also the human potential: a number of an offshore-branch specialists and the first postgraduate studies in Poland aimed at training the staff of offshore wind energy launched at the Gdańsk University of Technology from 2019. (PG 2019) (lack of source)

60 small hydropower plants are located in the Pomeranian Voivodeship, including 31 professional ones, supplying electricity to the central grid. (KOWALCZYK, CIEŚLIŃSKI 2018: 74) Since the differences in the height of the land in the province are small and the decrease in the area is low the maximum power of hydroelectric power plants are: 7.2 MW for the hydroelectric power plant in Bielkówko on the Radunia River and 4.16MW for power plant in Gałązina Mała on the Słupia River. On a provincial scale, classical hydropower plants generate around 0.9% of the energy consumed per year.

Pomerania Gdańsk is distinguished from other regions also by having on its territory the largest Polish pumped-storage power plant in Żarnowec which main task is to equalize the power balance in the electricity system, i.e., allows through the possibility of accumulation of water energy, optimal operation of thermal power plants and in the future nuclear (in this context, in 1983, the indicated complex with a capacity of 716 MW was created).

What is worth noting, also in terms of the usage of biomass energy which is important in the trend of decarbonization, the Pomeranian Voivodeship is at the forefront of Poland. On the territory of Pomerania one of the largest power plants in Poland using agricultural biogas to produce electricity in the cogeneration system are located. These are included in the report of the Director-General of the National Agricultural Support Centre of 2019: power plants in Koczale, Darżyno and Miastko (with a total installed capacity of about 2.5 MWe each). An innovative at European scale biomass plantation was also established in Kwidzyn. The fast-growing hybrid poplar was planted on an area of about 25,000 square hectares and is used to produce energy in the International Paper Kwidzyn combined heat and power plant.

When analyzing the potential of the Pomeranian Voivodeship, it is impossible not to mention the production of pure hydrogen. Several hydrogen production and recovery facilities are operating at the LOTOS oil refinery in Gdańsk. It is mainly used in several technological processes, however, there is a prospect of a wider use of pure hydrogen (99,999% purity), to drive buses in Gdańsk, Gdynia, Tczew or Wejherowo (the Pomeranian Hydrogen Valley project implemented under the so-called Hydrogen Cluster, foresees the implementation of this solution by 2024), in the long term the project assumes the usage of hydrogen in regional trains on the Gdynia - Hel line and passenger ships. In addition, the LOTOS Group announced in May 2020 that it intends to obtain electrolysers (generators that use electricity to decompose water into hydrogen and oxygen) in order to produce so-called "green hydrogen" (hydrogen produced using fossil fuels is "grey hydrogen"), and to verify the possibility of these devices cooperating with the variable generation of electricity from renewable energy sources (especially declining cost of offshore wind energy production creates unique opportunities that are already being used in the Western Europe) , which fits perfectly into the utilization of wind energy at sea.

In the context of innovative clusters, we should also mention the local initiative of the Municipal Energy Cluster, which associating 6 municipalities of the Bytowski district, with the aim of gradual ensuring independence from the energy supplier through investments in RES (mainly photovoltaics, heat pumps but also the use of high-efficiency cogeneration in the combined heat and power plant). Another notable local initiative is the one established in September 2020 by Rumia Invest Park "Pomeranian Platform for the Development of Offshore Wind Energy in the Baltic Sea", an initiative which is intended to prepare the region for the challenges and opportunities related to the development of offshore wind energy in Pomerania.(POMORSKIE 2020) (source?)

Summary

As can be seen from the above examples, innovative approach, human and technical base, R&D potential, local initiatives and, above all, the location on the shores of the Baltic Sea make it possible to assume that, during the ongoing energy transition in the era of the so-called "energy trilemma" when energy sources are required to be both accessible, reliable, stable and sustainable, the Pomeranian Voivodeship has the potential to become a national leader in the use of renewable energy sources and achieve energy self-sufficiency despite small fossil fuel deposits and energy-intensive industries in the area.

In the course of analyses following conclusions can be formulated:

- The investments described above will definitely affect on RES market in the Pomeranian Voivodeship;
- Those projects (especially Offshore Wind Energy) contribute to an overall reduction in the level of emissions generated by the Polish energy system;
- Import of key less-CO2 energy carriers and development of modern energetics branches especially hydrogen usage and progressive nuclear power plants will allow fulfil the goal of making the Polish climate neutral by 2050 - Pomeranian Voivodeship will have a chance to be an important part of this process.

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Analysis of energy efficiency in Poland in 2008-2018 in the context of sustainable development

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Abstract: analysing the Polish energy sector, changes in the market can be seen as a consequence of growing role of EU regulations, which increasingly affect the functionality of national and local markets. As a general rule, the basis of regulation is set out in the adopted strategy papers, indicating developmental desires within the energy market. The energy policies that are taken, which define the implementation measures, should guarantee the security of investment in the long term. The increase in energy efficiency generates significant financial savings while generating benefits for the environment, industry, transport or households. As part of monitoring the level of energy efficiency, the ODYSSEE-MURE programme has developed the ODEX indicator. The aim of the study was to analyze the level of efficiency in Poland in general and with an indication of three main sectors, as well as the level of Polish energy savings in the years 2008-2018. The research showed that the increase in energy efficiency of the Polish economy in the period under consideration is systematically increasing. Overall, between 2008 and 2018, the average rate of energy efficiency improvement was 1. 7% per year. On the other hand, savings achieved in 2018 within the indicated sectors amounted to 0.10 Mtoe.

Key words: energy efficiency, ODEX index, energy management, energy production

1.0. Instruduction

As the economic development of regional integration in Europe progressed, activities between countries were initiated as part of the development of a collective energy policy and, consequently, further climate and energy policy measures. Due to the increasing changes, mainly in the external environment of the European Union, climate protection issues have increasingly been addressed by policy makers. At present, despite the advanced specialisation, the implementation of energy policy objectives requires that climate policy objectives be taken into account at the same time. Given the considerable number of overlapping aspects of these policies, it is understood that they are implemented jointly as part of the European Union's climate and energy policy. The priorities in the field of energy management in the territory of the European Union include: security of energy supply to the internal market, liberalisation of the electricity and gas markets, change in the generic structure of energy carriers used in terms of their impact on the environment, as well as development of modern energy technologies and research.

In the international and European sphere, significant changes are being made to the legislation, which emphasises the importance of energy efficiency in terms of reducing energy consumption and CO2 emissions. The sustainable development objectives for 2016-2020 announced by the SBOs in 2015 indicate, inter alia, an improvement in energy efficiency of 27% (with reference to 1990).

As part of the implementation of the new energy policy, it is crucial to adequately select tools for monitoring the undertaken projects. To this end, the use of indicators aimed at assessing the extent to which the objectives have been met and at producing internationally comparable statistics is justified.A dedicated meter is the ODEX energy efficiency index for monitoring targets. The ODEX index was developed in the framework of the ODYSSEE-MURE programme, in which 28 countries from the EU and Norway cooperate. The main objective of the programme is to regularly monitor changes in energy consumption through two complementary databases: ODYSSEE related to energy efficiency and CO2 emissions, and the MURE database indicating actions taken to reduce energy consumption.

The aim of the study is to analyse the ODEX index and energy savings in Poland, taking into account the main economic sectors in the context of sustainable development. The analysis period adopted covers the period 2008-2018.

Energy efficiency – the EU regulatory framework

Both the Member States and the EU institutions are responsible for shaping and implementing climate and energy policy in the European Union. Projects carried out in the wider energy sector have been initiated since the beginning of the European Communities. However, it was only with the Lisbon Treaty that Title XXI - Energy - was included in the Treaty on the Functioning of the European Union (Treaty on the Functioning of the European Union, Article 194. which has contributed to formalising the competences and responsibilities in this area, which have been shared between the Member States and the European Union, and formally strengthening EU climate and energy policy.

The objectives indicated for climate and energy policy should include ensuring the operation of the energy market, and should be implemented in accordance with an approach of solidarity between Member States. In addition, they contribute to energy saving and the promotion of energy efficiency, to the development of new and renewable forms of energy, to the interconnection of energy networks, and to the security of energy supply in the EU (Treaty on the Functioning of the European Union, Article 194).

The priority objectives of the EU climate and energy policy have been specified within the so-called Climate and Energy Package, which is a set of six acts that were adopted by the European Commission in 2007 and 2008 (European Commission 2007). The first strategy was the 2007 European Energy Policy, which set targets (Paska, Surma 2013: 8):

- to reduce greenhouse gas emissions by at least 20% by 2020 with reference to 1990 (base year) and, in case a global agreement on greenhouse gas reduction is reached, to reduce greenhouse gas emissions by 30% by 2020 in the EU,
- to increase the share of energy from renewable sources in the context of final energy consumption to 20% by 2020, including a 10% share of biofuels in total fuel consumption,
- to increase energy efficiency by 20% by 2020 with reference to the forecast for energy and fuel demand.

The indicated objectives of the climate and energy policy have been specified and included in the strategies drawn up by the European Commission, as well as in the actions implemented. Among the most important solutions for improving energy efficiency, the EU economy's Europe 2020 strategy for smart, sustainable and inclusive growth (European Commission

2010), based on increasing competitiveness, stands out, as well as the long-term strategy for developing a competitive low-carbon economy by 2050 contained in the Roadmap for moving to a competitive low-carbon economy (European Commission 2011a). Subsequently, the climate and energy policy objectives have been taken into account in the Committee of the Regions' Opinion on 'The climate and energy policy framework for 2020-2030' (European Commission 2014b), which sets out the EU policy objectives and targets for the period 2021-2030, and these objectives have been included in the European Energy Security Strategy (European Commission, 2014a).

Energy efficiency is one of the most important economic issues alongside productivity, efficiency, effectiveness and quality (Czerwińska, Pacana 2019: 3-4). The concepts presented are closely linked by a complex series of relationships that require a deepening of certain definitions and aspects.

When considering the concept of energy efficiency, the first step should be to understand its essence. In the narrow definition, economic efficiency should be understood as the relationship between the effect and the effort (Roszek 2008: 125-133; Pionek 2001: 32-33; Paterson 1996: 377-390). On the other hand, in the context of referring the achieved effect to the amount of energy consumed (for example, in the production process, in the implementation of its individual stages or in the consumption of individual machines and equipment), it is possible to apply the concept of energy efficiency and define it as the ratio of the obtained results, goods, services or energy to the input of energy (Skoczkowski, Bielecki 2016: 173-184; Michalski 2010: 33-34). Economic efficiency is not only linked to technological processes in a qualitative sense, but also means efficient energy consumption. Therefore, energy efficiency is a measure of the use of energy in economic activity and is a fundamental factor in improving competitiveness, expected environmental effects, as well as energy security of the country. Its improvement reduces the energy and material intensity of the economy and creates a relative supply surplus (Mastelarska 2011: 281-296).

Energy efficiency in the context of sustainable development

Improving the level of energy efficiency is one of the key issues in terms of implementing the idea of sustainable development. According to the concept of this idea, there is a compromise solution between the economy, society and environmental resources, i. e. between progressing economic development and leaving the natural environment in the best possible condition for future generations to use it (Mazur-Wierzbicka 2006: 317-320; Tester, Drake, et all 2005: 19; Pacana, Czerwińska, et all 2020: 151-153). Energy efficiency measures are directly linked to the sustainable development objectives set out in the UN Agenda for Sustainable Development 2030. (United Nations 2015):

- Target seven: 'Ensure an affordable, reliable, sustainable and modern energy supply for all'
- Target thirteen: 'Take urgent action to mitigate climate change and its effects".

The aim of EU energy policy and legislation relating to the energy sector is to implement actions consistent with the rationale of sustainable development, mainly through the evolution of technologies using renewable energy resources and the development of cogeneration of electricity and heat (Skoczkowski 2002: 2-10). The Green Paper presented on 8 March 2006 was a kind of attempt to direct the EU strategy towards sustainable development in the field of energy (European Commission 2006).

Energy policy is a key level of sustainable energy development. Sustainable energy can be defined as the conversion of primary energy into heat and electricity, together with its supply to the final consumer in such a way as to meet the needs of both current and future generations, taking into account social, economic and environmental considerations of the development of the social unit. Issues relating to the concept of sustainable energy consumption are to be considered as part of energy policy, not energy itself (Prandecki 2014: 247).

The concept of sustainability also exists in energy systems. It is emphasised that a sustainable energy system should be based on: 'a combination of renewable energy technologies, renewable fuel transport, renewable heat, demand reduction, efficiency of use, as well as co-generation of energy production' (Mitchell 2010: 121-124). The features of this type of energy system include (Wach 2008):

- increasing use of renewable energy sources,
- emphasis on achieving long-term economic and environmental goals,
- functioning in competitive markets,
- growing interest in and penetration of new technologies,
- emphasis on taking into account external costs,
- functioning in international markets with identical competition rules.

A special role in balancing development processes in the energy aspect is attributed to renewable energy sources. However, it was often pointed out that it is difficult to indicate a situation in which the energy obtained was generated only from RES. The main barriers were: significant costs, limited electricity storage capacity or lack of capacity to produce mass-scale installations. However, the lack of political will was indicated as the most significant barrier (Malko 2006: 190; Graczyk 2017:56). Currently, sustainable energy is a different and broader concept than renewable energy, because all energy sources with a simultaneous relatively long life cycle and low environmental impact should be classified as such energy. (Pradecki 2014: 243).

An interesting definition of sustainable energy has been developed by the LG Action organisation, which brings together local authorities taking actions contributing to sustainable development. According to the representatives of the organisation, sustainable energy is not only a problem in terms of sustainability, but also in terms of allowing the use of energy sources that cause relatively little harm to humans and the environment. This is important because in practice there is no energy source that does not generate environmental damage. Therefore, all the theories indicating the possibility of harmless energy production are utopian in nature (Prandecki 2014: 239-240).

ODEX energy efficiency index methodology

The ODEX index is an aggregated indicator of energy efficiency. Among aggergated indicators of Energy efficiency, ODEX is presently one of the most complete for monitoring the implementation of the indicative target, within the framework of energy end-use efficiency indicated in Directive 2006/32/EC (Directive of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services) (Arcipowska, Tomaszewska 2012: 7). The ODEX index provides a measure of progress on energy efficiency in relation to three strategic sectors: transport, industry and households, as well as the country's economy as a whole. The methodology used allows to calculate the index in several stages with different levels of aggregation (Weber 2009: 1563-1564). ODEX is a weighted average of the indices of unit consumption of particular sub-sectors, where the weights assigned indicate the share of a particular sub-sector in total energy consumption. The subsystem indicators are calculated based on observed changes in specific energy consumption. These changes are expressed in physical units (for example, square metres of housing). Some sectors are not included in the ODEX calculation, such as construction and mining. This is due to the difficulty of obtaining data, and it is assumed that all sub-sectors have energy efficiency gains equal to the sector average (Enerdata 2016).

The ODEX indicator is obtained by aggregating the changes in specific energy consumption observed over time at specific end-use levels. It is calculated for each year as the quotient of the actual energy consumption in a given year and the theoretical energy consumption not taking into account the effect of the unit consumption, i. e. assuming the existing energy intensity of the production processes of the products concerned. A 3-year moving average is calculated to reduce accidental variations. A decrease in the value of the indicator means an increase in energy efficiency. The ODEX indicator does not show the current level of energy intensity, but progress from the base year 1990 (Zając 2010: 2453-2454).

The ODEX is calculated using the following formula:

$$\frac{I_t}{I_{t-1}} = \frac{\sum_i EC_{i,t}}{\sum_i A_{i,t} \cdot UC_{i,t-1}} \tag{1}$$

where:

$EC_{i,t}$ – energy consumption in the *i* sector in year *t*,
$A_{i,t}$ – variable activity of sector *i* in year *t*,
$UC_{i,t}$ – unit consumption of sector *i* in year *t.*

In the formula It is the index value for year t, so the ratio It/It-1 indicates the level of energy consumption in year t divided by the energy consumption that would have occurred in year t, where the specific consumption was the same as in year t-1 (Enerdata 2016).

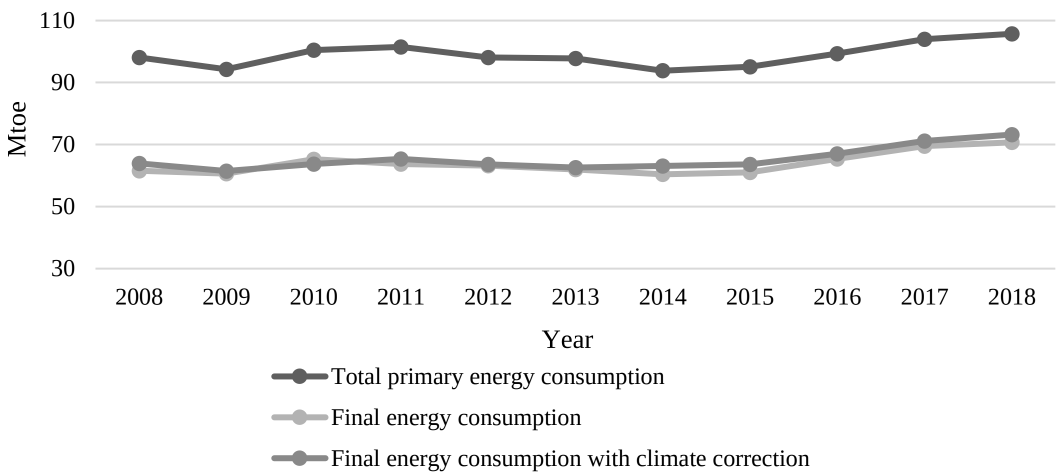
This indicator is not focused on absolute values as it illustrates the change that has occurred in relation to the energy efficiency level of the reference year. A shortcoming of this approach is that the result of the ODEX index is significantly influenced by the situation in the base year. Reading the value of ODEX, it should be noted that its value at the level of 99 indicates an improvement of 1%, so a decrease in the value of the indicator indicates an increase in energy efficiency (Lapillonne, Pollier 2011; Kicki, Jezierowska 2015:31).

In industry, for example, the overall effect of unit consumption will be obtained by aggregating the effects of unit consumption within individual departments. The ODEX indicator is calculated for each year by dividing actual energy consumption by theoretical energy consumption without taking into account the effect of unit consumption (i. e. without saving the energy obtained by reducing the unit energy consumption as part of energy efficiency improvement measures for the production process of the product). If the energy efficiency index was 85 in 2000, this means an improvement in energy efficiency of 15% compared to energy technologies and practices in 1990 (Zając 2010: 2453-2454).

Energy efficiency and energy savings 2008-2018

The analysis of energy efficiency and energy savings is based on an analysis of the level of energy consumption (Figure 1). In the period under consideration, total primary energy consumption increased by 7. 6 Mtoe - from 98. 1 Mtoe to 105. 7 Mtoe, which meant an increase of 0. 8%/year. The highest consumption took place in 2018 (105. 7 Mtoe) and was 1. 7 points higher than in 2017. The lowest energy consumption, after a three-year decline, was recorded in 2014 - 93. 8 Mtoe. The dynamics of growth of energy consumption is connected with significant economic growth that took place in the last three bars of the examined district. With regard to the final increase in energy consumption, an average annual blunt increase of 1. 4% was observed. In 2009 and the years 2011 - 2014 a decrease in consumption was recorded, reaching 60. 6 Mtoe, followed by 63. 7 Mtoe, 63. 2 Mtoe, 62. 0 Mtoe and finally 61. 0 Mtoe.

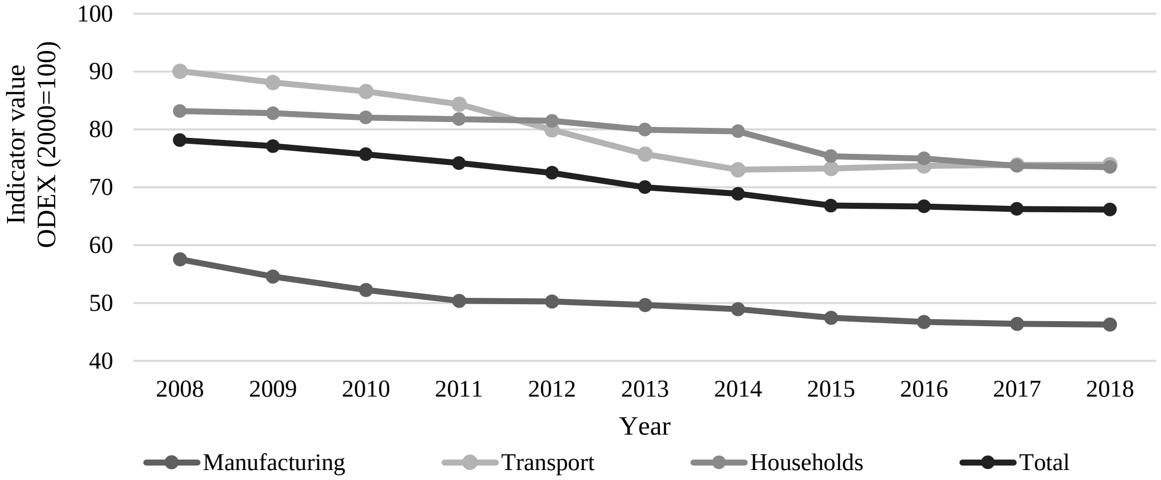
Fig. 1. Energy consumption 2008 – 2018 in Poland



Source: www.stat.gov.pl (access: 11.11.2020)

The ODEX index in the study is calculated to the base 2000=100. Overall, in the years 2008-2018 the value of the index decreased from 78. 1 to 66. 2 points. The average rate of energy efficiency improvement was 1. 7% per year. The slowest rate of improvement was observed in the household sector - the annual improvement in the period 2009-2018 reached 1. 2% (down from 83. 2 to 73. 5 points). In the transport sector, the average rate of improvement was 2. 0%, and the value of the 2018 index was normalized at 73. 9 points. On the other hand, the fastest rate of improvement (2. 2% annually) was recorded in the processing industry, for which the value of the indicator amounted to 46. 3 points. in 2018. The indicated data are presented in Figure 2 concerning the value of ODEX in the years 2008 - 2018 in Poland.

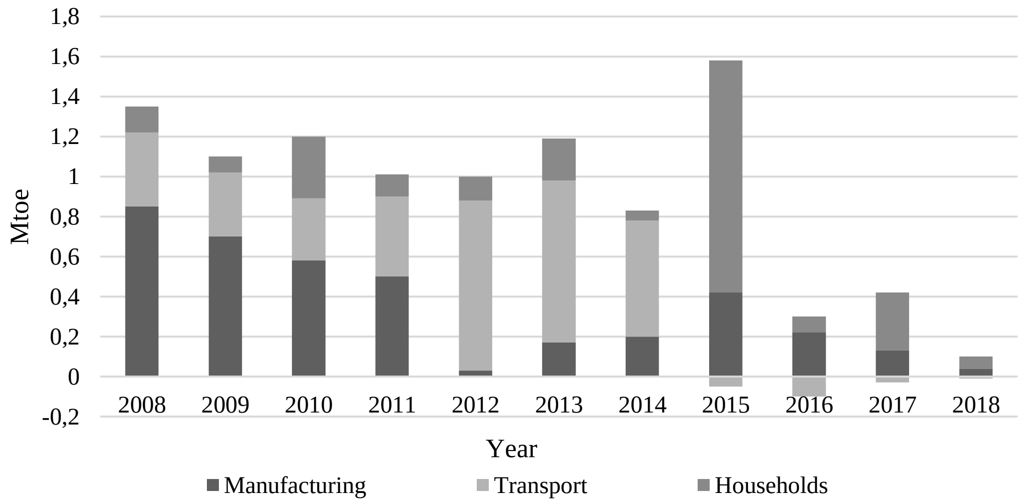
Fig. 2. ODEX values from 2008 - 2018 in Poland



Source: www.stat.gov.pl (access: 11.11.2020)

Energy savings in the most important sectors (processing industry, transport and households) have been achieved for almost the entire period under study. An exception was made for the period 2015-2018 in the transport sector. Savings achieved in 2018 within the indicated sectors amounted to 0. 10 Mtoe (million tonnes of oil equivalent). This figure was made up of savings made in the processing industry and in households, as well as a slight decrease in energy efficiency in transport. The level of savings within the key sectors is shown in Figure 3.

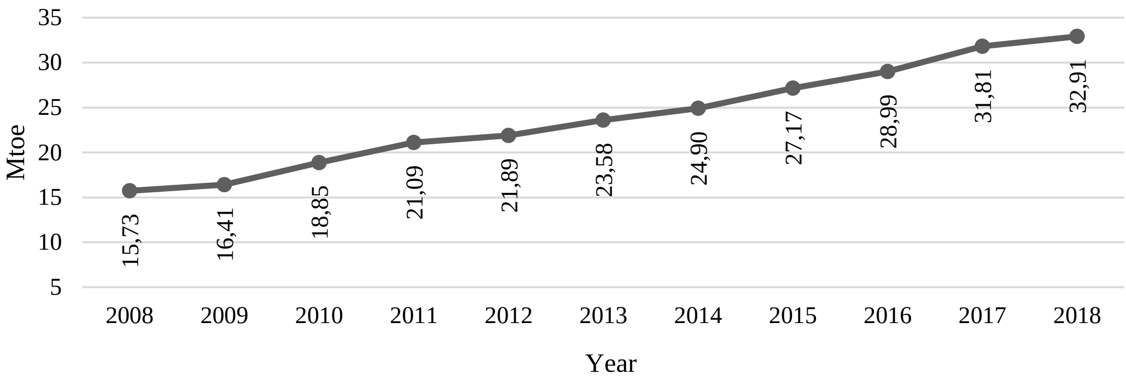
Fig. 3. Level of savings in the most important sectors between 2008 and 2018 in Poland



Source: www.stat.gov.pl (access: 11.11.2020)

The cumulative energy savings since 2000 (shown in Figure 4) illustrates how much energy consumption would have been higher in that year if energy efficiency improvements had not been implemented after 2000. The figures in the chart also take into account the savings made by sectors that are covered by the European Emissions Trading Scheme (EU ETS) (e. g. energy-intensive industry, including oil refineries, ironworks and aluminium production, metals, lime, glass, cement, ceramics, paper, cellulose, cardboard, organic chemicals and bulk acids). The data contained in Figure 4 has been calculated according to the assumption that the initial ODEX value for 2000 is equal to 100).

Fig. 4. Level of energy savings from 2000 in 2008 - 2018 in Poland

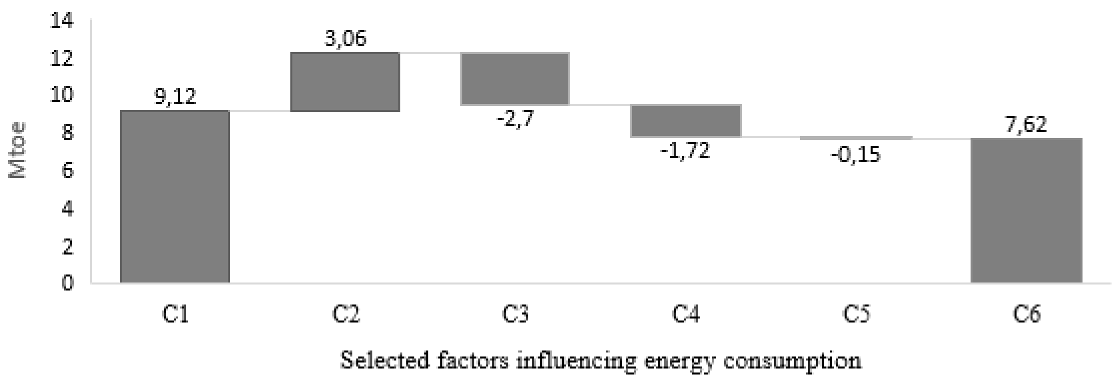


Source: www.stat.gov.pl (access: 11.11.2020)

In 2008, energy savings amounted to 15.73 Mtoe, and in 2018 it reached 32.9 Mtoe.

An important issue in analysing energy efficiency and energy savings is to determine the impact of individual factors on the level of energy consumption. In Figure 5 showing the decomposition of changes in primary energy consumption, the following are indicated: C1: change in consumption - final energy; C2: prevalence of energy; C3: efficiency of the combined heat and power plant; C4: energy mix; C5: other factors; C6: change in consumption - primary energy.

Fig. 5. Factors influencing energy consumption between 2008 - 2018 in Poland



Source: www.stat.gov.pl (access: 11.11.2020)

Between 2008 and 2018, total primary energy consumption increased by 7. 62 Mtoe. According to Figure 5, the increase in energy consumption was influenced by the increase in final energy consumption (9. 12 Mtoe), as well as the increase in the scale of electricity distribution (increase in electricity generation), which contributed to the escalation of demand for primary energy (3. 06 Mtoe).. On the other hand, the decrease in demand for primary energy was influenced by the appropriate efficiency of the heat and power plant (- 2. 7 Mtoe) and the increased use of energy from renewable sources (- 1. 72 Mtoe), which was also influenced by other factors - a decrease of 0. 2 Mtoe.

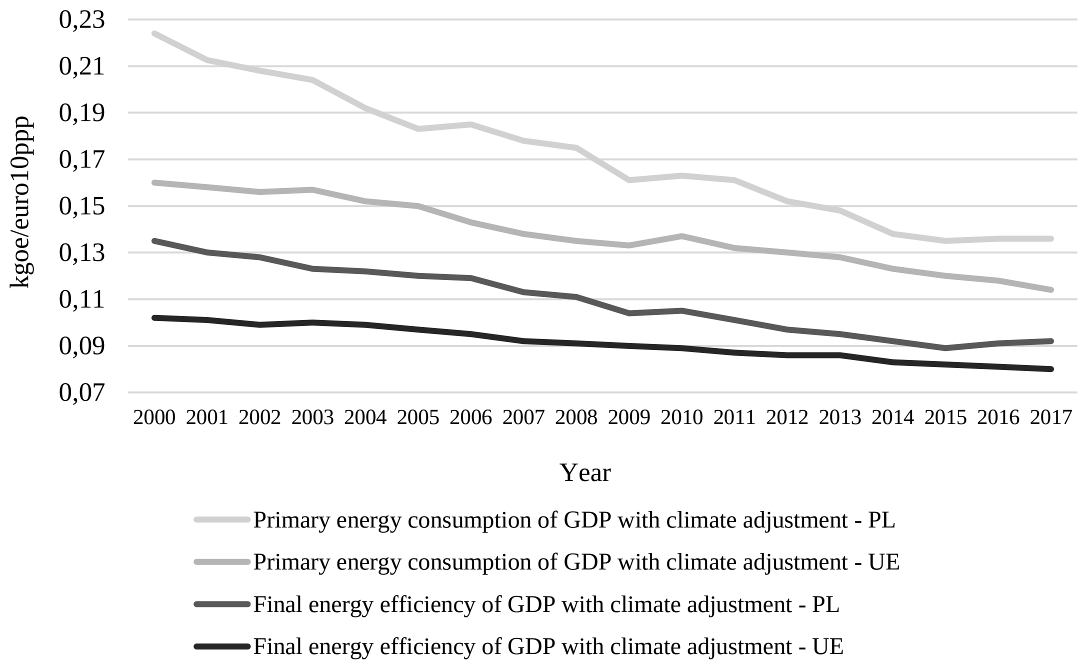
Poland in relation to the European Union 2000-2018

In making international comparisons, an important issue is to eliminate the impact of price differences between services and goods on the level of economic indicators, which can be achieved by taking purchasing power parity into account.In the situation of the analysis of a country with a significantly lower level of services and prices of goods than the area under consideration (e. g. Poland in relation to the European Union), the elimination of the differences identified contributes to the reduction of the level of the energy intensity indicator, thus indicating more clearly the actual difference in energy efficiency.

The primary energy intensity of Poland's Gross Domestic Product (GDP) including climate change, expressed in constant 2010 prices, taking into account purchasing power parity in 2017, reached 0. 137 kgoe/euro10ppp (kilogram of oil equivalent/euro expressed in the market rate in 2010 including purchasing power parity) and was 16. 6% higher than the European average (0. 118). The indicated difference was reduced by 24. 9 percentage points in relation to 2000, when the value of energy intensity of Poland's primary GDP including the climate correction reached 0. 221 kgoe/euro10pppp, while for the European Union it reached 0. 156 kgoe/euro10pp. It is noteworthy that the rate of improvement in energy intensity in our country (2. 8%/year) was in the years 2000-2017 almost twice as high as the EU average (1. 7%/year). The presented changes in primary energy intensity of GDP with climate change are shown in Figure 5.

As regards the final energy intensity of GDP, the gap is slightly smaller. In 2017 it was 14. 9% between Poland and the EU average. Also, the difference in the rate of efficiency improvement in the period 2000-2017 was lower and amounted to 2. 2%/year for our country, compared to the European average, which reached 1. 4%/year. Information on energy intensity of final GDP (including climate change) for Poland and the EU is presented in Figure 6.

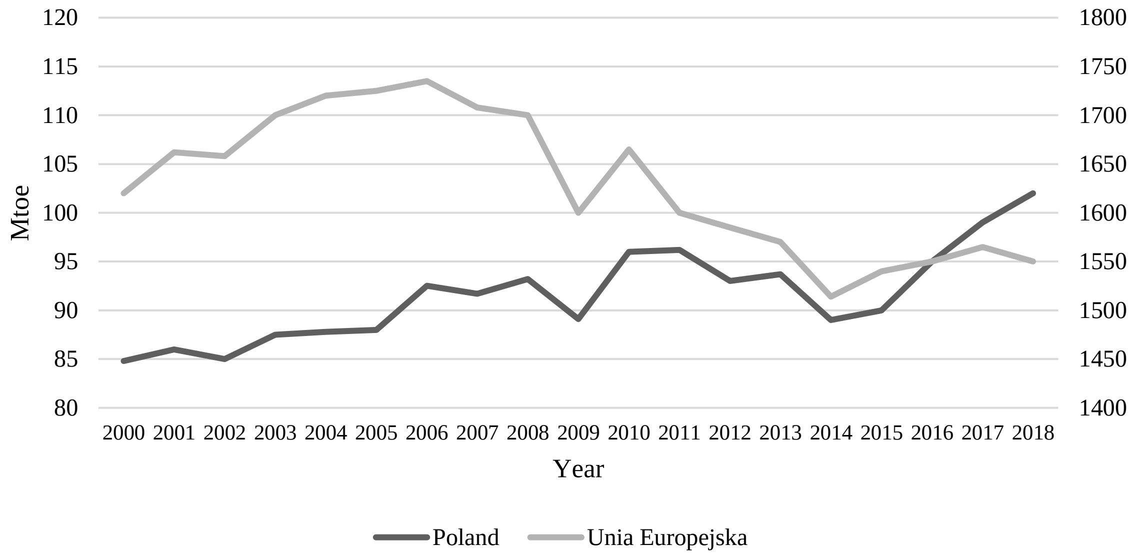
Fig. 6. Primary energy consumption of GDP with climate adjustment and final energy consumption of GDP with climate adjustment 2000-2017



Source: www.oddysse-mure.eu (access: 19.11.2020)

To supervise the implementation of the Europe 2020 Strategy, the indicator "primary energy consumption" is used, calculated as gross inland energy consumption excluding non-energy consumption (Directive 2012/27/EU). The primary energy consumption indicator values are shown in Figure 7.

Fig. 7. Primary energy consumption 2000 - 2018



Source: ec.europa.eu/eurostat (access: 19.11.2020)

The primary energy consumption index for Poland in 2018 reached 101. 1 Mteo and is above the target adopted for 2020. (96,4 Mteo).

Energy efficiency of Poland after 2020

Poland's energy policy is governed by strategic framework documents, including the Polish Energy Policy. The obligation to draw up this document is imposed on the minister in charge of energy, which is regulated by the Energy Law Act, which in Articles 13-15a specifies the content, objectives and shape of the document (Energy Law Act Dz. U. of 2020 pos. 833). The overarching objectives of Poland's energy policy are to ensure energy security, increase energy efficiency and competitiveness of the economy and environmental protection.

In accordance with the obligation imposed by the provisions of the Regulation of the European Parliament and the Council on the Member States of the European Union, a National Energy and Climate Plan for 2021-2030 has been drawn up. This document was submitted on 30 December 2019 to the European Commission, by which it was adopted on 18 December 2019. The National Energy and Climate Plan 2021-2030 indicates Poland's objectives, policies and actions to implement the five dimensions of the energy union, which include:

- energy security,
- decarbonisation,
- internal energy market,
- energy efficiency,
- research, innovation and competitiveness.

This document was prepared on the basis of national development strategies approved at the government level (including on the basis of the State Environmental Policy 2030, the Strategy for Sustainable Development of Transport to 2030 and the Strategy for Sustainable Development of Rural Areas, Agriculture and Fisheries 2030), as well as taking into account the draft Energy Policy of Poland to 2040 (www. gov. pl), with the development of the Plan resulting from the Regulation on the management of the Energy Union (Regulation (EU)

2018/1999 of the European Parliament and of the Council of 11 December 2018 on the management of the Energy Union and Climate Action).

The National Energy and Climate Plan for 2021-2030 indicates the 2030 climate and energy targets for:

- 7% reduction of greenhouse gas emissions in sectors not covered by the ETS compared to 2005 levels,
- 21-23% share of RES in gross final energy consumption (the 23% target will be achievable if Poland is granted additional EU funds, including those for a fair transformation), taking into account:
    - 14% share of RES in transport,
    - annual increase of RES share in heating and cooling by 1. 1 points. percent. On average.
- increase in energy efficiency by 23% as compared to PRIMES2007 forecasts,
- reduction to 56-60% of the share of coal in electricity production.

Projections for the National Energy and Climate Plan 2021-2030 indicate that the level of primary energy consumption in 2030 will be around 91. 3 Mtoe. Expressing in natural values, this objective will translate into a reduction in primary energy consumption of about 27. 3 Mteo in relation to PRIMES 2007 forecasts which simulate a market balance solution for energy supply and demand (Energy - Economics - Environment Modelling Laboratory Research and Policy Analysis National Technical University of Athens, 2009). PRIMES 2007 forecasts indicate primary energy consumption this year at the level of approx. 118. 6 Mtoe. The final energy consumption by 2030 is also expected to be around 67 Mteo, which indicates that the actions indicated in the National Plan will contribute to a reduction in final energy consumption of around 18. 4 Mtre in relation to PRIMES 2007 forecasts. By contrast, the projected total cumulative final energy savings, calculated on the basis of the guidelines of the revised Energy Efficiency Directive using data from forecasts of average annual final energy consumption for the period 2016-2018, will be 30 635 Mtoe (Energy Efficiency 2008-2018, 2020: 38).

Summary

Energy efficiency as the optimal instrument to increase security of energy supply and at the same time reduce greenhouse gas emissions and is a central part of the EU's strategy for sustainable development. Energy efficiency in the context of EU regulations and programme arrangements is becoming an important additional source of energy, indicating the level of energy saved. It has been reflected in the process of shaping the European Union's energy efficiency policy in the form of an energy and climate policy, the long-term economic development strategy "Europe 2020", as well as in the attempt to build a European low-carbon economy by 2015.

The European Commission, through its strategies and action programs, defines guidelines for actions and reforms that should be implemented by the EU Member States, in the regional and local scope. Besides, the Commission uses several instruments delineating the desired areas of change as well as supporting states in their actions. The Commission uses financial and tax instruments which play an important role in reducing economic barriers. The indicated instruments may indirectly increase the importance of activities aimed at increasing the level of energy efficiency.

It is worth noting the increase in energy efficiency of the Polish economy, which, during the period considered, is steadily increasing - both concerning the entire economy and the three analyzed sectors in the period from 2008 to 2018. Overall, in 2008-2018, the average rate of improvement in energy efficiency was 1, 7% annually. The fastest rate of improvement (2.2% annually) was recorded in the processing industry. The savings achieved in 2018 in the indicated sectors amounted to 0.10 Mtoe (million tonnes of oil equivalent). Within the most important sectors (processing industry, transport and households), energy savings have been achieved during almost the entire period under review. To further increase the level of energy efficiency and the level of savings, increasing knowledge and reducing the lack of information in this regard still play an important role.

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Belarusian energy diversification - conclusions for Poland

Jakub Jacyszyn

Abstract: More than market laws, the Belarusian energy sector is influenced by political considerations. Good relations with the Russian Federation, access to cheap raw materials in the form of gas and oil, preferential prices, concessions or loans are the driving force behind the Belarusian economy. Therefore, events related to growing sentiments of social dissatisfaction with the current government are becoming very important in view of the future appearance and structure of energy in Belarus. The aim of this article is to present the energy sector in Belarus, the current state and the prospects and possibilities for diversifying energy sources.

Key words: Belarus, energy, cooperation, Poland, diversification, oil, gas, nuclear Energy

1.0 Introduction

The recent events in Belarus related to the presidential elections have become the subject of global debate and great interest in the political situation of the country. Therefore, it is worth looking at its structure and characteristics of the economy. An important issue of Belarusian policy is the energy sector. It is precisely its analysis which will make it possible to bring closer the subject of diversification of Belarusian energy sources, its energy security and, in the context of the Polish economy, further prospects for cooperation between countries. The article presents the area of energy in Belarus, indicating the conditions that determine it and the conclusions, taking into account possible solutions to problem situations.

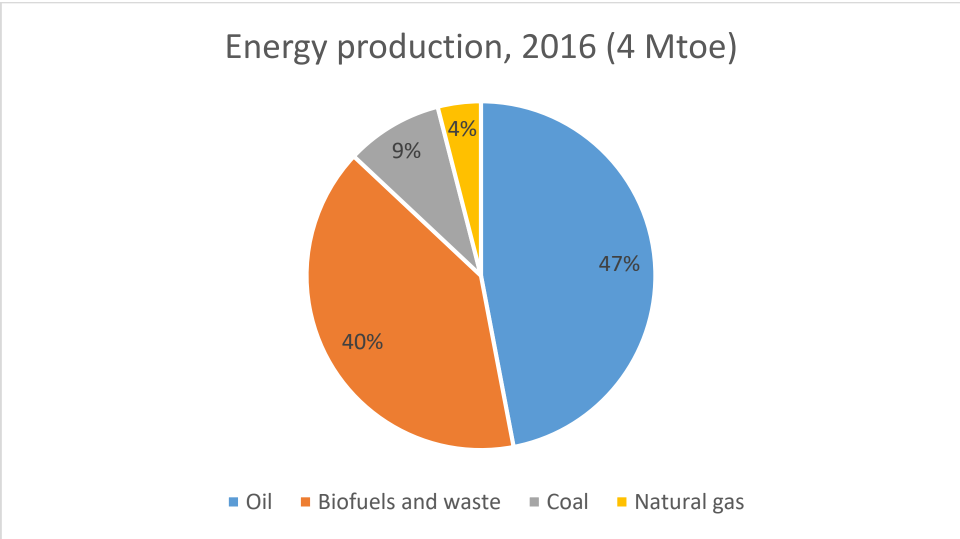
One of the most important issues affecting the policy of Belarus is the energy sector, which has been greatly influenced and influenced by the Russian Federation. However, the emerging differences and conflicts of interest between Belarus and Russia have caused the Belarusian authorities to start considering the possibilities of diversifying energy sources. The rising prices of raw materials and the reduction in subsidies to Belarus by the Russian Federation are contributing to this. Diversification can be seen as a political game with Vladimir Putin, which President Lukashenko has been playing for many years, forcing concessions from the Russian side.

2.0 Energy structure of Belarus

The energy structure of Belarus is mainly based on imports of raw materials from abroad. This is due to a lack of own resources and self-sufficiency in this area. Due to its historical intimacy, neighbourhood and closeness to relations, the Russian Federation is the main partner in supplying fuels and energy resources. Its own energy resources are mainly based on wood, peat, lignite and hydro energy. However, they represent only around 15% of demand, which makes Belarus one of the least self-sufficient countries in the world in terms of Energy

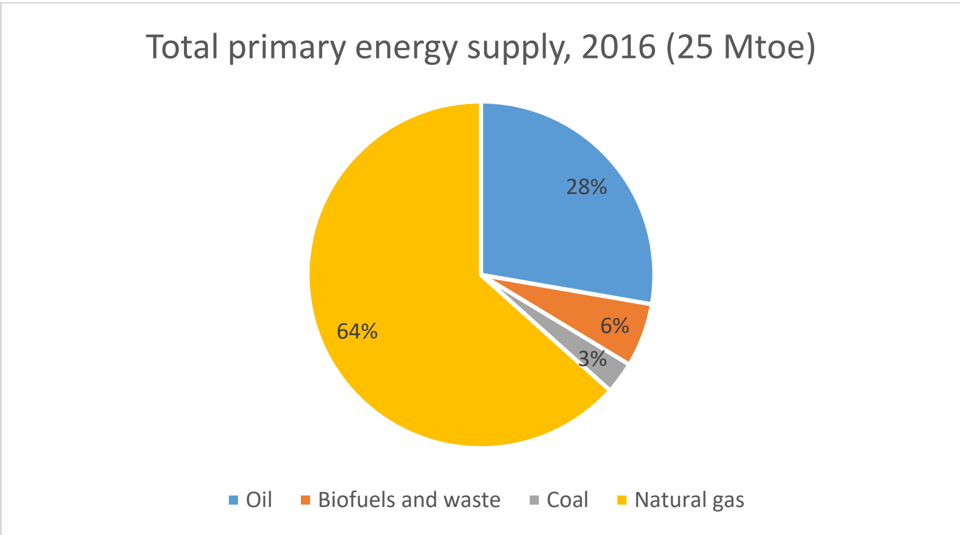
(International Energy Agency, 2020) The rest is imported hydrocarbons. For this reason, more than 97% of electricity in Belarus is produced by means of natural gas, mostly in cogeneration plants and power stations. (Novikau, 2019) The remainder is imported, among others, from the Russian Atomic Power Plant in Smolensk. Below are the characteristics of the most important Belarusian energy areas and graphs based on data from 2016. The total installed capacity in Belarus is 10 069 MW. Of this, 89% belongs to the state-owned company Belenergo, which reports to the Ministry of Energy of the Republic of Belarus. (Novikau, 2019) Belenergo is a monopolist on the market for production, transmission, distribution and sale of electricity and heat. It manages the energy system and owns generation units such as thermal, hydro and wind power plants. Since 1 January 2020. Belenergo comprises 27 organisations, including 6 regional companies. (Belenergo Website, 2019) The gas used to produce energy is mainly imported from the Russian Federation. The instability of supply, rising prices and the choice of a gas supplier coming practically from only one direction make an informal link with the Russian state control system.

Figure 1. Energy production in 2016 *(International Energy Agency for EU4Energy, 2016)*



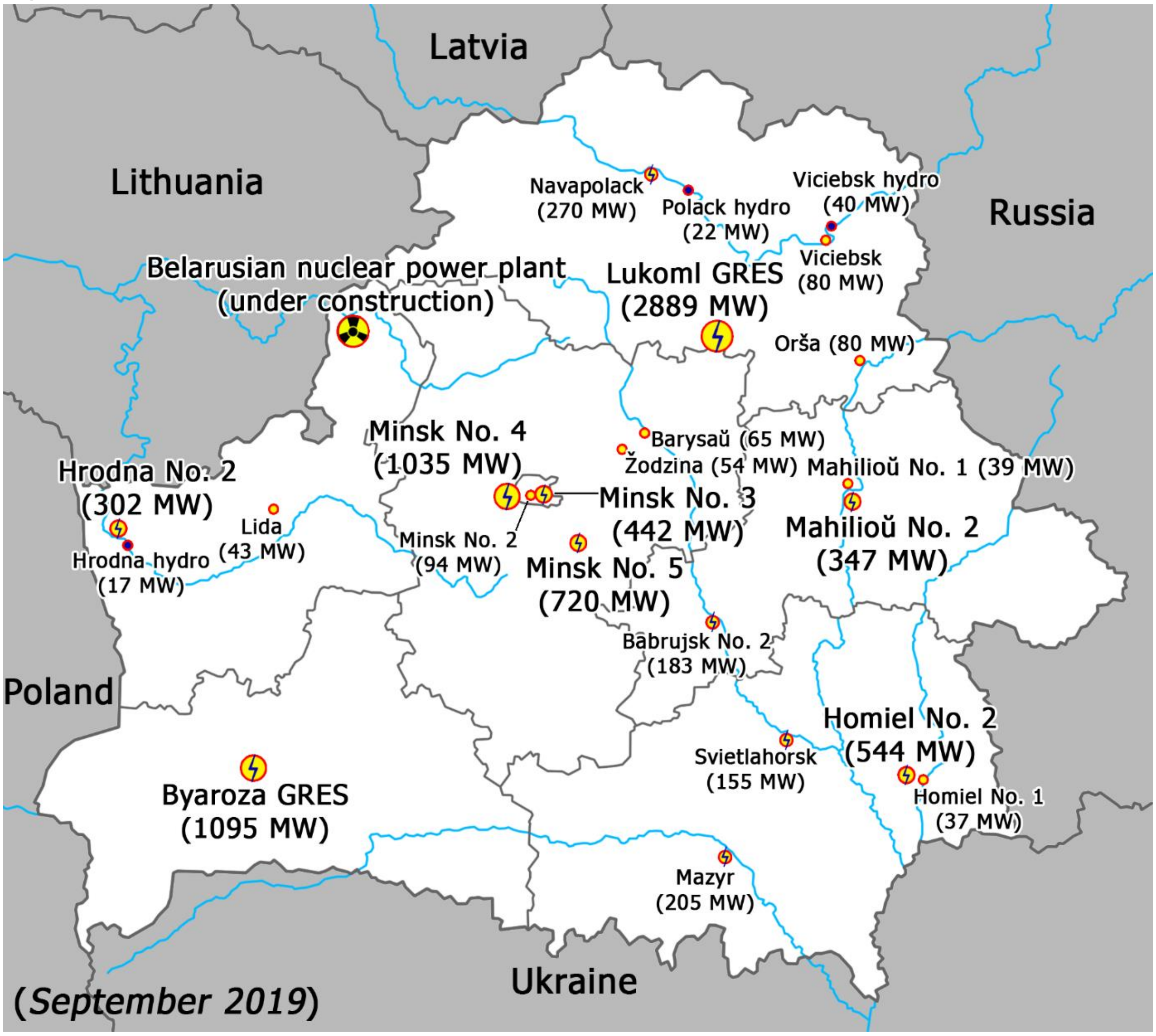
Source: Own elaboration based on: https://www.eu4energy.iea.org/data-tools (access: 23.11.2020 r.).

Figure 2. Total primary energy supply in 2016 *(International Energy Agency for EU4Energy, 2016)*



Source: Own elaboration based on: https://www.eu4energy.iea.org/data-tools (access: 23.11.2020 r.).

Figure 3. Map of power plants *(Belenergo Website, 2019)*



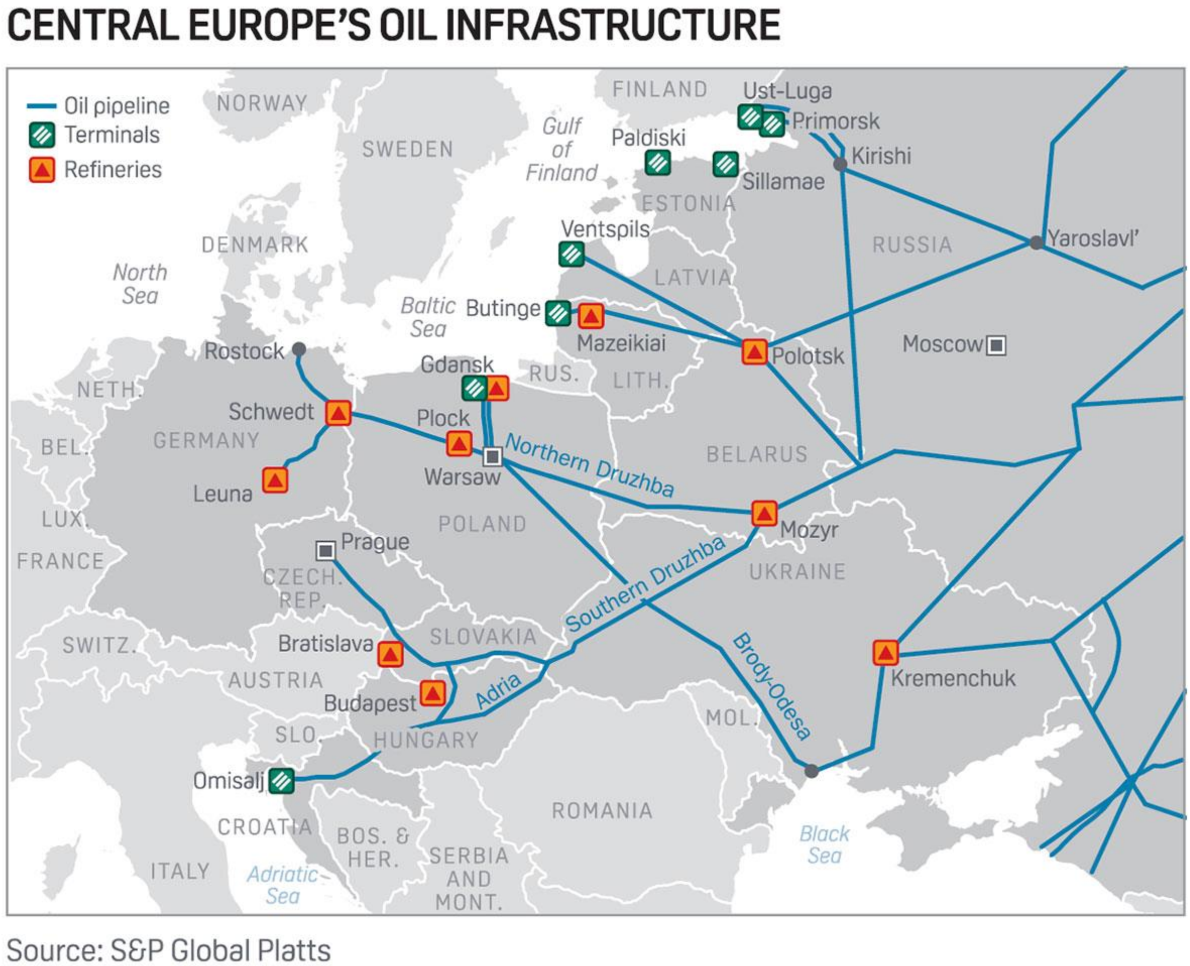
Source: https://en.wikipedia.org/wiki/Energy_in_Belarus (access: 23.11.2020 r.).

2.1 Oil

For Belarus, oil is important not only because of its own energy needs, but also as a raw material for processing, generating specific revenues for the state. The raw material is imported into Belarus in the amount of 17 Mtoe (in 2018), a significant part of which (11.4 Mtoe) is - after processing in Belarusian refineries - petroleum products intended for re-export. (International Energy Agency, 2020) It is responsible for revenues, amounting to approximately 20% of Belarusian GDP (10.5 billion USD). (Dyner, 2018) Relations with the Russian Federation, the main supplier of cheap raw material, were very important and had a strong impact on strategic sectors of the economy. Dependence on relations with one supplier is extremely risky and prone to monopoly. Adding to this the rising prices of Russian oil puts Belarusians in a difficult position. Therefore, Belarus is looking for alternatives in the form of diversification of sources of this raw material.

Previous supplies of oil from directions other than Russia were reduced to occasional, showcase cargoes from Norway, Azerbaijan, Venezuela or Saudi Arabia, for example. However, these were not long-term contracts, but often building a negotiating position in talks with the Kremlin. Belarus has two major refineries in Novopolotsk and Mozyr which process raw materials into fuel products, including diesel and mazout. In addition to the refineries, Belarus also controls a section of the Druzhba oil pipeline running through its territory, making it a transit country. It is worth noting, however, that over 42% of Mozyr shares are held by the Russian company Sławnieft. (OJSC „Mozyr Oil Refinery" Website, 2020) This sector generates significant revenues to the state budget through taxes and the sale of products abroad, mainly to European markets and to Russia. Therefore, Belarus' strategy is to purchase cheap Russian oil, process it and sell it, generating large profits. That is why Belarusian refineries use almost all their processing capacity, amounting to 24 million tonnes per year. (CIRE, 2015) The threats that arise from such activity are the fact that Russia controls its course, because, as the main supplier of raw materials, it also controls its prices and, at the same time, how much and if at all, the Belarusian side earns from it. The entry of foreign investors, e.g. from Poland or other Western countries, would not only open up Belarus to European countries, but could also provide security against the Russian side taking over the shares, and could also make it somewhat independent of its pressure. This is both a challenge and an opportunity that could provide not only an important economic partner, but also financial gains. However, this requires willingness and openness on the part of Belarus.

Figure 4. Location of the Mozyr and Novopolotsk (Polotsk) refineries *(Nadia Rodova, 2019)*



Source: https://www.spglobal.com/platts/en/market-insights/latest-news/oil/042519-russia-expects-clean-urals-crude-exports-via-druzhba-to-resume-mon-report (access: 23.11.2020 r.).

The second aspect is deliveries. Alternatives to Belarus include importing raw materials from Poland. Both the Americans and the Polish oil operator PERN have declared their readiness to allow oil supplies to Belarus via Poland. The reverse side of the Druzhba oil pipeline and the Gdańsk oil port could be used for this purpose. An important investment which increases the chance of success of this initiative is the construction of the Homel-Gorki oil pipeline, the aim of which will be to connect the Druzhba oil pipeline with the Novopolotsk refinery, which has so far been receiving supplies by Russian oil pipeline or rail tankers. (CIRE, 2020) The first major initiatives in this area can be seen in the form of the first two oil deliveries from the USA. The Polish company Unimot had a significant share in this transaction. (Energetyka 24, 2020) (BiznesAlert, 2020) A special blend of White Eagle Blend (WEB) has arrived in Belarus via the port of Klaipeda, which is able to replace the currently used Russian blend URALS. This is a landmark step that gives a perspective on the future, in which Poland and the new Washington-Warsaw-Minsk agreement can play an important role.

2.2 Gas

The consumption of natural gas in Belarus is around 20 billion cubic metres, making it one of the largest consumers and importers of this raw material in Europe, highlighting its population of just 9 million. (BiznesAlert, 2020) A significant proportion of natural gas is used for industrial purposes. It is worth stressing that the majority of Belarusian thermal power stations are based on this very raw material. Until now, Belarus has been able to enjoy a very low price for gas supplied by Russian Gazprom. This was an important bargaining chip in political relations between both countries. With time, when market prices began to fall, those in Belarus were no longer competitive. This became the subject of difficult negotiations between Russia and Belarus. In view, too, of the fact that Gazprom has been the owner of the gas transmission system in Belarus since 2011, it puts Minsk in a difficult position when planning to diversify natural gas supplies. These factors make diversification of gas in Belarus a much more difficult subject than the oil sector. This is why Belarus is striving to make its prices dependent on quotations on European exchanges, which would in a way improve its situation.

There is an alternative in the form of using the reverse side of the Polish section of the Yamal pipeline after the expiry of the contract for the supply of gas to Poland. Then gas would be supplied on the basis of auctions, and after the technical adjustment of the transmission infrastructure, it would theoretically be possible for Poland to supply Belarus. In such a scenario, the source of gas could be the LNG terminal in Świnoujście, the Klaipeda gas port or, in the future, the Baltic Pipe or the floating FSRU terminal in the Gulf of Gdańsk. This would enable diversification of sources of this raw material and a reduction in Russian supplies, and thus a better negotiating position as regards their prices. The American side, as a potential supplier of LNG, is also strongly interested in this subject, just as it is in the diversification of oil supplies. In addition, Lithuanians are ensuring the possibility of using the Klaipeda LNG terminal to supply Belarus with gas via the Poland-Lithuania gas pipeline under construction. (BiznesAlert, 2020)

Figure 5. Gas trunklines in Republic of Belarus *(Gazprom, 2012)*

Source: https://www.gazprom.com/press/news/2012/november/article149318/ (access: 23.11.2020 r.).

It is also possible to have a stock exchange swap involving virtual gas supplies to Belarus. Such a scenario could consist of Russian gas remaining in Belarus as part of the settlement of supplies from the West. In connection with the sale of Gazprom Biełtransgaz, the operator of Belarusian gas pipelines, to Gazprom Biełtransgaz, this operation requires cooperation with Russia, which could be extremely difficult. The same would apply to the physical reverse of the Polish-Belarusian border. Gazprom Belarus, the current owner of gas pipelines in Belarus, would have to technically adapt the system and prepare the infrastructure, including supplying it with appropriate installations such as compressor stations. The price of gas is a constant subject of talks between countries when establishing and correcting long-term contracts. Until the time when Belarus paid less for Russian gas than it did on the stock exchange, in the event of a sudden fall in the price of this raw material, it gave rise to claims against Gazprom. In February 2020, the price of gas for supply to Belarus was set at USD 127 per 1 000 cubic metres. (Energetyka 24, 2020) In view of the market drop of this raw material below USD 100, at the beginning of April, President Alexander Lukashenko called for the price for Belarus to be reduced almost threefold. Furthermore, in the search for alternatives, the Belarusian government offered to buy gas on the stock exchange at more favourable and competitive prices.

2.3 Nuclear energy

Although the Belarusian nuclear power plant in Ostrowiec will soon produce nearly 2400 MW, it is not yet included in the energy share of the current analysis. It is estimated that its establishment will enable gas imports from Russia to be reduced by up to 25%. (Kamil

Kłysiński, 2020) This is an important investment for this country, which can be an element of diversification. Unfortunately, although Belarus will import less Russian gas, Russian companies are the main contractor and lender. Furthermore, the Russians will have a major influence on energy distribution and the operation of power plants, taking control of part of the Belarusian electricity system. This leads to a degree of dependence, especially as nuclear fuel will also be supplied by Russia. Given the surplus energy to be produced in Ostrowiec, the Belarusian people have volunteered to sell electricity to neighbouring countries. This has met with a lack of interest on the part of Poland and Lithuania, as if to protest against the doubts and dangers surrounding this investment. Establishing contacts with the Belarusian side may, however, open up certain wickets for greater cooperation between the two countries. The energy surpluses that will be generated by the operation of the Ostrowiec nuclear power plant also provide opportunities for greater interest and development of electromobility in Belarus. This is an area for development which could also be of interest to Polish companies developing vehicle charging stations or manufacturers of electric cars, such as ElectroMobility Poland, the founder of the future Izera car brand.

3.0 Development perspectives

Increasing dependence on Russia is a barrier to development and a serious political and economic constraint on Belarus. Projects such as Nord Stream 2 are also unfavourable to the Belarusian economy, because they limit the influence that Belarus has through the transmission of gas through its territory. There are many threats, so in this difficult time for Belarus it is worth considering several scenarios.

Belarusian society is expressing its dissatisfaction with the 26-year-old government of Alexander Lukashenko and the dubious results of the recent presidential elections. In addition, the economic problems affecting Belarus are exacerbated by the crisis related to the SARS-Cov-2 epidemic. As a result of these events, President Lukashenko is having problems maintaining a stable situation in the country and pacifying the protesters. It is possible that Lukashenko will remain in office and that he will become more integrated with the Russian Federation. It would then be extremely difficult to establish cooperation with the Belarusian people. The option of further Alexander Lukashenko's rule and turning away from Russia is unlikely, but further slow diversification and cooperation with both Russia and Western countries is possible. In the event of a change of government and Alexander Lukashenko's resignation, the approach of the European Union, including Poland, to Belarus is extremely important. At the same time, it would be an opportunity for the Belarusian people themselves to open up to Europe and try to become independent politically and economically.

When analysing the Belarusian energy sector, it is the oil area that seems most promising in terms of diversification of supply. Disputes over the oil agreement and the turbulence around the OPEC+ group may contribute to breakthroughs and significant economic impacts. It is no secret that both Saudi Arabia and the USA are in favour of oil exports to Central and Eastern Europe, especially to the sphere of greater influence of the Russian Federation. It is precisely the price differences caused by the economic slowdown and the crisis that may intensify oil diversification in Belarus. The prospect of losing Russia's sphere of influence forces it, as it were, to fight price wars or to take other political action to maintain the dominant position on the Belarusian market. It is possible that it is precisely the destabilisation of Belarus, as in 2014 in Ukraine, that may be a deliberate action by the Russians, who want to stop the supply of raw materials from other countries. On the other hand, because of the economic crisis caused by the coronavirus pandemic and the complicated situation on the fuel market, Russia cannot afford to lose an important customer, Belarus. The determination of the Kremlin authorities and the use of various methods are therefore justified. One of these could be the appearance of a group of mercenaries from Russia before the presidential elections in Belarus, which took place on 9 August 2020. It is worth highlighting the motives of Russia, for which Alexander Lukashenko's over-strong position is not a good situation either. The President of Belarus is skilfully balancing between good contacts with Russia and negotiations on the price of raw materials and privileges for his country. He is using not only his dictatorial power, but also Western countries which are counting on the opening of the Belarusian market and greater integration with Europe. In view of the increase in competition on the oil market and problems with limiting extraction, one of the Kremlin's options is to exit the oil agreement and to gain the interests of potential and current customers by reducing raw material prices. Such a scenario is, however, unlikely. The current post-election events are becoming very important in the context of halting Belarusian diversification projects. The US, in cooperation with the European Union, is considering sanctions or restrictions on supplies of Belarusian oil products. Talks are under way on this subject, and the political option chosen may be crucial for the Belarusian energy sector.

Other important areas are investment in renewable energy sources. The maintenance of the nuclear power plant and the repayment of the loan for its construction may block the development of this sector in Belarus. The solution can be foreign entities investing in Belarus in such installations as biogas plants, photovoltaics, heat pumps or wind power plants. Electromobility is also an important sector. The prospects for these areas are large and undeveloped. In addition, they can provide a viable alternative and a gradual diversification of energy sources in our eastern neighbour. Polish companies could provide technological support and the construction of ecological installations, which would contribute to the creation of dispersed energy and gradual independence from current sources. Belarus would gain not only greater political freedom, but also an increase in the level of technological advancement, a greater share of renewable energy sources and deepening cooperation with European companies, and thus with the western economy. For Poland, this is an opportunity to gain a partner, to establish cooperation and, in the future, to become involved in European structures. This is a very crucial moment in history, not only for Belarus, so it is extremely important how Poland will behave and whether it wants to open up to help its eastern neighbour.

4.0 Conclusion

More than market laws, the Belarusian energy sector is affected by political considerations. Good relations with the Russian Federation to date, access to cheap raw materials in the form of gas and oil, preferential prices, concessions or loans are the driving force behind the Belarusian economy. Therefore, events related to growing sentiments of social dissatisfaction with the current government are becoming very important in view of the future appearance and structure of energy in Belarus.

Belarus has its own energy resources in the form of, among other things, wood, peat or lignite, which represents only 10% of its energy needs. The rest of the energy sources are imported, mainly from Russia. The Belarusian economy is based on energy-intensive industry such as the production of artificial fertilisers or fuel processing. In addition, around 90% of electricity is produced from natural gas from Russia. So does the oil, which is processed at the two Belarusian refineries in Novopolotsk and Mozyr. From there it reaches western markets, among others, which provides significant income for the Belarusian budget. Strong dependence on a single supplier threatens the country's energy security. This is why Belarus is looking for alternatives, for example, in the form of oil supplies from the USA, Azerbaijan or the reverse of the Druzhba oil pipeline from Poland. In the case of the natural gas market, it is, in principle, impossible to supply this raw material from any other direction than Russia, because the owner of the gas transmission system in Belarus is Gazprom. This fact makes Belarus strongly dependent on the Russian supplier and seriously threatens its energy security. Therefore, the Ostrowiec nuclear power plant will soon be opened, which is intended to reduce gas imports from Russia by more than 20%. As part of the diversification of energy sources, the Ostrowiec power plant could be an important step in terms of becoming independent and increasing energy security. However, the lender and contractor for this investment is the Russian Federation, which strongly limits these opportunities. This investment also raises another, equally important security issue. According to many, it threatens nuclear safety in Europe. This view is strongly supported by the Lithuanian Government, which states that there are many doubts about the safety of the emerging facility, motivated by its particularly close proximity to the Lithuanian border. As a result, both Lithuania and Poland have announced their unwillingness to purchase electricity that would be generated by Belarusian nuclear power plants, with the most obvious accent being the physical decommissioning of the power link on the Polish-Belarusian border. This therefore restricts potential customers, for the time being, to domestic and Russian customers, which could make Belarus even more dependent on its eastern neighbour.

There is no support from European neighbours for the events that have taken place in Belarus, which may turn into various types of sanctions and restrictions on cooperation with Western countries. This may hit the Belarusian economy even harder. All these aspects emphasise the importance of energy independence and make us think whether and how this may affect Poland and what its role should be.

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Implications of LNG import on the European Union's energy security

Łukasz Kordowina

Abstract: Due to insufficient level of domestic natural gas production, the European Union countries are forced to import this key energy resource from the third countries. This involves political and economic as well as physical risks. In order to ensure energy security, it is necessary to mitigate the threats that in the case of natural gas supplies are primarily related to various types of dependencies. The dependency grows in the situation of low diversification of energy sources and resources suppliers. The aim of this paper is to analyze the impact of LNG imports on the European Union's energy security, which would not be possible without showing the structure of the regional natural gas market. Implications of LNG trade will be shown in comparison with pipeline gas supplies, which are dominant on this market.

Key words: LNG, natural gas, energy security, European Union

Introduction

Natural gas is the second most important source of energy in the European Union. Due to systematically decreasing European Union's[1] gas production, member states are forced to import this fossil fuel from outside of the bloc. Ensuring uninterrupted and cost-effective supplies of energy resources is the key element of energy security in the event of insufficient own resources. The energy security is – according to the classic definition – the state of availability of sufficient supplies at affordable prices (Yergin 2006: 70-71). The article examines the importance of LNG supplies in ensuring the European Union's energy security in the situation of growing dependence on natural gas imports. The paper begins with showing the significance of natural gas for ensuring the energy security and then discusses the state and capabilities of the EU imports of LNG. A key part of this article analyses the effects of receiving natural gas in a liquefied form by tankers in comparison to the most common form of pipeline deliveries, regarding the risks associated with both methods of supply. At the end, the article discusses differences that are visible in the impact of LNG on particular EU regions.

To maintain natural gas security, countries must deal with threats to their supplies. Jonathan Stern lists three types of import dependence, which are considered as a risk to natural gas security: source dependence, transit dependence and facility dependence (Stern 2002: 12). The dependence means a situation where one actor has an advantage over its partner. Usually, the consumer is the weaker party, especially when it is one-sidedly dependent on the producer in

[1] For the purpose of this paper, the EU will be defined as the bloc of 28 countries, including the United Kingdom because of its important position on the European gas market and the availability of data.

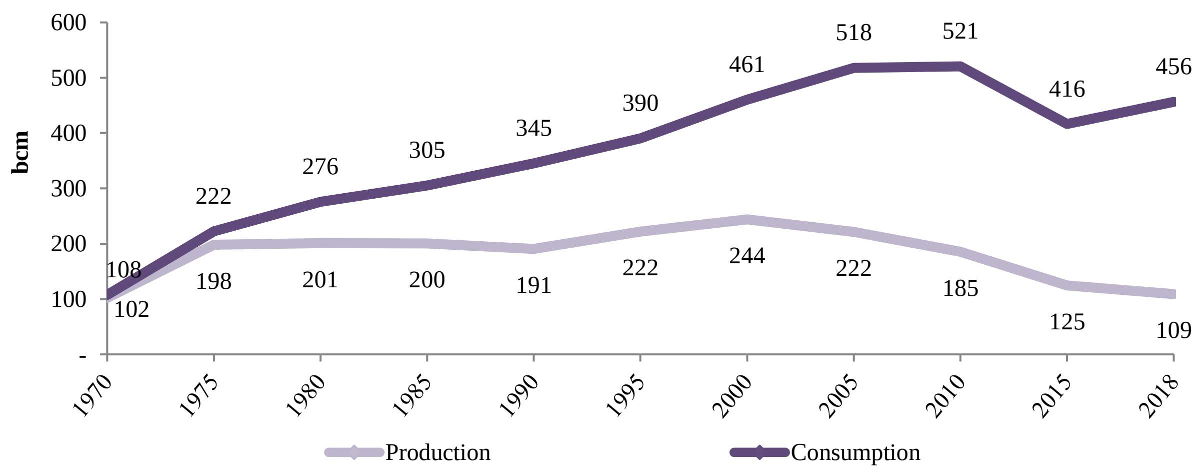
a situation of monopoly and the lack of substitutes (Nyga-Łukaszewska 2019: 15-16). Source dependence rises in the situation of a small number of natural resources suppliers and means of transport, unstable geopolitical situation and will to disrupt supplies among exporters (Ritter 2011: 8-9). The second type of aforementioned import dependence occurs when natural gas is transmitted indirectly, passing through the territory of another state. In the situation of transit risk, the interests of another state or states are becoming important. The risk rises in the situation of conflict between the transit country and one of the trade partners (Ritter 2011: 9). One cannot also ignore the facility risk, which means the danger of physical damage to extraction plants, gas storages, pipelines and other infrastructure located in the territory of exporter, importer or transit country (Stern 2002: 14-15).

The natural gas market of the European Union

Since the end of the 1960s, countries forming today's European Union and the United Kingdom, have been consuming more natural gas, than they produce. Even the Dutch giant gas field Groningen and the new British discoveries in the North Sea could not satisfy rapidly growing demand. The import from outside of the block was indispensable.

The liquefied natural gas (LNG) has been used in this trade since 1964 (earlier LNG transport on *Methane Spirit* from the USA to Great Britain in 1959 was on a non-commercial scale), when the first LNG tanker arrived from Algeria to Great Britain and France (Jensen 2004: 7-8). Before LNG trade could well develop in Europe, pipeline transport of natural gas (traditionally used in trade between members of the Community) from third countries had surpassed the volumes arriving by the ships. In 1968 Austria signed a contract on pipeline trade from the Soviet Union. European connections to Siberian gas have been developed further and in 1973 resources from the East flood to the Federal Republic of Germany and in the next year to Italy. After the discovery of new gas fields, Norway became the second pipeline gas exporter to the European Community, with its first transport to Germany in 1977. The culmination of gas connections network to Europe was at that time the TransMed pipeline from Algeria to Italy which became operational in 1983.

Chart 1. Production and consumption of natural gas [bcm] in the European Union (EU28) from 1970 to 2018



Source: Own elaboration based on Eurostat, https://ec.europa.eu/ and BP Statistical Review of World Energy 2019, https://www.bp.com/.

The Soviet Union and its legal successor – Russian Federation, became the main natural gas supplier to the European Union. As can be seen in Table 1., resources from this country dominated the market with the deliveries of 150.5 bcm or 33% of total EU gas import in 2018. The second biggest exporter of natural gas to the EU became Norway, after an incremental increase in exported volumes, that reached 103.1 (23% share in total EU imports) in 2018, followed by Algeria (42.2 bcm, 9% share) which natural gas trade with the Old Continent was partially halted after the terrorist attacks on its natural gas facilities in 2013 (U.S. Energy Information Administration 2019: 3).

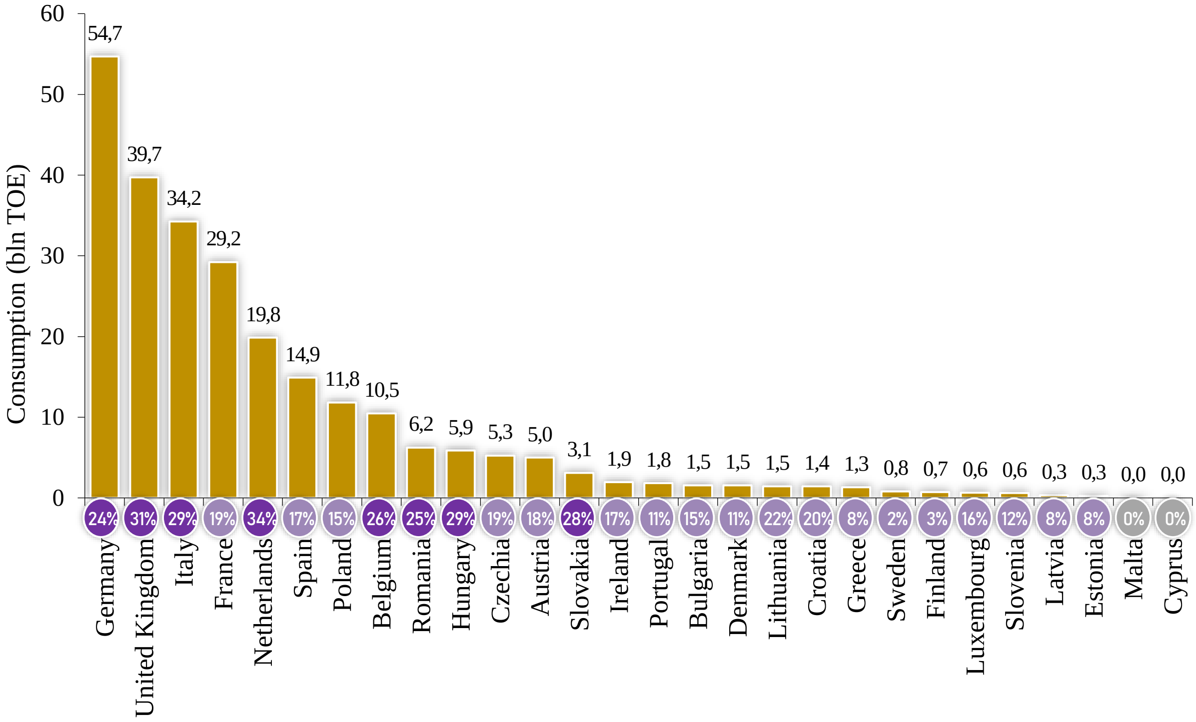
Table 1. Natural gas import sources of the European Union (EU28) from 1990 to 2018 [bcm]

Exporter	1990	1995	2000	2005	2010	2015	2018
Russia	111.7	112.1	120.7	136.3	119.7	124.3	150.5
Norway	25.3	29.0	47.9	79.3	102.7	105.3	103.1
Algeria	26.6	33.6	55.5	57.0	50.4	34.2	42.2
Qatar	-	-	0.3	4.9	35.0	24.7	19.5
Nigeria	-	-	4.4	10.6	14.0	6.2	10.5
Libya	1.0	1.4	0.8	5.4	10.0	7.1	4.5
Trinidad and Tobago	-	-	0.9	0.8	5.1	1.9	3.6
USA	-	-	-	-	-	-	3.1
Rest of the world	35.3	44.2	64.0	96.0	104.3	111.0	114.6

Source: Own elaboration based on Eurostat, https://ec.europa.eu/.

Within the bloc of 28 countries, natural gas is the second (after crude oil) most important energy source. In 2018 this fossil fuel represented 26% of total EU primary energy consumption (BP 2019). The biggest part of natural gas in EU is consumed by Germany - 54.7 bln tons of oil equivalent (TOE). It represents 24% of the total energy resources consumption of this country. The highest share of gas in domestic energy resources consumption was recorded at this time in the Netherlands (34%), and in the United Kingdom, Italy, Hungary, Slovakia, Belgium and Romania it is also higher than EU average of 22%. On the opposite side stands Cyprus and Malta, where the usage of this hydrocarbon is at a negligible level.

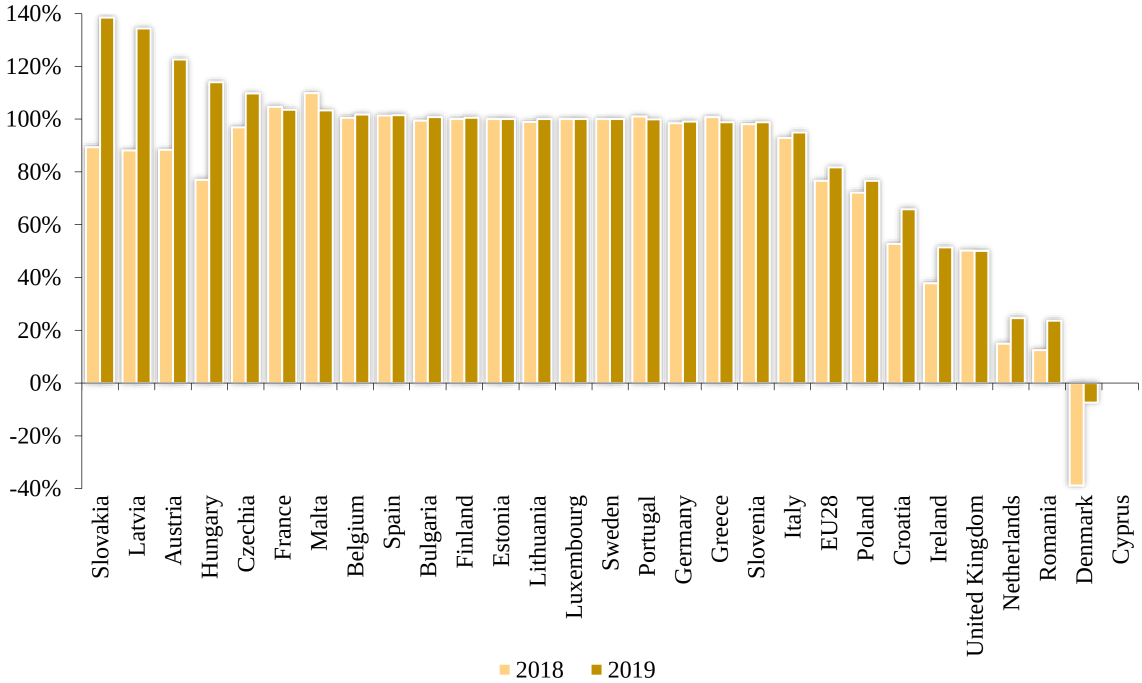
Chart 2. Consumption of natural gas [bln TOE] in the EU member states in 2018 and share [%] of natural gas in total energy sources consumption



Source: Own elaboration based on Eurostat, https://ec.europa.eu/.

Nearly all EU members need to import natural gas. The import dependency rate, calculated as net imports, divided by total domestic consumption, shows how high the level of dependence on external supplies is. As can be seen in Chart 3., the only significant producers are the United Kingdom and the Netherlands, but even they need to import natural gas to meet their demand. Only Denmark exports more natural gas than it imports. All the other EU members are net importers of this fossil fuel (except Cyprus, which does not consume any statistically measurable volumes of natural gas).

Chart 3. Import dependency level of the European Union (EU28) and its members in 2018 and 2019

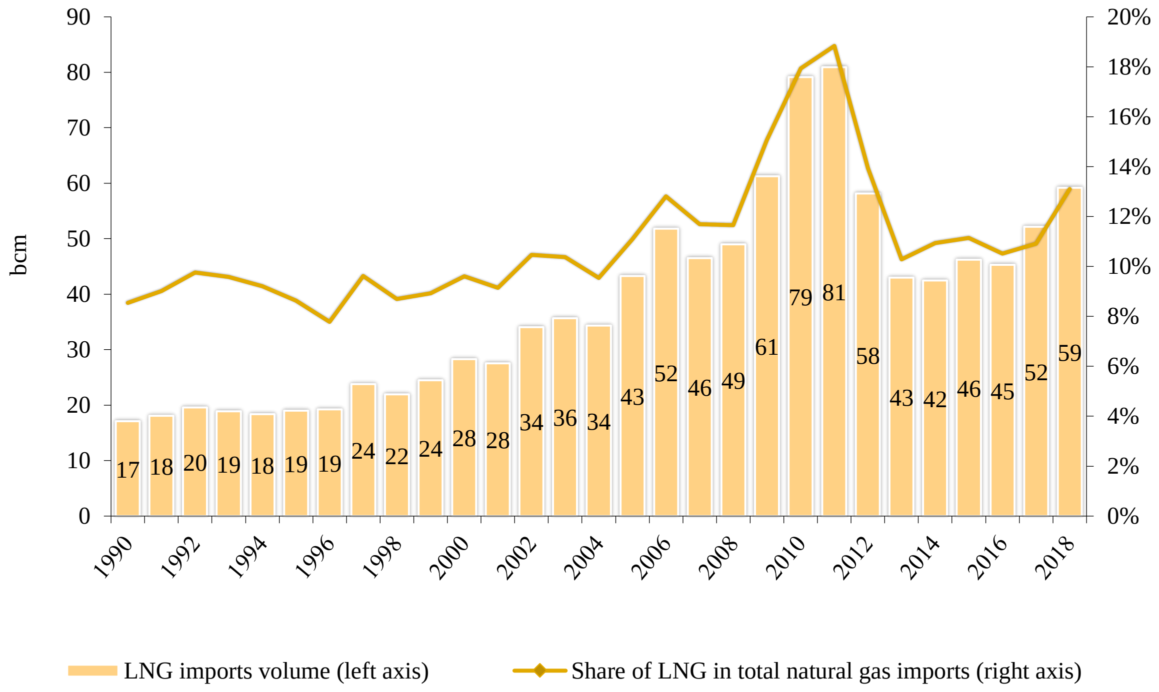


Source: Own elaboration based on Eurostat, https://ec.europa.eu/.

LNG on the EU gas market

Europe as a continent is the second, largest recipient of liquefied natural gas, after Asia. The volume of LNG imports by the countries that make up the European Union grew for many decades, until 2012, when increased demand and higher prices in Asia caused the supply to shift to this market (European Commission 2013: 1). On average, in the period 1990-2018 presented in Chart 4., gas transported in liquefied form accounted for 11% of natural gas imports to the EU. This means that almost nine out of ten cubic meters of this hydrocarbon is imported via pipelines.

Chart 4. LNG import volume [bcm] and its share in total natural gas imports to the European Union (EU28)

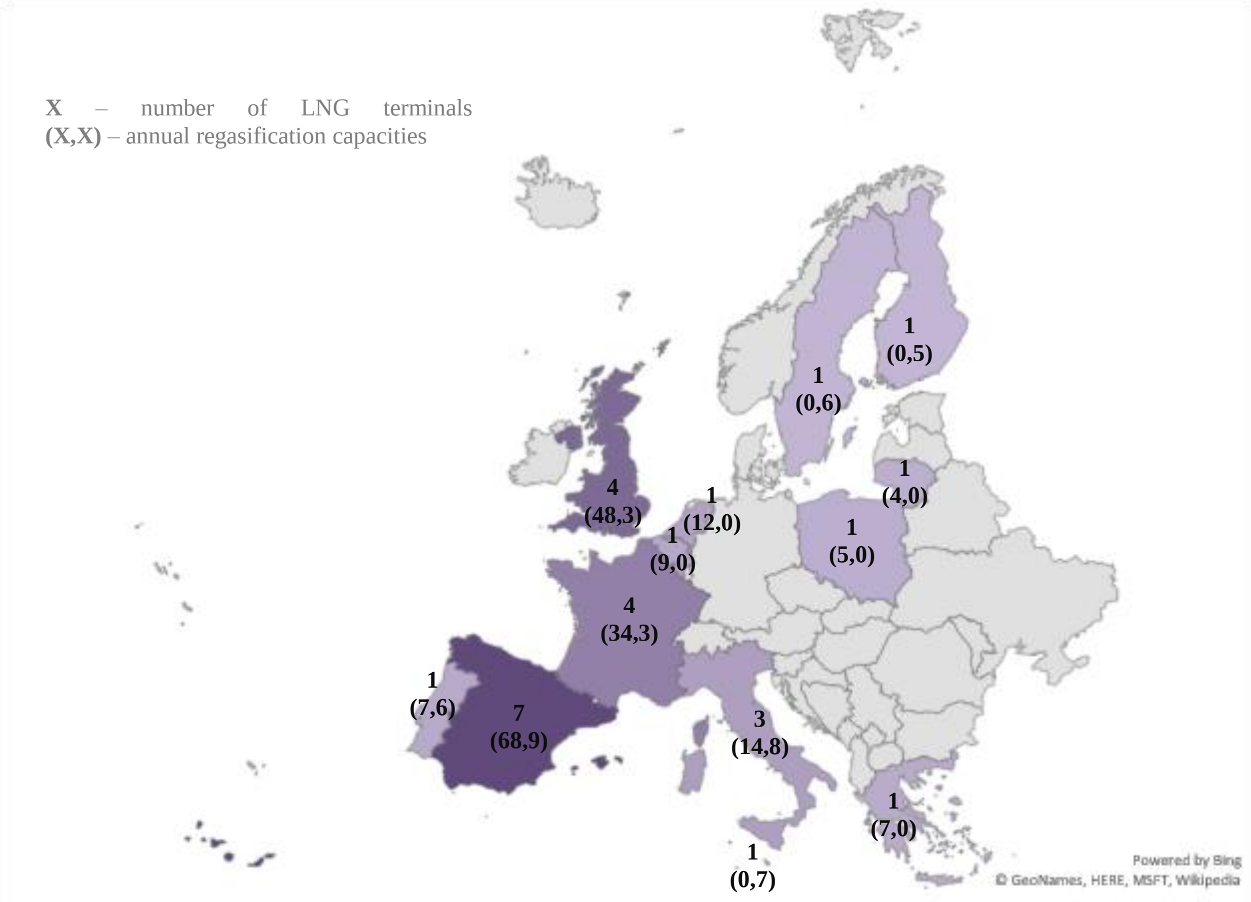


Source: Own elaboration based on Eurostat, https://ec.europa.eu/.

The LNG infrastructure in Europe is improving every year. At the time of writing this paper, there are 29 LNG terminals operational in EU countries. Not all member states have installations of this type. Spain is the leader with seven terminals, four each are in France and Great Britain, three in Italy, two each in Finland and Sweden, and one each in Belgium, Greece, the Netherlands, Poland, Portugal, Lithuania and Malta. Another six projects are under construction and 18 are in the planning stage (Gas Infrastructure Europe 2019).

The entire regasification infrastructure located in the EU is currently able to receive 212 bcm of natural gas (volume after regasification) per annum, which means that it can cover almost half of the demand for this raw material in this way. The terminals are also used to store this strategic resource in liquefied form. Their capacities in this respect amount to 10 mcm (after regasification) of gas stored in liquefied form (Gas Infrastructure Europe 2019).

Map 1. Number of LNG terminals and countries regasification capacities [bcm] per annum in the European Union countries in 2019



Source: Own elaboration based on Gas Infrastructure Europe, https://www.gie.eu/.

LNG imports to the EU are more diversified than import via gas pipelines. As shown in Table 2., 19,5 bcm or one-third of the liquefied gas supplied to member states in 2018 came from Qatar, but Nigeria, Norway and Algeria are also significant trading partners, accounting for 18%, 13% and 12% of the EU LNG imports respectively. Trinidad and Tobago, Russia, the United States and Peru had a share of several percent each. The most important partners are located on four different continents. Within the European Union, the biggest recipient was Spain, which has the best developed infrastructure in this area. In 2018, 25% of the total of 59 bcm of LNG imported by member states (after regasification) was transported there.

Table 2. European Union's (EU28) LNG import sources in 1990-2018 [bcm]

Exporter	1990	1995	2000	2005	2010	2015	2018
Qatar	-	-	0,3	4,9	35,0	24,7	19,5
Nigeria	-	-	4,4	10,6	14,0	6,2	10,5
Norway	-	-	-	-	3,4	3,4	7,5
Algeria	16,0	16,5	21,1	18,9	14,8	8,8	7,4
Trinidad and Tobago	-	-	0,9	0,8	5,1	1,9	3,6
Russia	-	-	-	-	0,0	0,0	3,4
USA	-	-	-	-	-	-	3,1
Peru	-	-	-	-	0,1	1,0	1,9
Rest of the world	1,0	2,5	1,6	8,2	6,6	0,1	2,4

Source: Own elaboration based on Eurostat, https://ec.europa.eu/.

LNG versus pipeline transport of natural gas

With high dependence on two major natural gas suppliers, LNG is one of the few ways to ensure supplies from different directions for the EU. As Mariusz Ruszel (2014) points out, the possession of LNG terminals has a positive effect on the improvement of state's energy security. This type of infrastructure is another entry point to the internal gas system and increases the number of available delivery routes. This makes the internal gas market more resistant to supply disruptions (Ruszel 2014: 52-53). The International Energy Agency (IEA) created a model for assessing the short-term energy security of countries, where – apart from dependence on imports which is largely independent of the will of the states – one of the basic factors is the level of suppliers diversification, expressed by the Herfindahl-Hirschman Index (HHI) (Jewell 2011: 25-28). The HHI is calculated as a sum of the squares of individual exporters market share:

Formula 1. Herfindahl-Hirschman Index

$$HHI = s_1^2 + s_2^2 + \cdots + s_n^2$$

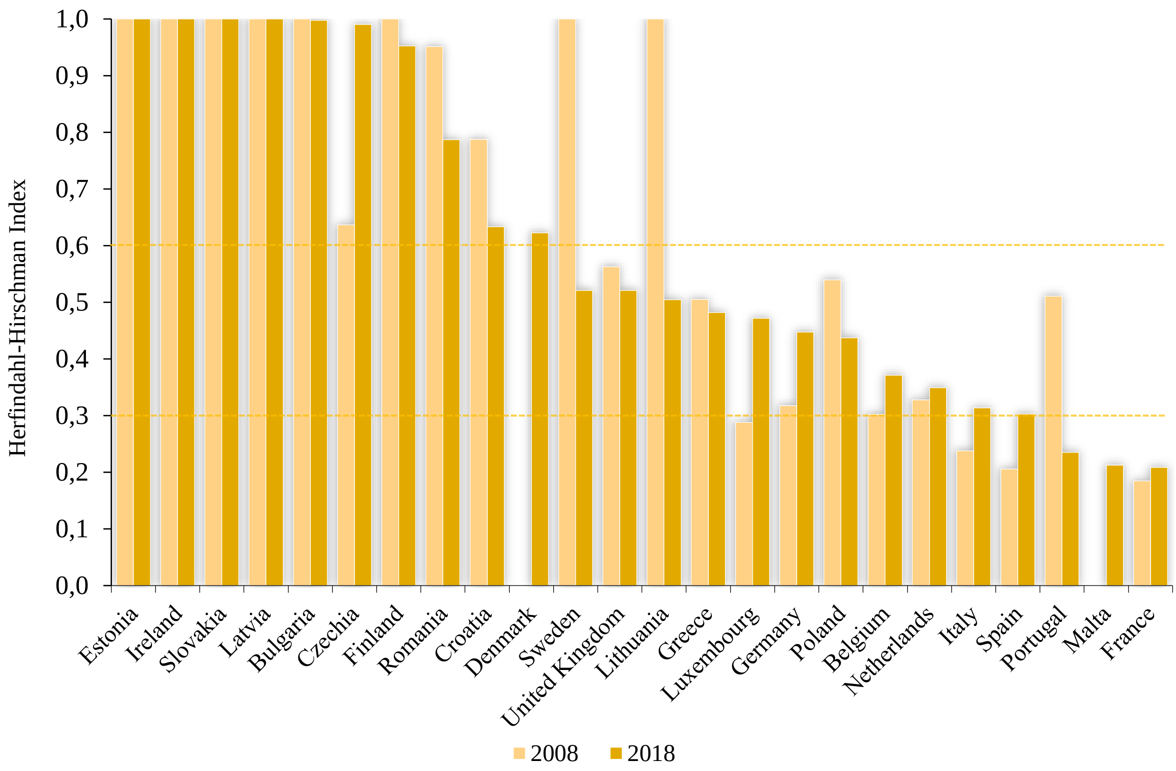
where:

S – market share of a single supplier,
n – number of the last supplier.

According to this model, a high level of security of natural gas supply can be ensured with an indicator of fewer than 0.3 point. Higher HHI means moderate (0.3-0.6 point) or low (>0.6 point) security of gas supply. Among the member states importing natural gas, only three achieved a high level of security in terms of supplier diversification in 2018, as shown in the chart 5. All of them (France, Malta and Portugal) have LNG terminals, as does Spain, which only slightly exceeded the 0.3 level. Finland is the only country using liquefied natural gas that is highly dependent on a single supply route, but its LNG infrastructure is still very small in scale. The largest decrease in the concentration of suppliers can be observed in the case of Lithuania and Sweden, which between 2008 and 2018 reduced their dependence on a single supplier (Russia and Denmark, respectively) from the situation of monopoly to a moderate concentration level, opening their first LNG terminals in 2011-2014. The comparison of changes in the HHI in Poland and Germany is worth noting. During this ten-year period, both countries made major investments and commissioned new import infrastructure - the LNG terminal in Świnoujście and Nord Stream gas pipeline. It is clearly visible that the HHI level in Germany has increased since 2008 from a level close to 0.3 point, to more than 0.4 point a decade later. Poland, unlike its western neighbor, decreased its supplier concentration by 0.1 point on the index. It should also be noted that in Poland gas consumption increased at this time, while in the compared country it slightly decreased.

The calculations show that among the EU countries with the lowest level of dependence on single suppliers, there are those that use LNG on a large scale. The flagship example of diversification is Malta, which started to import gas only in 2017 - entirely in liquefied form. A year later, its small demand was met by maritime deliveries from as many as six producers on five different continents (GIIGNL 2019: 28-29). Other large markets that, apart from gas pipeline supplies, also use LNG to meet their demand, are characterized by a significant diversification of the directions of supplies, literally: France, Spain and Italy. Ireland can be placed at the opposite side of the spectrum. As an island, the country has the potential to build infrastructure for receiving liquefied resources, however, Dublin has opted to fill all its import via a gas pipeline from only one direction – the United Kingdom.

Chart 5. Herfindahl-Hirschman Index of natural gas trade partners diversification in the European Union countries in 2008 and 2018*



Source: Own elaboration based on IEA Natural Gas Information Statistics 2020, IEA. *Due to some small non-classified volumes of import in several countries, the real HHI might have deviations of no more than 0.02 point. Austria, Slovenia and Hungary are not included as there was no calculable data available, and Cyprus was not importing natural gas at this time.

Table 3. Herfindahl-Hirschman Index of natural gas trade partners diversification in the European Union countries in 2008 and 2018*

Country	2008	2018	Country cont.	2008	2018
Estonia	1,00	1,00	**Lithuania**	1,00	0,50
Ireland	1,00	1,00	**Greece**	0,50	0,48
Slovakia	1,00	1,00	**Luxembourg**	0,29	0,47
Latvia	1,00	1,00	**Germany**	0,32	0,45
Bulgaria	1,00	1,00	**Poland**	0,54	0,44
Czechia	0,64	0,99	**Belgium**	0,30	0,37
Finland	1,00	0,95	**Netherlands**	0,33	0,35
Romania	0,95	0,79	**Italy**	0,24	0,31
Croatia	0,79	0,63	**Spain**	0,21	0,30
Denmark	-	0,62	**Portugal**	0,51	0,24
Sweden	1,00	0,52	**Malta**	-	0,21
United Kingdom	0,56	0,52	**France**	0,18	0,21

Source: Own elaboration based on IEA Natural Gas Information Statistics 2020, IEA. *Due to some small non-classified volumes of import in several countries, the real HHI might have deviations of no more than 0.02 point. Austria, Slovenia and Hungary are not included as there was no calculable data available, and Cyprus was not importing natural gas at this time.

In its recent history, Europe has already experienced the dangers of a too high concentration of natural gas suppliers. While the Soviet Union did not cut off gas supplies to the European Community at any time throughout the Cold War (Kaczmarski 2010: 64), politicians and researchers have been pointing to such a threat from its legal heir, the Russian Federation, for years. In January 2006, as a result of a dispute over the supply and transit of gas through the territory of Ukraine, Russia limited the transmission of gas through this transit country for four days. Nine EU countries experienced a temporary reduction in the volume of Russian gas supplies by up to 40% (Zadorozhna 2012: 6). The most significant, however, was the repetition of this conflict in 2009. At that time, gas supplies through Ukraine to EU were suspended or limited for more than two weeks. The EU Gas Coordination Group reported that Russian gas supplies for 12 member states were limited. The conflict between Kyiv and Moscow had the greatest impact on Bulgaria and Slovakia, completely dependent on imports from the East, which lost respectively 100% and 97% of their gas supplies for several days. The third largest cut-off, at the level of 80%, was experienced by Greece, which was diversifying Russian supplies only by LNG. In response, Greece ordered additional shipments by sea within a few days (Zadorozhna 2012: 6). In its assessment of the gas crisis in early 2009, the European Commission (EC) identified the country's increase in LNG imports as one of the examples of effective assurance of security of natural gas supply. LNG terminals, together with interconnectors, were presented as the effective elements of diversification of suppliers (European Commission 2009: 8-15).

A few years later, the Arab Spring showed that the supply direction from the Middle East and North Africa (MENA) region is also exposed to political destabilization (Ruszel 2014: 55). The revolutions in the countries south of Europe also affected partners of EU in natural gas trade – both in traditional and liquified form. Among the EU members, the civil war in Libya of 2011 affected Italy most significantly. The country had been receiving most of its gas exports from this direction. For about six months, gas production and transmission in the country ruled by Muamammar al-Gaddafi were largely stopped. This resulted in a reduction of pipeline gas supplies to Italy from the level of 9.4 bcm in 2010, to 2.3 bcm in 2011 (Statista 2020). The events in the region also stopped the developing LNG exports from Egypt and Yemen. The production and transmission of natural gas have not been stopped at the most important EU partners in trade in natural gas - Algeria and Qatar (Simonet 2013: 191). However, unrests in Algeria and the terrorist attack on one of its gas production facilities grew awareness in European partners (De Micco: 35-37).

In the 2016 LNG strategy (European Commission 2016), the European Commission noted that the regasification capacity of the terminals located in the EU is large, but their distribution between individual areas of the bloc leaves much to be desired. The aforementioned disruptions of natural gas supplies had a smaller impact on the situation of the countries of southern part of the continent than on the countries in central and eastern parts of the bloc. Italy reacted to the limited supplies from North Africa and Russia by increasing gas pipeline supplies from other countries (Darbouche 2011: 30). Spain, in response to the unstable situation in Algeria, reduced the volumes received from this direction and increased LNG supplies from the United States and Russia, which quickly exceeded the volumes supplied via pipelines from Spain's most important partner so far (Kasraoui 2020). Cutting off the eastern EU from supplies of Russian gas forced the shutdown of some factories in countries such as Romania and Bulgaria, or even the introduction of a state of emergency in Slovakia (Zadorozhna 2012: 8). This was mainly due to the small number of interconnections, low storage capacity and the lack of LNG infrastructure. Most of the countries in this part of Europe were unable to replace Russian supplies. The 2014 endurance test for interruptions in Russian gas supplies indicated that LNG has the greatest potential to replace the missing volumes. European Network of Transmission System Operators for Gas, who carried out the study for the EC, stated that the global LNG market is large enough and can offer a quick redirection of short-term deliveries. According to the developed scenario, liquefied gas would fill the largest part (33%) of the lost gas volumes. According to ENTSOG, gas supplies from Norway would be able to increase only enough to fill 13% of the gap, and gas pipelines from the MENA region are already fully exploited and would not provide support in this situation (European Commission 2014: 12).

An additional benefit of LNG imports is the elimination of the transit risk that occurs in gas pipeline transport. Maritime trade eliminates the need to contract with third countries and the necessity to share the profit in the form of transit fees. As the recent history of transit through the territory of Ukraine has shown, it may also pose a threat of disruptions to supplies due to political instability or conflict between the two partners. The transit risk is also visible in the case of an intermediary country that is Belarus. In 2010, President Aleksandr Lukashenka threatened to cut off Russian gas supplies to the West as a result of a dispute with Gazprom (Le Coq, Paltseva 2011: 2). Eventually, the flow was temporarily limited only to Lithuania, but the EU energy commissioner saw it as "*an attack against the whole European Union*" (Schwirtz 2010). In the case of LNG maritime trade, the passage through the seas and oceans is guaranteed by the 1982 Convention on the Law of the Sea, which gives all merchant ships the right of transit passage (Hartwig 2019).

When discussing security issues, one cannot ignore the aspect of the physical security of infrastructure. LNG terminals, as well as gas pipelines, belong to the states' critical infrastructure, and within the European Union, international projects constitute the so-called European Critical Infrastructure. Member states are responsible for its protection and in the case of infrastructure the destruction of which would affect more than one country, countries should cooperate in maintaining its security (OJ EU 2008 L 345/75). So far, there have been no cases of terrorist attacks on LNG terminals in the world (Parfomak, Fritelli 2007: 20). To date, the only recorded case of terrorism targeting a methane carrier has been a failed 2016 bomb attack attempt from Yemen, territory targeting cargo from Qatar to Egypt (Saul 2016). Pirate incidents aimed at stealing a ship, cargo or taking a ransom are slightly more common. The International Maritime Organization informed that in 2018 and 2019 each there were two events of pirate attacks on LNG carriers. However, all of them were aimed at stealing equipment and crew supplies or obtaining a ransom - not the cargo (International Maritime Bureau 2020). Opinions on the threat of LNG infrastructure by terrorism are divided. Some national security experts point out the potential great damage such an attack could cause. The methane carriers are compared to oil tankers, which have already been the victim of successful terrorist attacks. Other researchers point out, that currently used tank protection systems make them well protected, and there are easier and more attractive targets for terrorist groups (Parfomak, Fritelli 2007: 20-22). Nevertheless, it should be noted that gas pipeline transport is also threatened by terrorism, and due to the access to the installations (most of them are located above the ground), it is relatively easy to disrupt. Numerous damages to the gas pipelines were noted during various conflicts in the Middle East (Steinhäusler et al. 2008: 2). In 2014, the Ukrainian government reported a similar terrorist attack when the part of the Trans-Siberian Gas Pipeline – through which gas is supplied to EU countries – exploded (Euractiv 2014). The circumstances of this incident remain unclear.

The role of LNG in European Union regions

The development of LNG infrastructure is supported at the EU level. In its 2010 communication on an action plan for an integrated European energy network (European Commission 2010), the European Commission identified LNG infrastructure as one of the building blocks for a better-connected EU gas system. In a communication of February 16, 2016 (European Commission 2016), EC confirmed the importance of LNG infrastructure for the diversification of gas supplies, increasing competitiveness on the internal market and limiting the negative impact on the environment by replacing it with more emitting energy sources. Allowing all member states (directly or through other members) to access the international LNG market has been included as one of the goals of the EU's liquefied natural gas strategy (Łoskot-Strachota 2016). Such investment projects may apply for loans and co-financing from EU funds, including the European Regional Development Fund, the European Fund for Strategic Investments, or the Connecting Europe Facility (formerly TEN-E mechanism).

Such financial support was granted to the former Eastern Bloc countries – most strongly dependent on a single supplier. One of the key elements of increasing the integration of this region was the creation of a gas corridor between the terminal in Świnoujście and a facility on the Krk island. Thanks to the network of interconnectors, it was supposed to provide access to overseas gas supplies for the Czech Republic, Slovakia and Hungary, which do not have coastlines (Kochanek 2019: 32). The Polish regasification plant was put into operation in 2016, and the Croatian LNG infrastructure shall become operational January 1, 2021. As Agata Łoskot-Strachota points out, the mere construction of LNG terminals in this region may favor the further development of infrastructure and the creation of local gas hubs or connection with the neighboring ones (Łoskot-Strachota 2016: 4). Lithuania has already proved earlier that other member states can benefit from having an LNG receiving infrastructure by one country. Lithuanian, on a small scale, re-export the gas received in their terminal to neighboring Latvia, as well as to Estonia and Poland (Łoskot-Strachota 2016: 4). In 2015, the European Commission recognized that Latvia, due to access to gas from the Lithuanian terminal in Klaipeda, ceased to be an "energy island" – the status that formerly allowed it to refrain from applying the liberalization provisions of the Third Energy Package (Prontera 2017: 159). Further LNG projects are at the planning stage in all Baltic states, and for several years small-scale terminals have also been operating in Finland.

In this part of Europe, due to the high dependence on a single supplier, the negotiating position of importers is particularly low. The possibility for a state with an LNG terminal to use other import sources exerts a price pressure on the dominant suppliers (Sikora, Sikora 2018: 10). This is exactly the approach taken by Lithuania, for which Gazprom was the only gas supplier until the construction of the country's first LNG terminal in 2014. President Dalia Grybauskaitė said at this time that Lithuania "can very seriously consider the option of not having any agreements" with Gazprom after the expiry of the gas contract, but added that Lithuania does not "strictly reject Russian gas, especially if it comes at a cheaper and competitive price" (Seputyte 2014). The Lithuanian energy minister announced later, that his country was paying for gas one of the highest prices in Europe and after Lithuania started buying Norwegian LNG, it negotiated a 23% discount from Gazprom to the current contract (Seputyte 2014).

A similar role to regasification plants in the Baltic Sea may play the LNG terminal in Greece for the region of south-eastern Europe. Bulgaria makes the most of the third-party access law to which the Revithoussa plant is subject and in 2019 purchased gas supplies directly from the USA and Trinidad and Tobago. After regasification at the Greek terminal, the gas is piped to the Bulgarian market. In addition, the gas operator from Sofia purchased 20% of shares in the second LNG terminal in Greece, which should be built by 2023. For Bulgaria, the ability to import LNG, was one of the arguments in negotiations with Gazprom, which resulted in 40% cut in gas prices from Russia (Reuters 2020). The EC financially supports both the creation of a new terminal and the planned network of interconnectors, which would allow access to the resources delivered to Greece also to other countries of south-eastern Europe (Skarżyński 2018: 91).

At the western end of the Mediterranean, the situation is different. In the 1990s, Spain imported more than half of the gas it consumed only from Algeria. Given the great distance from Norway and even greater distance from Russia, the development of LNG infrastructure was considered the most advantageous diversification option (Prontera 2017: 163-164). Spain – similarly to neighboring Portugal – has the capacity to absorb more than twice as much LNG volumes as it needs (Kaya Caner et al. 2018: 12). Madrid uses some of its methane carriers as supplementary gas storage facilities, capable of quickly replenishing demand in the event of sudden increases or interruptions in supply (Dančák et al. 2010: 67). In recent years, however, imports have exceeded the demand so significantly that Spain was forced to sell gas at cost to other EU countries, via an interconnector with France (Kravtsova 2019). Nevertheless, the Iberian Peninsula is still very poorly connected with the gas markets of other member states (Heather 2019: 3). M. Ruszel puts forward the thesis, that countries equipped with the ability to satisfy a large part of the demand with LNG imports, show less incentive to integrate with neighboring markets (Ruszel 2014: 54).

In the most mature gas markets in north-western Europe, LNG is primarily a supplementary energy source. The issues of the impact of LNG on the security of supply are of less importance here, with economic issues in the foreground. Member states in this area have a relatively well-developed network of interconnections, as well as access to their own resources (especially Great Britain, the Netherlands and Denmark). This part of Europe is well connected with various external gas suppliers, including Norway, which is considered to be a more stable and safer exporter than Russia for member states in the east or Algeria for southern countries. Thanks to this, the countries of south-western Europe can send the imported fossil fuel to the east after regasification. Nevertheless, the limitation is still the insufficient number of interconnections, so that a large part of the regasification capacity of the terminals in this region remains unfilled (Corbeau 2017: 175).

Conclusions

The European Union's LNG market is growing with the development of regasification infrastructure. Connection with maritime natural gas supplies has been recognized by the European Commission as one of its key strategies for ensuring energy security of the bloc. Construction and expansion of existing regasification terminals is supported with EU funds as these are projects that have the potential to give access to the global market through interconnectors even to landlocked member states.

The possession of LNG infrastructure gives access to the growing global market, where new exporters are appearing with the time. For the European Union, which is dependent on supplies from outside, it gives the opportunity to achieve a greater level of diversification. Although LNG trade and transport presents a number of risks, as does gas pipeline supply, it is another entry point to the gas system and provides an alternative. The transport of natural gas by methane carries in practice eliminates the threat related to the transmission through a transit state. Moreover, having access to more suppliers, give countries a better negotiating position with exporters. In the case of European Union countries, this means, first of all, the ability to choose suppliers more freely and to limit the monopoly of largest suppliers: Russia, Norway and Algeria.

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The vertical restriction on abuse of a dominant position of the Gazprom under Gas Directive

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Abstract: The subject of the research is a presentation of the right to compensation in vertical relationships due to unfair practices under international agreements and the Gas Directive. The thesis centres on the presentation of proof that Gazprom abuses its dominant position. The paper presents the multidimensional content of Gazprom's dominant activities, which significantly distorts the European energy market. Initially, the author indicates the history of Gazprom's activities and economic way of transparency in pricing based on the latest American research. The matrix of research is a presentation of proceedings before the Court of Justice of the European Union and the Arbitrage Tribunal in Stockholm. In the last part of paper, there is clarification of the doctrine of *direct effect* and the procedure of an action for damages. The Gas Directive provisions are subject to the *direct effect* principle and in vertical relation, the individuals may bring an action for damages. *In fine*, the appearance of dominant and unfair practices means that individual proceedings against a country will constitute a majority in the future in the scope of energy law in the European Union. In this dogmatic study, the tools were criticisms, heuristics, hermeneutics and experiments.

Key words: action for damage, Gazprom, energy law, direct effect.

1.0 Introduction

Unfair practices in global turnover are not a rare phenomenon. The Gazprom enterprise has infringed national law in certain Member States and European provisions from a long time. One of the material problems is overpricing for the same quantity of natural gas.

The research interprets the problem of Gazprom's dominant position, which significantly distort fair international trade. Furthermore, its unfair practices have been a challenge for the European Union, and therefore the European legislator decided to codify the Gas Directive under which Gazprom falls in terms of European provisions and jurisdiction.

The study shall be composed of four sections. In first part, the author presents the history of the establishment of Gazprom and the Russian ideology of ведомственность. Then, there are discussions in the field of the EU-Russia relationship and proceedings before the Court of Justice of the European Union and the Arbitration Institute of the Stockholm Chamber of Commerce. The final section focuses attention on *direct effect* and the procedure of action for damages. The scientific description will clear up the right to compensation in the vertical relationship. This comprehensive study substantiates the right to bring an action for damages brought by individuals.

1.2 Introductory remarks

The Russian gas market features large-scale gas reserves. *Prima facie*, it seems that Gazprom abuses its dominant position. Nonetheless, acceptance of this assertion requires a deeper analysis. Initially, it has to take a closer look at Gazprom's history of natural gas mass production. Its origins date back to 1999, when the total gas capacity reached 100 billion cubic metres (Moe, Kryukov, 2013:2). From 1965-1980 there was an extension of pipelines. The most favourable sources were discovered in the North Caucasus and Ukraine by the end of 1950. In 1970, there was further rapid expansion of natural gas consumption. Some data specify the gas pipeline quantity, which reached 50,000 kilometres of main pipelines, 690 compressor stations and 22 underground warehouses. The total distribution amounts to 340,000 kilometres. The total kilowatt continuous load reaches 42 million (Moe, Kryukov 2013:2). Furthermore, the production and distribution operate under the Russian regime in force. *Ad exemplum*, the first market sharing of oil and natural gas industries was under the decision of the Ministry of the Gas Industry (Mingazprom) (Moe, Kryukov 2013:4).

As is known, Russia went through a crisis during the 1960s and they had to store gas reserves due to the Cuban Missile Crisis, US concession and finally the Sino-Soviet border conflict. Therefore, they wanted to restore the national economy. It is worth considering whether Gazprom's present dominant position is rooted in twentieth-century Russian ideology. One of the latest phases of Russian reforms concentrated on the establishment of the state gas enterprise "Gazprom" at the end of 1989 (Aron 2013:4). It was allied with the "ведомственность" phenomenon, which was a control measure introduced in order to increase government power (Whitefiled 1993:54). It appears that Gazprom's political and economic behaviour results from previous incautiousness in relation to the US. It may be that excessive prices arise from previous Russian lessons. Currently, the overpricing problem is considered unfair practice.

According to data, in 2019 the production and distribution of natural gas constituted 11% of GDP (Gaddy, Ickes 2013:3). Currently, demand for natural gas has fallen slightly to 8.7% (Oxford Analytica). Moreover, Russia possesses 65 billion bcm natural gas reserves for the year 2020 (112 UA 2020: 1). However, it is difficult to produce a reason for the decrease in natural gas demand. It may result from the EU decision declaring Gazprom's dominant position or the COVID-19 global pandemic.

1.3 EU-Russia Energy Relations

For the purpose of research on unfair practices, we shall consider the relationship between the Federation of Russia and the European Union. From 1951, the European Coal and Steel Community did not recognise EU energy policy as a substantial priority. For the first time, the ECSC had striven to establish coal and steel production in France and Germany. The primary project included judicial control in order to maintain a competitive market and provide the development of a coal and steel market. Nonetheless, according to the European Community, energy policy was still a primary issue for the ECSC. However, the diversification of European geopolitics had substantive implications for energy policies. The Arab oil crisis was the first handicap, and during this time, the ECSC did not recognise EU-Russia relations (Kopp 2015, 68).

The initial energy relationship between the European Community and the Federation of Russia dates back to the adoption of the Partnership and Cooperation Agreement on 24 June 1994 on the island of the Corfu (Tichý 2019: 15). This act had a 10-year period of validity under art. 106 of the Partnership and Cooperation Agreement (Agreement on Partnership and Cooperation:85). The European Community had adopted its first energy package soon after adoption of the PCA. Then, there was codification of competition provision, liberalisation of the energy market under the Directive on the improvement in gas industries within the territory of the European Union (Dz.U.UE L 185). The basic objective was to avoid the abuse of monopolist practices (Gao 2010:99). The packages are considered to be a “harbour”. Therefore, this problem ought to have already been eradicated in 1998.

While the beginning of the development of an energy legal framework sparked a meeting between the President of the European Commission – Romano Prodi and the 1st Deputy Minister of Russia – Viktor Khristenko by the end of 2000s, where again there was re-initiation of energy dialogue. Nonetheless, these activities seem to be a form of diversion (Talseth 2017: 17). In relation to the ineffectiveness of the previous energy package, there was the adoption of a 2nd energy package, which came into force in 2003. This package concentrated on the establishment of common procedures and principles on gas transit pipelines. Also, the European Union took into account supervisory role of the European Commission during transactions in relation to the supply of natural gas (Gao 2010: 99). The Russian favourable approach ensured that the parties reciprocally agreed that any progress to be made in the area of energy policy should provide a sustainable level of competition (Talseth 2017: 1). According to Gazprom, the joint energy dialogue constituted a first step towards adopting the Energy Charter Treaty (Talseth 2017:46).

The aforementioned activities were allegedly supposed to lay down a secure relationship between the Member States of the European Union and the Federation of Russia. However, the consequences were different. Gazprom could not deliver on the promises made for unknown reasons. Taking into consideration Gazprom’s non-compliance with EU competition rules, in 2005 the European Commission initiated inquiry proceedings concerning gas supply. Gazprom breached art. 17 of Regulation 1/2003. The matrix of the inquiry proceeding was the instability of prices and the politicisation of Gazprom, who made prices dependent on political relations (Dz.U.UE L 1/1: 13).

1.4 Measuring gas rents

With reference to the inquiry procedure against Gazprom, it is worth discussing the method of calculating gas prices. This is because the method at issue is regarded as an unfair practice.

The Russian gas sector provides $^2/_3$ of total national exports reaching 11 % of the Russian Gross Domestic Product (GDP) for 2019. According to the assumptions, the rents are revenue from the sale of gas taking into consideration the deduction resulting from economic and opportunity costs. Occasionally, Gazprom will deduct guarantee costs. Furthermore, it is worth taking into consideration the indexation of liquid assets. The gas sector distinguishes the "natural cost", which hinges on the production price determined in certain brackets (Gray 1998: 44). The research of Gaddy and Ickes accepted the following formula in calculating gas prices:

$$R_t \equiv P_t Q_t - C_t$$

1. *Source: Gaddy, Ickes 2018: 3.*

The authors pointed out that P is the price, Q is the actual quantity produced, and C is the natural gas price. Moreover, the following method may be carried out by manipulating the changing variable, which is the overestimated costs of gas production.

$$\hat{C}_t = P_t Q_t - C_t$$

6. Gaddy, Ickes 2018: 3-4.

However, the formula means gas price reduction and therefore there occurs a inquiry concerning offset and cost compensation. The literature indicates further Gazprom price manipulation. However, selling after a price reduction brings with it certain consequences. First of all, Gazprom ought to and must align costs in order to maintain financial stability. Such reduction in prices defined the term "subsidy prices", which in practice is each payment on an exporter account. The subsidy constitutes a refund of part of the costs related to gas production, which entail additional costs i.e. fiscal and social, known as the phenomena of "windfall" (Coady, Baig, Ntamatungiro 2007: 9). The subsidy should be converted using the following formula:

$$S = P_{per\ unit} Q$$

7. Own elaboration based on Gaddy, Ickes 2013: 4.

The symbol P is price per unit of resources, while the symbol Q is quantity of supply. There we should observe the correctness of the formula of subsidy admission. Nonetheless, when the total amount of price and costs is excessive, then the operation profits go up, as in the following formula:

$$T_p = \widehat{P}_t Q_t - \hat{C}_t$$

8. Own elaboration based on Gaddy, Ickes 2013: 4.

By introducing excessive costs, they are certainly going to levy some informal and formal taxes. It may assumed that the following formula presents the relevant manipulation of Gazprom practices. It is worth indicating that excessive operating costs (pretax) may be deducted from income in the tax return. It may be assumed that Gazprom may levy informal taxes which arise by virtue of law or informally, which simply allow it to survive on the global market. As one of the last formulae presents a tax cascade, whose main purpose is the deduction of informal and formal taxes and operational profits.

$$T_t = \left(1 - T^f T^i\right) O^p$$

9. Own elaboration based on Gaddy, Ickes 2013: 4.

In fine, assuming the aforementioned formulas, there is an identification of five excessive surpluses. The gas enterprise may boost amount of rents by:

1. overabundant extraction gas cost;
2. subsidies;
3. formal taxes;
4. informal taxes;
5. remaining profits.

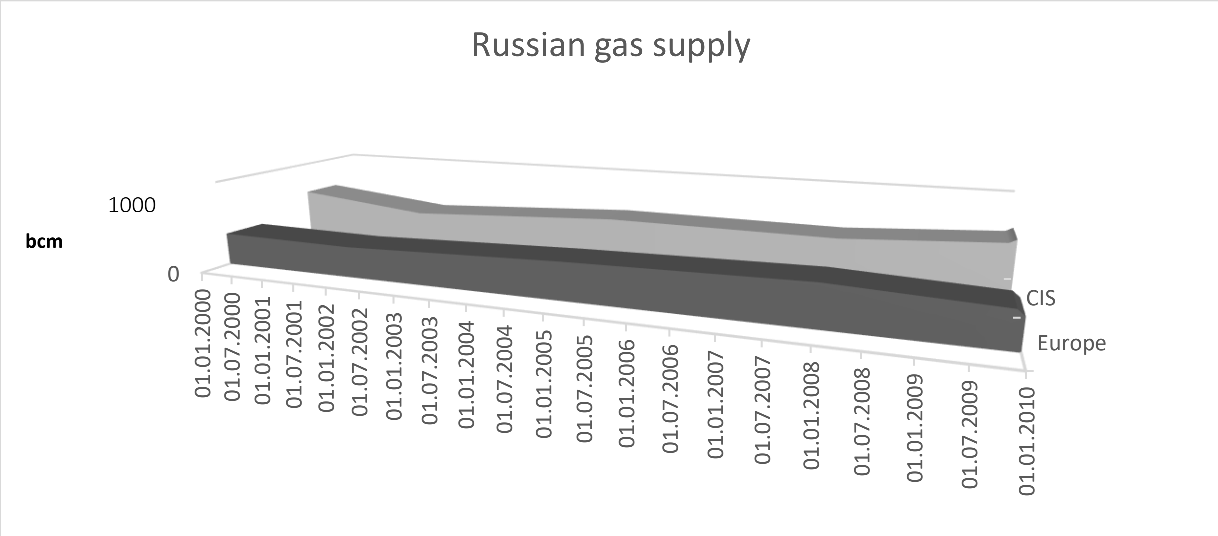
The variant method of calculation of gas rents indicates the differentiation of the European gas price and the price paid, which is the amount of export subsidy.

$$E_P - P_P = S$$

10. Own elaboration based on Orttung and Overland 2011: 80.

Before the gas conflict, the Ukraine paid 20 % more than standard gas price (Chow and Elkind 2009: 83). Furthermore in 2006, the subsidies reached a peak of $17 billion. While in the subsequent years the subsidy prices fell dramatically to $5 billion (Ibidem: 80).

The European Union and the Member States are not able to predict gas price manipulation due to excluding Russia as a 3rd national country from EU legislation and the Court of Justice of the European Union jurisdiction. *Ad exemplum*, the manipulation of gas prices precisely described Russia-Ukraine gas disputes, when Gazprom inflated the value of gas prices by increasing subsidised prices. These events have resulted in the breakdown of Ukraine-Russia relations by cutting off access and supply to natural gas (Wilson-Rowe, Torjesen 2000: 93). The Ukraine-Russia gas dispute has launched a discussion on EU summit on energy issues, i.e. energy security and diversification of supply. The following chart presents EU demand for natural gas exactly, which has not been impoverished since the gas dispute.



11. Source: Melling 2010: 4.

Presently, Gazprom have three pipelines, the Nord Stream, the Jamal Pipeline, and Nord Stream II. However, the manipulation of gas prices still hinders competitive supply to EU countries. As per the latest information, the total cost of natural gas for Germany amounts to 371 USD per 1,000 bcm, while Lithuania has been paying 484 USD per 1,000 bcm. However, that is much less than the price of natural gas for Poland, which will have to pay 570 USD per 1,000 bcm till the end of 2022 by virtue of the contract (Martewicz, Strzelecki).

The average gas prices fell $94 per 1,000 bcm. The table below presents the amount of subsidies for Germany, Lithuania and Poland.

German	**$277**
Lithuania	$390
Poland	$476

The gas enterprise is suspected of hindering the free supply of natural gas by concluding "destination clauses" in primary contracts, too. Under this clause, it is prohibited to re-sell gas to 3rd parties (Sartori 2013: 5). This significantly obstructs fair sale.

1.5 Gazprom activities before the CJEU and the SCC

The proceedings before the Court of Justice of the European Union and Arbitration Institute of the Stockholm Chamber of Commerce exposed the problem of Gazprom's unfair practices. Although the initial CJEU decision was unfavourable for the Polish company, then over time the CJEU jurisdiction and Gas Directive codification committed to the introduction of compensation for damage brought by individuals.

Gazprom has already abused its dominant position since 2015, when the Polish company PGNiG had a dispute before the Arbitral Tribunal. Initially, the illicit supply of natural gas relied on a request for enhancement of pipeline throughput operation by the Bundesnetzagentur known as the OPAL. On 16th December 2016, Poland submitted an application on the validity of the European Commission decision of 28th October 2016 on gas transmission by raising an objection by entering a demurrer of art. 18 and 25 of the Directive 2003/55/EC (ECLI*:*EU*:*T*:*2017:544: *1/2*). *In bervi*, the German transmission of natural gas known as the OPAL is an extension of the Nord Stream. On the basis of previous a European Commission decision, Gazprom, as one of the major gas enterprises, is not entitled to use more than 50 % of total gas capacity in a one year period (ECLI:EU:T:2017:544: 2). This limit may be exceeded if the gas enterprise is going to offer 3 billion m^3 with acceptance of the competitive rules under art. 18 of the Gas Directive issued (Dz.U.UE L 176: 240/243).This provision is required to adopt a common methodology in order to provide access to the gas transmission system. Moreover, an expired art. 18 called for the publication of gas tariffs. The subsequent art. 25 of Directive 2003/55/EC required the appointment of a National Regulatory Office, which should assure a competitive and non-discriminatory gas market. As already shown, the NROs had to publish a national methodology and common tariffs at least one year before the implementation of the conditions. It seems that the 2003 Gas Directive has been an operable mechanism for implementing the common gas market. It is supposed to mean parity of prices between Member States.

In the first decision, the European Commission excluded the third party from gas access. Nonetheless, Gazprom started implementation of the Gas Transfer Program, in relation to which the main transmission operator had to share the OPAL pipeline on competitive, just, and non-discriminative auctions. Also, the European Commission provided for the proper functioning of the competitive gas market by indicating that in the event of higher demand than 90% of OPAL capacity at the annual bidding procedure, the BNetzA was required to increase the FZK capacities by 1.6 million kWh. Moreover, the price may not exceed the average amount and it had to be comparable in relation to other products. As the aforementioned evidence suggests, Gazprom did not observe the EC decision, which increasingly exposed the problem of Gazprom's unfair practices.

With reference to price inequalities, PGNiG S.A. requested an action for annulment. According to the case files, the work on the German gas pipeline was completed on 13 June 2011 and it had 36.5 bln m^3 of total throughput. The applicant asked for the suspension of execution of the European Commission decision, suspension of execution by BNetzA, OGT, OAO Gazprom, and OOO Gazprom of the public contract, and a Gazprom commitment to adjust to the new conditions. In the opinion of the Court of Justice of the European Union, the urgency prerequisites had not been accomplished and that application should be dismissed under the principle of *"fumus boni iuris"*. The CJEU considered the application incomplete, which affected its final decision.

The complaints against Gazprom were surprisingly many. On 19 July 2019, the European Parliament along with the Council codified the Gas Directive on common rules for internal gas markets (Dz.U.UE L 211: 1/2). The legislative shortcomings proceeded from the exclusion of EU jurisdiction in the previous Gas Directive. Art. 49b of the Directive 2019/692/EU describes the notification procedure and the European Commission supervision order thoroughly (Dz.U.UE L 117*:* 45b). Basically, it means a restriction on the Nord Stream II pipeline. Gazprom must respect EU provision even at the first interconnection point with the Member States' network, located in the area of the territorial sea of the Member States. This means that Nord Stream belongs to the territorial sea of Denmark and Sweden, and Gazprom must uphold the provisions under the Gas Directive from 2019. The injustice of Gazprom actions have resulted in subsequent appeals to the European Commission and this must be borne in mind.

The Republic of Poland and the Republic of Latvia have requested the European Commission decision, which stated the legality of the OPAL manufacturing hub in the scope of exclusion from access by 3rd parties to Gazprom's gas under art. 18 of 2009 Gas Directive, be annulled. (ECLI:EU:T:2019:567: 29/30). Furthermore, the Republic of Poland has brought six complaints against the decision. According to the case record, which basically concerned breaches of the principle of solidarity, *ius certum*, the provisions of the international agreement, art. 36 Gas Directive, which referred to the violation of energy security and competition, and art. 101-102 of the Treaty on the functioning of the European Union (the scope of exclusion from access by 3rd parties to Gazprom gas under art. 18 of the 2009 Gas Directive) (ECLI:EU:T:2019:567: 48). Referring to art. 194 of the Treaty on the Functioning of the European Union, the CJEU has recognised an infringement identifying a restriction or even complete containment of gas transmission through the Jamal Pipeline due to the full capacity of the Nord Stream throughput (ECLI:EU:T:2019:567: 61/62). The Republic of Poland also raised concerns about the distortion of gas supply and increase in costs, which were not the subject of deliberations by the European Commission (Ibidem: 63). The CJEU dismissed the European Commission claims concerning due consideration of art. 194 of the Treaty on the Functioning of the European Union along with art. 36 of the Gas Directive. The CJEU made a clarification that the European Union Energy Policy could not bring negative effects for the Member States under art. 194 of the Treaty on the functioning of the European Union. Therefore, the European Commission ought to make an assessment in the scope of the legality of Gazprom activities on the energy market before issuing a decision (Ibidem, 77/78). And yet Gazprom still contended that the judgement of the CJEU should have been different. The Nord Stream I and Nord Stream II enterprises brought a complaint which was negative *in fine*. They demanded action for an annulment judgement (ECLI:EU:T:2020:210: 1-2). The claims concerned firstly, exemption from the exclusion from access of 3rd parties to the gas transmissions, secondly, to provide an unbundling and lastly, transparency in pricing (Ibidem: 1). In a deep analysis, there are some doubts as to whether Gazprom possesses a dominant position. The requirements placed by the aforementioned company bulldoze competition in the energy market proposed by the European Union in its 3rd energy package. The Tribunal just allowed for bring an application before the German Regulatory Office in order to obtain permission to be exempted. However, on 15 May

2020, the Regulatory Office dismissed Nord Stream's claims (News Polsat: 2019). This means support for the EU's fair, competitive and free energy market *in fine*. In the literature, the inquiry proceedings between the European Commission and Gazprom were called the "antitrust clash of the decade".

There were arbitration proceedings simultaneously. The Arbitration Institute of the Stockholm Chamber of Commerce launched a conciliation procedure by PGNiG against Gazprom. The matrix of the procedure was reduction of prices under the agreement on gas transmission via the Jamal pipeline. There was an amendment in the recalculation of the gas price system as given by the President of PGNiG. The codified system had to take into consideration the average natural gas prices in the EU market under the Jamal contract. Furthermore, the conciliation judgement manages 1.5 bln USD compensation for the Republic of Poland (aleBank: 2020). This may mean that Gazprom will perform the provisions of the agreements fairly, at last.

The newest information indicates PGNiG's growth in financial results, because Gazprom has paid the compensation amount. However, in the case of a different scenario and damages for individuals, Gazprom would fall under the doctrine of direct effect.

1.6 The doctrine of direct effect and the procedure action for damages

The doctrine of *direct effect* means uniform application of the European Community provisions, and now the Treaty on the Functioning of the European Union, the Treaty on the European Union, and the Charter of Fundamental Rights. This concept was developed in the judgement Costa v. ENEL at the end of 1963 (Martines 2014: 129-131). It may be applied horizontally or vertically.

The vertical right to bring an action for damages refers to a natural person who was injured due to the violation of principles and provisions resulting not just from international agreements. However, the directive's provisions fall under the doctrine of direct effect, too.

As is known, art. 101-102 of the Treaty on the functioning of the European Union prohibit any undertakings or abuse of a dominant position even if it resulted from functioning international conventions in which the European Union is a party. However, the right to bring an action for damages resulting from *acquis communautaire* of the European Union remains undisputable.

It is worth pointing out that the codified Gas Directive introduced new set of rules in the area of actions for damages. It adopted more restrictive rules on energy distribution. Firstly, the gas companies have to act in compliance with European gas transmission rules. Furthermore, it includes the right to interpretation by the CJEU. The Gas Directive imposes more restrictive conditions for receiving derogations.

While in the scope of the right to an action for damages in a vertical relation, the person who was aggrieved even financially shall be entitled to bring the issued action. *Ad exemplum*, the overpricing problem for an individual may led to compensation *in fine*. The present research points out that three premises have to arise, i.e:

1. real damage;
2. provisions are unconditional and do not depend on any other provisions;
3. causal link between conferred right and real damage;

However, in the case of PGNiG, the individuals had paid a plateaued price, and therefore in this case, solely PGNiG may bring an action for damages in a vertical relation.

On the other hand, the right to bring an action for damages resulting from agreement was doubtful till 1987. It was confirmed by the ruling of the Court of Justice of the European Union *Demirel* from 30 September 1987, which stated that a provision of the agreement may be applicable entirely if that provision is clear, precise and conditional (ECLI:EU:C:1987:400: 2). Any parties cannot experience negative effects from concluding and executing international agreements. In my opinion, these kinds of measures constitute a legal certainty for performing international agreements, in which the European Union is party under art. 218 of the Treaty on the functioning of the European Union.

Definitely, the codification of the Gas Directive has introduced a new system of protection from undesirable Gazprom practices. On 21 August 2020, the newest information communicated the average natural gas prices for 2020. Gazprom communicated that the average price would reach $133 per thousand cubic metres for 2020. However, it is difficult to assess whether these promises will come true.

It is unknown whether Gazprom has changed trade politics and the right to damages there will go away. Definitely, currently this kind of action for damages does not occur, but then it may happen if such illicit practices occur over time.

Summary

It worth emphasising that the European energy market requires challenges in the area of conclusion of international agreements. Despite the codification of the Gas Directive, Gazprom strives to show its congregation back through bringing appeals and complaints. Gazprom's solvency of compensation was precarious. However, recent information points out the fulfilment of European provisions and the SCC judgement. Despite giving Gazprom a statement concerning average natural gas prices, it can be assumed that the Russian natural gas supply may be significantly affected and may determine trends and prices, too, in future.

The legal and natural bodies await the development of a procedure against unfair practices and abuse of a dominant position with great hope. Although, currently this has not occurred, a right to an action for damages resulting from international agreements, the individuals have the right to bring an action for damages arising from illicit Gazprom actions under the 2019 Gas Directive. Due to the fact that from 2019 Gazprom belongs to EU legislation and jurisdiction gives it a sense of expectation.

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