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RENEWABLE ENERGY SOURCES OR NUCLEAR POWER – WHAT IS NEEDED FOR POLAND?

ODNAWIALNE ŹRÓDŁA ENERGII CZY ENERGETYKA JĄDROWA – CZEGO POTRZEBA POLSCE ?

***Summary**: The air pollution in Poland is high and the health impacts significant, which is related to the fact that the main source of electric energy is coal. Coal burning results in CO_2 emissions, and in emissions of pollutants such as SO_2, NOx, particulate matter PM and others. In the case of PM2.5, which has the most detrimental influence on human health, Poland has the worst position in Europe regarding amount of the emitted pollutant per number of population. The emissions of CO_2 per unit of electric energy were in 2020 also the highest in Europe. Meanwhile, the costs of CO_2 emissions grow and grow. The production of electric energy per inhabitant in Poland is low compared to other countries, so reducing energy production cannot be the solution. Poland must find other energy sources besides coal.*

An analysis of various energy sources demonstrates that the lowest CO_2 and pollutant emissions are due to nuclear power and Renewable Energy Sources RES. However, strong RES development is hardly the solution, because operation of RES involves strong variability in energy production, and even intervals of no energy production, which can last up to 5 days and nights. In case of wind loss in one country, the import of wind energy from other countries may be impossible, because wind loss periods can occur in many regions of Europe at the same time. What is more, the amounts of materials and terrain needed for wind mills are much larger than for nuclear power plants, while CO_2 emissions are twice larger than for nuclear power plants. The example of Germany shows that introduction of RES does not provide lower energy costs, contrarily, much higher, and CO_2 emissions are much larger than in France which bases energy production on nuclear power.

Evaluation of possibilities to cover wind calm periods in Poland shows that in the case of electricity production from RES amounting yearly to 40 TWh, using all possible reserves in hydroelectric plants would be sufficient to maintain electricity production by only 2 hours. Thus, variability of RES electricity production poses a serious problem in continuous energy supply to the users. On the other hand, nuclear power plants can operate in load-follow mode, and their reliability is high. The radiation from nuclear power plants does not create health hazards. The choice for Poland is clear – the nuclear power is the best.

***Keywords**: Pollutants in atmosphere in Poland, emissions of CO_2 and atmospheric pollutants due to coal burning, emissions from various sources, variability of wind, periods of wind calm, wind power in various countries, materials and terrain needed for wind power plants. CO_2 emissions from wind and nuclear energy, costs of energy production in Germany, costs of energy*

***Streszczenie**: Zanieczyszczenie powietrza w Polsce jest wysokie, co wiąże się z faktem, że głównym źródłem energii elektrycznej są elektrownie węglowe. Spalanie węgla powoduje emisje CO_2, a także zanieczyszczeń takich jak SO_2, NOx, pyły i inne. W przypadku emisji pyłów PM2,5 mających największy ujemny wpływ na zdrowie ludzi Polska w odniesieniu do liczby ludności ma najgorszą pozycję w Europie. Również emisje CO_2 na jednostkę energii elektrycznej były w Polsce w 2020 r. najwyższe w Europie. Jednocześnie koszty emisji CO_2 rosną. Produkcja energii elektrycznej na mieszkańca w Polsce jest mała w porównaniu z innymi krajami, więc ograniczanie produkcji energii nie jest wyjściem, Polska musi znaleźć inne źródła energii poza węglem.*

Analiza różnych źródeł energii pokazuje, że najniższe emisje CO_2 i zanieczyszczeń występują dla energii jądrowej i OZE. Ale rozbudowa OZE powoduje silną zmienność produkcji energii, a nawet przerwy w tej produkcji, mogące sięgać 5 dni i nocy. W razie ciszy wiatrowej import energii z elektrowni wiatrowych w innych krajach może być niemożliwy, bo braki wiatru występują równocześnie w wielu rejonach Europy. W dodatku zapotrzebowanie na teren i na materiały potrzebne dla wiatraków są dużo większe niż dla elektrowni jądrowych a emisje CO_2 dwukrotnie większe niż przy wykorzystaniu energii jądrowej. Przykład Niemiec pokazuje, że wprowadzanie OZE nie daje obniżenia kosztów energii, przeciwnie, podnosi je, a emisje CO_2 są dużo większe niż we Francji dla energii jądrowej.

Ocena możliwości pokrycia luki w dostawach energii z OZE wykazuje, że w Polsce w przypadku udziału produkcji w wysokości 40 TWh rocznie z OZE wykorzystanie rezerw w elektrowniach pompowo--szczytowych pozwoliłoby na utrzymanie ciągłości zasilania tylko przez 2 godziny. Problem dostosowania produkcji elektryczności z OZE do potrzeb odbiorców jest więc trudny do rozwiązania. Natomiast elektrownie jądrowe mogą pracować w systemie nadążania za obciążeniem, a ich niezawodność jest bardzo wysoka. Promieniowanie z elektrowni jądrowych nie stanowi zagrożenia dla zdrowia ludzi. Wybór dla Polski jest jasny – energia jądrowa jest najkorzystniejsza.

***Słowa kluczowe**: Zanieczyszczenia atmosfery w Polsce, emisje CO_2 i zanieczyszczeń atmosfery powodowane spalaniem węgla, wielkości emisji zanieczyszczeń z różnych źródeł, zmienność wiatru, okresy braku produkcji prądu z elektrowni wiatrowych, moc wiatru w różnych krajach, potrzeby materiału i terenu dla wiatraków, emisje CO_2 z wiatru i energii jądrowej, koszty produkcji energii w Niemczech, koszt energii*

Introduction

In the light of the efforts, undertaken all over the world with the aim to reduce greenhouse gases' emission and, also, to preserve the coal for the future generations and to reduce air contamination, Poland is faced with the necessity to change its profile of electric power generation and to pass from coal burning to low-emission energy sources. One of the options of transforming Polish power system consists in basing on the wind mills and photovoltaic power plants, as being presented by the activists of renewable energy sources RES (in Polish: OZE) as clean and economically profitable because "after all, the sun shines for free" and "the wind blows for free". The second option includes utilization of nuclear energy, ensuring the constant power supply to the electric energy system, irrespectively of the atmospheric changes and seasons of the year, and constituting the proven, cheap and reliable low-energy source of energy. In the present paper, the author will consider the real advantages and short comings of the mentioned above options of development of our country energy system.

High air contamination in Poland and its impact on the health

In Poland, coal-fired power plants are currently the main source of electric energy. Burning of the coal causes CO_2 emissions and contamination of the air with SO_2, NOx, dusts PM10 and P2.5, benzo[a] pyrene and others.

In the case of PM10, the mean annual permissible level, as recommended by WHO (*World Health Organization*) is equal to 20 μg/m^3 and that one admitted in Poland is 40 μg/m^3. In the case of the daily (24h) concentration, the level above 50 μg/m^3 cannot be exceeded in Poland more than during 35 days in a calendar year [1]. In the case of PM2.5 in absolute value, Poland has been classified at the third place among the European countries, with 46.3 thousand deaths connected with PM2.5 contamination; in relation to the population number, Poland is found at the infamous first place. Similarly as in the case of cancerogenic benzo(a)pyrene B(a)P, the mean annual admissible value has been established at the level of 1 ng/m^3 and in Poland the mentioned value has been exceeded in 136 from 139 measuring points. It places our country at the first place in respect of BaP contamination among from the most contaminated countries of the European Union [2]. The mean concentration of B[a]P amounted in Poland to 4.5 ng/m^3 and the record level was as high as 18.3 ng/m^3.

CO_2 emissions as calculated per unit of the energy produced were in 2020 in Poland the highest in the European Union as can be seen in Fig. 1.

The meaning of CO_2 emission is the subject of the concern of the governments all over the world, and the price of CO_2 emission, as being established by the European Union is constantly growing. In July 2024 it reached 67 EURO/t of CO_2. At such price, production of electric energy in coal-fired power plants is unprofitable and Poland must find other sources of electric energy.

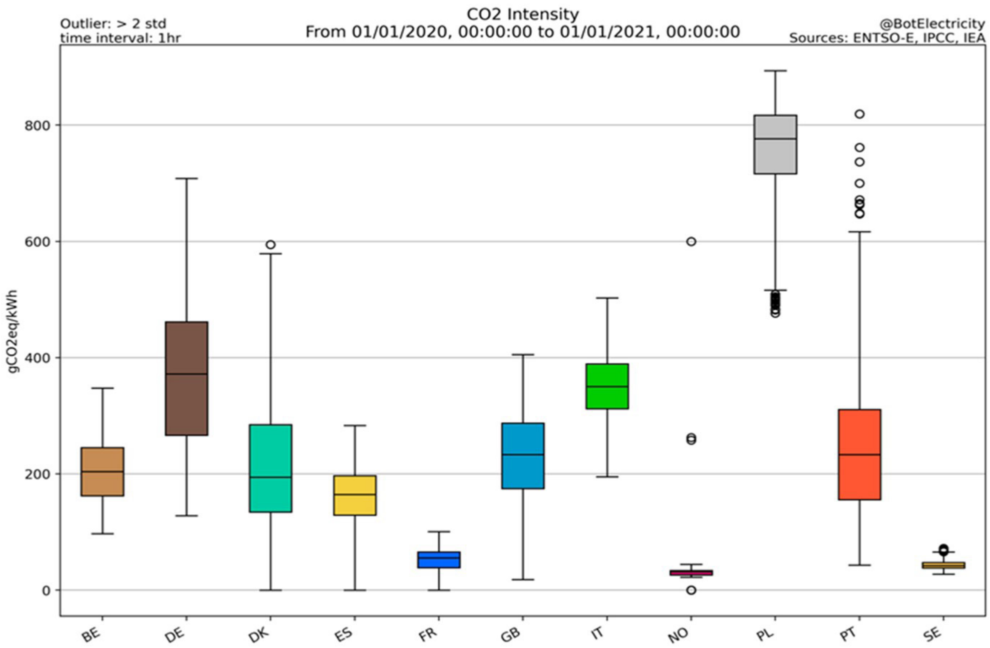


Fig. 1. CO_2 intensity per unit of electricity gCO_2 eq/kWh for various countries in the European Union, average values for 2020. Data from ENTSO-E; author Thomas Auriel,

Source: the drawing developed by the author for this paper and quoted by his kind permission

We should also remember that a high level of the air contamination with the dusts causes the measurable losses of health. The US studies conducted in the cities with a small concentration of the air contamination indicate that as early as at the concentration of a fine dust o PM2,5 amounting to 20–30 μg/m^3, a distinct shortening of the life period of the inhabitants is observed. The discussed results are given in Fig. 2. In Poland the mean value of PM2.5 during the year cannot exceed 25 μg/m^3. Unfortunately, in practice, the mentioned value is exceeded in many regions of the country.

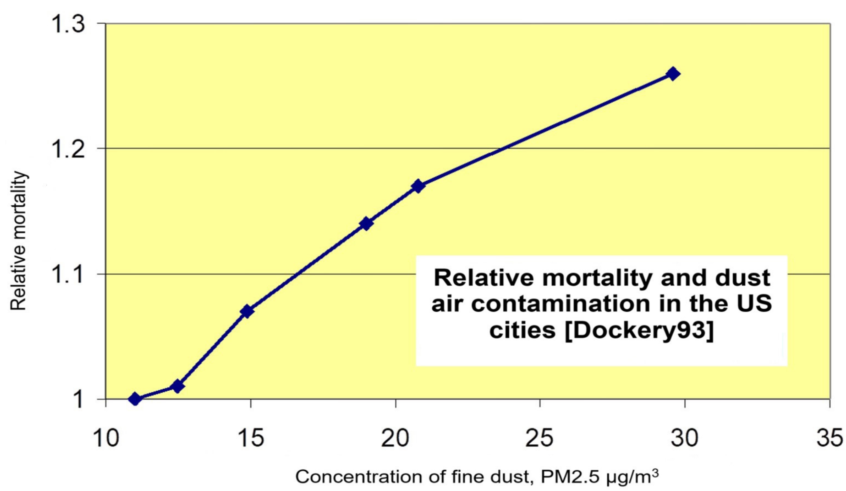


Fig. 2. The results of the studies of the relative mortality in the US cities conducted at densities of PM2.5, on the air lower than the boundary values set by the standards. Data from the paper of Dockery et al. 1993 [3],

Source: drawing by the author

Low production of electric energy in Poland as compared to other EU countries

We will focus now on the consumption of electric energy *per capita* in Poland and in the other European countries.

In the group of the countries with the lowest electric energy consumption in the households, which, unfortunately, includes Poland, the amount of the mentioned energy is found below 1 MWh/person per year whereas in the group of the wealthiest countries such as Germany, Denmark or Austria, the consumption of electric energy in the households is equal to 1.5–2.0 MWh/inhabitant. Of course, the discussed consumption in the countries situated at the North such as Sweden or Finland is still higher, i.e. above 4 MWh/per person annually, but for Poland the reference value may be the consumption in the countries of the Central Europe and the mentioned comparison is very unfavorable for our country. The discussed electric energy consumption affects the most important features of our life: cleanliness and preservation of food, hygienic level, education, incomes, easiness of life and, in effect, the health and length of human life.

The length of life in the group of the countries with a high total (not only in the households) national electric energy consumption, amounts from 83 years (Switzerland, 7091 kWh/person/year), to 81.8 years (Finland, 14732 kWh/person/year). On the other hand, in the European countries with a low electric energy consumption, the expected life length is from 74.3 (Lithuania, 3468 kWh/person/year) to 75 (Rumania, 2222 kWh/person/year). In Poland, we have the mean expected length of life at the level of 77.5 years and electric energy consumption equal to 4124 kWh/person/year. It may be seen that to equalize the level of life of the Poles with the leading EU countries – and even with the average value in the European Union – we must decidedly increase the availability of the electric energy in Poland.

Consumption of the electric energy in Poland per GNP (*in Polish: PKB*) is similar as in Germany and the Czech Republic.

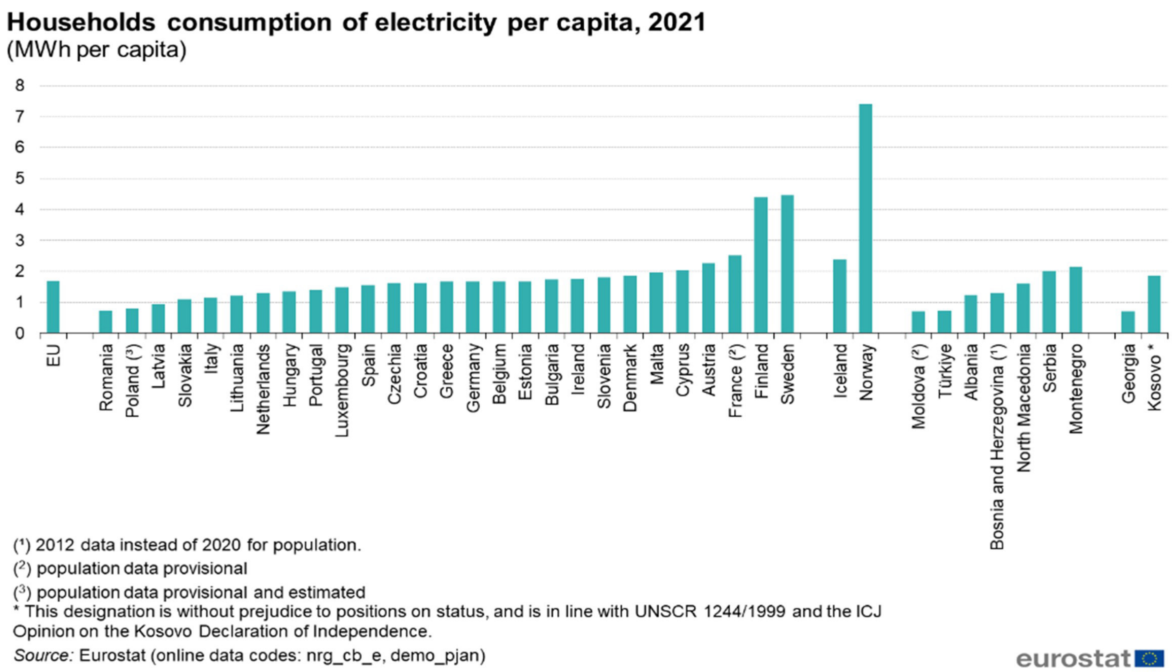


Fig. 3. Electric energy consumption per capita in households in the European Union countries (MWh per capita). Source: Eurostat (nrg_cb_e), (demo_pjan) [4]

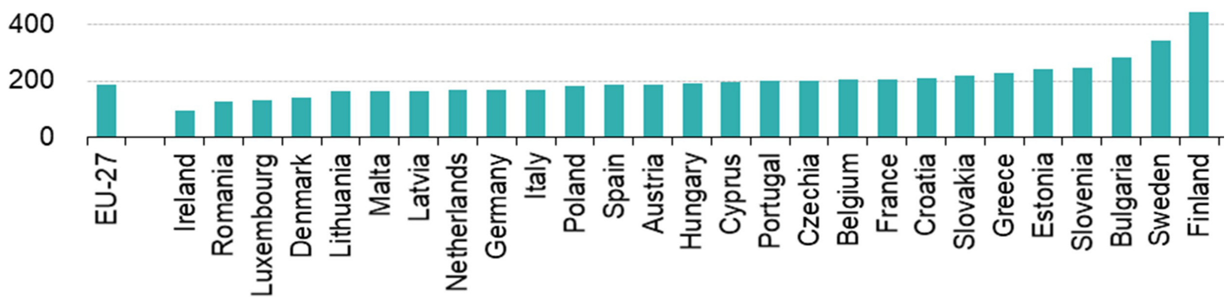


Fig. 4. Electric energy used per unit of gross domestic product (GDP), as measured by the Purchasing Power Standard (PPS), kWh/1000 euro (PPS) [5]

The mean electric energy consumption in the European Union countries in 2018 was equal to 188.3 kWh/1000 euro of GDP, calculated according to the purchasing power standard (PPS). Evaluation of GDP acc. to PPS allows better comparison between different countries than the evaluation performed according to monetary calculation into euro.

As it can be seen, the electric energy consumption per unit of the national income in Poland does not much differ from the mean value for the EU. It is lower than in the Chechia, Austria, Belgium, France or Slovakia and somewhat higher than in Germany or the Netherlands. Thus, the high contamination of the air in Poland cannot be ascribed to a low effectiveness of the industry – the main reason for a high CO_2 emission is the employment of coal as the main fuel in power plants and households. Moreover, the coal used in the households is of a low quality and high content of contamination; the exhaust fumes escape via low chimneys and the filters are not installed. The situation in such countries as France or Finland is completely different – the houses are heated with the cheap electric current which is generated in clean, zero-emission nuclear power plants.

We have, therefore, not only to supplement the power lost as a result of reduction of coal burning but also to increase the electric energy production per inhabitant. Let's consider then the following questions:

- What sources may ensure a stable production of electric energy?
- Which ones would cause reduction of CO_2 emission from our energetic system? And
- Which of them would give a cheap electric energy without subsidies?

Emissions of greenhouse gases from different energy sources

The data on maximum emission, as shown in Fig.5 include the emissions in all stages of life cycle "from cradle to the grave", so, not only at the construction and operation of electric energy power plant but also during obtaining of the constructional materials and fuels, their processing and transport and during a final liquidation of electric energy plant and its waste.

When considering values of different energy sources, we should also consider to what degree they may ensure the reliable supply of electric energy to its users, from individual consumers to hospitals, metro lines and big industrial enterprises.

Variable power delivered by wind power plants

German newspaper *Die Welt* has commented the data from Fig. 6 in a following way: "At the beginning of December 2013, production of energy coming from wind and solar plants was almost completely stopped. More than 23 000 wind turbines did not perform their work. Million photovoltaic systems almost completely stopped producing the current. The coal fired power plants, nuclear energy producing plants and gas power plants had to satisfy ca 95% of the whole demand in Germany". Similar several day breaks occurred also many times during the subsequent years, e.g. in 2014.

The breaks in electric energy generation occur also in the offshore wind farms.

During the period of the sea calm, lasting for 4.5 days and nights, as it has been shown in Fig. 7, the mean MFW power was

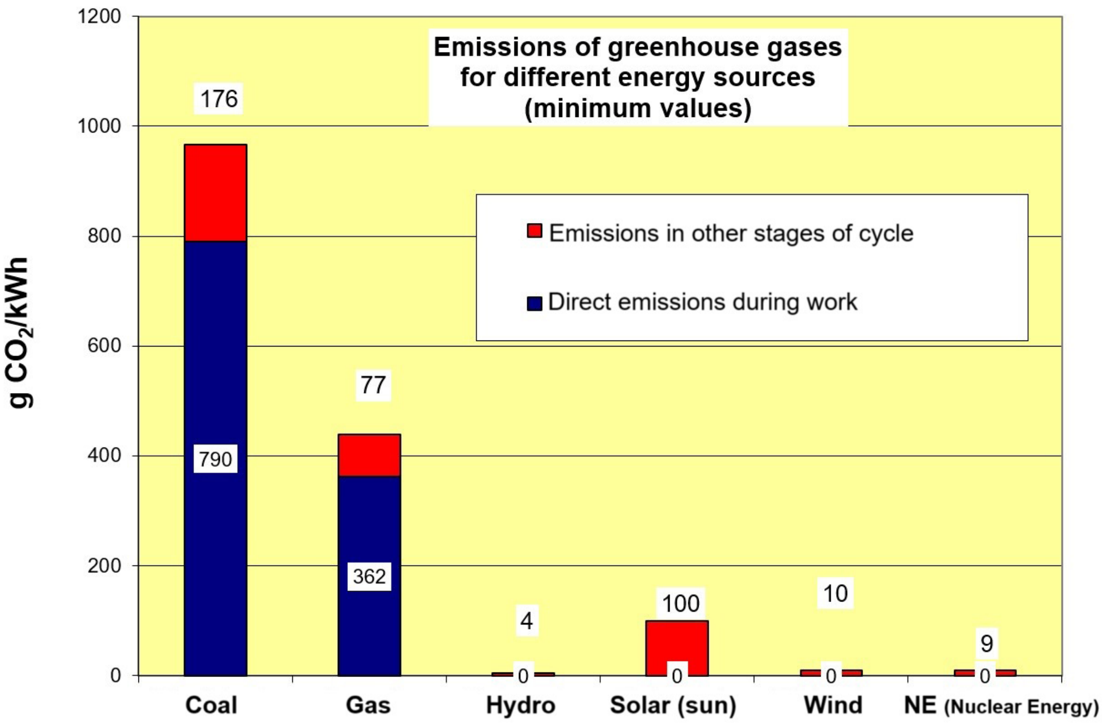
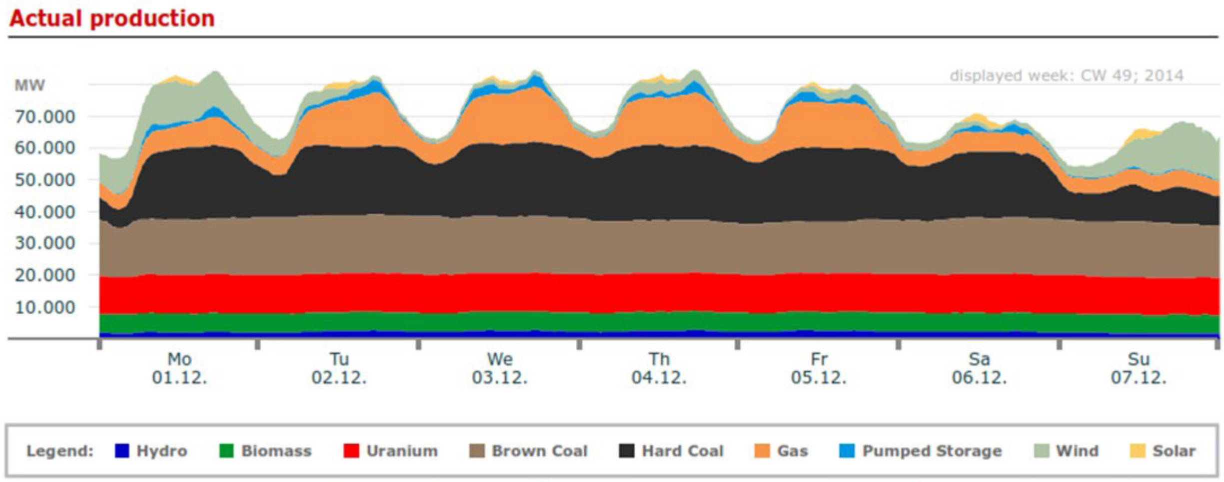


Fig. 5. Emissions of greenhouse gases for various energy sources (minimum values); Source: Author's own drawing, data from the World Energy Council [6]



	Hyd	Bio	Uran	BC	HC	Gas	PSt	Wind	Solar
min. power (GW)	1.4		11.44	15.36	5.81	4.52	0.01	0.65	0
max. power (GW)	2.02		12.11	18.43	23.85	17.36	4.19	15.43	3.13
weekly energy (TWh)	0.35	1.0	2.04	2.91	3.19	1.52	0.19	0.73	0.06

Graph: Bruno Burger, Fraunhofer ISE; Data: EEX Transparency Platform

Fig. 6. Breakdown of weekly electricity production from RES (Renewable Energy Sources), Germany, December 2014 [7], week 49. Coloured fields represent the electric energy production during the 49th week in 2014 in Germany. The vertical axis shows the real power in MW. The blue colour shows the power from wind, the yellow – photoelectric electricity.

Source: Drawing from [7], quoted by the permission

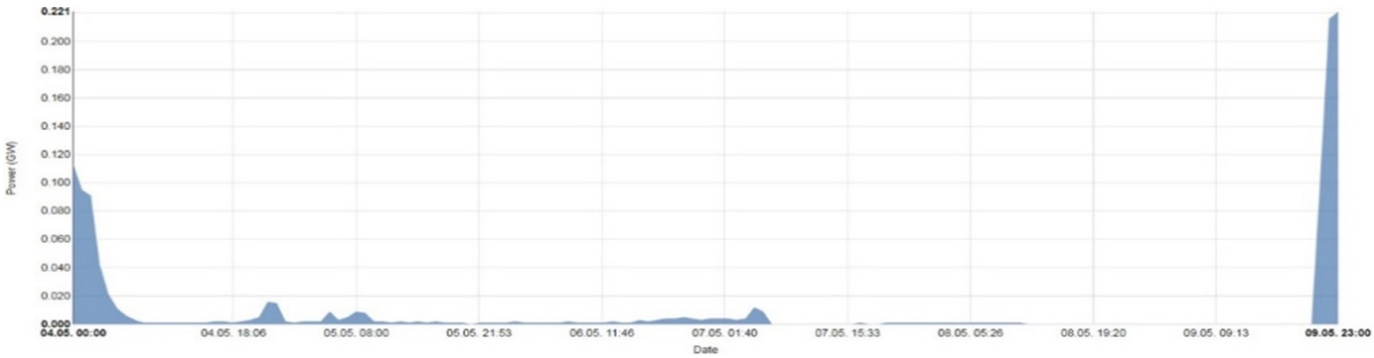


Fig. 7. Offshore wind power production (MFW) in Baltic sea, May 2018; Data for Baltic 1 and 2 [8] Energy-charts.de,

Source: drawing by the author

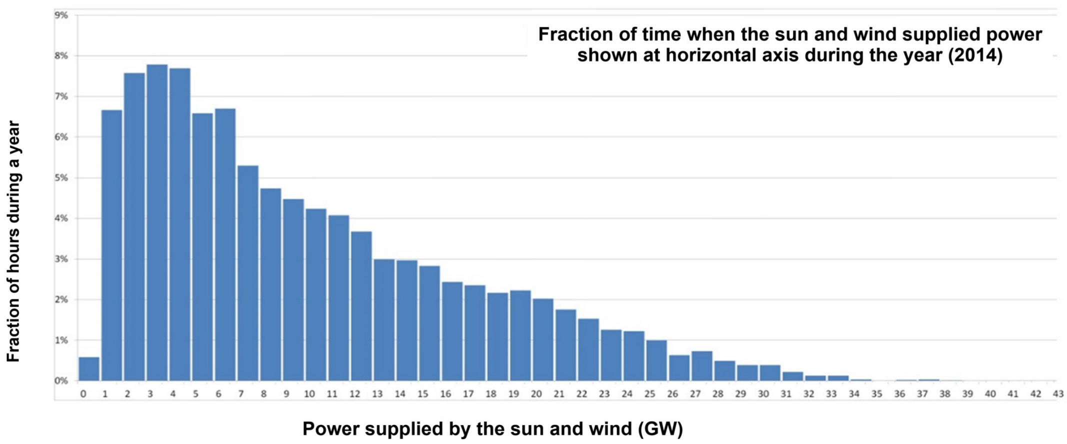


Fig. 8. Fraction of time (%) when the sun and wind delivered (in 2014) in Germany the power GW indicated on the horizontal axis, while the total installed RES power was 73.26 GW;

Source: drawing by the author, data from [9] equal to 0.6% nominal power. We must take such periods of the sea calm into account when planning introduction of off-shore wind farms (MFW).

In effect of a high variation of the wind power, the utilization of the power installed in the wind turbines is low. In Germany where the wind power plants have been intensively constructed for many years, the mean annual utilization of the installed wind land power, is equal to 19–20.9%; e.g. in the first half of 2021 it was 20.9%. Fig. 8 shows how many hours during a year the utilized power have constituted a specified fraction of the nominal maximum power.

The problems occurring in energy import from other countries in the case of the wind calm

When the wind is missing in one of the European countries, the lack of the wind occurs also in other countries, from Finland to Spain. It can be seen in Fig. 9. It illustrates the variations in the wind power in 14 European countries. As we can see, the power generated in the wind power plants varied from 78 GW to 3.7 GW, so the differences between the maximum and minimum power of the wind power plants in Europe exceeded 74 GW! The standard answer of OZE followers that “wind always somewhere blows” is not true. Moreover, when we construct the new wind plants, their additional production of electric energy lowers the value of energy generated from the already existing wind plants because at the energy excess it becomes cheap and, perhaps even unnecessary.

The requirements of materials and territory for RES (*OZE*)

When we look realistically on the needs of materials and territory connected with the introduction of RES, it is revealed that the wind mills and solar panels consume more materials per unit of the generated energy and require a greater space to be built-in than the apparently heavy nuclear energy plants.

There is no sense, of course, to compare the size of the needs and, in consequence, financial outlays from the viewpoint of electric energy generation if we do not consider that the wind power plants work only for a part of the time as it was mentioned above based upon the official German data. In Poland, such comparisons have been performed at the Wrocław University of Technology [10]. The quotient of the mean power utilized during a year and the total time of work of the power plant was adopted as the reference point. In the case of wind at the land territory, the mean coefficient of power utilization i.e. 0.24 annually (as in the West Denmark) and 20 years of work was adopted. For nuclear energy plant, there was employed the coefficient of utilization of the installed power equal to 0.88 and 40 years of work. It means that at the power amounting to 1000 MWe, the wind power plant, being currently under construction, will deliver 42 TWh during its life and the nuclear power plant – 308 TWh. The mentioned assumptions are very favourable for wind turbines, as being achievable at wind conditions in the West Denmark, but they are obviously not available in Poland where the real power utilization may amount to 0.25–0.30. To compare, in the first half of 2021, the discussed coefficients in Germany as the mean for the whole country were equal to 0.209 and 0.39, respectively for land wind and

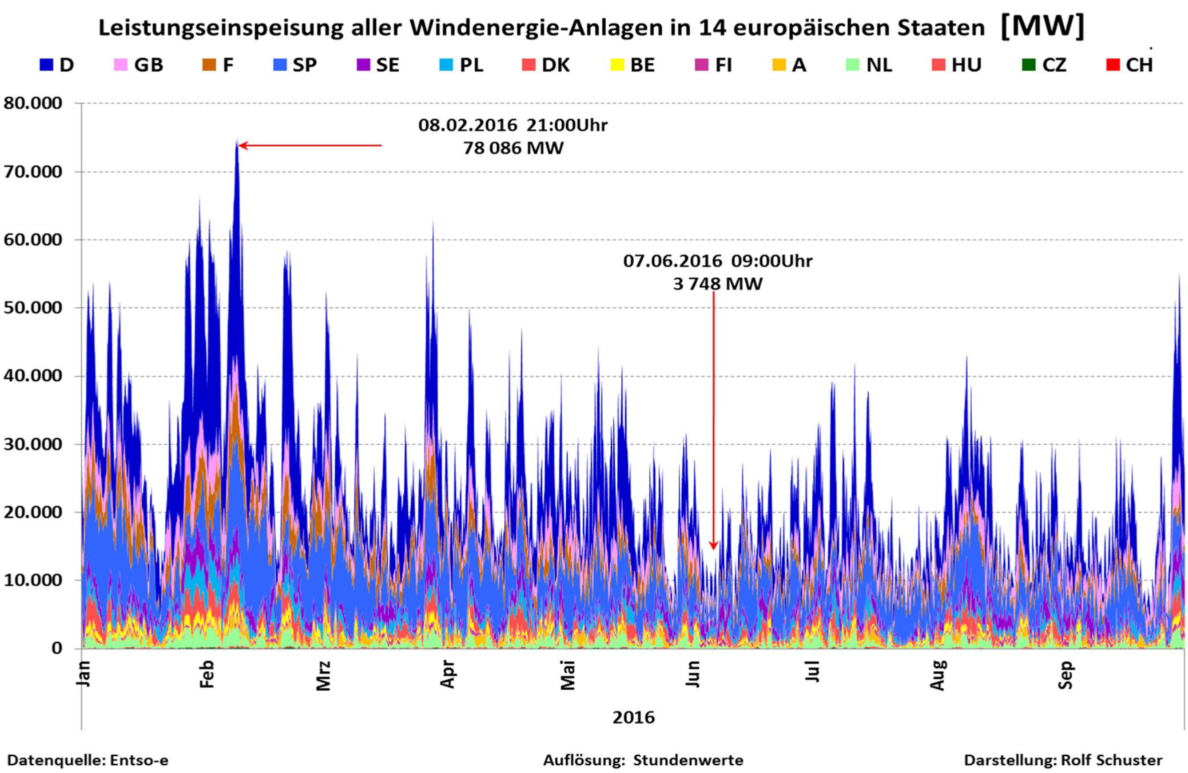


Fig. 9. Electric energy production from wind farms in 14 countries of the European Union in 2016. The data presented by NGO Vernunftkraft; Source: drawing made by R. Schuster, cited at the permission of the author

offshore wind power plants. It should be added that the mentioned indicators are very unfavourable for nuclear power plants of the 3rd generation for which the guaranteed time of operation is 60 years and the anticipated coefficient of utilization of the installed power is 0.90. The employment of the discussed indices would give the total generation of electricity during the life of nuclear power plant (EJ) equal to 473 TWh.

The total quantity of the energy produced during the whole life of the electric power plant was adopted as the reference value. After calculation per unit of electric energy, the characteristic indicators for the both types of power plants, as being defined by the University of Technology in Wrocław are as follows [10]:

- ***CO_2 emission***, with the consideration of the whole cycle of building and liquidation of the power plant is **twice higher than that one for wind energy plant**.
- ***The material requirements*** as referred to the total amount of the energy produced during the life cycle in the wind energy plant is **more than twice higher than for the nuclear energy plant!** The surprising results: although it is considered that the nuclear power plant is "huge and heavy", it requires less than a half of materials used for "light" and eco-friendly" wind farms per unit of the produced electric energy.
- The ratio ***of the total energy outlays*** as born during the construction stage of wind farm and the **total amount of energy generated** during the whole life cycle of power plant, is by **4.5 times HIGHER FOR WIND THAN for nuclear power plant**. The statement of Greenpeace that the wind farms give 2.5 times more electric energy per unit of investment is in the contradiction to neutral assessments of the German Institute and Polish University of Technology.
- The demand for aluminium as referred to the total installed power of the energy plant is by 75 TIMES HIGHER for wind farm. It results from the fact that each of many wind power plants is equipped with turbo-generator and the systems of control and power output whereas in the nuclear power plant only one discussed system is needed [11]. There are many such comparisons submitted and they all are similarly unfavourable for wind energy. We should bear in mind aluminium as its production is connected with considerable air-contaminating emissions; some years ago, in Poland it brought about to closing of aluminium manufacturing plant in Skawina [12] because the inhabitants of Cracow could not bear longer the air contamination. It is a good illustration of the meaning of emissions, occurring even before commencing the work by wind farm.

Values of CO_2 emissions as given in the forecast are consistent with the assessments of the most competent international organizations, including the World Energy Council, European Commission (not only ExternE study but also other publications [13], International Atomic Energy Agency and other organizations.

The needs of the territory for the low-emission power plants are illustrated in Fig. 10, based upon the NREL elaboration, i.e. the main US laboratory, supporting the development of RES energy.

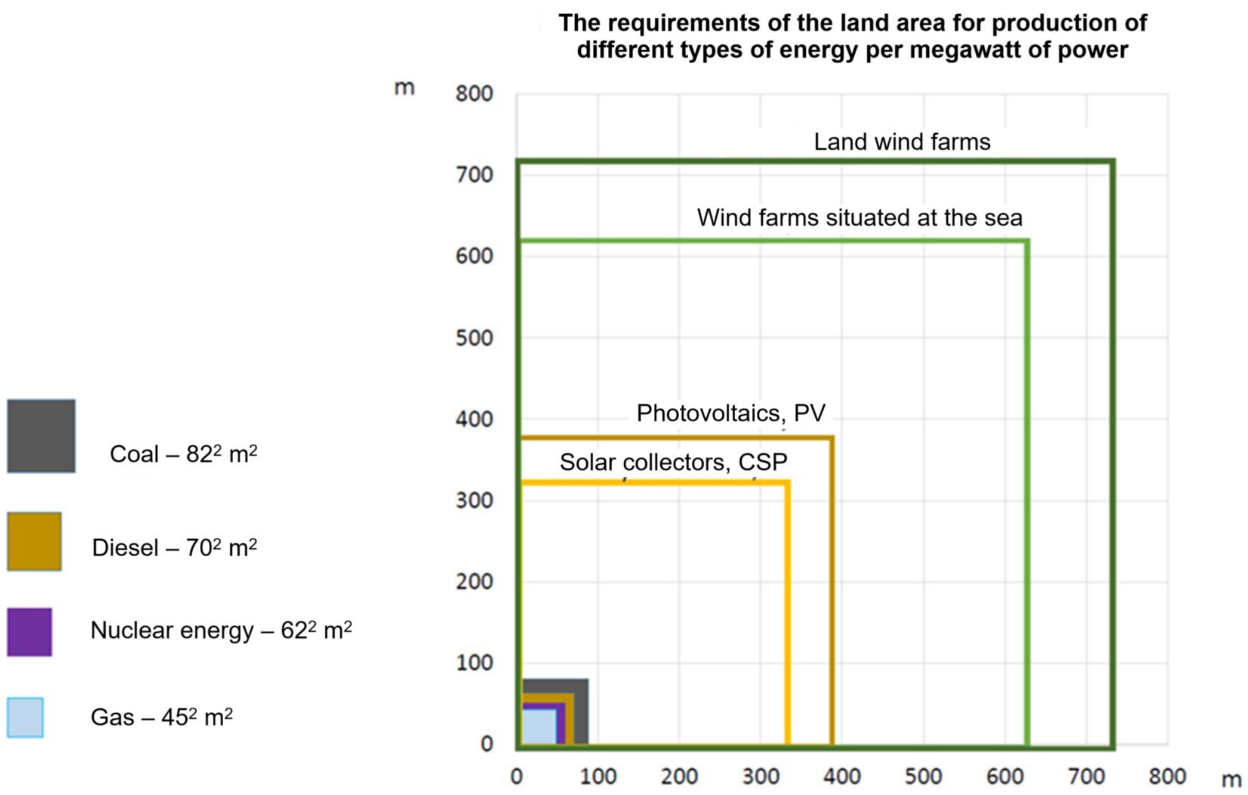


Fig. 10. Land needed for various types of power plants in the USA; drawing from NREL report, Source: cited owing to the courtesy of Prof. W. Gudowski [15]

Costs of German energy transformation Energiewende

The costs of German energy transformation result not only from the necessity of paying the high rates to the developers of wind and solar farms which in spite of the optimistic statements of RES followers need much more materials and territory than the nuclear power plants but also from the necessity of bearing the high expenses on ensuring the continuity of supplying the users via the electric energy system.

In the scale of the whole country the expenditures on RES in Germany are constantly increasing. In 2020, they were expected to reach the amount of 29 billion euro annually whereas actually they exceeded 31 billion Euro as it is illustrated in Fig.11. It means the additional sum above 1500 euro per each 4-person family in Germany annually. And it is not expected that the mentioned loads would be decreased! On the contrary, the costs born by the system will increase what – in spite of the reduction in the prices of the wind plants and photovoltaic panels' building – may cause the further increase of the additional costs [16].

We will analyse the expenses born by the electric energy system on the example of Germany as it is given in the table below.

In the mentioned table, there were submitted the components of the costs of cooperation of RES and the energy system for two levels of the participation in energy production for nuclear power, coal, gas, land wind farms and off-shore wind farms, and of solar energy supplying the photovoltaic batteries. After the passage from 10% to 30%, the costs of RES cooperation with the electric energy system are by twice increased. The highest costs were found for solar energy – more than 82 USD/MWh and the lower ones for wind at land and at the sea – ca. 43 USD/MWh.

The network needs for RES are considerably higher than for nuclear energy. Introduction of RES requires high subsidies paid by all energy users, for the installations as well as for the development of the network, being considerably greater as compared to the system based upon the stable energy sources.

The costs of cooperation of the power plant and the power system occur, of course, also in the case of the system power plants but they are considerably lower – for nuclear energy: 2.25, for coal – 0.97 and for gas 0.54 USD/MWh.

No wonder that in order to cover the costs of materials and the required space higher than for nuclear power plants and the system costs many times higher than for the controllable power plants, the German society must pay much for electric energy. As it can be seen from the Eurostat data, the prices of electricity in German are almost twice higher (31 euroc/kWh) than in France (17 euroc/kWh) which bases its energetic system upon the nuclear power plants.

For the household consumers in the European Union with the annual demand on energy equal to 2 500 kWh – 5 000 kWh, the prices of electric energy in the second half of 2023 were the highest ones in Germany – €0.4020 for kWh (see Fig. 12) and the lowest ones in Hungary and Bulgaria (€0.1192 for kWh). The users of electric energy in Germany paid by 41% more for 1 kWh as compared to the average price in the EU and the consumers in Hungary and Bulgaria paid by a half less.

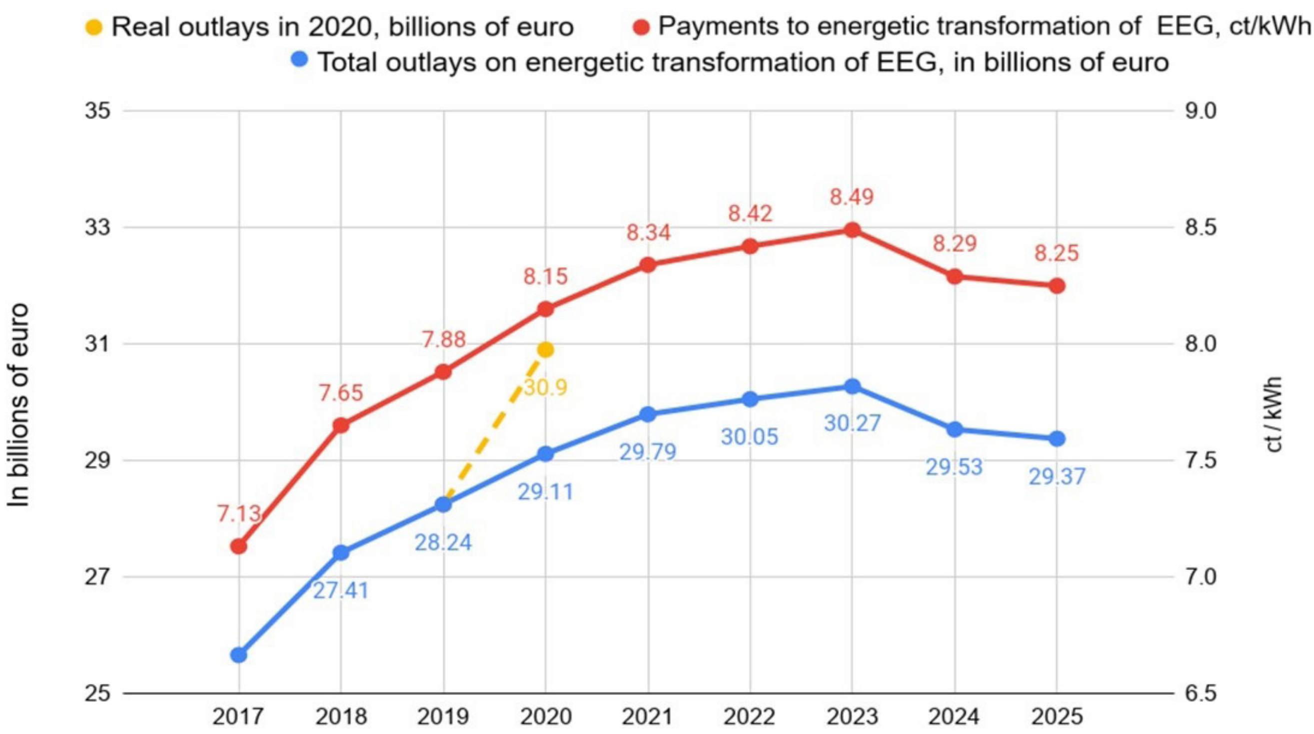


Fig. 11. Total subventions for RES and individual additional costs of energy due to RES in Germany in the period of 2017–2025 forecasted by German scientific institutes [17] and real additional subventions for RES in 2020 in Germany [18],

Source: drawing by the author

Germany												
Technology	NE		Carbon		**Gas**		**Land wind**		**Off shore wind**		**Sun, pV**	
Participation in energy production	**10%**	**30%**	**10%**	**30%**	**10%**	**30%**	**10%**	**30%**	**10%**	**30%**	**10%**	**30%**
Costs of preservation	0.00	0.00	0.04	0.04	0.00	0.00	7.9	8.8	7.9	8.8	19.2	19.7
Costs of balancing	0.52	0.35	0.00	0.00	0.00	0.00	3.3	6.4	3.3	6.4	3.3	6.41
Connection with the network	1.90	1.90	0.93	0.93	0.54	0.54	6.4	6.4	15.7	15.7	9.4	9.44
Consolidation and development of the network	0.00	0.00	0.00	0.00	0.00	0.00	1.7	22.2	0.9	11.9	3.7	47.4
Total costs at the level of electric energy system	**2.42**	**2.25**	**0.97**	**0.97**	**0.54**	**0.54**	**19.4**	**43.8**	**27.9**	**42.8**	**35.6**	**82.9**

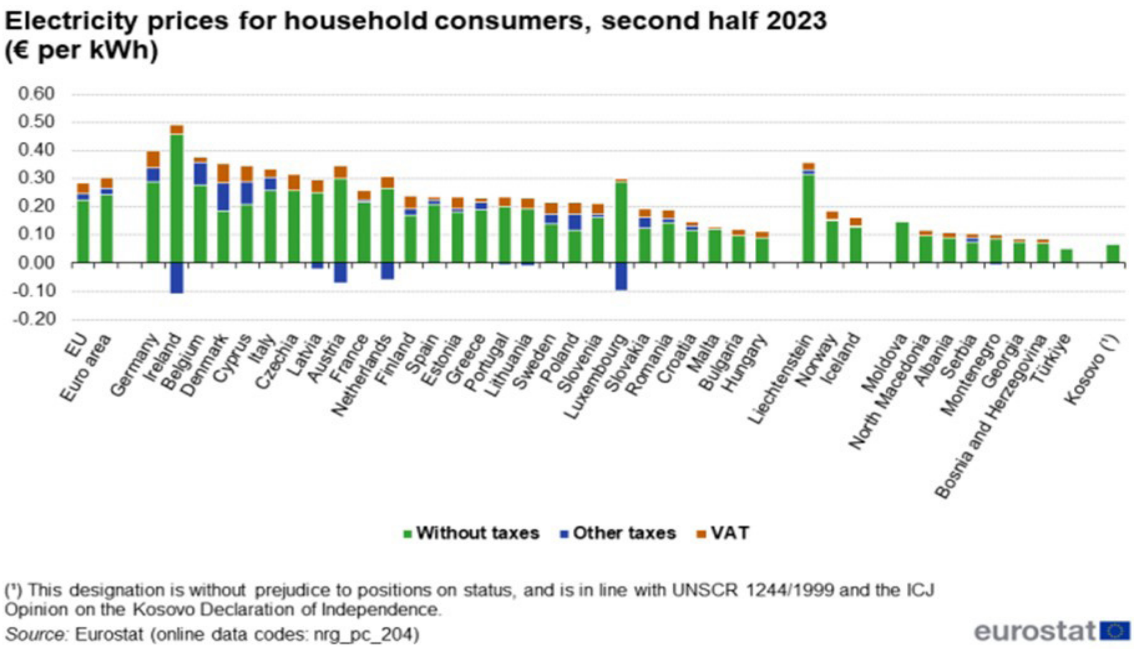


Fig. 12. Prices of electricity for the households in the EU countries in the second half of 2023 [20] (€ per kWh).
Source: Eurostat (nrg_pc_2024)

The average price in the EU in the second half of 2023 for individual consumers was equal to €0.284 for kWh.

Effects of introducing RES instead of nuclear power plants in Germany

After 20 years of intensive introduction of RES at the cost of nuclear power, Germany has the most expensive electric energy in Europe; they lost beautiful landscapes of fields and forests but… perhaps they have reduced decidedly CO_2 emissions? The fact indicate, however, that **NO!** The losses of zero-emission nuclear power plants cannot be replaced by development of wind farms and burning of natural gas. The comparison of the level of CO_2 emissions as reported by the Statistical Office of the EU shows that CO_2 emissions per one inhabitant are in Germany higher (**9.3 t/year**) than in Poland (7.8 t/year) and much higher than in France (5.0 t/year) (Fig. 1).

Was the year 2020 exceptional? No, it wasn't; in the previous years of the Energiewende implementation, the situation was worse as it can be seen e.g. from the analysis conducted for Environmental Progress portal [21]. The introduction of wind farms and solar panels has, therefore, a sense only within the certain limits.

Compensating the lack of wind in Poland

For how long will be the energy reserves in water power plants sufficient enough in the case of wind silence? According to PEP 2040, the energy generated annually from MFW (*in Polish: Off-shore wind farms*) in 2040 is expected to amount to 40 TWh.

It means the power of MFW amounting in average to 4.56 GW. The lack of the wind at the sea for 130 hours will mean the energy gap equal to 593 GWh. The maximum anergy accumulated in the pumped-storage hydro power plants is 7.8 GWh – the time of their work until emptying is 1.7 h. And what later?

To say that wind power production is unstable, means to say little. If it was necessary to ensure the whole energy supply to, it would be necessary to develop more than 200 times wind plants more than now. It would be also the trouble with the huge energy surplus at the time when when they operate at full nominal power. It is shown by the data for January 2023 when the wind plants were able to give more than one third of the power in the system and there was also a day with only 0.4%.

During a month, the discussed devices were able to yield only 1.8 GWh one day and few days later, it was as much as 171 GWh. For the successive 6 days, 30% of the energy produced in Poland came from the wind installations but for other four days it was no more than 2%. The renewable energy in the form of wind plants and photovoltaics proved in January that once more that it could not be, unfortunately, reliable every day (Business Insider, February 2023).

Would be the electric energy from electric car batteries sufficient?

Let us assume that there will be a million of electricity-driven cars in Poland, each with the battery with capacity of 85 kWh. Let's assume that in the peak hours, 10% of the mentioned cars would supply the electric current to the network. Thus, we would have the country-scale energetic reserve at the level of 8.5 GWh. The reserve coming from the car batteries would be sufficient to cover the energetic gap for 2 hours. If even 50% of the owners of electric cars had agreed not to use them but only to supply the network (!) it would be sufficient for 10 h. And what later?

What about the costs? The developers say that building of wind plants and photovoltaic panels leads to reduction in the price of electric energy. The situation in Germany – which distinctly decided on the RES development – has been discussed in the previous chapter. Great Britain is the second country which decidedly expects the advantages coming from the development of wind farms. But in spite of the subsidies amounting to tens of billions of pounds (£), the developers of the wind plants say that it is too little for them.

The reliability of nuclear power plants

In the previous chapter, we have criticised the lack of availability of wind plants which deliver the energy not when it is needed but when the wind blows. Are the nuclear power plants better? The answer may be found in Fig. 13.

It is also not true that nuclear power plants must work at the constant power. NE may operate in the system of following the load and… they work in such a way!

French nuclear power plants work similarly. And UK EPR were designed for cyclic changes of power within the limits of 25%–100%.

What is the admitted rate of the power changes for different energy sources? It is illustrated in Fig. 15.

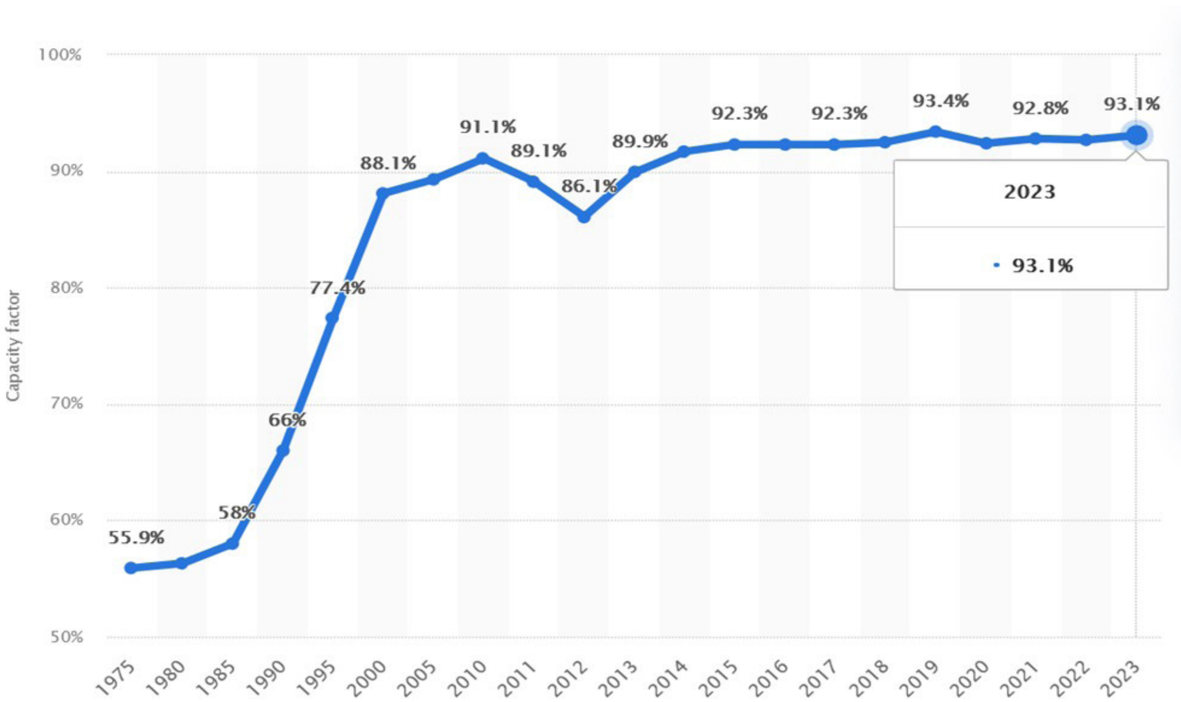


Fig. 13. Average capacity factor for all nuclear power plants in the USA. Data from the US nuclear power plants' capacity factor Statista.htm [22], Source: drawing by the author. In 2023, it was equal to 93.1%

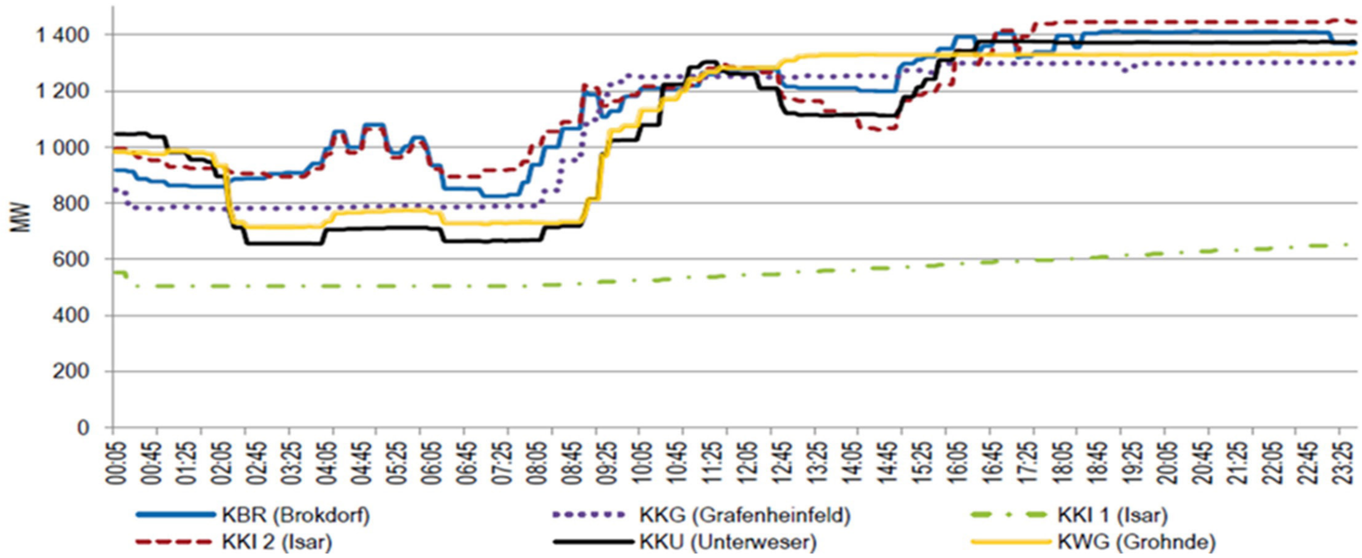


Fig. 14. Power changes of German NPP during 24 h in function of load, as recorded before the order of the German authorities to close all nuclear power plants [23]

In German nuclear power plants, it was possible to implement the power changes up to 10 000 MW as early as in 2010. In France, 2 from 3 reactors, in average, may compensate the changes in load; the total possible change in the power for the reactor park is equal to 21 000 MW (it is the equivalent of the power of 21 reactors) during less than 30 minutes and, additionally, it is possible to detach temporarily the nuclear unit from the electric energy network, and to start it up again. If they are maintained at the state of readiness (stand-by) they may come back to the work at the full power within a few hours [25].

Do we have to be afraid of the radiation from nuclear power plants?

The doses coming from the nuclear power plants are smaller than the difference in background of the natural radiation:

- Dose from Nuclear Power Plant (NPP) – 0.01 mSv/year,
- Difference in the background of gamma radiation between Kraków and Wrocław – 0.39 mSv/year.

For the reactor of the 3rd generation, e.g. EPR after a failure – even such one with melting of the core – the interventions measures outside the zone of 3 km are not necessary.

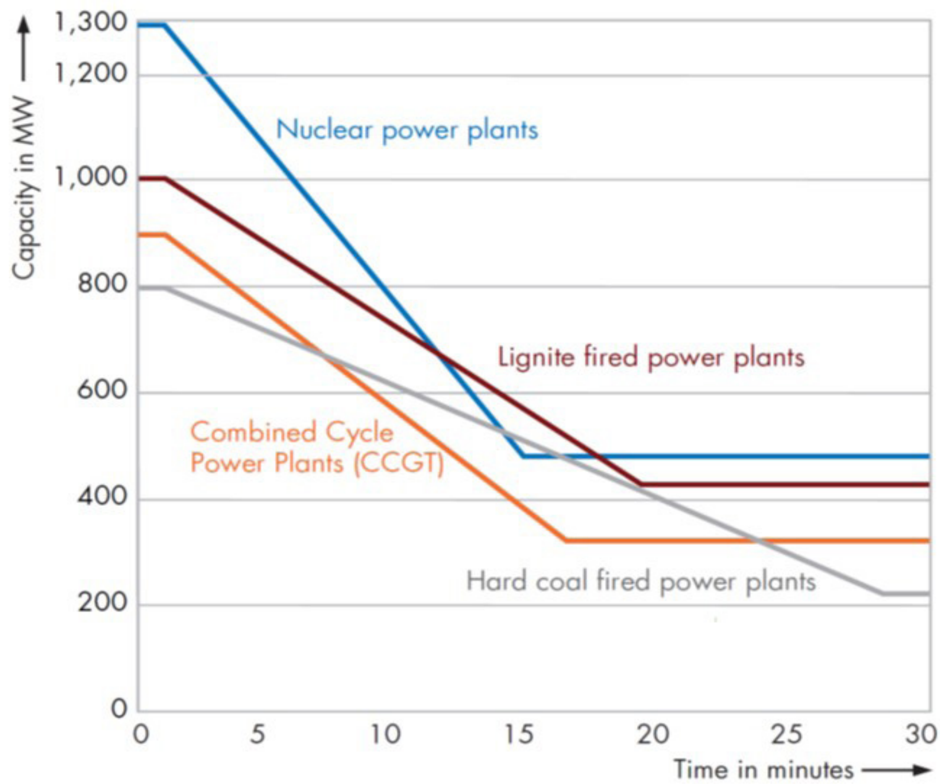


Fig. 15. Speed of the power changes for various type of power plants; a) Power, MW, b) Time, min., c) nuclear power plants, d) Brown coal-fired power plants; e) Gas power plants, gas-steam cycle, e) Black coal-fired power plants

Source:VGB [24], Facts and Figures, Electricity generation 2020/2021

The results of the EU study indicate that the nuclear energy belongs to the most favourable sources of powers for people and nature.

The ExternE study, as conducted in the years 1993–2021 in which the external costs i.e. the costs paid by the society (due to health loss, early deaths, zone of damage to the environment) were adopted as the criterion for comparisons, showed that nuclear power is the most reliable and human friendly source of power.

In the discussed study, the external costs were assessed for all energy sources, for the whole construction cycle, for work and liquidation "from cradle to grave". It was found that the shortening of human life due to the diseases caused by air contaminating emissions had the dominating effect on the results of the studies.

The consistent results of many EU countries have revealed as follows:

- **The lowest external costs are caused by wind energy, nuclear energy and hydro-energy**
- The greatest ones – burning of coal and petroleum
- The average costs – burning of gas and application of solar batteries.

The total costs for the society – i.e. the costs of production and the external costs – are the lowest for nuclear energy

The health consequences of electricity generation from various sources in the 15-EU countries [Rabl 04] are given in Fig. 17. According to the consistent opinion of World Energy Council, IPCC and IAEA, nuclear energy is the best low-emission source.

Summing up – The Choice for Poland

Either nuclear energy – high investment outlays, cheap nuclear energy.

- RES: Investment outlays per unit of average power higher than for nuclear energy, covered from the obligatory payments by the citizens (inhabitants);
- Subventions in Germany – in total, 30 billion euro/year per 80 million citizens makes 1500 Euro/year/4-person family, year after year.

Will the Poles agree for the additional sum, paid by every 4-person family, to the bill for electricity, equal to 6 000 PLN per year for the privilege of generating the electric energy from wind and photovoltaic panels?

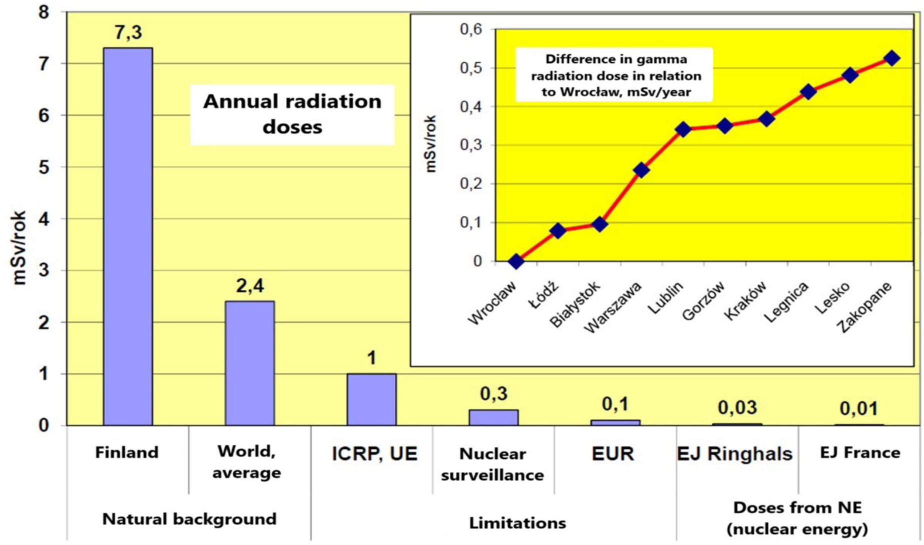


Fig. 16. Annual doses of natural radiation, radiation doses allowed by nuclear safety organs, and the doses received from nuclear power plants as compared to the differences of external gamma radiation in various cities of Poland.

Source: Drawing by the author

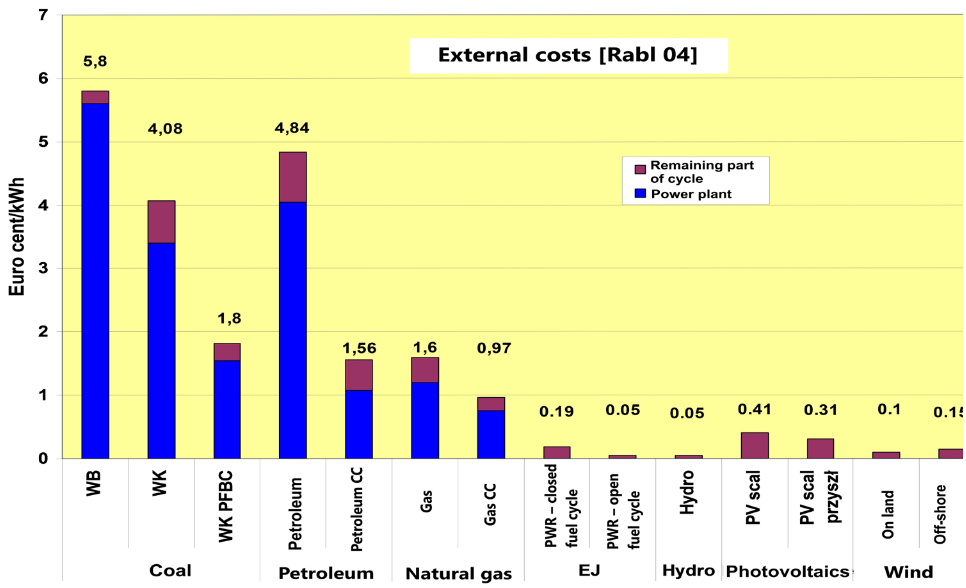


Fig. 17. External costs of producing the electric energy form various sources, shown in monetary units according to ExternE program. Data from Rabl [26], drawing by the author. PFBC – burning in fluidal bed under the pressure, CC – combined cycle; PWR otw – open fuel cycle ; PWR zamk – closed fuel cycle

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