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DETERMINANTS OF ENERGY TRENDS BASED ON RENEWABLE ENERGY SOURCES

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Purpose: The aim of the article is to analyze the energy economy in terms of conditions influencing contemporary energy trends. In particular, new requirements are compared with existing habits and the role of the state in shaping the desired energy trends is indicated. An attempt was also made to indicate how to improve the efficiency of energy management. The role of the local energy market was taken into account.
Design/methodology/approach: The article consists of literature studies, which are a review of publications and legal acts on the energy economy, in particular that based on renewable energy sources. The research allowed us to characterize new energy trends occurring in the economies of many developed countries.
Findings: During the research, an attempt was made to identify the determinants of energy trends, in particular those involving renewable energy sources.
Research limitations/implications: Based on the research conducted, future implications can be identified. They may involve stimulating selected energy trends in such a way that they effectively translate into positive effects for the environment.
Practical implications: The practical implications of the obtained results may concern the further use by decision-makers of appropriate instruments that, introduced into the economy, would stimulate the development of renewable energy sources.
Originality/value: The article compares energy trends observed in various developed countries. The value of such research is the ability to stimulate positive environmental effects through the use of appropriate tools to stimulate the development of renewable energy sources.
Keywords: energy economy, energy crisis, renewable energy.
Category of the paper: Research paper.

1. Introduction

The number of inhabitants on our planet is increasing very quickly. In 1800, the planet had 1 billion inhabitants. In 1900, there were already 1.6 billion of us. Population growth was much greater in the next century (Poborski, Kraska, 2023). In 1987, the planet was inhabited by 5 billion people, and in 2024 it will be 8.1 billion (Janicki, 2024). The rapid increase in population combined with economic development and an increase in the standard of living resulted in a sharp increase in energy demand. This resulted in the rapid exploitation of fossil fuels in the form of coal and oil. The burning of fossil fuels has disturbed the biological balance. The amount of carbon dioxide released when burning fossil fuels is too large to be absorbed by the plant world. The area of forests, especially tropical ones, is rapidly decreasing, and the cleared areas are being developed for development.

Disturbance of biological balance has led to drastic and dangerous climate changes. Immediate changes to energy policy are required to restore biological balance.

2. New requirements for energy management

The current energy situation requires immediate changes in the field of energy management. Changes in energy management must be taken into account:

- improving the energy efficiency of devices - improving energy efficiency is the most economically effective method of reducing energy demand (Dołęga, 2022; Sochacki, 2023);
- implementation of renewable energy sources at the user level - photovoltaic energy, wind energy, geothermal energy, solar thermal energy, etc. - these are very expensive projects (Wojciechowska, 2021);
- decentralization of the energy market and creation of local energy markets – selling and buying energy from neighbors using the existing network and an appropriate Internet program enabling energy trading bypassing the energy company. Prices are agreed between the seller and the buyer without the involvement of an intermediary (Bałamut A. et al., 2024; Mól et al., 2022);
- changing old habits - this is the most difficult to implement, and the main barrier is people's tendency to expect immediate reward. People's behavior is largely influenced by the behavior of neighbors/social norms. In some environments, positive trends towards the construction of small passive houses that are self-sufficient in terms of energy are already visible. They are more expensive to build, but profitable in the long run;

- installations of "smart" electricity meters that track the current cost of energy - the cost of energy depends on demand. Smart meters can turn individual energy receivers off and on depending on the energy cost (KIGEiT, 2022). The energy consumer programs the smart meter to turn on and off individual receivers depending on the current energy price (turning off the air conditioning, refrigerator or heating for a few hours may not even be noticeable to the user).

3. The role of the state in promoting future-proof solutions

All initiatives related to the implementation of energy-saving devices as well as renewable energy sources are expensive. Passive buildings that are self-sufficient in energy, as well as electric and hybrid vehicles, are also expensive. These investments pay off only after a longer period. In some cases, the payback period is 10 - 20 years. People tend to make decisions based on immediate benefits. The role of the state is to reward investments aimed at promoting renewable energies, as well as reducing energy consumption by increasing the energy efficiency of devices. The most effective method is tax breaks that reward people who make energy-saving investments. One of the most extensive tax relief systems for the clean energy sector is the system in force in the United States. It is referred to as the "Investing in America" program. In the USA, there are currently, among others: the following tax breaks:

- 26% tax relief for the installation of photovoltaic panels, geothermal systems and wind turbines - 26% of the installation costs are deducted from income tax;
- a tax credit of up to $7600 for the purchase of an electric or hybrid car with a battery capacity greater than 5 kWh;
- tax relief for the purchase and installation of an energy-saving heating and air-conditioning system, energy-saving refrigerators, water heaters, washing machines, etc. - the amount of the relief changes annually;
- low-interest loans for the purchase and installation of energy-saving heating and air conditioning systems as well as the construction of passive houses that are self-sufficient in terms of Energy;
- tax credits for energy communities and businesses and state and local governments under the Qualifying Advanced Energy Project Tax Credit program - under selected projects, the entities listed may receive a 30 percent tax credit for clean energy investments.

In the European Union, there are also many tax breaks and subsidies promoting renewable energy sources, as well as increasing energy efficiency to reduce energy consumption. Individual European Union countries take a number of actions to support renewable energy sources (Guidelines..., 2022), create programs for enterprises from the "net-zero" sector, and support local investments. For example, in 2023 Spain spent EUR 1.1 billion on supporting enterprises in the form of subsidies, France allocated EUR 2.9 billion for this purpose, and Portugal EUR 350 million (List of Member…, 2024). EU Member States, under the Temporary Crisis Framework and Guidelines (Guidelines..., 2022), create, among others: subsidy mechanisms dedicated to investments in green hydrogen, renewable energy and industrial decarbonization. Some of these countries also receive funds from the Cohesion Fund and the Recovery and Resilience Facility. As part of the latter, a total of EUR 18.61 billion in the form of subsidies has so far been paid to EU countries for the purposes of green transformation. Italy, Spain and France received over 70% of this amount (Zawadzka, Hofman, 2024).

The role of the state in promoting future-oriented solutions is very important. Each new technology is initially expensive and requires financial support from the state. The development of new technologies related to the generation of renewable energy as well as the improvement of the energy efficiency of devices stimulates economic development and contributes to the creation of new jobs. Currently, there is a great demand for specialists in various fields related to sustainable development. The energy transformation is associated with the need for green technology specialists, energy efficiency engineers, data analysts using artificial intelligence for forecasting and energy demand management, as well as people responsible for creating smart grids that allow the integration of AI with energy systems. Experts from the World Economic Forum forecast that the green transformation has the potential to create over 10 million new jobs globally this decade. Employment growth will be driven primarily by energy efficiency, which may generate up to 3.2 million jobs. Specialists responsible for applying technologies and practices that enable sustainable development will be extremely desirable on the labor market (https://www.money.pl, 2024).

4. Economy energy intensity index and energy mix

The energy intensity of an economy is measured by the "energy intensity coefficient", which shows the amount of energy involved in economic processes, and in particular the amount of energy needed to produce a given amount of products. The energy intensity index is most often related to GDP. The use of energy carriers in economic processes is of key importance for the sustainable development of the economy. Energy has no substitutes and therefore can determine the rate of economic growth (Peet, 2004). The role of energy in economic processes, and especially as a factor in sustainable development, is constantly growing and is expected to grow even more in the future (Plich, Skrzypek, 2016). This makes striving to ensure energy security a priority of every economy. At the same time, the growing demand for energy has intensified both the global and national discussion on the structure of energy consumption, ensuring energy security and contributing to limiting the negative effects of energy production and consumption on the natural environment, i.e. the so-called optimal energy mix.

Table 1 contains the energy intensity coefficient of the economy of selected countries (from the most to the least energy intensive), calculated as energy inputs per unit of GDP. Poland is in the middle of the table.

Table 1.
Energy intensity coefficient of the economy of selected countries

Country	Energy Intensity Ratio of the Economy [kWh/dolar]
Iran	11.12
Russia (Russian Federation)	8.10
Ukraine	6.95
United States	4.40
Australia	4.30
Sweden	3.80
Poland	3.42
Norway	3.33
France	3.29
Germany	2.76
Spain	2.64
Great Britain	2.30
Ireland	2.30

Source: own study based on European Commission, Directorate-General for Energy, (2024) *EU energy in figures: statistical pocketbook 2024*. Publications Office of the European Union. https://data.europa.eu/doi/10.2833/802460.

Improving the energy efficiency of devices reduces the energy consumption rate. This is an effective and economically justified method of energy management. If we superimpose changes in the energy mix on this process, we can talk about a general energy trend. World total energy supply by fuel is presented in Tables 2 and 3 and in Figure 1.

Table 2.
World Total Energy Supply by Fuel [Mtoe]

[Mtoe]	2000	2010	2019	2020	2021	2022
Petroleum and Products	3 683	4 152	4 552	4 130	4 376	4 488
Solid Fuels	2 316	3 652	3 870	3 762	4 032	4 106
Gas	2 068	2 736	3 314	3 292	3 477	3 437
Renewables, including:	1 170	1 439	1 876	1 927	2 006	2 080
*Hydro	225	297	366	375	370	374
*Geothermal	52	62	101	107	110	116
*Solar/Wind/Other	8	48	222	249	290	339
*Biofuels and Waste	906	1 065	1 235	1 243	1 284	1 301
Nuclear	675	719	728	698	734	700
Other	23	34	49	48	49	48
Total	9 935	12 732	14 389	13 857	14 674	14 859

Source: European Commission, Directorate-General for Energy, (2024) *EU energy in figures: statistical pocketbook 2024*. Publications Office of the European Union. https://data.europa.eu/doi/ 10.2833/802460.

As shown by the above data, energy consumption in the world has increased by 50% in the last twenty years, from less than 10,000 Mtoe to almost 15,000 Mtoe. A positive trend can be observed related to the increase in the share of renewable energy sources. Energy from renewable sources has almost doubled in value over the last twenty years.

Table 3.
Structure of World Total Energy Supply by Fuel [%]

[%]	2000	2010	2019	2020	2021	2022
Petroleum and Products	37,07%	32,61%	31,64%	29,80%	29,82%	30,20%
Solid Fuels	23,31%	28,68%	26,90%	27,15%	27,48%	27,63%
Gas	20,82%	21,49%	23,03%	23,76%	23,69%	23,13%
Renewables, including:	11,78%	11,30%	13,04%	13,91%	13,67%	14,00%
*Hydro	2,26%	2,33%	2,54%	2,71%	2,52%	2,52%
*Geothermal	0,52%	0,49%	0,70%	0,77%	0,75%	0,78%
*Solar/Wind/Other	0,08%	0,38%	1,54%	1,80%	1,98%	2,28%
*Biofuels and Waste	9,12%	8,36%	8,58%	8,97%	8,75%	8,76%
Nuclear	6,79%	5,65%	5,06%	5,04%	5,00%	4,71%
Other	0,23%	0,27%	0,34%	0,35%	0,33%	0,32%
Total	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

Source: own study.

The structure of the global energy mix has been improving over the last twenty years. We are observing a clear increase in renewable energy sources. Sources such as wind and photovoltaic cells deserve special attention. Although they constitute only 2.28% of the energy mix, the amount of energy obtained from these sources is growing most dynamically over the period under study. In 2020, these sources accounted for only 0.08% of the energy mix.

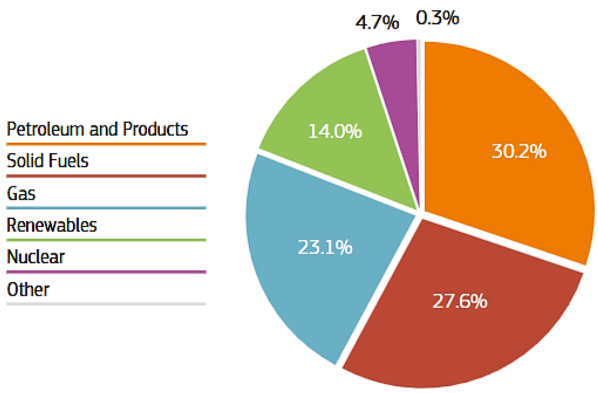

Figure 1. Structure of the total world energy supply by fuel in 2022.

Source: own collaboration.

The structure of the global energy mix in 2022 already includes approximately 14% of energy from renewable sources. This situation looks even more favorable if we look at the energy mix of the European Union, and in particular Poland. Table 4 shows energy production in the EU-27 and Poland in 2019-2022, detailing energy obtained from renewable sources.

Table 4.
Total Energy Supply by Fuel UE-27 and Poland [Mtoe]

[Mtoe]	2019	2020	2021	2022
EU-27 total, including:	618,1	573,1	598,2	562,9
* from renewable sources	227,4	233,5	244,6	243,3
Poland total, including:	62,1	58,0	60,1	59,4
* from renewable sources	12,3	12,5	12,8	13,4

Source: Energy from renewable sources in 2023, GUS, Statistical Office in Rzeszow, Warszawa-Rzeszów 2024, https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/energia-ze-zrodel-odnawialnych-w-2023-roku,3,18.html.

In recent years, in the EU and in Poland, we have observed a general decline in the amount of energy obtained. This decrease in 2022 compared to 2019 amounted to over 9% in the EU, while in Poland in the same period energy production decreased by 4.5%. This was influenced by, among others, a decrease in the energy intensity index of European economies. At the same time, both in the EU and in Poland, we are observing an increase in the volume of energy production from renewable sources. In the EU, during the analyzed period, the production of energy from renewable sources increased by almost 7%, while in Poland by almost 9%. The percentage of energy from renewable sources in the total energy production in the EU and Poland is presented in Table 5.

Table 5.
Strukture of Total Energy Supply by Fuel UE-27 and Poland [%]

[%]	2019	2020	2021	2022
EU-27 total, including:	100,0%	100,0%	100,0%	100,0%
* from renewable sources	36,8%	40,7%	40,9%	43,2%
Poland total, including:	100,0%	100,0%	100,0%	100,0%
* from renewable sources	19,8%	21,6%	21,3%	22,6%

Source: own study.

As shown in the data in Table 5, the share of renewable energy sources in energy production in Poland, although growing dynamically, still remains much lower than in the EU-27. In 2022, renewable energy sources provided over 43% of the energy produced in the EU-27, while in Poland it was only 22.6%.

5. Renewable energy – an alternative or necessity

Currently, fossil fuels dominate as an energy source. Hard coal and brown coal dominate as fuel for electricity generation. In the USA, 30.4% of electricity comes from coal, in India 44%, in England 35% (European Commission, Directorate-General for Energy, 2024). Coal is a fuel often contaminated with sulfur and mercury. To generate 3000 kWh of electricity, 100 kg of carbon dioxide is released into the atmosphere (71.4 kg when burning crude oil, 53 kg when burning natural gas). Environmental and health risks are the biggest drawback of coal-fired power plants. Sulfur dioxide released into the atmosphere along with carbon dioxide causes lung and respiratory diseases. Fossil fuels as an energy source are no longer a long-term alternative.

Nuclear energy sources, on the other hand, have always been controversial. Nuclear power plants are expensive to build, but then cheaper to operate. Uranium is a relatively cheap fuel and easy to transport. Nuclear reactors can operate for 1-2 years on one charge of uranium. Nuclear power plants do not emit carbon dioxide. Nuclear reactors have triple protection to prevent uncontrolled reaction and radioactive contamination of the area. However, unexpected breakdowns and accidents are possible. In 1979 in Pennsylvania (USA) there was an uncontrolled reaction at the "Three Mile Island" power plant. One reactor was accidentally destroyed and the large amount of radiation caused the need to evacuate a large number of residents. The health risk was very serious. Based on this unfortunate accident, additional security measures and additional crew training were introduced. The revised technology is safer but still controversial. The process of mining and enriching uranium is also controversial due to the danger of radioactive contamination. Removing, transporting and storing spent uranium is also difficult and environmentally hazardous. Spent uranium is cooled in 2-meter-deep water tanks for several weeks. Water in spent uranium cooling tanks becomes highly radioactive. Contamination with such water occurred at the Japanese Fukushima power plant. A large amount of radioactive heavy metals entered the sea, threatening the environment. Several reactors in the US have been closed for safety reasons. These reactors are no longer operational, but they still pose a threat. Dismantling these reactors is very expensive and risky due to the possibility of site contamination. Cooled, spent uranium was until recently transported to underground storage facilities in Nevada. Local residents protested against transporting spent uranium to underground storage facilities for fear of road or rail accidents. The transportation of spent uranium has been suspended. There is only one power plant in the final stage of investment in the USA. No more new nuclear power plants are being built due to negative public reactions and concerns. In 2022, only 18% of electricity generated in the US came from nuclear power plants (even though 30% of the world's nuclear energy is generated in the US).

For the reasons described above, energy from renewable sources is gaining popularity. In 2022, 13% of electricity generated in the US came from renewable sources (www.americangeosciences.org, 2024). In Europe, this indicator reached 43% (Energy from renewable sources, 2023). The use of renewable energy sources has become the main path to achieving sustainable development.

6. Decentralization of the energy market as a method of effective energy management

The energy market has long been monopolized by energy companies. Any kind of monopolization is unfavorable for the customer (energy user). The antitrust law in the USA allows energy users to choose the energy company from which they want to buy energy. This system forces energy companies to fight for customers by reducing prices. A customer whose priority is environmental protection can only purchase renewable energy (mainly wind and photovoltaic). Prices for renewable energy may be a little higher, but a significant number of conscious customers choose this option to protect the environment. The electric transmission lines are owned by another independent company that has a monopoly in a given area. This company's business activities and fees charged are monitored by state authorities. Any fee increase must be justified and approved by the state and customer association.

Renewable energy generation is very dispersed. A large number of customers have their own photovoltaic panels or small wind turbines. There are also a large number of local small energy companies generating electricity mainly from solar and wind. These are private companies that sell energy to the grid. Energy companies are trying to maintain centralized energy distribution at all costs. Energy companies purchase electricity from individual small energy producers (individual customers and small energy companies). This energy is transferred to the central grid and sold centrally to individual users at a much higher price. This is a very economical form of energy management. This system is beneficial for the central energy company, but very disadvantageous for the customer. The electricity produced by the user with solar panels is transmitted to the central grid and then sold, often to the producer's neighbor. Energy transmission involves losses due to the efficiency of the transmission lines. Transmitting electricity to the central grid and then to the user blocks the capacity of transmission lines. When there is a lot of sunlight or a lot of wind, the energy company cannot buy excess energy due to the capacity of transmission lines.

In recent years, decentralization of the electricity market has become possible through the use of specially developed internet programs and smart meters. Electricity in the U.S. can be sold and purchased locally without the involvement of a utility company. Prices are agreed between the seller and the buyer without any mark-up from the energy company. Of course, the seller and buyer pays a small fee (subscription) for using the online energy trading platform. However, these fees are negligible compared to the energy company's overheads. The energy company buys energy at wholesale prices and sells it at retail prices. Direct decentralized energy trading benefits both the seller and the buyer of electricity. Of course, large energy companies are losing their monopoly on energy trading and perceive it as a threat limiting their profits and total control of the energy market.

Electricity prices in a decentralized system are variable and are controlled by the market law of supply and demand. When there is a lot of sunlight or a lot of wind, energy is cheaper. In the evenings, the price of energy may be higher. An individual electricity producer who has the ability to store energy by charging batteries can sell this energy at a higher price during periods of high demand for electricity.

The decentralized energy market and dynamically changing electricity prices allow for effective and economical energy management. Smart energy meters allow you to program the processes of switching on and off various electrical devices (air conditioning, water heating, etc.) depending on energy prices.

7. Local energy market in the conditions of the existing energy network

The buying and selling of electricity between individual customers connected to the electricity grid is called "Peer-to-Peer Energy Trading" (P2P). This is a very beneficial form of selling and buying excess electricity and wind energy between residents of the local community. Online platforms such as Blockchain, PO3, Grid+ and several others allow you to choose the seller and buyer of energy. The price for electricity varies depending on the current supply and demand. The price is agreed between the seller and the buyer. The energy company is not involved in the transaction. The advantages of the local energy market (P2P) are as follows:

- residents without solar panels or wind turbines can buy renewable energy from neighbors at prices lower than the energy company sells,
- residents generating their own electricity can sell it at prices higher than the tariff rates of the energy company,
- electricity does not have to be transmitted over long distances from a centrally located power plant, which reduces the costs of electricity transmission (the cost of energy transmission over long distances can be up to 40% of energy costs),
- local energy comes from renewable sources,
- residents have the opportunity to choose who they buy energy from and can support local energy producers,
- transactions take place between the seller and the buyer of energy (all types of intermediation by energy companies are eliminated),
- all transactions on the blockchain platform are visible to the seller and buyer and are fully secure and objective,
- fees charged for using "blockchain" are very low.

The first global experiment with Peer-to-Peer Trading (P2P) took place in Brooklyn, New York in 2016. Since then, the idea of "P2P" has spread around the world. The platforms for selling and purchasing energy have been improved. They are safe and transparent for the seller and buyer. However, the implementation of "P2P" is very slow. Energy companies are not interested in losing their monopoly on the sale of electricity.

8. Conclusions

To summarize the analysis of the energy problem, the following conclusions can be drawn:

1. The use of fossil fuels as an energy source to generate electricity should be gradually limited. The share of renewable energy sources in the energy mix is growing worldwide, especially in the EU-27, where the share of renewable energy sources in total energy production is approximately 43%.
2. Nuclear energy is very controversial. Existing nuclear power plants were mostly built in the 1960s and 1970s. Currently, much fewer new nuclear power plants are being built due to the high cost of construction and negative reactions and justified public concerns. Transport and storage of spent uranium is also a problem.
3. Using renewable energy sources to generate electricity is no longer an alternative and has become a necessity.
4. Rapidly developing modern computer technology and artificial intelligence allows for local energy trading bypassing energy companies. This ensures energy supplies (energy security) for small consumers in the event of failure of large power plants. Smart electricity meters allow you to stabilize energy demand through changing energy prices in accordance with the law of supply and demand. Smart meters allow you to turn selected electrical devices off and on depending on the current energy price.
5. Modern computer technology creates new opportunities for energy trading. However, legal regulations are required allowing for the decentralization of the energy market and the implementation of direct energy trading bypassing energy companies. Legal regulations must also define the principles of operation of the local energy market.

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