

THE USE OF RENEWABLE ENERGY SOURCES AND THEIR INFLUENCE ON THE NATURAL ENVIRONMENT IN SELECTED EUROPEAN STATES

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Purpose: The aim of the article is to evaluate and characterize the use of renewable energy sources and their impact on the environment in selected European countries.

Design/methodology/approach: relying on renewable energy sources is one of the fundamental goals of the European Union, which is constantly striving to improve the quality of life of societies, and to secure the welfare of present and future generations. The authors performed an analysis of energy consumption in 2010-2020 based on statistical data obtained from the European Statistical Office "EUROSTAT". Numerous statistical analyzes, including data composition and decomposition, have been carried out. The authors relied on the analysis of change dynamics technique. The article presents indexes with a variable base (chain) and relative increments with a constant base.

Findings: It has been established that the use of renewable energy in the following analyzed sectors such as electricity, transport, heating and cooling is diversified, with the highest use being noted in the field of heating and cooling. The most developed country in Europe in terms of the use of renewable energy sources is Iceland, followed by Norway and Sweden. The countries with the lowest use of renewable energy are Malta, the Netherlands and Luxembourg although these countries are exhibiting a growing tendency towards using renewable energy sources.

Originality/value: The article presents the results of data composition regarding the use of renewable energy and its impact on the natural environment. Due to the analyzes used, it may be regarded as an interesting overview of the use of renewable energy sources.

Keywords: renewable energy sources (RES), environmental protection, analysis of the dynamics of change.

Category of the paper: Research paper.

Introduction

One of the key requirements for renewable energy sources is their ability to provide sufficient amount of energy to meet the basic demands such as starting cars, heating houses or powering cities with energy (Bieńkowska-Gołas, 2017). It is also important to consider how these resources could be used in the long term, and what impact they exert on the natural environment. There are numerous resources that are theoretically inexhaustible, and therefore regarded as renewable (Guła, Paruch, Gałusza, 2008). Such resources are used to produce clean energy, they generate less pollution or greenhouse gas emissions, which are one of the major contributors to climate change.

For many years, the state of the natural environment has become a very important issue in Poland and Europe (Jabłoński, Wnuk, 2009). The environment is an inseparable element of life on Earth as it provides all living organisms with natural resources. Its effective protection and management will help to maintain the natural environment at an appropriate level. However, due to the current model of living, we are facing numerous environmental problems that require intense action (Graczyk, 2011). Having said that, it seems highly important to increase the use of renewable resources in order to enrich the natural environment instead of causing it burden, such as contamination of surface waters or exceeding the air pollution norms (Bień, 2010). One of the most important challenges is the elimination of emissions, which are created by the municipal and housing sector. Numerous buildings still rely on low-quality coal and waste incineration for heating purposes. Another important aspect are urbanized areas located in the vicinity of roads with high traffic (Kowalski, Zajdel, Michalcewicz-Kaniowska, 2014). Air pollution safety norms in these areas are exceeded by too high emissions from transportation. In the process of combustion, harmful elements such as carbon dioxide, nitrogen oxide, hydrocarbons, sulfur oxide and carbon monoxide penetrate the atmosphere and have a detrimental effect on human health (Janka, 2013). Another important reason is the increasing development of road infrastructure and buildings, which happens at the cost of green areas. (Wójcik, 2005) Their depletion leads to the deterioration of the quality of life and climatic conditions. They adversely affect the ability to restore oxygen and water resources.

Renewable Energy Sources (RES)

The use of energy has been an important element of human life for centuries. Today power outages could cause huge losses (e.g. shutting down production lines powered by electricity) and general chaos (e.g. trains losing power, traffic lights failures) (Michalcewicz-Kaniowska, Zajdel, 2013). Modern societies are dependent on electricity and ensuring its continuity is of

paramount importance. Primary energy sources can be classified as conventional (non-renewable) or renewable (wind, water, sun, biomass and sea waves). Today's economy is largely based on fossil fuels such as natural gas, oil and coal, which provide about 80% of all energy. These resources are very efficient and easily stored. Currently, large emissions of dust, heavy metal residue, damage related to oil or coal extraction, traffic accidents, geopolitical problems and increased carbon dioxide emissions are the key factors responsible for such serious side effects as shifting climatic zones, and even extinction of the whole species inhabiting the planet (Sonbierajska, Starzomska, Piotrska, 2009). Therefore, the logical alternative to using conventional energy sources based on fossil fuels are renewable energy sources obtained from such inexhaustible resources as sea waves, solar power, and wind (Lasota, 2013). As opposed to the conventional energy sources, the use of renewable energy sources does not lead to irreversible losses and deficits of this type of energy in the environment. These are resources cannot be exhausted and are constantly replenishing. What is more, the replenishment process is spontaneous and independent from human labor. Renewable energy sources can be used to obtain not only electricity, but also heat, cold as well as biocomponents (biogas, oil used to power vehicles, vegetable oil). The use of renewable energy sources contributes to the improvement of the environment (by reducing water and air pollution and reducing the amount of waste produced) and to saving energy resources. In the nineties, there has been a significant increase in interest in this type of energy.

In the coming years, one should expect increased interest in using renewable energy sources due to their benefits (both ecological and local, increasing energy security and creating new jobs). This increase can be also attributed to the rapid economic development and the growing awareness of the society about pollution (Michalcewicz-Kaniowska, Zajdel, 2017). The energy balance in municipal and even provincial areas is changing. It is estimated that the largest energy consumers are agriculture, housing, transportation, and industry. The role of agriculture in production and use of renewable energy can be growing crops in contaminated areas and using the harvest in production of biofuels (Ligus, 2010).

Methodology

The aim of the article is to assess and characterize the use of renewable energy sources and its impact on the environment in selected European countries.

In the article, the authors presented the state of use of renewable energy sources, which is also one of the basic goals of the European Union, which constantly strives to improve the quality of life of societies and the welfare of present and future generations. This target will be based on the analysis of energy consumption in 2010-2020. The EU has a unified and coherent strategy for renewables, which sets out how the EU will be able to effectively meet the

challenges that come with this. Climate and energy changes have been evident over the past years, despite certain signs of improvement in some indicators.

The survey was carried out over eleven years (2010-2020), and the data was obtained from the website of the European Statistical Office (Eurostat, 2021). "EUROSTAT" is the Office of the European Commission, established in 1972 by the European Parliament and has its seat in Luxembourg.

The authors used numerous statistical analyzes involving data composition and decomposition. They used the analysis of change dynamic as well as indexes with a variable base (chain) and relative increments with a constant base.

Research results and discussion of results

For more than 25 years, the scope of use of renewable energy sources has been determined by the European Union. It was assumed that by 2010, 12% of all energy would come from renewable energy sources and would satisfy 22% of the total demand for electricity (Nelson, Starcher, 2016). These are the average numbers for European countries, and each country-specific target is written in a separate directive (Springer, 2020). After 2010, the EU extended the legal framework as there was no progress towards achieving the goals. After eight years, another revised Renewable Energy Directive came into force, which included the "Clean Energy for All Europeans" package. The aim of the EU remains in maintaining its leading position as the enforcer of the changes, and to meet the emission reduction goals as set by the Paris Treaty (Cenian, Pietrzykowski, 2018). The "Clean Energy for All Europeans" package has set the following target: 32% of all energy produced in the EU, and 14% of energy used in transport must be obtained from renewable energy sources by 2030. It is different from the original version of the directive, which assumed that as much as 20% of energy in the EU would be obtained from RES by the year 2020 (Chelminak, 2021). What is more, all Member States were obliged to enforce a 10% RES fuel share in transport. Apart from setting the new goals, the Directive also offers guidelines on how member states should meet these objectives, namely by co-operation between countries, energy origin guarantee, support systems, joint projects, and establishing criteria for the production of biofuels. The directive includes two regulatory systems. They assess the use of renewable energy sources across European countries and take into account their RES potential. For example, in the case of Malta, it equals 10%, while as much as 49% for Sweden. The member states set targets and agree on an action plan. Progress towards achieving the targets is measured every 2 years and therefore European countries publish biennial progress reports on renewable energy over this period.

As part of spreading the Clean Energy for Europeans strategy, a proposal has been made to recast the existing directive on the promotion and use of energy from renewable sources. The following six areas are being promoted: further development of renewable sources in the field of electricity, introduction of energy from renewable sources to the heating and cooling sector, strengthening the position of customers and increased information transfer in the field of renewable energy sources, reduction of emissions and diversification of the transport sector, establishing a timely and binding target, and strengthening bioenergy criteria (Cenian, Pietrzykowski, 2018). The targets for biofuels are, firstly, to achieve a 10% share of all fuels in transport (target by 2020), and secondly, to reduce the intensity greenhouse gases emissions by six percent (2020 target). The document "Policy framework for climate and energy for the period 2020-2030" proposed to deviate from the above targets as it is currently uncertain how to reduce the impact of indirect factor emissions that result from land use change caused by the production of biofuels (Den Boer 2018). The directive relating to the quality of fuels is aimed at reducing their negative impact on the natural environment and include fuels produced from sugar, oil, grain and other high-starch crops. This is due to a change in land use methods and related gas emissions. The reduction introduced in final energy consumption relating to the transport sector amounts to 7% in the EU countries. As part of the review of offshore wind energy and ocean energy, the Communication "Offshore Wind Energy: Actions Necessary to Achieve Energy Policy Objectives for 2020 and Beyond" was issued to support the development of areas outlined in the Communication from European countries. In the following years, goals for the development of energy-using fluids and waves, energy conversion, and the use of water salinity and energy production were revealed. The potential inputs of offshore energy sources are currently being assessed. Table 1 presents the use of renewable energy sources in European countries.

Table 1.

The use of RES across European states (kWh)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electricity	408,2	532,3	702,1	841,5	1 053,8	1 404,7	1 412,8	1 652,9	1 826,5	1 854,1	1 856,5
Heating and cooling	3 931,0	4 027,4	4 189,5	4 641,6	4 917,1	5 060,8	5 278,0	4 963,7	5 116,7	5 452,3	5 579,9
Transportation	143,6	483,9	680,4	916,2	969,7	861,5	806,4	766,1	721,2	535,0	687,3
Total use	4 482,9	5 043,6	5 572,0	6 399,3	6 940,7	7 327,0	7 497,2	7 382,7	7 664,4	7 841,4	8 123,6

Source: own research based on data from Eurostat.

The production of electricity amounted to 408.2 kWh in the whole energy consumption in 2010-2019, while in 2020 the figure increased to 1856.5 kWh. A slight slowdown in this consumption can be noted in 2015 and 2016, but after 2016 it started to increase again. However, in terms of heating and cooling, the initial energy consumption in 2010 is much higher and amounts to 3,931, and in the last year of the analysis it is 5,579.9 kWh. The difference indicates an increase of about 1648.9 kWh. The last category is the use of energy in transport, and so from 2010 to 2014 an upward trend can be observed, starting from the consumption of 143.6 kWh to 969.7 kWh in 2014. However, from this year a downward trend

can be observed until 2019, where consumption was 535.0 kWh, and in the last analyzed year 2020 - 687.3 kWh. The highest use of this energy occurred in 2014.

The next analysis presents the use of renewable energy sources according to its production methods (solar, water, wind, biofuels and other) (table 2).

Hydropower is one of the oldest methods of obtaining energy from renewable sources and has been in use for thousands of years (Bujakiewicz-Grabowska, 2009). Hydroelectric power plants are designed to use the flow of rivers and streams and, at the same time, to rotate a turbine, the purpose of which is to power a generator that produces electricity.

Another type of RES is geothermal energy, which is obtained from the depths of the Earth's core. Geothermal reservoirs are usually located on the boundaries of tectonic plates, near volcanic eruption zones or deep underground (Cappetti, 2004). Geothermal energy is obtained by drilling wells to pump hot water or steam into the power plant. This energy is most often used for heating or generating electricity.

Wind turbines make use of wind energy in order to produce electricity. The wind pushes blades of the turbine, which are connected to the generator, which in turn converts mechanical energy into electricity (Taubman, 2016). Electricity produced in this way is typically used to supply homes and other buildings, but its great advantage is that it can be stored in the power grid.

Another type of RES is the solar radiation (Tytko, 2021). Photovoltaic cells make use of solar power to create electricity. Although while used individually, these cells can only produce enough energy to power a calculator, it is when they are combined into larger circuits, they can provide more electricity.

Table 2.

The use of energy in 2010-2020 (kWh)

Energy source	water	wind	solar	solid biofuels	other
2010	29 269,3	8 219,0	324,6	4 098,7	3 183,1
2011	29 252,6	9 612,2	639,5	4 572,5	3 533,7
2012	29 350,1	11 025,2	1 212,7	4 930,9	3 944,7
2013	29 684,2	12 492,0	1 996,9	5 581,0	4 525,3
2014	29 682,8	14 009,4	4 066,1	5 772,4	5 014,7
2015	29 552,9	15 604,6	6 034,1	6 197,4	5 742,7
2016	29 714,7	17 308,2	7 231,7	6 063,3	6 420,7
2017	29 642,1	19 010,7	8 097,1	6 081,8	6 902,3
2018	29 682,0	21 450,4	8 672,2	6 196,8	7 260,9
2019	29 601,1	23 379,4	8 687,4	6 224,7	7 393,4
2020	29 460,7	25 705,9	9 279,9	6 383,4	7 462,2
max	29 714,7	25 705,9	9 279,9	6 383,4	7 462,2
min	29 252,6	8 219,0	324,6	4 098,7	3 183,1

Source: own research based on data from Eurostat.

Table 2 shows the use of energy from individual renewable energy sources. The largest growth can be observed in the wind, solar, biofuel and other energy sectors. While energy produced by hydropower plants remains static, the consumption of its energy is the highest. The next table presents the analysis of the dynamics of changes in the characterized factors.

Only selected analyzes are presented in the paper. Chain indexes have been presented in Table 3.

Table 3.

The Analysis of Change Dynamics – chain indexes

Chain indexes	water	wind	solar	solid biofuels	other
2010	1	1.17	1.97	1.12	1.11
2011	1	1.15	1.9	1.08	1.12
2012	1.01	1.13	1.65	1.13	1.15
2013	1	1.12	2.04	1.03	1.11
2014	1	1.11	1.48	1.87	1.15
2015	1.01	1.11	1.2	0.98	1.12
2016	1	1.1	1.12	1	1.08
2017	1	1.13	1.07	1.02	1.05
2018	1	1.09	1	1	1.02
2019	1	1.1	1.07	1.03	1.01
2020	1.01	1	1	1	1

Source: own research based on data from Eurostat.

The conducted analysis shows that the use of hydropower has not changed over the years, which is confirmed by the value of the index (1.0), while the remaining resources are used to a greater extent in subsequent years, as evidenced by the increasing index values.

The next presented analysis concerns energy consumption for selected European countries over the years. Table 4 presents only selected countries due to the large volume of the analysis, as all European countries were assessed.

Table 4.

The Analysis of Change Dynamics – relative increases based on 2010 constant

Relative increase	Malta	Poland	Cyprus	Denmark	Germany
2010	0,00%	0,00%	0,00%	0,00	0,00
2011	10,17%	11,27%	28,22%	4,49%	0,33%
2012	24,86%	25,53%	47,98%	12,40%	8,09%
2013	453,11%	34,20%	54,17%	23,33%	16,22%
2014	945,20%	49,41%	56,37%	31,79%	24,05%
2015	1516,95%	58,30%	78,25%	43,49%	34,90%
2016	2024,29%	65,41%	111,19%	53,11%	37,07%
2017	2580,23%	67,59%	129,10%	65,22%	43,29%
2018	2792,09%	71,54%	147,98%	73,91%	48,48%
2019	3407,34%	64,50%	146,23%	80,59%	48,31%
2020	3978,53%	60,42%	162,31%	95,39%	54,16%

Source: own research based on data from Eurostat.

Table 4 shows the increases on a fixed basis (2010), the highest increase was observed in Malta (almost 4,000%) and in Cyprus (an increase by 163%), however, similar trends are observed in all European countries. A detailed analysis of energy consumption showed that the highest increase was in Denmark in 2020 and amounted to 16.93 kWh, while the lowest in 2011 in Romania – it was -3.87 kWh.

To sum up, the shortcoming of using renewable resources to produce energy is that it depends on weather conditions while non-renewable resources do not. However, scientists are constantly searching for new ways to improve the reliability of using renewable resources.

Conclusions

The use of renewable energy in the following sectors: electricity, transport, heating and cooling is diversified. The highest recorded use is for heating and cooling purposes, which means that using renewable energy sources is becoming more and more popular and translates into lower costs. Electricity comes second in the field of energy use. As in the case of heating and cooling, the use has also grown from year to year, which means that people living in European countries are increasingly using electricity produced from renewable energy sources. The last sector that was analyzed is transport. Energy use in this sector grew until 2015 after which it dropped until 2019. The reason behind changing to electric transport is aimed at reducing CO₂ emissions.

The most developed country in Europe in terms of the use of renewable energy sources is Iceland, followed by Norway and Sweden. The countries with the lowest use of renewable energy are Malta, the Netherlands and Luxembourg. As shown by the research, despite the lowest use, they showed a growing tendency.

Replacing fossil-fuel based energy with clean energy obtained from renewable sources can be observed from year to year. This trend is evolving with different intensity in different parts of the European continent. Poland also shows a growing tendency and, compared to other European countries, ranks 28th in terms of the use of energy from renewable sources. Although Poland did not experience such a fundamental modernization as Iceland until 2020, the growing tendency indicates an increasing interest in renewable energy. There are many benefits to this transformation, such as: reducing environmental impact, economic gains, climate protection, energy security.

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