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THEORETICAL AND METHODOLOGICAL PROBLEMS

ENVIRONMENTAL POLICY AND MANAGEMENT

STUDIES AND MATERIALS

GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

THEORETICAL AND METHODOLOGICAL PROBLEMS

Dorota MICHALAK • Paulina SZYJA

DETERMINANTS OF CLIMATE SECURITY – AN ATTEMPT AT INDICATOR ANALYSIS

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ABSTRACT: The article addresses the issue of climate security, a topic not sufficiently explored in the literature. The purpose of the article is to fill the gap in the literature on explaining the link between climate change and security, defining the term climate security, and attempting to select indicators (based on a selection from those already existing) for diagnosing the level of climatic security. The research established a lack of studies clarifying the term climate security. Hence, the authors' definition was adopted. In turn, a review of existing indicators indicated their limitations. Nevertheless, it allows us to verify whether there is a threat to climate security.

KEYWORDS: climate security, climate security indicators, national security

 DOI: 10.34659/eis.2023.84.1.551 JEL: H56, Q54, F63

Introduction

The growing climate crisis caused by, inter alia, anthropogenic greenhouse gas emissions is a fact that many governments and, above all, European Union (EU) member states are reckoning with. Therefore, a number of adaptation and mitigation measures are being taken.

The purpose of the article is to define climate security, taking into account all of its elements, determine its possible impact on national security, and attempt to select indicators to ascertain whether climate security is at risk. It is necessary to clarify the issue of the climate crisis in the context of the consequences. Next, the issue of the connection between climate change and national security needs clarification. And in this case, it is important to define the concept of climate security and its relationship to other national security sectors. Then, we should answer the following question: Can we talk nowadays about climate security? Is it a state when the risk of change (disruption) will be close to zero, which is possible with economic, social, and environmental security? Going one step further, it is worth asking whether climate security is at risk.

We conducted a literature review, then reviewed the indicators and finally made a selection for the conceptual category of climate security.

Literature review – climate crisis: social, economic and environmental dimensions

The current climate change is considered one of the most significant challenges of the 21st century. It strongly affects nature, including the risk of extinction of some plant and animal species and human living conditions. In the latter regard, both environmental and socioeconomic consequences of progressive climate change can be distinguished (IPCC, 2013; IPCC, 2018). Environmental impacts can affect the quality of life through the deterioration of food quality and/or reduced access to food and drinking water, among others. There is also an increased risk of many diseases. Socio-economic consequences, on the other hand, include an increase in the cost of adapting to climate change, tensions caused by migration (or, in extreme cases, climate refugees (UNHCR, 2022)), conflicts over resources (mainly water), and changing regional balances of political power as a result of these conditions. In practice, climate conflicts cannot be ruled out. The scale of these consequences of progressive climate change is difficult to predict, but it is estimated that they will have a strong impact. For this reason, in the long term, climate change will leave a significant mark on the face of the world (Prandecki, 2021).

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The current consequences of climate change are being felt in all corners of the globe, including in areas where they were not yet expected. To make matters worse, those predicted in the near future will be unprecedented in the history of civilisation. Therefore, more and more people are talking not about the negative consequences of climate change but about the evidence of the ongoing climate-environmental crisis (Jasikowska & Pałasz, 2022).

The literature contains a growing number of analyses on the impact of the (mostly negative) climate on several aspects related to the economy, society, and the environment. These analyses include:

- the impact of extreme weather events on short-term and long-term development. Albala-Bertrand (1993), Raddatz (2007), Noy (2009), Hochrainer (2009) and Loayza et al. (2012) indicate a negative correlation between extreme weather events and development,
- climate impacts on the following sectors:
  - agriculture. The first studies on the subject appeared in 1989 (Adams) and 1993 (Kaiser et al.). Based on regression lines, they indicated the negative impact of climate on agricultural production. Later analyses were conducted by, among others, Lobell and Field (2007), Olesen et al. (2011), Tubielo and Schmidhuber (2008), Gornall et al. (2010), Trnka et al. (2011), Kozyra and Górski (2008), Stempel (2011), Florek and Czerwińska-Kayzer (2013), Koźmiński and Michalska (2010), Olkiewicz (2015), and Janowicz-Lomott and Łyskawa (2014). The issue is also addressed in reports/analyses of the World Bank (2010), the IPCC (2014) and the European Commission (2013). Studies by many authors, e.g., Dillon et al. (2015), Seddon et al. (2016), Tripathi et al. (2016), Kłoczko-Gajewska and Sulewski (2009), Sulewski (2014), Sobiech and Kurdyś-Kujawska (2014), Kurdyś-Kujawska (2016), and Palinkas and Szekala (2008) indicate that climate change is the most significant threat to farm operations for farmers,
  - energy. The following have been analysed: the impact of climate change on the energy performance and thermal comfort of a building (Firląg et al., 2020), the impact of extreme weather events on the power supply (Kongorld, 2014), and energy security (Cevik, 2022). The negative correlation between temperature change resulting from climate change and the amount of energy purchased (Michalak, 2012), as well as climate change challenges for the energy sector (Ashford & Hall, 2018), have been identified,
  - tourism. The impact of variations in thermal, solar, and wind conditions on the number of tourists and revenues in this industry was analysed (i.e., Biernacik & Jakusik, 2016; Michalak, 2013),

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- the impact of climate on society, including health (Hajat et al., 2007; Szwed et al., 2010; Robine et al., 2008) and employee productivity (Kjellstrom et al., 2008; Michalak, 2018; Brenner & Lee, 2014),
- the impact of climate on the environment, including water resources (i.e., Kundzewicz et al., 2008; Piniewski et al., 2014; Schneider et al., 2013; Van Vilent et al., 2013; Wang et al., 2016; Vatter et al., 2016), forest ecosystems (Kornatowska & Smogorzewska, 2010), losses in the world of living nature (Nordhaus, 2021) and the threat to the seas and oceans (Nordhaus, 2021).

Climate change significantly conditions the functioning of the economy, society, and the environment. However, this dependence is not one-sided. Intensification of the greenhouse effect due to human activity (Hoegh-Guldberg et al., 2018), such as through fossil fuel energy consumption (Elias, 2017) or agricultural practices, e.g., converting natural land to agricultural use, overexploitation of the water resource for irrigation, and the use of fertilisers (Sadowski, 2018) exacerbates climate change.

In November 2019, the scientific journal Nature published an article entitled “Climate tipping points – too risky to bet against”. The authors wrote, “Here we summarise evidence on the threat of exceeding tipping points, identify knowledge gaps and suggest how these should be plugged. We explore the effects of such large-scale changes, how quickly they might unfold and whether we still have any control over them”. They went on to say, “the consideration of tipping points helps to define that we are in a climate emergency and strengthens this year’s chorus of calls for urgent climate action – from schoolchildren to scientists, cities and countries” (Lenton et al., 2019).

In turn, in January 2020, “BioScience” published a letter by Ripple, Wolf, Newsome, Barnard, Moomaw and 11,258 scientists from 153 countries. It stated, “Scientists have a moral obligation to clearly warn humanity of any catastrophic threat and to ‘tell it like it is.’ On the basis of this obligation and the graphical indicators presented below, we declare, with more than 11,000 scientist signatories from around the world, clearly and unequivocally that planet Earth is facing a climate emergency” (Ripple et al., 2020). So, we have diagnosed conditions that, according to scientists, have led to a situation of alarm, which is referred to in the press as a climate crisis. The question arises as to how this state of affairs is related to ensuring climate security. To answer it, it will be necessary to clarify the following:

a) What is climate security, and where can this sector be placed in the national security system?
b) Can the level of climate security be measured based on certain indicators?
c) Does analysing selected indicators appropriately make it possible to clarify when we can speak of a secure climate?

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Climate security

A discussion of the concept of climate security should begin with the issue of the climate-security nexus. This is how the issue is clarified by the United Nations Environment Program (UNEP): “Security concerns linked to climate change include impacts on food, water and energy supplies, increased competition over natural resources, loss of livelihoods, climate-related disasters, and forced migration and displacement. Despite growing recognition of the interlinkages between climate change, peace and security, few examples of integrated programmatic approaches that address specific risks at the intersection of climate change and insecurity exist. Conflict and crisis-affected contexts are more susceptible to being overwhelmed by climate change, but too often, peacebuilding and stabilisation efforts often do not consider climate-related impacts or environmental hazards. At the same time, insecurity hinders climate change adaptation efforts, leaving already vulnerable communities even poorer and less resilient to interlinked climate and security crises, but climate change adaptation initiatives often fail to fully integrate peacebuilding or conflict prevention objectives” (UNEP, 2022).

It is worth returning to the genesis of the issue of climate security in the activities of the UN, or rather UNEP. In 2008, UN Special Envoy for Climate Change Jan Egeland asked for an analysis of climate change and security risks in the Sahel region. “The UN Special Envoy visited the region in 2008 and concluded it was ‘ground zero’ for climate change risks due to its extreme climatic conditions and highly vulnerable population” (UNEP, 2022). In 2009, the report “Livelihood Security Climate Change, Migration and Conflict in the Sahel” (UNEP, 2011) was published. There have been opinions in the literature that the conflict in Darfur is the first to be traced back to climate change (Mazzo, 2009). However, “Climate change and natural hazards generally do not directly produce intra-state violence or conflict. More often, climate change acts as a threat multiplier by triggering or aggravating existing pressures within societies, including demographic, social, economic, or political strains, that potentially develop as underlying drivers of instability and insecurity. Especially when climate change overburdens the capacity of governments to effectively deal with these accumulating pressures, societies become more vulnerable to social or political instability” (Remmits et al., 2020).

According to the UN Secretary-General’s Peacebuilding Fund: “Climate security means preventing and resolving violent conflicts caused by global warming by improving the management of transhumance corridors, resolving land ownership issues, reducing competition over access to natural resources and extractive industries and fostering agreements over climate adaptation strategies as well as local level resilience and livelihoods” (UN,

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2020). According to the Transnational Institute, climate security is "a political and policy framework that analyses the impact of climate change on security. It anticipates that the extreme weather events and climate instability resulting from rising greenhouse gas emissions (GHGs) will cause disruption to be economic, social and environmental systems – and therefore undermine security" (TNI, 2021). In turn, the Pacific Northwest National Laboratory states: "Climate security represents the physical, economic, or societal impacts associated with climate change that substantially alter political stability, human security, or national security infrastructure" (PNNL, 2022).

The term "climate insecurity" also appears in the literature, which has been explained by, inter alia, Mason (2014): "Climate insecurity denotes a condition under which the effects of climate variability and/or change are represented as threatening to a group of affected actors".

In analysing these two terms, one can see common features:

- the impact of climate change on national security,
- the impact of increased greenhouse gas emissions on disruptions in social, economic and environmental dimensions,
- conflicts resulting from the consequences of global warming,
- the political dimension.

On this basis, the following definition of climate security was formulated: the materialisation of threats resulting from the dynamic growth of greenhouse gases in the atmosphere implies serious multidimensional consequences, i.e., social (climate refugees), economic (limited water resources, and limited quantity and quality of food) and environmental (limitation and disappearance of biodiversity), which in turn can cause political and, in extreme cases, military conflicts.

Another issue is the placement of climate security in the national security system, which has not yet been identified as one of its elements (Figure 1).

The impact of climate security on national security is multidimensional. As indicated in Figure 2, climate security depends on and simultaneously affects ecological and economic security, indirectly on food and energy security, and directly and indirectly on social and water security. The illustrated two-way dependencies signal that a disruption of one of the presented elements of national security is enough for climate security to be threatened; on the other hand, a disruption of climate security reflects negatively on all three pillars of sustainable development and national security.

As Trombetta (2008) points out, "Climate security suggests a concern for the security of the climate which is understood as the maintenance of stable climatic conditions as a prerequisite of all human enterprises, rather than the security of the climate itself. Climate security is evoked to secure people and societies that depend on it".

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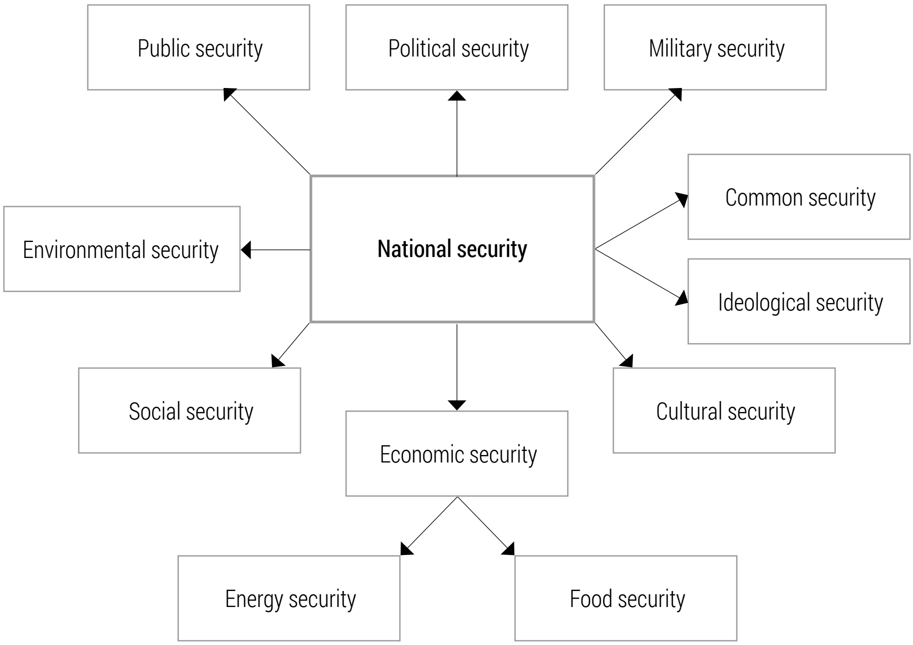

Figure 1. National security sectors
Source: authors' work based on Kitler, 2011.

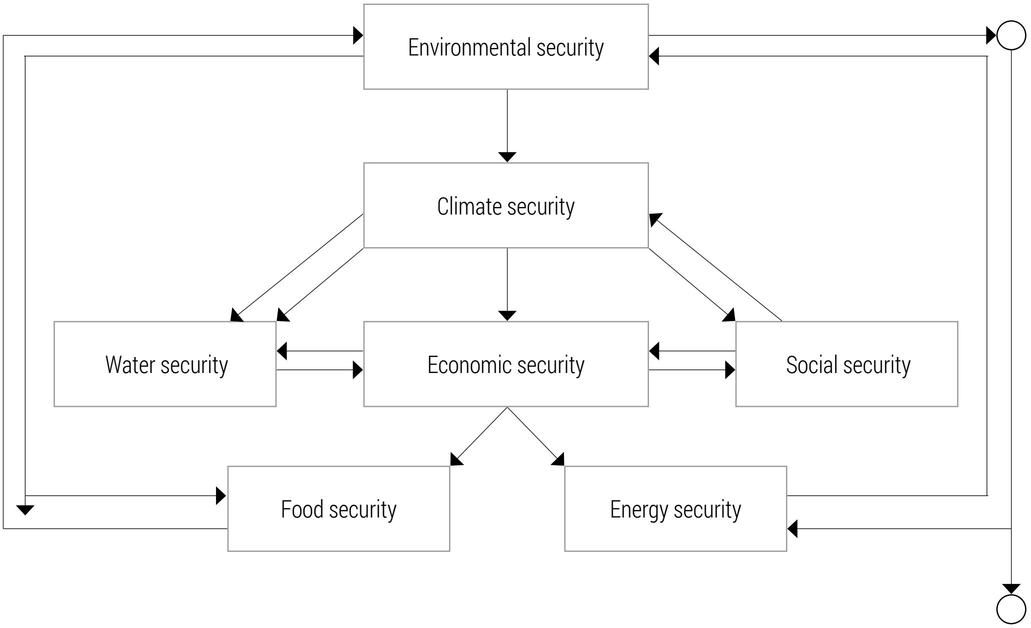

Figure 2. The multidimensionality of climate security

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Climate security indicators – research method

So, when can we talk about a safe climate? According to the above considerations, it is a state where the risk of change (disruption) is close to zero, which is possible with economic, social, and environmental security. Going one step further, it is worth asking whether climate security is at risk at the moment.

In order to answer such a question, an attempt was made to select indicators, which were classified into three areas according to the above-mentioned division:

1. economic – including selected factors that affect energy, water, and food security,
2. social – covering selected factors that affect social security, including health and welfare,
3. environmental – covering selected factors that affect environmental security.

The main limitations of the analysis relate to its narrowness to the countries of the EU, since climate security is a global issue, and the selectivity of indicators, which is mainly due to the lack of availability of data and its low quality.

In order to keep the analysis transparent, the indicators were classified; however, the dividing line is fluid, and the very selection of indicators reinforces the above-presented conclusions about the interdependence of different areas on each other.

Table 1. Climate security indicators

Area	Indicator	Description
Economic	Energy balance	This indicator allows users to see the total amount of energy extracted from the environment, traded, transformed and used by different types of end-users. It also makes it possible to see the relative contribution of each energy carrier (fuel, product). The energy balance makes it possible to study the overall domestic energy market and monitor the impacts of energy policies. The energy balance offers a complete view of a country's energy situation in a compact format, such as the energy consumption of the whole economy and individual sectors. The energy balance presents all of a country's statistically significant energy products (fuels) and how they are produced, transformed and consumed by different types of economic actors (industry, transport, etc.). Therefore, an energy balance is the natural starting point for studying the energy sector.
	Energy efficiency	This indicator covers indicators for monitoring progress towards energy efficiency targets of the Europe 2020 strategy implemented by Directive 2012/27/EU on energy efficiency. Targets for 2030 are included on the basis of Directive (EU) 2018/2002.
	Share of energy from renewable sources	This dataset covers the indicator for monitoring progress towards renewable energy targets of the Europe 2020 strategy implemented by Directive 2009/28/EC on the promotion of the use of energy from renewable sources.
	Available energy, energy supply and final energy consumption per capita	Annual data on quantities for crude oil, petroleum products, natural gas and manufactured gases, electricity and derived heat, solid fossil fuels, renewables and wastes covering the full spectrum of the energy sector from supply through transformation to final consumption by sector and fuel type.
	Water statistics on the national level	Yearly data on freshwater resources, water abstraction and use, connection rates of resident population to wastewater treatment, sewage sludge production and disposal, generation and discharge of wastewater collected biennially by means of the OECD/Eurostat Joint Questionnaire – Inland Waters. Data aggregation: national territories.
	Agricultural factor income per annual work unit (AWU)	The indicator is a partial labor productivity measure in agriculture. Agricultural factor income measures the income generated by farming, which is used to remunerate borrowed or rented factors of production (capital, wages and land rents) as well as own production factors (own labor, capital and land). Factor income corresponds to the deflated (real) net value added at the factor cost of agriculture. The implicit price index of GDP is used as a deflator. AWUs are defined as full-time equivalent employment (corresponding to the number of full-time equivalent jobs), i.e., total hours worked divided by the average annual number of hours worked in full-time jobs within the economic territory.
Social	Healthy life years by sex	The indicator of healthy life years (HLY) measures the number of remaining years that a person of a specific age is expected to live without any severe or moderate health problems. The notion of a health problem for Eurostat's HLY reflects a disability dimension and is based on a self-perceived question which aims to measure the extent of any limitations, for at least six months, because of a health problem that may have affected respondents as regards activities they usually do. HLY is a composite indicator that combines mortality data with health status data.

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Area	Indicator	Description
Social	People at risk of poverty or social exclusion	This indicator corresponds to the sum of people who are: at risk of poverty after social transfers, severely materially deprived or living in households with very low work intensity. People are counted only once, even if they are affected by more than one of these phenomena. People are considered to be at risk of poverty after social transfers if they have an equivalized disposable income below the risk-of-poverty threshold, which is set at 60% of the national median equivalized disposable income. Severely materially or socially deprived people have living conditions severely constrained by a lack of resources, and they experience at least 7 out of the 13 following deprivations items: cannot afford i) to pay rent or utility bills; ii) keep their home adequately warm; iii) face unexpected expenses; iv) eat meat, fish or a protein equivalent every second day; v) a week's holiday away from home; vi) have access to a car/van for personal use; vii) replace worn out furniture; viii) replace worn-out clothes with some new ones; ix) have two pairs of properly fitting shoes; x) spend a small amount of money each week on him/herself ("pocket money"); xi) have regular leisure activities; xii) get together with friends/family for a drink/meal at least once a month; and xiii) have an internet connection. People living in households with very low work intensity are those aged 0-64 living in households where the adults (aged 18-64) worked 20% or less of their total work potential during the past year. In order to measure child poverty, the indicator is available for the age group 0-17.
	Years of life lost due to PM2.5 exposure	The indicator measures the years of life lost (YLL) due to exposure to particulate matter (PM2.5). PM2.5 are particulates whose diameter is less than 2.5 micrometers and which can be carried deep into the lungs, where they can cause inflammation and exacerbate the condition of people suffering from heart and lung diseases. YLL is defined as the years of potential life lost as a result of premature death. It is an estimate of the average number of years that a person would have lived if they had not died prematurely.
	Population connected to public water supply	Percentage of the population that has access to public water.
	Crop production in the EU	Harvested production, mainly dried pulses, root crops, fodder, and industrial crops.
Environmental	Air emissions accounts totals bridging to emission inventory totals	This indicator includes so-called bridging items, which show the differences between the national totals derived from two internationally established approaches/methods for reporting emissions of greenhouse gases and air pollutants.
	Environmental protection investments of the total economy	This indicator presents investments of the total economy (general governments and corporations) to provide environmental protection services (e.g., waste and wastewater management, decontamination of soil). Investments undertaken by corporations to manage their own environmental pressures are included.
	Resource productivity	This indicator provides ratios of gross domestic product (GDP) over domestic material consumption (DMC) in various units of measure. The term "resource productivity" designates an indicator that reflects the GDP generated per unit of resources used by the economy. This is typically a macro-economic concept that can be presented alongside labor or capital productivity.

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Area	Indicator	Description
Environmental	Water exploitation index, plus	The Water Exploitation Index plus (WEI+) is a measure of total freshwater use as a percentage of the renewable freshwater resources (groundwater and surface water) at a given time and place. It quantifies how much water is abstracted and how much water is returned after use to the environment. The difference between water abstraction and return is regarded as water use and illustrates the pressure on renewable freshwater resources due to water demand. In the absence of Europe-wide agreed formal targets, values above 20% are generally considered an indication of water scarcity, while values equal to or bigger than 40% indicate situations of severe water scarcity, i.e., the use of freshwater resources is clearly unsustainable. The indicator is presented as annual average values. Annual calculations at the national level, however, cannot reflect the uneven spatial and seasonal distribution of resources and may therefore mask water scarcity that occurs on a seasonal or regional basis. The indicator is a result of estimations by EEA based on data from the WISE SoE – Water quantity database (WISE 3) and other open sources (JRC, Eurostat, OECD, FAO) and including gap-filling methods.
	Protected areas	The indicator measures the surface of terrestrial and marine protected areas. The indicator comprises nationally designated protected areas and Natura 2000 sites. A nationally designated area is an area protected by national legislation. The Natura 2000 network comprises both marine and terrestrial protected areas designated under the EU Habitats and Birds Directives with the goal of maintaining or restoring a favorable conservation status for habitat types and species of EU interest.

Source: authors' work based on Eurostat.

Research results

The indicators are presented in detail below.

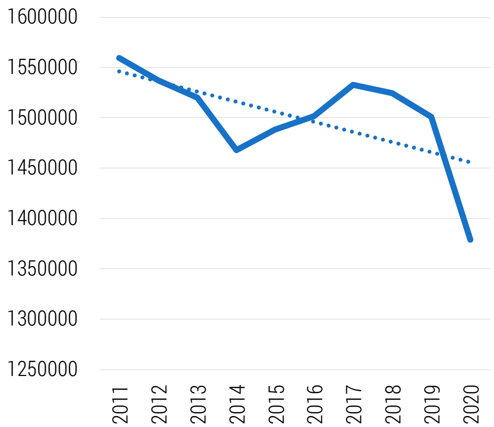

Figure 3. Energy balance 2011-2020 [annual, total, gross available energy, millions tonnes of oil equivalent]

Source: authors' work based on Eurostat.

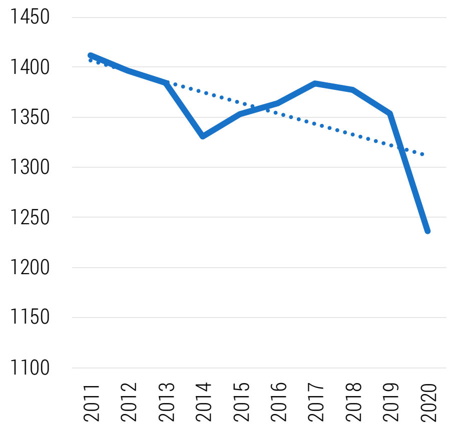

Figure 4. Energy efficiency 2011-2020 [annual, primary energy consumption, million tonnes of oil equivalent]

Source: authors' work based on Eurostat.

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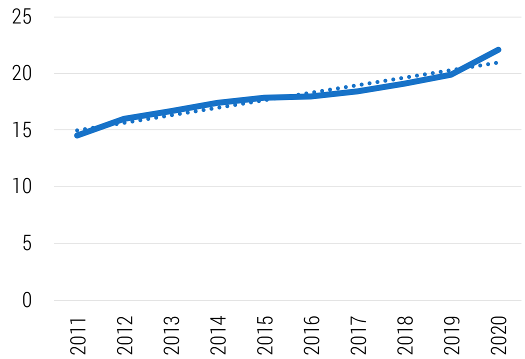

Figure 5. Share of energy from renewable sources [annual, percentage]

Source: authors' work based on Eurostat.

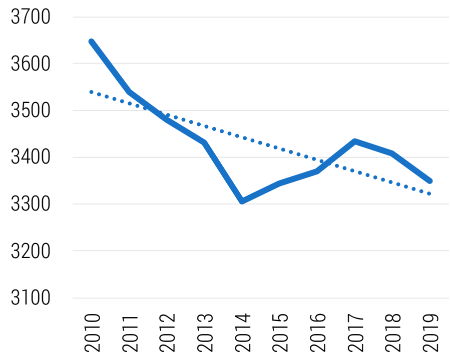

Figure 6. Available energy, energy supply, and final energy Consumption per capita 2010-2019 [annual, total, gross available energy, kilograms of oil equivalent (KGOE) per capita]

Source: authors' work based on Eurostat.

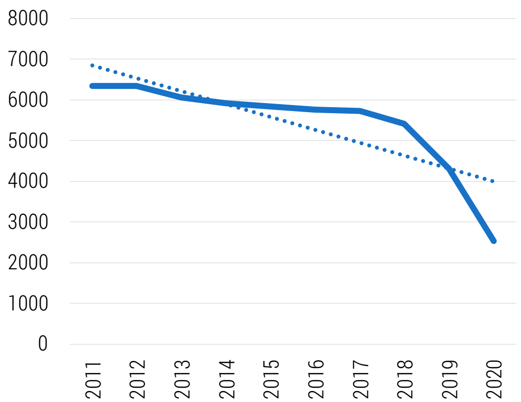

Figure 7. Water statistics on the national level 2011-2020 [total gross abstraction, fresh surface and groundwater, million cubic meters]

Source: authors' work based on Eurostat.

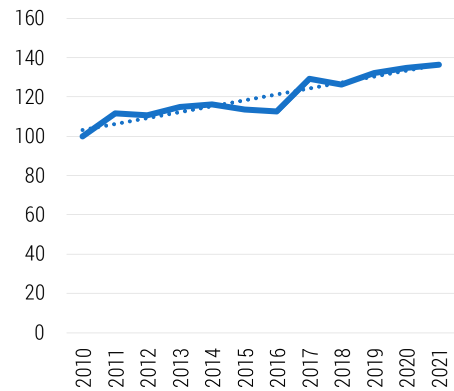

Figure 8. Agricultural factor income per annual work unit 2010-2021 [Index, 2010=100]

Source: authors' work based on Eurostat.

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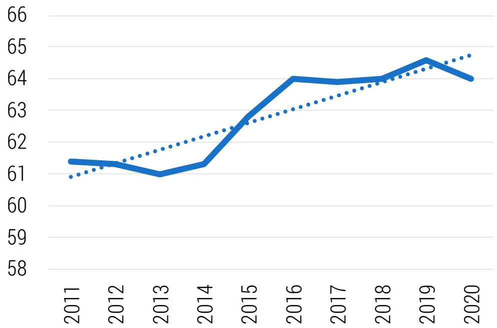

Figure 9. Healthy life years by sex 2011-2020 [annual, year, total]

Source: author's work based on Eurostat.

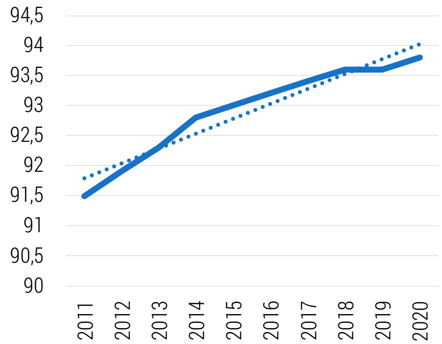

Figure 10. Population connected to public water supply 2011-2020 [annual, percentage]

Source: authors' work based on Eurostat.

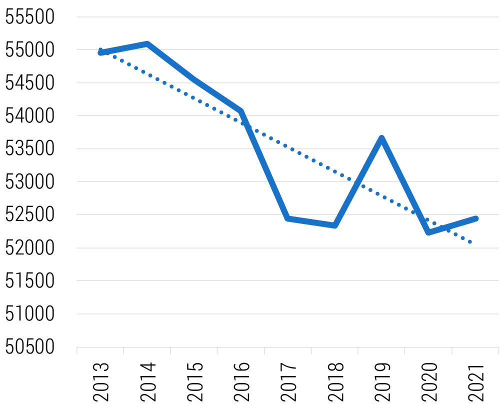

Figure 11. Crop production in EU standard humidity 2013-2021 [annual, crop production in EU standard humidity, area -cultivation/harvested/production, 1000 ha)]

Source: authors' work based on Eurostat.

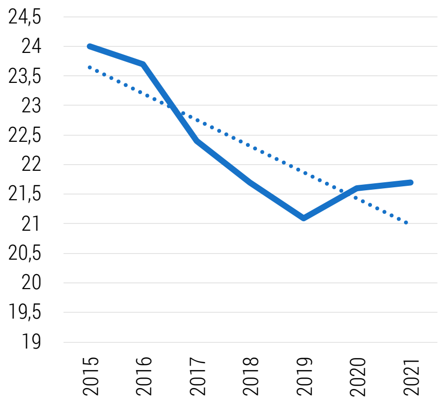

Figure 12. People at risk of poverty or social exclusion [annual, percentage]

Source: author's work based on Eurostat.

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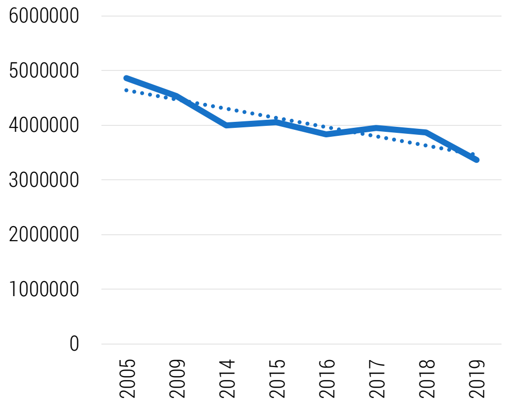

Figure 13. Years of life lost due to PM2.5 exposure [annual, particulates < 2.5μm, years of life lost]

Source: authors' work based on Eurostat.

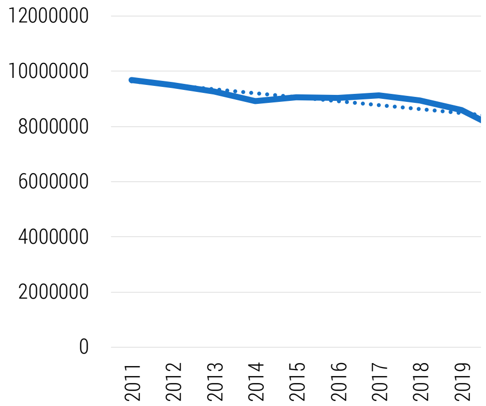

Figure 14. Air emissions accounts totals bridging to emission inventory totals [annual, greenhouse gases (CO_2, N_2O in CO_2 equivalent, CH_4 in CO_2 equivalent, HFC in CO_2 equivalent, PFC in CO_2 equivalent, SF6 in CO_2 equivalent, NF3 in CO_2 equivalent)]

Source: authors' work based on Eurostat.

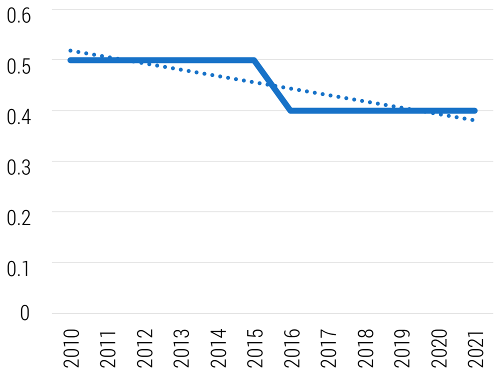

Figure 15. Environmental protection investments of total economy 2010-2021[annual, percentage of GDP]

Source: authors' work based on Eurostat.

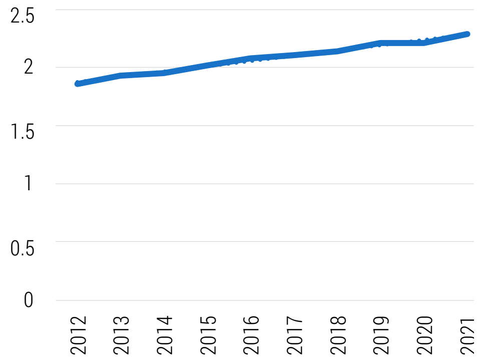

Figure 16. Resource productivity 2012-2021 [annual, euro per kilogram]

Source: authors' work based on Eurostat.

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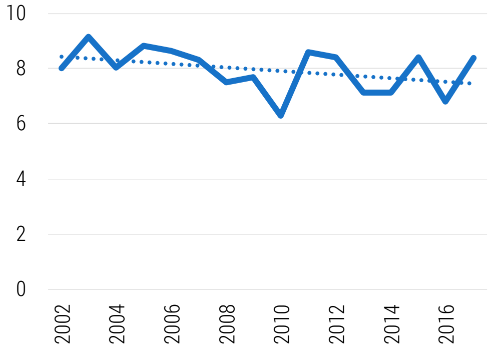

Figure 17. Water exploitation index 2002-2017 [annual, percentage]

Source: authors' work based on Eurostat.

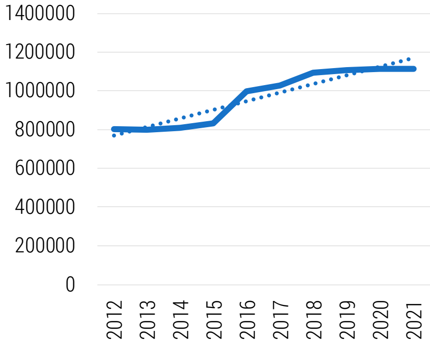

Figure 18. Protected areas 2012-2021 [annual, square kilometer, terrestrial protected area]

Source: authors' work based on Eurostat.

Analysis of the selected indicators of the economic area of climate security (Figures 3-8) indicates a decline in the effectiveness of energy policy, as well as declining energy efficiency in the countries of the EU. The index of energy balance, energy efficiency, as well as available energy sources is characterised by a decreasing trend line (the decrease between the first year of the analysis and the last year was 11.5%, 12.4%, and 8.2%, respectively). Freshwater resources and water intake are also characterised by a declining trend line; this indicator fell by 60% between the first and last years of the analysis. Of the selected economic indicators, only those for the share of Renewable Energy Sources (up 34 percentage points) and agricultural factor income per annual work unit (up 36.65 percentage points) increased.

The desired direction of change is shown by the indicators selected for the social area, i.e., the number of years of healthy life (an increase of 2.6 years between the first and last years of analysis, Figure 9), the population with access to public water (an increase of 2.3 percentage points, Figure 10), the number of people at risk of poverty (a decrease of 2.3 percentage points, Figure 12), and the number of years of life lost due to exposure to PM2.5 particulate matter (a decrease of 30%, Figure 13). The indicator aimed at determining food security, i.e., crop production, is characterised by a declining trend line; a decrease of 4.5% was recorded (Figure 11).

Indicators of the environmental area show increases in resource productivity (up by 18.7%, Figure 16) and protected areas (up 28%, Figure 18). Despite the decreasing trend line for water exploitation, in the last year of the analysis, the indicator increases between the first and last years by 0.39 percentage points (Figure 17). Figure 15 illustrates the declining trend line for environmental investment (down 0.1 percentage points).

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The analysis reveals the weakest areas of climate security. In the case of the economic area, it is energy and the endangered energy security of the EU countries, as well as water security and the declining freshwater resource, with increasing water exploitation and pressure on renewable freshwater resources resulting from the demand for water. Data for the energy sector is available through 2020. Thus, events in 2022, i.e., Russia's attack on Ukraine, will exacerbate the declining trend. Despite rising agricultural income, crop production is declining, which may threaten food security. Declining spending on environmental investment means a decline in the measures taken in this area, which may ultimately threaten environmental security. Resuming the above considerations, we can answer the question posed earlier and conclude that climate security is under serious threat.

Conclusions

Climate change is causing a number of consequences in environmental, social, and economic dimensions. The literature addresses this issue in a very broad way. Qualitatively new to these considerations is the issue of ensuring climate security. This paper addresses this issue, filling a gap in the literature by identifying the links between climate change and security in the context of the climate crisis, then de-emphasizing the concept of climate security (due to the limited number of texts containing a definition of the issue), and finally answering the question of when we can talk about climate security and whether we can determine the level of climate security based on properly selected indicators. A selection of indicators was made, which were classified into three groups. The limitation of the analysis is mainly the de-selectivity of the indicators, which is mainly due to the lack of data availability and their low quality. Analysis of the data for selected indicators showed weak areas in each of the areas mentioned and allowed us to conclude that climate security is at risk. Based on the argument thus made, there is a need for detailed development of climate security indicators based on the criterion of vulnerability to climate change.

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The contribution of the authors

Conception – D. Michalak (50%), P. Szyja (50%).

Literature review – D. Michalak (50%), P. Szyja (50%).

Acquisition of data – D. Michalak (50%), P. Szyja (50%).

Analysis and interpretation of data – D. Michalak (50%), P. Szyja (50%).

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ENVIRONMENTAL POLICY AND MANAGEMENT

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FORECASTING THE DEVELOPMENT OF ELECTRICITY FROM RENEWABLE ENERGY SOURCES IN POLAND AGAINST THE BACKGROUND OF THE EUROPEAN UNION COUNTRIES

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ABSTRACT: One of the key elements in the development of countries is energy stability particularly related to ensuring, among other things, continuity of power supply. The European Commission is trying to protect the security of energy supply by introducing internal conditions regarding the share of RES in everyday life. The aim of this article is to forecast the share of RES in electricity production for all the EU member states. The study covers the years 1985-2021, the research is based on two models: the autoregressive (AR) model and the Holt-Winters model, whereas the prediction values were determined for the period 2022-2030. The prediction values showed that Denmark, as the only one of the community countries, may turn out to be self-sufficient in terms of electricity production from RES already at the turn of 2026-2027. In the case of Poland, there is a high probability that the projected RES share for 2030 will not be met. Potentially, for most EU countries, the energy produced from RES will satisfy at least 50% of electricity demand by 2030. A projection of the chances of meeting the commitments presented in the National Energy and Climate Plans regarding the share of renewable energy sources in electricity production in the EU member states in 2030 indicates that they will not be met in most EU economies.

KEYWORDS: electricity, forecasting, RES in the European Union, Holt-Winters model, autoregressive model

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Introduction

Electricity is vital to the productive sector and society's life (Sokulski et al., 2022, p. 1). The electricity supply determines productivity and economic development, as well as influences the well-being of society (Raugei, 2020, p. 1). Electricity is one of the most important energy carriers for several production processes and therefore has a significant impact on resource consumption. Furthermore, the generation of electricity by fossil fuel power plants produces harmful waste and greenhouse gases, which have a devastating impact on environmental well-being (Stanek et al., 2018, p. 87). The increase in electricity demand and dwindling fossil fuel resources determine the need to work towards the decarbonisation of electricity systems (Sokulski et al., 2022, p. 1), which should contribute to the reduction of greenhouse gas emissions into the atmosphere (Mac Domhnaill & Ryan, 2020, p. 954).

Global concerns about the climate crisis have prompted efforts to shift to renewable electricity (Yang & Kim, 2020, p. 1). Due to its specificity, renewable electricity plays a key role in reducing the mentioned emissions, mainly because of its potential to be used in other consumption sectors. The decarbonisation of the energy supply makes electrification of both heating and transport necessary. Such a shift would make no economic sense if electricity generation itself relied on fossil fuels (Mac Domhnaill & Ryan, 2020, p. 963). Renewable sources used for electricity generation include solar, hydro, wind, geothermal, tidal and biomass (Sokulski et al., 2022, p. 3).

Russia's military invasion of Ukraine has caused serious consequences for the functioning of the global energy system. Energy prices have risen, and energy security has been disturbed, which has clearly highlighted the EU's excessive dependence on imports of conventional energy sources from Russia (European Commission, 2022). In this situation, the European Commission reacted quickly and announced the REPowerEU strategy in March 2022. This strategy aims to reduce Russian gas imports by two-thirds by the end of 2022 and entirely by 2030. It considers three key aspects: ensuring gas and oil imports from outside Russia, improving energy efficiency and increasing the use of renewable energy (IRENA, 2022). In the current situation of the energy crisis, RES can support the energy security of individual EU Member States. The use of natural resources for the environment and energy is a matter of sustainable development of each country (Kurzak, 2010); therefore, renewable energy will play a vital role in the future development of EU countries. In addition, ensuring clean and accessible power for all is a focus of the UN Sustainable Development Goal 7 (Tomala et al., 2021). The European Union uses selected indicators to verify progress in the implementation of all sustainable development goals (Pleśniarska, 2019), including the aforemen-

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tioned seventh goal – the most related to the development of RES. For this reason, the authors of this study decided to analyse an indispensable element of the functioning of society, which is electricity, the future of which is based on renewable energy sources.

The aim of the article is an attempt at preliminary verification of the accepted declarations of European Union Member States regarding the share of RES in electricity production. A literature query on the subject indicates a high interest in research on the development of RES in the European Union. In the context of this organisation, works forecasting the share of RES in energy consumption in its member states were presented (e.g. Manowska, 2021; Utkucan, 2021; Firlej & Stanuch, 2022). Several studies concerned the forecast of the share of RES in electricity consumption in individual EU countries (Table 1). To the knowledge of the authors, no research has been carried out so far forecasting the possibility of fulfilling national declarations in terms of the share of RES in electricity production (included in the national energy and climate plans) separately by each EU member state until 2030. This study fills this research gap in the literature. In order to determine the possibility of shaping this share, the study was based on two predictive models: the autoregressive model and the Holt-Winters model. On their basis, predictive values for the years 2022-2030 were determined.

In connection with the implementation of the research objective, a research methodology was formulated, including successive steps, which were illustrated in Figure 1.

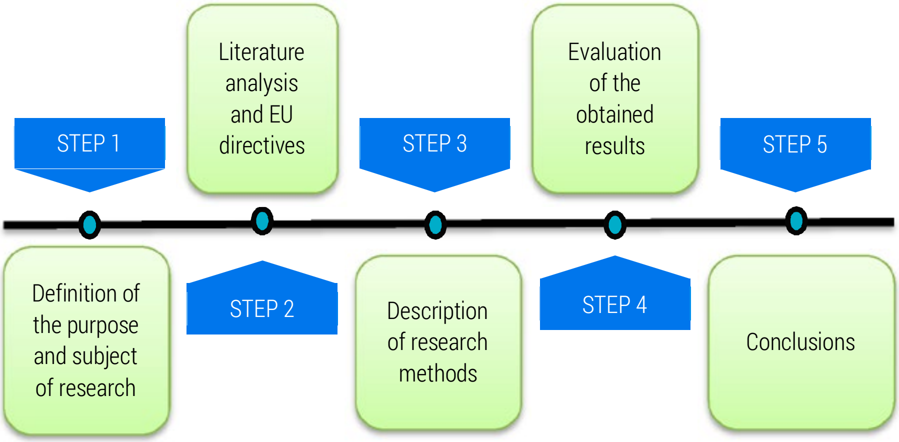

Figure 1. Research methodology

Electricity and renewable energy sources in the energy policy of the European Union

The European Union aims to create a secure, sustainable, competitive energy market. It is pointed out that electricity from renewable energy sources (RES-E) has a special role to play in shaping this market, the development of which is the cornerstone of the energy policy pursued in the EU member states (De Jonghe et al., 2009, p. 4743). Electricity from renewable sources plays an important role in the context of ensuring the energy security of the European Union, which is of particular importance in an era of war conflict in Ukraine and reduced cooperation in the supply of energy resources from Russia. A greater diversity of energy sources enhances energy security, which comes from considering the security of supply and demand for energy, as well as monitoring energy shortages and surpluses (Blum & Legey, 2012, p. 1986). However, ensuring a sustainable energy supply is subject to a number of requirements, such as climate compatibility, reasonable exploitation of sources, low investment risk, equity and social acceptance. At the same time, the deployment of renewable energy sources should support innovation and growth of the economy and generate new jobs (Paska & Surma, 2014, p. 293).

In 2018. European Union adopted the Renewable Energy Directive (Directive (EU) 2018/2001) (European Parliament and Council, 2018). It targets that at least 32% of the final energy consumed in the European Union should be obtained from renewable sources by 2030. Furthermore, the 2018 Regulation (EU) 2018/1999 of the European Parliament and of the Council on Governance of the Energy Union and Climate Action obliged member states to submit National Energy and Climate Plans (NEEAPs) to the European Commission by the end of 2019. These plans should set out ways to meet targets in the area of greenhouse gas emissions reductions, which should contribute to the European Union's goal of consuming 32% of energy from renewable sources in the global energy mix by 2030 (Institute for Sustainable Development Foundation, 2020). The aforementioned documents also indicate, among other things, declarations regarding the share of renewable sources in electricity production.

In 2019, the European Commission presented the 'Clean Energy for All Europeans' package (European Commission, 2019), which contains a number of proposals for the energy development strategy in the European Union. The crucial and strategic importance of electricity for the future of the European Union was identified. Furthermore, electricity is projected to supply more than half of the European Union's energy needs by 2050. At the same time, renewable energy sources and nuclear energy are expected to account for 80% of the European Union's electricity generation (Matuszewska-Janica, 2021, p. 3).

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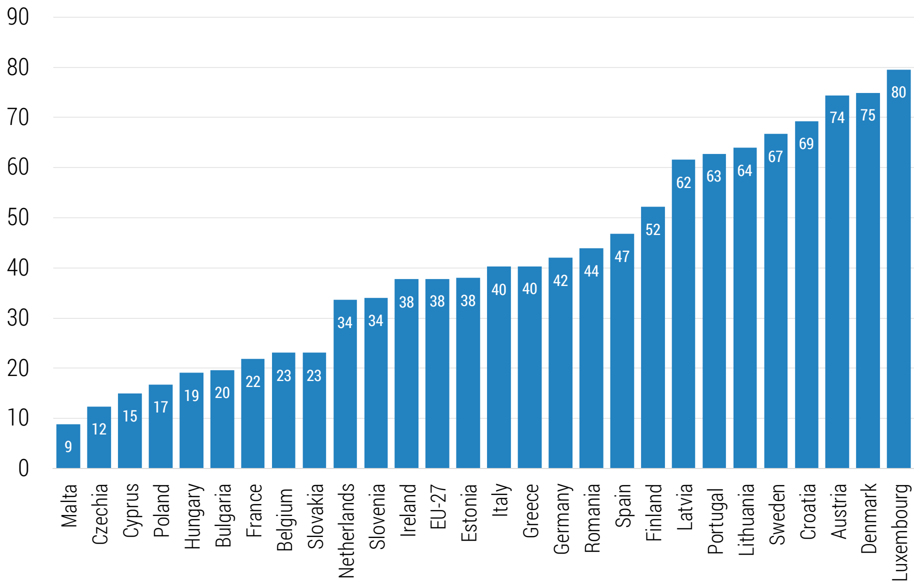

Figure 2. Electricity from renewables in 2021 [%]

Source: authors' work based on Our World in Data, 2022a.

The European Union member states are characterised by varying levels of renewable electricity generation, with an average of 38% in 2021 for the EU-27. Compared to the aforementioned average, a higher level of electricity generation from renewable energy sources was recorded in 15 member countries, of which as many as 10 were EU-15 economies. 12 member countries were below the EU-27 average, with the EU-10 dominating (8 economies) (Figure 2).

Forecasting the development of electricity from renewable sources is a tool for assessing the chances of achieving the targets proposed in the European Union documents and national energy and climate plans and enabling their possible adjustment. In the literature, one can find studies that include renewable electricity development forecasts that have been carried out for selected areas using various econometric methods. Among studies on the selected EU (and other) member states, one can point to those containing forecasts of, among others, the share of renewable energy sources in total electricity production in France, Germany, Spain, Turkey and the UK by 2021 (Şahin et al., 2021); the share of renewables in electricity consumption in the European Union and Romania by 2030 (Mehedintu et al., 2021). Multidimensional projections of the development of renewable energy sources that also include their share of electricity consumption in Poland (IRENA, 2015) and the European Union (IRENA, 2018) in 2030 are presented in the International Renewable Energy Agency reports.

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Table 1. Selected forecasts for electricity from renewable sources

Author	Publication year	Projected years	Forecast	Method	Results
International Renewable Energy Agency (IRENA)	2015	2020, 2030	Share of renewables in electricity consumption	Original program IRENA's REmap	The share of RES in electricity generation (for Poland) in the case of REmap for 2020 was supposed to be 27% and for 2030 it was estimated at 37.7%.
International Renewable Energy Agency (IRENA)	2018	2030	Share of renewables in electricity consumption	Original program IRENA's REmap	The overall share of renewable energy generation in the power sector could reach 50% by 2030.
Şahin, U., Ballı, S., & Chen, Y.	2021	From the third quarter of 2020 to the end of 2021	Share of renewable energy sources in total electricity production	Time regression model and autoregression model	All forecasting models estimate an increase in the share of annual renewable electricity production in total electricity production compared to previous years for the analyzed countries.
Mehedintu, A., Soava, G., Sterpu, M., & Grecu, E.	2021	2030	Share of renewables in electricity consumption	Genetic algorithm based-seasonal fractional nonlinear grey Bernoulli model	All four evolution scenarios for the share of renewable energy consumption in electricity prefigures values close to the desired one 50% in UE.

Source: authors' work based on: IRENA, 2015; IRENA, 2018; Mehedintu et al., 2021; Şahin et al., 2021.

Research methods

The study focused on trying to predict the share of renewable energy sources (RES) in electricity production in the European Union Member States. The study uses the statistical data resources of the electronic scientific publication "Our World in Data" (Our World in Data, 2022b), where the period of study is based on the data from 1985 to 2021. For seven countries, the period of study is shorter, due to the lack of statistical data that may result, inter alia, from the collapse of the USSR, and they are as follows: Estonia since 1995, Croatia 1991, Cyprus 2003, Latvia, Lithuania, Slovenia 1990 and Malta 2012. In order to obtain the prediction values of RES share in electricity production, two models were used: the Holt-Winters model and the autoregressive (AR) model. The Holt-Winters model allows forecasts to be obtained in additive and multiplicative variants and allows variables with seasonal variations to be forecast in terms of complete time series. The forecasting process is defined by the following formulas (Szumksta-Zawadzka & Zawadzki, 2014):

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Additive variance:

$$m_t = \alpha(Y_t - C_{t-m}) + (1-\alpha)m_{t-1}, \tag{1}$$

$$S_t = \beta(m_t - m_{t-1}) + (1-\beta)S_{t-1}, \tag{2}$$

$$C_t = \gamma(Y_t - m_t) + (1-\gamma)C_{t-p}. \tag{3}$$

Multiplicative variant:

$$m_t = \frac{\alpha Y_t}{C_{t-m}} + (1-\alpha)(m_{t-1} + S_{t-1}), \tag{4}$$

$$S_t = \beta(m_t - m_{t-1}) + (1-\beta)S_{t-1}, \tag{5}$$

$$C_t = \frac{\gamma Y_t}{m_t} + (1-\gamma)C_{t-m}. \tag{6}$$

where:
m_t – average value assessment,
S_t – trend directional parameter,
C_t – seasonality assessment,
p – the length of the periodic fluctuation period,
α, β, γ – fluctuation and trend smoothing constants – value in the range [0,1].

The predictor in the additive model is expressed by the formula:

$$Y_t = m_{t_0} + S_{t_0}h + C_{t_{0-m+h}}. \tag{7}$$

In terms of the multiplicative model:

$$Y_t = (m_{t_0} + S_{t_0}h)C_{t_{0-m+h}}. \tag{8}$$

The initial forecast values are calculated as follows:

$$m_1 = \frac{1}{r}\sum_{i=1}^{r} y_i, \tag{9}$$

$$S_1 = \frac{1}{r}\sum_{i=r}^{2r} y_i - \frac{1}{r}\sum_{i=1}^{r} y_i. \tag{10}$$

In the case of the additive model:

$$C_m = y_m - \bar{y}. \tag{11}$$

And for the multiplicative model:

$$C_m = \frac{y_m}{\bar{y}}. \tag{12}$$

For the second model, the autoregressive (AR) model, which is the tool used to model and predict ex post variables in time series analysis, the equation is as follows (Autoregressive models, 2021):

$$X_n = \alpha_0 + \alpha_1 X_{n-1} + \alpha_2 X_{n-2} + \cdots + \alpha_k X_{n-k} + \varepsilon, \tag{13}$$

where:
X_n – the value of the time series,
$\alpha_0, \alpha_1, \ldots, \alpha_k$ – ratios,
ε – white noise,
k – row of autoregression.

The root mean square error (RMSE) was used to estimate the statistical error of the prediction results, which tends to better reveal differences in the model performance (Chai & Draxler, 2014, p. 1249):

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}, \tag{14}$$

where:
n – number of samples,
e – model errors.

The European Commission is introducing a number of directives aimed at achieving climate neutrality set for 2050. In terms of achieving the set headline target, there is a need to adopt and implement several smaller targets, such as the already realised share of at least 20% of energy from RES in the gross final energy consumption of EU member states by 2020. In the 2018 directive, the European Commission set a target of 32% RES share in gross final energy production for the entire EU community to be met by 2030. (Directive (EU) 2018/2001). In the case of offshore wind energy, the European Commission has published a specific strategy which aims to increase offshore electricity production from 12 GW in 2020 to min. 60 GW by 2030 and 300 GW by 2050 on an EU-wide basis (European Commission (EU) COM(2020)/741 final). The adopted strategies were the object of interest of the authors of the study, who, based on up-to-date statistical data, attempted to check whether the defined targets are feasible to achieve for all the countries of the European Union Community. The following research hypotheses were therefore adopted:

H1: The share of RES in electricity production for 2030 will be at least 50% for most EU countries.

H2: The majority of EU countries will fulfil their commitments to the defined targets for the share of RES in electricity production by 2030.

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Results of the research

Table 2 shows the prediction values for the all European Union countries for the years 2022-2030 using two forecasting models: Holt-Winters and AR. In the case of Malta, the values are only for the first 4 years, which results from the small amount of statistical data made available by the "Our World in Data" database since 2012.

Table 2. Forecast values of RES share in electricity production for 2022-2030 (with a step of 2 years), according to the Holt-Winters model (H-W) and the autoregression model (AR) [data in %]

COUNTRY	YEAR										RMSE	
	2022		2024		2026		2028		2030			
	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR
Austria	78.95	73.83	80.45	71.00	77.92	71.60	75.10	70.89	79.87	70.00	5.65	3.18
Belgium	25.51	23.46	27.31	24.66	29.00	30.13	30.82	33.90	32.31	35.21	1.88	1.60
Bulgaria	19.62	18.36	20.80	21.91	20.45	23.97	22.75	25.65	23.29	27.94	2.07	1.97
Croatia	77.29	69.61	76.19	66.34	68.99	68.43	78.77	68.09	77.89	67.83	8.05	6.55
Cyprus	10.19	17.50	11.69	20.71	13.44	22.05	15.99	25.00	21.55	30.51	2.71	0.74
Czech Republic	13.25	12.59	14.14	13.06	13.35	13.53	13.99	13.99	14.73	14.44	0.80	0.67
Denmark	82.31	88.58	89.78	95.44	98.31	108.10	106.51	121.05	108.85	133.93	5.25	3.73
Estonia	49.95	43.49	57.65	69.99	65.43	74.87	73.13	122.75	81.04	197.85	5.39	2.05
Finland	50.86	52.34	52.73	55.86	56.58	59.33	59.20	62.97	63.86	66.99	5.23	3.61
France	25.48	23.42	29.22	24.47	27.03	25.57	27.74	26.79	29.23	28.16	3.46	1.54
Germany	44.92	47.62	49.23	51.08	52.92	54.79	57.50	62.62	61.55	77.29	1.62	0.83
Greece	44.69	41.04	47.55	48.60	47.53	56.94	54.54	66.71	60.25	78.47	3.05	2.62
Hungary	21.18	22.47	25.26	29.79	29.41	37.21	33.40	44.55	37.39	53.28	1.05	0.76
Ireland	41.80	42.43	47.13	50.96	50.17	58.21	53.45	68.04	54.50	78.98	2.68	2.29
Italy	43.18	40.22	42.45	41.09	38.92	41.72	43.64	42.38	44.92	43.02	3.22	2.69
Latvia	63.02	59.36	56.56	55.17	68.34	59.92	58.97	55.95	69.73	59.66	9.62	5.07
Lithuania	50.01	55.41	51.62	57.57	54.23	60.87	55.93	63.88	61.10	66.90	6.38	5.21
Luxembourg	51.35	50.75	57.20	56.83	61.90	62.78	70.07	62.70	78.76	58.93	3.77	2.53
Malta	12.34	16.97	15.11	20.20	N/A	N/A	N/A	N/A	N/A	N/A	6.50	7.71
Netherlands	39.64	38.37	55.11	51.61	70.47	56.67	84.75	52.70	99.91	49.61	1.43	1.08
Poland	17.51	17.47	18.81	18.77	19.93	19.45	21.43	20.37	22.82	21.37	0.96	0.77

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COUNTRY	YEAR										RMSE	
	2022		2024		2026		2028		2030			
	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR	H-W	AR
Portugal	70.05	60.42	81.70	59.60	71.26	57.96	78.21	59.40	81.25	61.02	16.05	8.29
Romania	42.00	43.10	45.11	42.88	47.77	43.12	56.27	43.31	55.48	43.36	7.40	3.77
Slovakia	20.77	23.40	17.29	22.89	16.57	22.37	16.25	22.37	17.41	22.31	4.16	1.88
Slovenia	32.06	32.36	31.12	32.66	32.42	33.67	36.94	33.56	36.35	34.39	3.22	2.66
Spain	48.06	45.27	51.63	49.32	49.43	52.65	54.18	55.60	59.14	59.03	6.44	4.09
Sweden	62.34	66.02	68.72	63.47	70.95	68.61	72.73	70.39	75.53	70.97	6.27	4.22
UE – 27	38.86	39.20	41.85	43.15	42.27	47.49	45.80	52.34	48.25	57.90	1.62	1.10

Source: authors' work based on "Our World in Data" data.

An interesting example turns out to be Denmark, where models have shown that by 2026/2028 all electricity could come from RES. Wind power, whose energy transition has a very long history dating back to the mid-1970s, may prove to be the key to achieving such an outcome (Ruszel, 2016). The construction of a power hub in the North Sea, which is estimated to be able to cover the consumption of 10 million European households (Danish Ministry of Climate, Energy and Utilities, 2021), may prove to be the key to achieving self-sufficient electricity production from RES. It should be emphasized, that already on 7 July 2015, wind power was able to generate 140% of the daily electricity demand for the country (The Guardian, 2015), where the excess production was exported to neighbouring countries. The projected self-sufficiency of electricity from RES was also shown in the case of Estonia, where the AR model for 2028 showed a result of more than 122%, but compared to the Holt-Winters model (whose projection exceeds only 73%), it can be concluded that it is significantly overestimated. Similar results were obtained in the case of the Netherlands, where the initial values deviate slightly, while each subsequent year of prediction determines a larger distance, particularly evident in the case of 2030. The development of RES in the case of the Netherlands should be attributed to technological developments, where only in recent years the capacity of offshore wind turbines has been increased, allowing a capacity increase over 2019-2020 from 4500 MW to 6600 MW (Trade, 2021). For Romania, the AR forecast showed a stable share of RES in electricity production, whereas a similar forecast was presented by another team of researchers (Mehadintu et al., 2021) only in terms of the share of RES in final energy consumption. The largest forecast error was obtained in the case of Portugal, where the Holt-Winters model identified forecast deviations from the data in the range of more than 16 pp, and in the case of the autoregressive model, this value takes on more than 8 pp. This statistical error is due to the fitting of the model to the input data, which are characterised by particular fluctuations in the range of successive closely consecutive years. Irregular decreases and increases determine the troublesome fit of the model to further forecasts, where from 1985 to 2005 a significant downward trend was visible, while from 2006 onwards there was a rebound compounding the increase in the RES share in electricity production (Figure 3).

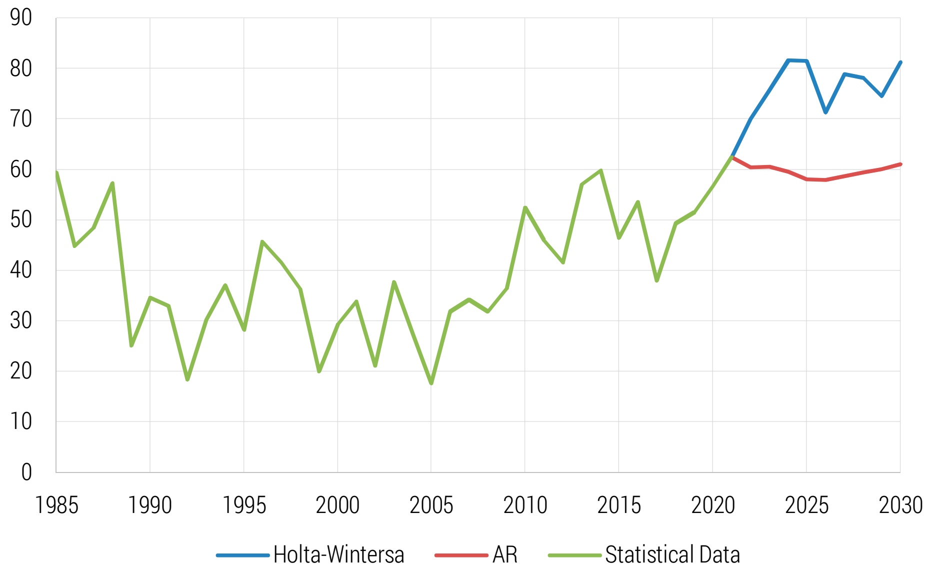

Figure 3. Current (Statistical Data) and projected values (Holt-Winters, AR) of the share of RES in electricity production [%] for Portugal

Source: authors' work based on "Our World in Data" data.

In the case of Poland (Figure 4), very similar results were obtained for both models, where the prediction value was about 17.47% for 2022 and increased to 21.37% in terms of the autoregression model or 22.82% in terms of the Holt-Winters model for 2030. This means, therefore, that the projected dynamics of change will develop at an average annual rate of about 0.5% which makes the obtained value of change too small to ensure that the projections for the share of RES in electricity production, where it was projected to increase to about 27% in terms of 2030, are met. (Ministry of Energy, 2019, p. 21), and was later raised to 32% (Ministry of State Assets, 2019, p. 31). Similar findings for Poland regarding the share of RES in electricity generation have been identified by the International Renewable Energy Agency (IRENA), which predicts a share of 19.2% in 2030 (IRENA, 2015, p.15), but noting that the final consumption of energy from renewable

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sources will increase significantly. This may be confirmed by the increase in the contracted capacity under corporate green energy purchase agreements, which increased in Europe by about 60% for 2020 compared to 2019 (CIRE. PL, 2022). According to the development plan of the Polish Power Grid, in 2030 half of the energy in Poland will come from renewable energy (PSE, 2022), but such optimistic forecasts will probably not be metThe document focuses on the potential of building wind farms, and the current legal status regarding, among others to the construction of wind farms (the so-called wind farm act) strictly defines the distances of wind farms to residential development – the 10H rule, which inhibits the development of wind energy (Dawid, 2017; Talarek et al., 2022). It should also be emphasised that the depicted prediction results in Figure 4 show a very characteristic alignment over time, and the standard statistical error obtained for both models did not exceed a value of 1, which may suggest very accurate prediction values. The high dynamics of RES participation in Poland, which has been evident since around 2007, could have been achieved thanks to the introduction of the so-called green certificates (Pająk & Mazurkiewicz, 2014). Unfortunately, the development of RES in Poland faces some difficulties, including those resulting from geographical conditions, which translate into the efficiency of photovoltaic panels resulting from the degree of insolation (Buriak, 2014).

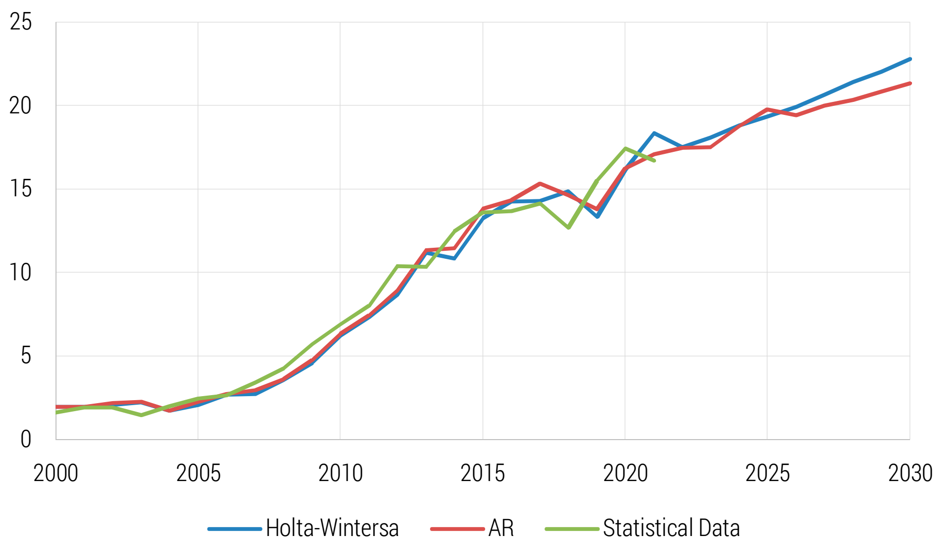

Figure 4. Current (Statistical Data) and projected values (Holt-Winters, AR) of RES share in electricity production [%] for Poland

Source: own study based on "Our World in Data" data.

In the case of Romania, very similar research results were obtained by another team of researchers, who made a forecast of the RES share within the framework of sustainable development of the EU and Romania. In their study, they showed that the average values of the EU share for 2030 oscillate between 48.33% and 52.10% which is in line with the results of the study for the Holt-Winters model in particular (Mehedintu et al., 2021, p. 18). Similarly, for Romania, where the forecast values are more divergent, with estimates ranging from 40.43% to 64.24%. The dynamic growth of the RES share in the case of the Holt-Winters model may be covered by future investments by the Italian energy group Enel, which envisages the construction of more than a dozen wind and photovoltaic farms cooperating with energy storage in the country (300economy, 2022). Romania expects the share of RES in the electricity segment to increase to 43.6% in 2025. (Romania-Insider, 2018), which would have coverage, especially in the AR prediction model of this study.

Referring therefore to the research hypothesis set, where the prediction values allow us to estimate that 15 Community countries will obtain min. 50% of their electricity from RES, which is expected to represent about 55% of all the EU member states, the authors of the study are therefore inclined to confirm the truth of the hypothesis (H1). It should be taken into account that energy efficiency can improve the pursuit of zero-energy economic growth, which aims at the security of energy supply, or the sustainable development of the entire European Community (Miciuła, 2015, p. 63).

In order to verify hypothesis 2 (H2), a summary statement setting out the national energy and climate plans up to 2030 was used as a framework for climate target and policy (Windeurope, 2022). A comparison of the results of the study with the development of EU Member State plans is presented in Table 3.

Table 3. Comparison of projection results of RES share in electricity production against adopted plans for EU member states

COUNTRY	DECLARATION [%]	FORECAST [%]		ACHIEVING THE GOAL		
		H-W	AR	H-W	AR	$\bar{x}$
Austria	100.00	79.87	70.00	no	no	no
Belgium	40.40	32.31	35.21	no	no	no
Bulgaria	30.33	23.29	27.94	no	no	no
Croatia	63.80	77.89	67.83	yes	yes	yes
Cyprus	40.00	21.55	30.51	no	no	no
Czech Republic	16.90	14.73	14.44	no	no	no
Denmark	100.00	108.85	133.93	yes	yes	yes

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COUNTRY	DECLARATION [%]	FORECAST [%]		ACHIEVING THE GOAL		
		H-W	AR	H-W	AR	$\bar{x}$
Estonia	40.00	81.04	197.85	yes	yes	yes
Finland	53.00	63.86	66.99	yes	yes	yes
France	40.00	29.23	28.16	no	no	no
Germany	65.00	61.55	77.29	no	yes	yes
Greece	61.00	60.25	78.47	no	yes	yes
Hungary	21.30	37.39	53.28	yes	yes	yes
Ireland	70.00	54.50	78.98	no	yes	no
Italy	55.00	44.92	43.02	no	no	no
Latvia	60.00	69.73	59.66	yes	no	yes
Lithuania	45.00	61.10	66.90	yes	yes	yes
Luxembourg	33.60	78.76	58.93	yes	yes	yes
Malta	N/A	N/A	N/A	N/A	N/A	N/A
Netherlands	70.00	99.91	49.61	yes	no	yes
Poland	32.00	22.82	21.37	no	no	no
Portugal	80.00	81.25	61.02	yes	no	no
Romania	49.40	55.48	43.36	yes	no	yes
Slovakia	27.30	17.41	22.31	no	no	no
Slovenia	43.00	36.35	34.39	no	no	no
Spain	74.00	59.14	59.03	no	no	no
Sweden	82.60	75.53	70.97	no	no	no
Total goal fulfillment				42%	38%	44%

Source: authors' work based on "Our World in Data" data and "Windeurope.pl".

The summary of Table 3 shows that, in the case of the Holt-Winters forecast, 11 EU countries will meet their commitments to the adopted targets, while for the autoregressive model the result is lower and concerns 10 countries. When considering the forecast results in terms of both models, where the prediction values for both models were averaged (, it was found that fulfilment applies to 12 countries. The situation of Malta also remains specific, where no comparison is defined, due to the lack of a target (only a final target is available) as well as the lack of prediction results for 2030. Therefore, the results for this country are not included in the final table summary. Accepting a summary of the fulfilment of the adopted targets from a general point of view, the Holt-Winters model indicated that 42% of the EU community countries would meet the targets; for the autoregressive model it would be 38%, and for the two-method alternative 44%. Relating the results obtained to hypothesis 2 (H2), the authors of the study found it to be disproved by determining that the majority of the EU countries will not meet the set targets for the share of RES in electricity production. Although the two-model alternative meets the assumptions made in hypothesis 2, the results of a single model and their arithmetic mean do not allow this to be concluded. The authors encourage further verification of the hypothesis by using other research methods in this regard.

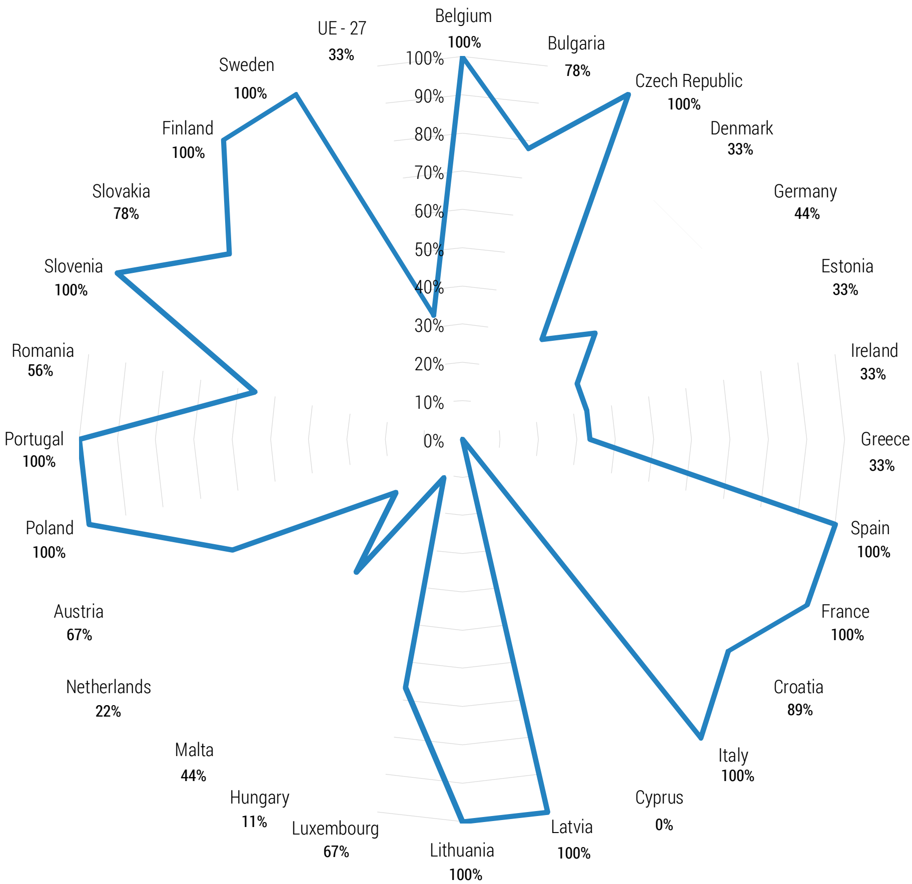

Figure 5. The results of prediction coverage for 2022-2030, where the values of one model fall within the prediction of the other

Figure 5 illustrates the results of the overlap between the prediction values for 2022-2030 for the two models with the resulting forecast error. The figure takes the aggregated values for the specified time interval. When detailed, it is 70% of the predicted values overlap (within the error), while the missing 30% diverges in terms of the specific forecast year. The most similar model predictions are for the next few years (up to 2025), with each subsequent year having a higher error. In the comparison, Cyprus stands out significantly, with a coverage value of 0%, which may be due to the specifics of the input data, which were available from 2004 onwards, and the models' estimates of initial values differed significantly from each other. It should also be noted that in the case of Malta, the values apply to only 4 projections – up to 2025. An overall summary of the prediction coverage allowed us to conclude that, for a given statistical period, it is the forecasts for 13 countries are almost 100% and concern countries such as Belgium, Bulgaria, Spain, France, Italy, Lithuania, Latvia, Malta, Poland, Portugal, Slovenia, Finland and Sweden.

Conclusions

The European Union, faced with limited resources of conventional energy sources and their destructive impact on the well-being of the natural environment, as well as threats to energy security, is forced to seek alternative solutions. An attempt to respond to the challenges of meeting the energy needs of Community member states is to implement renewable energy sources, which are an integral part of the energy policy pursued in the European Union. The different operating conditions of individual EU economies imply a different level of utilisation of renewable sources for electricity production, as well as different national obligations in this aspect in the 2030 perspective.

The research presented in this study fills the research gap in the dimension of forecasting the development of electricity production from renewable sources by 2030 and authorises the construction of the following research conclusions:

1. In the case of Poland, it is projected that there is a high probability of not meeting the commitment for the percentage of electricity generated from renewable sources in 2030.
2. Most EU member states (Austria, Croatia, Denmark, Estonia, Finland, Germany, Greece, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Portugal, Spain, and Sweden) are projected to generate more than 50% of their electricity from renewable energy sources in 2030.
3. The projection of the chances of meeting the commitments outlined in the National Energy and Climate Plans for the share of renewable energy sources in electricity generation in EU member states in 2030 indicates that they will not be met in most EU economies. The commitments are projected to be met only in: Croatia, Denmark, Estonia, Finland, Germany, Greece, Hungary, Latvia, Lithuania, Luxembourg, Netherlands, and Romania.

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4. The projection of both electricity production of more than 50% from renewable energy sources and meeting national commitments for the share of renewable energy sources in electricity production in 2030 is successful for 10 countries (Croatia, Denmark, Estonia, Finland, Germany, Greece, Latvia, Lithuania, Luxembourg, Netherlands). For these countries, this will have a particularly significant impact on the reduction of harmful gas emissions due to the reduction of fossil fuel combustion, as well as increasing the degree of energy security through partial or total independence from the supply of conventional energy sources from outside the European Union.
5. The wide variation in the projected increase in the share of renewable energy sources in electricity production in EU countries may be due to various reasons. For example, geographical location favourable to the development of renewable energy sources (e.g. Denmark) or technological development (e.g. the Netherlands).
6. In the conditions of disturbed energy security and unfavourable energy prices, EU Member States should strengthen actions to implement the declarations contained in the national plans for energy and climate. The unfavourable geopolitical situation requires not only the fulfilment of these declarations but also their verification in the direction of even greater expectations regarding the use of renewable sources for electricity production.

Like all studies, this one also has some limitations. Firstly, the study used two different forecasting models, which implied different results. Secondly, in the case of Malta, the availability of statistical data was limited.

The future of renewable energy sources is an extremely valuable and cognitively interesting topic and may prompt further studies that may address, for example, the determinants of its use for electricity generation.

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The contribution of the authors

Conceptualization, K.A.F.; methodology, K.A.F. and M.S.; obtaining data, M.S.; literature review, K.A.F.; estimation of models, M.S.; analysis and interpretation of data, M.S.; writing – original draft preparation, K.A.F. and M.S.; project administration, K.A.F.; funding acquisition, K.A.F. and M.S. All authors have read and agreed to the published version of the manuscript.

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CHANGE IN NATURAL GAS UTILISATION IN THE CONTEXT OF SUSTAINABLE ENERGY MANAGEMENT IN POLAND

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ABSTRACT: The energy transformation requires a change in the structure of the energy used. The article aims to determine the role of natural gas as a transition fuel in the European Union and Poland's energy policy in the context of the promoted sustainable development policy. In the analysed documents presenting visions of energy policy, a differentiated approach to the effects of using natural gas is observed. The possible effects of using natural gas in Poland's energy mix were analysed and evaluated. The study used the method of research document analysis. Six attributes of sustainable energy management and the relations between them were considered. The main results are as follows: 1. natural gas as an energy carrier does not fulfil the requirements of sustainable energy management, 2. from the point of view of utilisation effects, the use of natural gas for power generation purposes is better than using other fossil fuels, 3. in RES and nuclear energy development conditions, using natural gas for power generation will decrease, which should bring positive results for sustainable energy management. The main conclusion is the energy transition is mainly driven by political factors. Therefore, the energy carriers' sustainable management issue shall be approached comprehensively.

KEYWORDS: natural gas, sustainability, transformation, policy

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Introduction

Climate change observed since 2015 has been progressing faster than expected. Actions taken globally have become directed towards the set objectives. The war between Russia and Ukraine and decisions to resign from the Russian energy media supplies can accelerate the abandoning of fossil fuels. The European Union countries will take measures to ensure climate neutrality by 2050.

The development plans of the global and European economies assume resigning from fossil fuels. It applies primarily to abandoning the use of coal. Fossil fuels dominate the energy mix in Poland, and their change in the last decade has progressed very slowly. In 2020 in Poland, 45% of the energy consumed was generated based on coal (35% hard coal and 5% of lignite), 26% from oil, 17% from natural gas and only 7% was derived from renewable sources (including 5% from wood biomass) (Ministerstwo Klimatu i Środowiska, 2021). Between 2011 and 2020, coal's share decreased by eight percentage points, the share of oil and natural gas increased (by 3 and 5 percentage points, respectively), while the share of wood remained unchanged. Poland was ranked the sixth country globally for the emissivity of primary energy consumption (2.85 t CO_2/toe) (Dusiło, 2022).

Natural gas causes lower emissions of greenhouse gases in energy generation processes. That is why the Polish government's documents concerning energy transition stipulate that natural gas shall replace coal temporarily until low- or zero-carbon, economically efficient and effective energy supply methods become widespread.

The research problem applies to whether the transition of energy and climate policies relating to natural gas considers compliance with sustainable development. The paper aims to determine the role of natural gas in the EU's and Poland's energy policies as a transition fuel in the context of the promoted sustainable development policy. The issue is presented in the example of Poland because the Polish economy's adaptation to the EU's requirements can be particularly challenging due to the specific and coal-dominated structure of the energy mix.

Literature overview

The term "sustainable energy" has gained popularity owing to MacKay's book (2008). It was used in the Sustainable Energy for All Initiative (UN Global Compact and Accenture, 2011). The Initiative was aimed to accelerate actions for three essential objectives that should be attained by 2030: ensur-

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ing access to energy for all, significant improvement of energy efficiency and increasing the share of renewable energy in the global energy mix (UN Global Compact and Accenture, 2011).

Patterson (2009) defines sustainable power engineering as the consumption and supply of energy that satisfies parents' needs without compromising children's capacity to meet their needs. The International Energy Agency (IEA, 2005), operating under the OECD, defines sustainable power engineering as long-lasting power engineering with a global range, guaranteeing environmental protection, economic effectiveness, competitiveness, and social responsibility. Graczyk (2019) states that Patterson's definition does not reflect the essence of the notion, as it applies selectively to sustainable development aspects, emphasising the inter-generation fairness principle. Even though the IEA's definition emphasises development durability, it does not consider all the determinants of sustainable development dimensions. Graczyk systematises the notion that sustainable power engineering is the sustainable economy's sector where sustainable energy development occurs and sustainable energy policy is executed. Even if the economy cannot be considered generally sustainable, its part where sustainable development orders are balanced and its objectives and rules are fulfilled can be regarded as sustainable and named a sustainable economy.

A balanced power (energy) system is vital to sustainable power engineering (Graczyk, 2019). A sustainable energy system should be based on a combination of renewable energy generation/acquisition, renewable transport of fuels, renewable heat, demand reduction, effective use and energy cogeneration (Mitchel, 2010).

The issue of sustainable development measurement was mentioned in international organisations' documentation and scientific papers. For example, in 2004, the IEA developed the Energy Development Index (EDI), which was used in a publication cycle called the World Energy Outlook 2004 (International Energy Agency, 2004). The Index was supposed to "improve the understanding of the contemporary power engineering's role in the economic and social development". It consisted of three components: commercial energy consumption per capita, the share of commercial energy in the total energy consumption by end-users and the share of the population with access to electricity.

Scientific literature proposes various systems of power engineering sustainable development indices. The proposals represent two streams. One involves creating a set of indices that can comprehensively characterise sustainable development problems in the energy management area. Tsai (2010) analysed a system of Taiwan's sustainable development indices concerning energy. Streimikiene and Sivickas (2008) proposed applying an index framework to analyse the EU's policy on sustainable energy and presented a case

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study of using this policy tool in the Baltic countries. García-Álvarez et al. (2016) identified a comprehensive set of energy sustainability indices for the EU-15 member states. They grouped the indices according to three dimensions, including the security of energy supplies, competitive energy market and environmental protection. Gunnarsdóttir et al. (2020) presented an extensive literature overview analysing fifty-seven sets of indices for which various construction methods of complex indices are used.

Another stream in scientific literature covers the proposals of sustainable energy development comprehensive indicators for the power engineering sector or its selected elements, including but not limited to renewable energy. A publication authored by Iddrisu and Bhattachaaryya (2011) provided an impulse for this type of study; the authors evaluated the versatility of the existing indices and proposed an index focusing on determining the level of intra- and inter-generation needs' balance. Cucchiella et al. (2017) constructed a sustainable energy and environment index for the EU-28 using a multi-criteria analysis. Kauertz et al. (2020) developed an index describing the environmental aspects of the energy transition in Germany. A study by Ligus and Peternek of 2021 is worthy of special attention; the authors proposed a comprehensive system of indices related to sustainable development in the EU-28 energy policy, grouped into social, economic and environmental dimensions (Ligus & Peternek, 2021).

Only a few papers concern the assessment of natural gas management sustainability. The papers concentrate on environmental hazards along the entire natural gas supply chain. The studies published focus primarily on the first part of the chain and refer to the impact of search and mining on water resources and the emission of greenhouse gases. Crow et al. (2019) estimated the potential impact of greenhouse gas emissions from natural gas production, combining the estimated CO_2 and methane emissions with a dynamic, techno-economic gas supply model. Xu and Lin (2019) focused on the relationship between natural gas consumption and CO_2 emission downstream. Mac Kinnon et al. (2018) investigated natural gas emissions in the context of greenhouse gas emission reduction and air quality improvement. Fu et al. (2021) systematically reviewed the whole lifecycle of the natural gas industry chain. They focused on identifying such environmental aspects as air pollution, land use, water consumption, environmental impact and the greenhouse effect.

Lower emissions were the premise for creating concepts, scenarios and programmes of gradual coal replacement with natural gas until low-carbon technologies become widespread and stable. Such an approach can be noticed in the International Energy Agency's studies (IEA, 2019) or in the European Commission's Communication entitled "Clean Planet for All" of November 2018. Blazquez et al. (2019) pointed out that politics drive the

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energy transition. This feature is missing in the previous energy transitions, where the market played a key role. That is why every country can have its own energy transition path, depending on the decarbonisation policies.

In 2021, it was believed that the role of natural gas in the energy transition greatly depended on the transition course and on how the industry and public policies would handle the issue of methane leaks at the stage of gas mining and transport, as well as on the availability of other clean energy sources. The European energy policy experts treated the increase in gas prices in 2021 as a step in the right direction, i.e. towards limiting the use of fossil fuels. They assumed that higher prices of natural gas would discourage the use of gas for household heating and encourage house owners to invest in electric heat pumps, which would reduce CO_2 emissions in the EU even further and lessen the reliance on fossil fuels. The political narrative matters, highlighting actions for the climate and emphasising the significance of adapting to the future variability of prices and supporting customers during the energy transition. The specificity of such a narrative depends on various country-specific factors, e.g. availability and investments in renewable energy sources and/or the country's plans concerning future dependence on nuclear energy (Wong et al., 2021).

The policy towards natural gas changed in 2022 after significant price increases and actions were taken to reduce the import of natural gas from Russia. The change in the approach to natural gas was included synthetically in the IEA's report: "The traditional arguments in favour of natural gas have focused on its role as a reliable partner for the clean energy transition and its ability to step in to fill the gap left by declining coal and oil. … The depth and intensity of today's crisis have led to concerns about the future cost and availability of natural gas, which have damaged confidence in its reliability and put a major dent in the idea of it serving as a transition fuel. As a result, the era of rapid global growth in natural gas demand is drawing to a close" (IEA, 2019).

The literature review reveals that the issue of sustainable development in energy management was analysed primarily from the point of view of energy in general, without differentiating between the impact of individual energy carriers. The literature items on the sustainable management of natural gas focus on the environmental and climate issues related to the use of natural gas. Indicating the vital role of political factors in the decision about natural gas utilisation volume and method constitutes a significant aspect.

Therefore, there is a research gap concerning a comprehensive evaluation of the sustainable management of gas, exceeding the analyses of the natural gas supply chain or utilisation method. Because the place of gas in the energy mix has not been resolved yet, a question is justified if compliance with sustainable development is considered in the energy and climate policy

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transition in reference to natural gas. The research issue is whether using natural gas complies with the conditions of sustainable energy management.

Research methods

The European Union's intentions concerning economic transition were formulated in The European Green Deal (2019). The research method was developed while writing the monograph on sustainable energy management in the energy transition from the energy policy perspective (Graczyk et al., 2021). It was applied to the analysis of Poland's energy policy. Here the method is presented regarding the use of natural gas.

Following this concept, it can be assumed that sustainable development in energy management contributes to the durable improvement of life quality. An efficient and reliable sustainable energy system helps establish and strengthen social, economic and territorial cohesion. The dimensions typical for sustainable development are the social, economic and environmental ones. They apply to essential attributes of sustainable energy management (Graczyk et al., 2021):

- durable security of satisfying the energy needs,
- long-term economic effects of energy management, considering external costs,
- non-discriminating access to energy,
- energy generation/acquisition, processing and consumption safe for human health and the natural environment's balance,
- neutral impact on the natural environment – emissions limited to the level of pollution reduction and reception capacity,
- the scale of renewable resources uses enabling their renewal.

Relationships exist between these attributes. They are shown in Figure 1. The links and dependencies in the diagram refer to a positive interaction of the components in a long-term perspective.

The diagram above is the base for analysing energy and climate policy documents referring to natural gas formulated in Poland. The analysis applies to including these elements and considering the links between them. Poland was selected for the analysis because the energy transition starts with a stage that most European Union countries have already completed, i.e. the dominance of coal to satisfy energy needs. If such member states are ready to abandon fuel gases, it is an important signal for such countries as Poland that developing energy management with a higher share of natural gas might not be sustainable.

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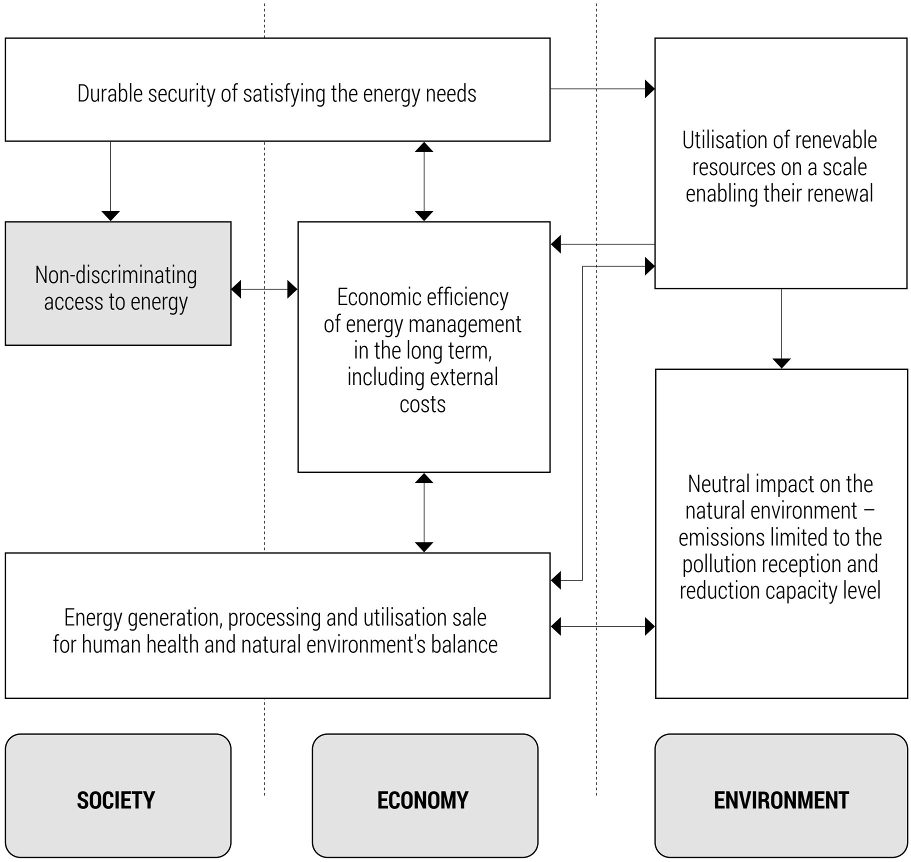

Figure 1. Attributes of sustainable energy management

Source: Graczyk et al., 2021.

This shall help assess if the transition of energy and climate policies in reference to natural gas takes into consideration compliance with sustainable energy management.

Observation of energy policy components relating to natural gas

The 2030 Energy Policy for Poland, effective in 2020 (Ministerstwo Gospodarki, 2009), prioritised "An increase in the security of fuel and energy supplies". *Reasonable and effective management of coal deposits in Poland* was highlighted as the energy policy's primary objective. It was pointed out that the *implementation of the coal supplies security policy posed a significant challenge in the analysed period due to fluctuations of the resource prices in the*

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global markets, the need for restructuring the sector and reducing the energy sector's environmental impact. Still, it was considered that *previous actions should be continued, especially those related to ensuring the sector's profitability and preventing the building-up of strategic resources of coal.* (Obwieszczenie, 2021). Strengthening Poland's position in the European market of natural gas was considered vital. To that end, necessary infrastructure shall be provided in order for the market to respond to the needs of new segments using this fuel and creating conditions to combine the gas and power sectors (Obwieszczenie, 2021).

The directions of the gas sector transition were indicated in another document called the National Plan for Energy and Climate in 2021-2030 (NPEC) (Ministerstwo Klimatu i Środowiska, 2019). Each member state had to present such a plan to the European Union, according to the regulation of the European Parliament and the Council (EU) No. 2018/1999 of 11 December 2018 on energy union management and climate actions. The document presents national objectives and actions to create a framework for Poland's fair transition towards a low-carbon economy. The role of natural gas in the process of reaching the zero-carbon economy status was described in the document in the context of implementing Poland's key climate and energy objectives by 2030; the objectives are divided into actions under five dimensions of energy union: emission reduction, energy efficiency and security, internal energy market, scientific research, innovation and competitiveness.

The significant objective of the Plan assumes reducing the share of hard coal and lignite in energy generation to 56-60% in 2030 and a further declining trend by 2040. The objective shall be attained through changes in the electricity generation sector, e.g. closing down the conventional, old generating units that do not fulfil environmental requirements on pollution emissions, implementing traditional high-performance technologies, gradual implementation of low- and zero-carbon technologies, including but not limited to renewable energy sources and nuclear energy. The important role of natural gas in this process was indicated; in Polish conditions, it has a vital role as it can temporarily become the fuel enabling energy transition. An increase in this fuel's significance was expected in power engineering as a support for renewable energy sources and in the district and individual heating and transport (as an alternative fuel, e.g. LNG or CNG). Investments in gas generation infrastructure were vital for balancing the national power grid because of the high technological flexibility of their operation.

The NPEC assumed the use of natural gas as fuel in cogeneration units. They shall replace old heat plants and cogeneration plants operating based on hard coal. After 2030 they shall also replace some currently operating gas-fired heat and power generating plants. The new gas-fired cogeneration units and gas and steam power plants were supposed to improve the reliability

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and flexibility of the national power grid. The necessary development of generation capacity based on gas sources was indicated, and in a long-term perspective, also the development of sources alternative to natural gas, e.g. biomethane, hydrogen and synthesis gas.

Polish Energy Policy by 2040 (PEP2040) is another vital document determining the direction of the Polish gas industry and identifying natural gas as the bridging fuel (Ministerstwo Klimatu i Środowiska, 2020). PEP2040 was the Polish government's response to the most significant challenges for the Polish energy sector in the upcoming decades in relation to the Paris Agreement provisions and the resulting European Union's climate and energy policy. It was supposed to determine the energy transition framework for Poland, considering the most significant assumption expressed in the European Green Deal – reaching climate neutrality by the member states by 2050. Natural gas was first mentioned as a bridging fuel in the energy transition in Poland. The extended gas capacity, in addition to the development of energy storage, was considered indispensable for balancing the operation of unstable renewable sources. They were supposed to support the reliable operation of the national power grid and hence the country's energy security.

The potential to increase the use of natural gas results from the development of district heating included in the PEP. The heating needs of all households shall be covered by district heating and zero- or low-carbon individual sources. Partial replacement of coal with natural gas in cogeneration plants shall help achieve the objective of greenhouse gas emissions reduction and air quality improvement due to the emissivity of natural gas lower than that of coal (Ministerstwo Klimatu i Środowiska, 2020). In order to ensure the status of bridging fuel for natural gas, PEP2040 highlights the need to extend gas infrastructure and diversify the directions and sources of supplies because the demand for natural gas will be covered mainly with imported resources.

State Resource Policy (PSP2050), adopted in March 2022 (Uchwała, 2022), identifies natural resources critical for the national economy, considering their individual specificity. When resources critical for the European Union are additionally accounted for, the Policy highlights the resources indispensable for implementing the set national and European economic objectives. According to PSP2050, in relation to the valid climate policy and quality parameters of natural gas, it was expected to gain significance in the Polish energy mix, especially in power engineering (because of its significant role in the power grid balancing) and district heating (cogeneration). Natural gas was considered a transition fuel, which is why it shall be gradually replaced by more environmentally friendly technologies, depending on their availability.

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The Russian invasion of Ukraine and the EU's adoption of successive action packages to reduce the import of energy carriers from Russia accelerated the actions to reduce the use of gas in the European Union. In March 2022, the European Commission published the REPowerEU communication containing a plan to stop importing fossil fuel energy from Russia long before 2030 (European Commission, 2022a). In the new reality, gas consumption in the EU will decrease sooner, limiting the role of gas as a transition fuel (European Commission, 2022a). It is expected that owing to the full implementation of the REPowerEU Plan, high prices, solutions alternative to gas (sustainable biomethane production, renewable hydrogen), further use of renewable energy sources and demand-related structural measures such as energy efficiency, the EU's demand for gas will decrease faster than expected under the "Fit for 55" package.

The arrangements above, made on the European Union's level, forced the Polish government to update the PEP2040's pillars and objectives at the end of March 2022 (Ministerstwo Klimatu i Środowiska, 2022). Polish government shall strive for a gradual reduction of the economy's dependence on natural gas. However, in the perspective of the upcoming decades, the security of supplies to customers must be guaranteed. Furthermore, measures shall be taken to replace the demand for natural gas with decarbonised gases and other proven fuels. It was announced that due to a change in the geopolitical situation and gas market unpredictability, gas-fired units would maintain their significant role in regulating the power grid's operation, but the utilisation level of the existing coal-fired units might increase in a mid-term perspective. As a result of these changes, the investment plans concerning new gas capacities shall be verified for production economics. In the heating sector, the conversion rate of coal-fired units into gas-fired ones shall depend on the availability of resources. Simultaneously, the possibilities of using other energy sources shall be investigated, making a real alternative to using natural gas for heating purposes. It can be observed that Poland intends to follow the direction of complying with the REPowerEU plan provisions related to reducing natural gas utilisation. Still, the announced maintenance of coal-fired units in the power and heating sector contradicts the "Fit for 55" intentions.

A similar inconsequence can be noticed in the determination of gas prices. The document presenting the assumptions for the PEP 2040 updates emphasises that the natural gas market in Poland requires continued liberalisation to release the last group of regulated users, i.e. households, from the tariff obligation for fuel gas sales. In the second half of the year, the government took contradictory measures – the stock exchange obligation was cancelled and setting the maximum gas price for households was announced.

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It was justified with customer protection against an excessive increase in fuel gas supply costs.

An analysis of the policy changes presented above in relation to natural gas accentuates some attributes of sustainable energy management. One of them is the strive to reduce greenhouse gas emissions. This policy direction results from the obligation adopted all over the European Union to reduce greenhouse gas emissions. Such an effect is achieved by replacing coal with natural gas. Still, it does not ensure fulfilling the essential premise of neutral impact on the natural environment. On the contrary, it would require reducing natural gas combustion emissions to the level of pollution reception and reduction capacity.

Reduced emissions apply directly to using natural gas instead of hard coal. Methane and carbon dioxide emissions also occur at the stage of mining and transport to the destination sites. They enhance the greenhouse effect, which has a global dimension. Additionally, the local natural environment's balance is disturbed, especially in the mining areas. Therefore it can be confirmed that utilising natural gas meets the requirements of energy generation/acquisition, processing and utilisation safe for human health and the natural environment's balance.

Natural gas is a non-renewable energy carrier. Even its limited use exhausts the resources, though at a slower rate. If the use of natural gas enables supplying the energy that renewable sources cannot supply, it prevents excessive use of renewable energy on a scale that makes their renewal impossible. It applies particularly to the renewable energy carriers which use biological material. The Polish potential of biomethane production amounts to 7,8 bln m^3 a year (Dach, 2022), and its use could reach 50% in 2030. Then, at least 7 per cent of the fuel mix will belong to advanced biofuels and biocomponents. A further increase in the use of biological materials will encounter agricultural production barriers and consequently reduce the plants' potential to absorb carbon dioxide. Using natural gas protects against such a situation and meets the requirement of sustainable energy management, not in reference to gas resources but in maintaining proper plant production.

The two previously mentioned aspects (excessive use of natural gas and excessive use of renewable energy sources) affect the level of energy generation/acquisition external costs. From a long-term perspective, generating renewable energy volumes adequate to the renewal capacity does not mean eliminating external costs completely. Their occurrence can result from a competitive use of resources. The optimisation of external costs level is determined during their internalisation. A state is responsible for the process, which is driven by the premise of maximising social well-being in a long-term perspective when making appropriate decisions about the energy mix structure.

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The problem applies to natural gas utilisation as well. External costs are among the components of gas management economic efficiency balance in a long-term perspective. Economically efficient energy management should ensure energy availability at acceptable costs and prices for all users. Subsidising energy generation or supporting the use of its specific forms makes no sense in the long term. A relevant market mechanism should ensure energy availability for all users. Appropriately designed infrastructure and organisational forms of providing access to energy play a crucial role, especially for supplies conditioned by the network development.

Investment costs matter a lot for efficiency assessment. Eliminating natural gas from the Polish economy by 2030 would require investment expenditures on the infrastructure of electrical energy transmission and distribution – amounting to 200-300 bn PLN, and on generation capacity – amounting to 150-200 bn PLN. The expenditures will not have to be incurred if natural gas is temporarily left and then a smooth transition to its green and low-carbon substitutes takes place; such a situation would require "standard" modernisation activities and investing in gas infrastructure (Izba Gospodarcza Gazownictwa & Instytut Studiów Energetycznych, 2022).

The possibility of energy storage plays a vital role in developing sustainable energy management. Due to its land topography, Poland has limited possibilities of building pumped-storage power plants. Current technologies of electrical energy storage in batteries are extremely costly. Underground natural gas storages located in salt caverns are a much cheaper solution.

Using gas in households is the area of adapting to the EU climate and energy policy objectives that is most challenging for economic efficiency. In Poland, households use ca. 7.1 M devices fired with solid fuels and ca. 4.1 M devices fired with fuel gas. Sticking to natural gas and replacing all coal-fired stoves with gas-fired ones means ca. 160 bn PLN investment in the whole country. An alternative solution involving shifting to electric heating is much more expensive. The cheapest option of selecting electric heaters means a cost of ca. 300 bn PLN for households; still, it significantly increases the current heating costs. The other option, assuming that half of the households shift to electric heaters and the other half chooses heat pumps, means that the investment outlays for households will reach 530 M PLN, while selecting the most energy-efficient solution (heat pumps) entails the cost of ca. 860 bn PLN (Izba Gospodarcza Gazownictwa & Instytut Studiów Energetycznych, 2022). Such a change in the heating method with no public support will be financially inaccessible for most households.

Replacing coal combustion in households would help reduce external costs caused by a high concentration level of particulate matter and benzo(a) pyrene in the atmospheric layer closest to the earth. The problem occurs primarily in winter and in most cities. Individual coal furnaces and wood com-

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bustion in households are the primary sources of such pollution emissions. According to the World Health Organisation's study, PM 2.5 is often used as the leading indicator of air pollution. Pollution exerts the most significant impact on long-term health effects. The estimated costs, presented in the Report, of premature deaths caused by air pollution in 2010 for Poland amounted to 101.8 bn USD (WHO, 2015). It is estimated that PM 2.5 emissions generate the external cost in Poland, amounting to 18.2 bn EUR/year, i.e. 76.4 bn PLN a year (Lachman & Mirowski, 2017).

In May 2008, the European Commission adopted Directive 2008/50/EC on „ambient air quality and cleaner air for Europe", setting new air quality objectives concerning PM 2.5. The effects of achieving the objectives set out in the Directive were estimated for all member states in 2020. If all countries achieved their objectives, whereby the emission reduction costs amounted to ca. 0.01% of GDP, on the EU scale, the GDP would rise by 1.28% between 2010 and 2020. Poland would achieve the highest GDP increase – by 2.9% – as a country with the highest particulate matter pollution level (Dechezleprêtre et al., 2020). The estimate indicates the high economic efficiency of reducing coal combustion emissions.

Investments in gas infrastructure development, which could potentially limit discrimination, suffer the risk of premature decarbonisation of the sector. In the gas sector, the currently designed infrastructure will be built within the next ten years and then used for 20-30 years, which means that gas investments planned nowadays can significantly deteriorate their profitability if the market starts to shrink considerably around 2035 and the executed projects will still be in the operating stage (Moskwik et al., 2020).

The problem occurred in relation to households as well. The current share of gas in the whole structure of household heat sources amounts to 24%. In 2018, the "Clean Air" Priority Programme was activated in Poland in collaboration with the World Bank under the European Commission's initiative called the "Catching-Up Regions". The Programme is aimed to reduce air pollution by improving the energy efficiency of heating systems in single-family buildings and the thermal efficiency improvement of buildings. Over 3 M residential premises/buildings with improved energy efficiency and 3 M of inefficient heat sources replaced were the indicators of reaching the programme's objectives. The programme's implementation period was set for 2018-2029, but the commitments (meant as signing the agreements) were supposed to be made by 31 December 2027, and funds were spent by 30 September 2029. A thermal efficiency improvement tax relief was an additional funding source for the tasks under the programme. The programme's budget was drawn up as 103.3 bn PLN. As of 1 October 2021, three years into the Programme implementation, the total amount of the agreements concluded with the beneficiaries constituted only 4.1% of the PPCP budget. The

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substantive effects of the plan after a quarter of its execution period passed include 66,343 ineffective heat sources (old generation boilers) replaced with low-carbon ones in existing buildings (2.2% of the plan), reducing the emission of particulate matter with diameters lower than 10 micrometres (0.8% of the plan); reducing benzo(a)pyrene emission (ca. 1.4% of the plan); and reducing carbon dioxide emissions – 4.1% of the plan (NIK, 2022).

The data above suggest that despite public financial support, a limited number of users are ready to replace coal-fired furnaces with gas-fired ones as heating sources. The estimated annual heating cost for a 150 m^2 area property for a family of four and WT 2088 energy standard building (i.e. with low thermal insulation efficiency), considering the tariffs effective in Q3 2022 (Zieniewicz, 2022), will amount to ca. 5,710 PLN a year for natural gas heating. This heating season, the cost of heating with 84% and 64% efficiency boilers will amount to 11,570 PLN and 15,130 PLN, respectively, because of an increase in coal prices. In 2023, owing to a protection programme for gas users, the cost of gas heating will increase by ca. 40%, while the following year when the protection programme expires, the cost of heating will likely increase four-fold compared to 2022 and exceed 22,000 PLN. The cost of coal and wood heating should not rise by more than 40% compared to 2022. The heating cost ratios will be unfavourable for households using fuel gas, and the scale of disadvantage is expected to increase further in the future. Moreover, it will contribute to the discrimination scale in the access to fuel gas utilisation. It results from the fact that the disposable monthly income of a household, which amounted to ca. 2,100 PLN in 2021, would have to be spent almost entirely on fuel gas purchases in 2024. It means no funds left for paying the loans taken (even with preferential terms) for replacing a coal-fired heating system with a gas-fired one.

The prices of CO_2 emissions are another component influencing the cost-effectiveness of using natural gas. If coal was utterly replaced with gas in the Polish economy, it would reduce monthly CO_2 emissions by ca. 106 M tons, i.e. by ca. one-third (Izba Gospodarcza Gazownictwa & Instytut Studiów Energetycznych, 2022). Taking the EUA and EUAA licence trading prices on the spot ICE and EEX and forward market ("ICE EUA Futures Dec" for 2022-2028) of 70-100 EUR per tonne between 30 September and 31 October 2022, the value of the annual expenditure reduction for emission licences can be estimated as 33-47 bn PLN. Future prices should not be lower despite the proposals to extend the pool of licences submitted by some countries (including Poland) in the second half of 2022. The high prices of licences are supposed to stimulate the European countries' shift from a coal-based economy. Still, they will place a burden on natural gas users.

The estimations above indicate the potentially high economic efficiency of eradicating environmental pollution owing to eliminating coal from energy

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generation processes. Replacing coal with natural gas greatly depends on other attributes of sustainable energy management, including but not limited to durable security of satisfying energy needs (gas supply security) and related gas prices.

Due to the need to ensure continuous supplies after resigning from Russian gas in March 2022, the European Commission and member states established an EU energy platform for the voluntary joint purchase of gas, LNG and hydrogen (The EU's energy platform will fulfil three functions supporting the common purchase of gas (European Commission, 2022a):

- joining and structuring the demand,
- optimised and transparent use of infrastructure to transport, store and transmit gas, maximising the security of supplies and complementary storage,
- international actions: combined international actions focus on establishing a long-term collaboration framework with trusted partners through binding or non-binding agreements supporting the purchase of gas and hydrogen and the development of clean energy projects, fully leveraging on the EU's joint power.

The activities seem to be able to ensure continuous resource supplies in the short term. Still, they must go along with developing gas transmission and storage infrastructure. The infrastructure will be useful in the distant future for transporting and storing green and low-carbon gases (most likely also hydrogen, after modernising the equipment).

The gas price is the factor influencing the assessment of natural gas utilisation efficiency. The attempt made in 2022 to determine a dynamic price ceiling for imported gas in the EU did not lead to a consensus among the member states. There were proposals to establish the maximum dynamic price ceiling for transactions in the Title Transfer Facility (TTF) gas hub in the Netherlands, which sets the reference price for gas trade in Europe. It is a temporary solution until developing a new price index supplementing the TTF that will better reflect the increasing significance of liquid natural gas in the EU market. A request was made to fill at least 15% of gas storages in the EU through common purchases before spring 2023. Another request concerned a mandatory solidarity mechanism of sharing gas between the EU countries during the crisis.

The activities mentioned above improve the security of natural gas supplies to the EU countries at the expected prices. They do not essentially mean secure supplies to the users in the member states. Technical conditions causing discriminating access to energy can affect sustainable gas management development. In Europe, and so in Poland, the gas network development level and access to connection points (LPG terminals, gas pipelines) vary locally. It can jeopardise the transition of district heating systems where coal

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constitutes 73 per cent of the combusted fuel mix, while the share of gas amounts only to 9 per cent.

Research results

Summarising the analyses above, fulfilling the attributes of sustainable energy management can be evaluated through natural gas utilisation in Poland.

Natural gas does not ensure durable security of satisfying the energy needs because:

- at the current consumption level, natural gas resources from conventional and non-conventional sources will expire within a dozen or so years,
- there is a permanent risk of political instability in most mining regions of the world, aggravating the risk of supply discontinuation,
- gas storage possibilities are limited,
- increasing LNG supplies can be a costly alternative to transport in gas pipelines.

Energy generation, processing and utilisation safe for human health and the natural environment's balance are not fulfilled because:

- numerous environmental hazards occur at the gas mining stage,
- gas mining, transmission, and storage processes are uncontrolled emission sources,
- unstable political conditions and terrorist attack hazards pose the risk of damage to gas networks and storage.

It shall be highlighted that emissivity and other environmental impact forms of using gas for energy generation are lower than for other fossil fuels. Moreover, at the stage of gas utilisation, known and proven technologies are employed, meaning a high-security level.

The requirement of neutral impact on the natural environment would be fulfilled if emissions were limited to the pollution reception and reduction capacity level. Still, in reality, the impact of gas mining, transmission and storage highly exceeds their neutralisation capacity.

The prerequisite of using renewable resources on a scale enabling their renewal is not fulfilled because natural gas is not a renewable resource. Nonetheless:

- gas infrastructure can be used to support the development of renewable energy sources – biomethane and hydrogen,
- gas can be used for hydrogen generation in the conditions of limited availability of supplies from wind and photovoltaic units.

The evaluation of meeting the requirement of energy management economic efficiency in the long term, considering external costs, involves the following aspects:

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- natural gas utilisation enables shifting from coal and reducing emissions on condition that energy generation costs are comparable (including external costs internalised in the charges for carbon dioxide and methane emissions),
- due to international agreements on reducing climate effects, new gas projects cannot rely on external funding,
- the economic risk for the development of gas infrastructure and systems of gas utilisation for energy generation increases at the rising gas prices,
- for many entities, including but not limited to households, natural gas is a component of choice when adapting to the increasing prices of heating, which also applies to saving measures or changing the heating technology; at adequately designed economic control instruments, the economic balance can stimulate the entities to reduce their environmental impact,
- with the growing use of renewable energy sources with unstable energy generation efficiency, depending on weather conditions, reserving the energy in the generating units fired with natural gas ensures higher power grid flexibility.

Fulfilling the requirement of non-discriminating access to energy is limited for natural gas due to the following:

- limitations in the transmission and distribution network extension,
- limited flow capacity of interconnectors and limited gas storage volumes,
- relatively high costs of shifting to gas and the risk of relatively high operating costs after such adaptation.

On the other hand, LNG can become an alternative for entities in regions with no access to the power grid.

The general evaluation, based on the analysis and assessment of fulfilling partial attributes by natural gas management, leads to three conclusions:

- natural gas as an energy carrier does not meet the requirements of sustainable energy management,
- from the application point of view, natural gas utilisation is better than the use of other fossil fuels,
- in the RES and nuclear energy technology development, gas utilisation will decrease, which should bring positive effects for sustainable energy management.

Discussion/Limitation and future research

The documents developed by the European Union bodies – the European Commission, Council and Parliament, determine the approach and perspective for all member states' activities. They should significantly affect the solutions adopted in each country. Still, it does not mean that the directions and

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implementation rate of the solutions will be identical. The solutions proposed on the EU level can provide grounds for a discussion, based on Poland's example, the analysis and assessment of natural gas significance for sustainable energy management.

The approach to accepting natural gas as a component of sustainable energy management was discussed and amended under the so-called taxonomy. It is a common name for the Regulation of the European Parliament and the Council (EU) No. 2020/852 of 18 June 2022 on establishing the framework facilitating sustainable investments and amending Regulation (EU) No. 2019/2088. It is a collection of pan-European rules and technical indicators reflecting the EU's climate objectives and ambitions for each economic area. It is also the EU's response to climate change and an opportunity to increase the scale of sustainable investments.

Covering the gas energy sector with the EU taxonomy raised some controversies mainly because of its role in the EU's economic decarbonisation. From the beginning of the works on the EU taxonomy, the issue of atoms and gas was discussed. The essence of the issue was presented by Jones et al. (2020), who claimed that the whole existing energy generation based on natural gas could not be considered compliant with the taxonomy because the related activities have to contribute significantly to achieving the objectives of the Paris Agreement and not only to maintaining the status quo. The authors also pointed out that under many circumstances and in the transition period by 2050, natural gas would help reduce greenhouse gas emissions when compared, e.g. with coal, and will still play an essential role as a support for growing RES. They pointed out that too strict taxonomy criteria (e.g. mandatory use of zero-carbon options by 2050) or following an approach "universal for all" in reference to gas can render results contrary to the expected ones because such zero-carbon options are currently technologically immature or so expensive that even if they were described as a standard in the EU Taxonomy, they would not be used anyway, and the standard approach will not reflect the reality of the EU's electrical energy market. Therefore, the EU taxonomy shall orient investments towards the most sustainable option available, and the actual circumstances occurring during the investment implementation must be considered.

Commission Delegated Regulation (2021) is the first delegated act issued based on the EU taxonomy. It embraces types of operations, including detailed technical criteria which can be considered sustainable from the perspective of climate change and adaptation to climate change. The Regulation specifies superior conditions that the given business activity shall fulfil to be qualified as environmentally sustainable. Gas energy-related operations were initially not included in Regulation No. 2021/2139.

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In February 2022, a decision was made to include natural gas in the EU taxonomy but under some conditions. The draft was formally adopted on 9 March 2022 (Commission Delegated Regulation, 2022). It was justified by the fact that the EU taxonomy covers not only climate-neutral and renewable investments but also business operations that can enable shifting to a sustainable energy system under strict conditions and in a limited time. They are activities for which there are no alternative low-carbon solutions feasible technologically and economically, but they support the transition to a climate-neutral economy, alleviate climate change, comply with the EU's objectives and do not jeopardise the implementation of low-carbon solutions. The inclusion of gas into the taxonomy will help accelerate the transition from solid or liquid fossil fuels, including coal, towards a climate-neutral future.

The following investment types were considered sustainable:

- electrical energy generation from gas fossil fuels,
- high-performance heat/cool and energy generation from gas fossil fuels,
- heat/cool generation from gas fossil fuels in an efficient heating and cooling system.

All types of operations mentioned above are transient by nature. It is worth noting that according to the proposed delegated act, the objects under which the aforementioned actions are carried out should be designed and constructed to use renewable and/or low-carbon fuel gas. The transition to full use of renewable and/or low-carbon fuel gas should occur by 31 December 2035.

The reasons for the change in the EU's natural gas policy were diagnosed in the middle of 2022. Russia's attack on Ukraine provided an additional impulse to discuss the role of gas in reaching climate neutrality by 2050. In order to adhere to the Paris Agreement objective of 1.5°C, unlimited use of fossil gas would have to end much earlier – by 2035. The EU's current policy entails a risk of prolonged dependence on fossil gas rather than striving for alternative solutions, particularly in the heating sector. In response to Russia's war against Ukraine, the EU forces a wave of new fossil gas import projects, many of which will probably turn out unnecessary considering the decreasing gas demand in the EU. Decision-makers should be more active in developing an approach to an immediate withdrawal from the use of fossil gases, simultaneously building a sustainable, zero-carbon power grid (Schwarzkopf, 2022).

In the next three decades, the gas industry will be under intense pressure from public opinion and the EU's carbon dioxide emissions reduction and elimination regulations. According to critics, natural gas is not the right solution to reach the EU's climate neutrality despite lower emissivity than coal. Those who criticise the validity of fossil fuel utilisation as a source of negative climate changes in power engineering, transport and other sectors of the

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economy do not perceive the technological necessity to use natural gas in controlling power systems ensuring stable operation of other power systems, including the national grid.

Concluding, it can be stated that ambiguous policy defining the role of natural gas in energy and climate policy results from considering selected aspects of this energy carrier management. Such an approach typically focuses on one aspect. Initially, it was about limiting the emissivity from gas combustion for energy generation, followed by energy security issues. The ambiguity of the "sustainable energy" term in the EU's policy seems critical. It can be noticed in the European Commission's communication stating that transition to green energy is the only way to simultaneously ensure sustainable, secure and affordable energy worldwide (European Commission, 2022b). Energy sustainability was treated separately against security and affordability attributes, which essentially belong to sustainable energy management.

Therefore, an attempt should be made to thoroughly analyse gas's role in sustainable energy management. It seems purposeful to refer the evaluations not only to other fossil fuels whose consumption can be reduced owing to gas utilisation. The evaluations shall also include the issue of making energy management sustainable through the use of hydrogen or biomethane. It should answer whether maintaining natural gas in the energy mix created through the energy policy of the European Union and each member state will be favourable for sustainable energy management in a long-term perspective. Such an answer seems pivotal for Poland and other countries that can "leap" in their energy management development from the management stage dominated by fossil fuels to the power generation stage based on renewable energy sources. Then, it might turn out that entering the stage of a "transition" increases in the gas share in the energy mix, which can last a dozen or so years, is unnecessary.

Conclusions

The research issue is whether the energy and climate policy transition in reference to natural gas takes into account compliance with sustainable energy management. The issue is of particular significance for Poland, where the broad use of natural gas is perceived as a solution for improving energy management efficiency and reducing air pollution emissions.

Based on the analysis and evaluation of natural gas management fulfilling the criteria of sustainable energy management's partial attributes, the following conclusions were formulated:

- natural gas as an energy carrier does not fulfil the requirements of sustainable energy management,
- from the point of view of utilisation effects, the use of natural gas for power generation purposes is better than using other fossil fuels,
- in RES and nuclear energy development conditions, using natural gas for power generation will decrease, which should bring positive results for sustainable energy management.

Energy transition in recent years has been triggered by factors other than the previous transition stages – shifting from renewable energy to coal and then to oil, gas and atom. They were mainly caused by economic and market factors. Using new energy generation forms caused more negative effects, including environmental pollution, greenhouse effect aggravation and more compromised security of energy supplies. The risk of resource exhaustion and adverse effects of the growing prices of resources were identified from a long-term perspective.

Although the article is theoretical, substantive evidence supporting the result and conclusions is reflected in the announced changes in energy policy. They indicate the need to abandon natural gas in a faster perspective than previously assumed.

The current energy transition is mainly driven by political factors. The EU's gas policy underwent a kind of evolution. Since 2015, it has emphasised the need to reduce the greenhouse effect. Natural gas was supposed to be used temporarily to enable shifting away from coal. Still, the progress in the development of renewable energy sources and the need to reduce supplies of energy carriers from Russia first resulted in perceiving natural gas as inadequate for the energy mix, but then some methods of its utilisation were considered compliant with the taxonomy criteria. It means treating natural gas as sustainable from the perspective of climate change and adaptation to climate change.

The deliberations presented in the article indicate the need for a comprehensive approach to the sustainable management of energy carriers. On the one hand, it means simultaneously considering many attributes of such management. On the other hand, the effects of the solutions proposed in the energy policy shall be analysed in a broader sustainability context, covering the use of other energy carriers in the long term.

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RELATION OF CO_2 EMISSION ALLOWANCE PRICES AND ELECTRICITY PRICES IN POLAND IN 2013-2020

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ABSTRACT: This paper investigates the relation between the prices of CO_2 emission allowances in the EU ETS (Emission Trading System) and wholesale prices of electricity in Poland. Linear regression models were used to assess carbon price pass-through rate to wholesale electricity prices during the entire III phase of ETS (2013-2020). It has been found that the entire cost of CO_2 emission allowances was included in the wholesale electricity price. As expected, the peak transmission parameter is higher than the off-peak one. Nevertheless, the difference is small and statistically insignificant. Hence the model does not allow for any far-reaching conclusions in this regard. Results show that electricity producers were able to pass the entire emission-related costs to the customers, which might raise a question of whether EU ETS is an effective tool to give sufficient incentives to decarbonise electricity production.

KEYWORDS: carbon price pass-through, electricity prices, CO_2 prices, emission Trading System

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Introduction

Emission Trading System

Emission Trading System, established in 2005, is the main tool of EU climate policy, aiming at decarbonisation of the given sectors of the economy, i.a. electricity production. It is a so-called cap-and-trade system, where a fixed volume of emissions is set, and participating companies need to cover their emissions with allowances. The total amount of the allowances in the system decreases over time, which (*ceteris paribus*) leads to an increase in their price. This, in turn, should give obliged entities an incentive to reduce emissions, as then they would need to buy fewer allowances or could sell their possessed allowances on the market.

The cost of CO_2 emission allowances is an additional production cost for electricity producers, and its amount depends on the price of carbon credits, which varies over time and on the technology of energy production, which determines the level of emissions.

Transferring the emission costs to end consumers

The producers may partially or fully transfer the additional production costs to energy consumers. From the point of view of the system objective, which is reducing greenhouse gas emissions, it is important to determine what part of this additional cost is borne by the purchasers. That is because if energy producers can transfer all or most of the cost of CO_2 emissions to the consumers, then they have no incentives to invest in low-emission technologies, and thus the goal of ETS implementation is not achieved in the intended way. It can be partially achieved, as the increase in prices will cause a decrease in demand, therefore also a decrease in emissions. On the other hand, if producers fail to transfer a significant part of the costs to their consumers, they should be motivated to reduce emissions by investing in low or zero-emission technologies.

The issue under study has become particularly important in recent times, when we can observe an unprecedented increase in the prices of CO_2 emission allowances – over 500%, during the examined period: 2013-2020. This creates significant pressure on energy prices, and thus reduces the competitiveness of the economy, acts as an inflationary incentive, and causes impoverishment of the society and increase of inequality, as the poorer spend a proportionally larger part of their income on energy than the wealthier. The effects of this phenomenon will, of course, depend on i.a. on the emissivity of the energy mix of a given country. The more fossil-based generation sources, the higher the costs associated with participating in the ETS system.

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The problem is particularly acute in Poland, where sources based on coal, which is the most emissive fuel, have a significant share in the production structure.

So far, the issue of transferring the CO_2 costs to electricity prices, the so-called CO_2 cost pass-through rate – PTR, has been tested many times, but most of the studies concerned the first phases of ETS implementation when firstly, allowances were relatively cheap, and secondly, a significant part of them was allocated free of charge, thus they formed an opportunity cost, not a real cost (Sijm et al., 2005). Additionally, most of these studies did not cover Poland. This article is the first empirical study to cover the relation between the prices of emission allowances and electricity prices in Poland during the entire third phase of the ETS.

Determining the transfer of emission costs to electricity prices

In the theoretical analysis of the conditions influencing the level of transferring the costs of emissions to energy end consumers (CO_2 cost pass-through rate), the following are stated to be the key factors:

- the number of companies on the market, determining the level of competition,
- the shape of the demand curve (linear or iso-elastic),
- the shape of the supply curve (fixed costs before the ETS – perfect flexibility, horizontal curve, or variable costs before the ETS – positive slope). Moreover, the following are also important (Sijm et al., 2005):
- company strategies (assumption can be profit maximisation, but sometimes, it can also be the maximisation of market share or a non-financial goal, e.g. ensuring energy security if it was a state-controlled company),
- market regulations (e.g. the method of allocating allowances),
- the possibility of demand-side response (e.g. switching from electricity to fuels),
- market failures (imperfect information, the need to maintain the continuity of power plant operation, costs of switching on/off, lack of liquidity in fuel markets),
- technological innovations in the field of emission reduction.

Additionally, the carbon intensity of marginal generation technology is a crucial factor in determining the carbon cost of electricity and influencing the pass-through rate. It depends on the fuel used and the thermal efficiency of the given technology. Marginal generation technology might change during peak and off-peak periods resulting in changes of carbon costs.

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Characteristics of the Polish electricity sector in 2013-2020

Polish energy system was historically dominated by fossil-based generation sources, with the dominant role of hard coal and lignite. During the entire III phase of ETS, we could observe a gradual transition from coal-based sources to renewable and gas-based generation. According to data from the transmission system operator (Polskie Sieci Elektroenergetyczne S.A.) structure of electricity generation by dominant sources in 2020 was as follows: hard coal – 47%, down from 52% in 2013, lignite – 24.9%, down from 35% in 2013, renewable energy sources – 10.7%, up from 3.6% in 2013, gas – 9.1%, up from 1.9% in 2013.

Indicated above transformation resulted in an overall decrease in emissivity of the polish energy sector from 150 mln tons of CO_2 equivalent in 2013 to about 124 mln tons of CO_2 equivalent in 2020. Despite the significant drop in emissivity, the Polish energy generation system remains one of the most emissive in the entire EU.

In 2013, the installed capacity in the National Power System was 38 406 MW and has increased to 49 238 MW in 2020. Installed capacity in 2020 by main generation sources was as follows: hard coal – 24.3 GW, lignite – 8.5 GW, renewables – 12.3 GW, gas and hydro – 4.1 GW. Among renewable energy sources, the largest share has an on-shore wind – 6.3 GW and PV – 4 GW.

Gross domestic electricity consumption in 2013 was 158.0 GWh and increased to 165.5 GWh in 2020. From a net exporter of electricity in 2013 – 4.5 TWh, Poland turned into a net importer – of 13.3 TWh in 2020. The increase in imports contributed to some extent to the reduction of GHG emissions from the energy sector.

The most important market for electricity trading is Polish Power Exchange (Towarowa Giełda Energii S.A. – TGE). The total volume of transactions concluded on all electricity markets at TGE S.A. was 176.5 TWh in 2013 and has increased to 243.2 TWh in 2020. The most liquid were one-year contracts.

According to the data of the president of the Energy Regulatory Office, the market share ratio of the three largest electricity producers, measured according to the energy dispatched into the grid (taking into account the amount of energy supplied by producers directly to end users), remained at a high level throughout the duration of the third phase of the ETS and accounted for 62.6% in 2013 and 63.8% in 2020.

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An overview of the literature

The issue of transferring the costs of carbon credits by electricity producers to end consumers was undertaken by many researchers. However, most of the studies concerned the early stages of the ETS implementation and focused on much shorter periods. Important papers in this area include the studies by Sjim (Sijm et al., 2005; Sijm et al., 2006). In the first study, the authors examined the degree of transferring emission allowance prices to energy prices in Germany and the Netherlands in the period of January – July 2005 using the OLS and PW regression method. The obtained results indicate that the coefficients of transferring costs to energy consumers in Germany were 0.72 (OLS), 0.69 (PW) for the PEAK period, and 0.42 (OLS and PW) for the OFF-PEAK period. In both cases, the marginal production technology was coal. In the Netherlands, the coefficients were 0.40 (OLS) and 0.44 (PW) in the PEAK period, where natural gas was considered as the marginal production technology, and 0.53 (OLS) and 0.47 (PW) for the OFF-PEAK, marginal technology – coal. In the second study, the authors investigated the transfer of carbon credit costs to energy prices in Germany and the Netherlands in the period of January – December 2005, using the linear regression method, estimating the parameter through the OLS method. The interesting thing is the fact that the results differed from the first study, covering the first half of 2005. The coefficients in Germany amounted to 1.17 in the PEAK period and 0.60 in the OFF-PEAK period, while in the Netherlands, they were 0.78 in the PEAK period and 0.80 in the OFF-PEAK period. For the PEAK period in the Netherlands, natural gas was adopted as the marginal source of production and for the remaining estimates – coal. A possible explanation given by the authors for the surprisingly high result for the PEAK period in Germany is a significant increase in gas prices in the examined period and the fact that gas could have been the marginal source of production in part of the PEAK period. The authors also refer to the significant differences between the coefficients for the first half of 2005 and the entire 2005, pointing to rising gas prices and delays in including the prices of emission allowances in energy prices as possible causes.

Jouvet and Solier (2013) examined the relations between the prices of CO_2 emission allowances and electricity prices in the period from June 2005 to April 2011 for selected EU countries: Germany, France, the Netherlands, Great Britain, Italy, Spain, and Nord Pool region (Sweden, Finland, Denmark, Norway), Poland, the Czech Republic and Austria. The authors conclude that in the first phase of the ETS, the impact of CO_2 emission allowance prices on energy prices was clearly visible, while in the second phase, it was not so evident. They explain it with the consequences of the economic crisis, result-

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ing in a decrease in demand for electricity, which in turn resulted in the lack of the possibility to transfer additional costs to consumers. In all cases, the emission cost pass-through coefficient was higher for the PEAK period than for the OFF-PEAK period, which, in the author's opinion, indicates a positive relationship between energy demand (energy consumption) and the transfer of CO_2 emission costs to consumers. At the same time, the R^2 coefficients indicate that the cost of carbon credits in the OFF-PEAK periods explains a greater part of the energy price variability than in the PEAK periods. As an explanation, the authors suggest production capacity shortages as an important element of price increases in the PEAK period. At the same time, only 42% of the pass-through rate coefficients turned out to be statistically significant, and 33% were statistically different from zero. The estimation of the parameter (the so-called pass-through rate) for Poland in the first phase of the ETS was 0.03 for the PEAK period and 0.1 for the OFF-PEAK period. However, in the second phase of the ETS, the estimates were 0.41 for the PEAK period and –0.35 for the off-peak period.

The issue of transferring the costs of CO_2 to electricity prices is also discussed by Pereira Freitas and Pereira da Silva (2015). The study covers the entire second phase and first year of the third phase of the EU ETS, i.e. from January 2008 to December 2013. The Vector Error Correction model was used. The authors, just like Jouvet and Solier (2013), note the weakening of the relation between the prices of emission allowances and the prices of electricity as a result of a marked decline in the records of the first ones resulting from the economic crisis. Estimated parameters amounted to 0.24 for the PEAK and OFF-PEAK periods and 0.25 for the BASE period.

Castagneto-Gissey (2014) investigated the relationship between the prices of emission allowances and the electricity prices in Germany, France, Great Britain and the Nord Pool region, using the VAR and GARCH models. The study used data from futures contracts expiring at the end of a given year, and the model takes into account such variables as the price of fuel (coal and natural gas). The results presented high values of the coefficient indicating the emission cost pass-through to electricity prices and amounted to 1.35 in Germany, 0.88 in France, 1.09 in Great Britain, and 1.37 for Nord Pool, which means that producers increased energy prices more than it would result from the cost of carbon credits in 3 of the above cases. The author speculates that transferring so much of the cost of CO_2 might suggest a lack of perfect competition in electricity markets.

The issue of transferring carbon costs to energy prices in markets where there is no perfect competition was examined by Chernyavs'ka and Gulli (2008). The authors focus on the Italian market, which is marked by a high concentration in the power generation sector. They conclude that depending on structural factors, such as the level of concentration on the power genera-

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tion market or the availability of generation capacity, the increase in energy prices may be higher or lower than the marginal cost of CO_2 emission allowances. In addition, the important factor is the level of demand, i.e. only a part of the marginal cost is transferred to energy consumers in the PEAK period, while in the OFF-PEAK period, the price includes all of this cost or even more.

Bonacina and Gulli (2007) analysed the theoretical, short-term impact of emission allowance prices on electricity prices. According to the research, CO_2 prices are completely transferred to energy prices if there is perfect competition in the market. In the situation of imperfect competition, the impact of allowance prices is higher than in the case of perfect competition only when the share of the most emitting sources is small, and there are generation overcapacities. In other situations, especially in the case of the absence of generation overcapacity, the impact of emission allowance prices on energy prices is smaller in the case of imperfect-than-perfect competition. Additionally, in the case of imperfect competition in the PEAK periods, producers transfer less than 100% of CO_2 costs to energy prices, at the same time, this ratio may be lower than in the OFF-PEAK periods.

The panel dataset, including data for 24 thermal power plants, was used by Dagoumas and Polemis (2020) to investigate carbon pass-through in the Greek electricity sector in the period from January 2014 to December 2017. Results showed very significant pass-through of the CO_2 permit costs to end-costumers, as the pass-through rate ranges from 0.639 to 1.196.

Impact of the EU emission trading system on the Nordic electricity market and on different market actors was investigated by Kara (Kara et al., 2008). The period under examination covered the first phase of ETS. The main finding was that for every tonne of $CO_{2,}$ the annual average electricity price rise by 0,74 EUR/MWh.

Huisman and Kilic (2015) found support for the time-varying of pass-through rate by applying a Kalman Filter approach. The study focused on future prices in UK and Germany. The main conclusion from the study is that pass-through might not be constant over time.

There are also examples of studies investigating CO_2 cost pass-through from non-EU cap and trade systems, e.g. in California (Woo et al., 2017). The period from January 2011 to December 2016 was investigated. Results showed, depending on the particular market, an increase in electricity prices by 0.41 US$/MWh and 0.59 US$/MWh, for each 1 US$ increase in a tonne of CO_2 price.

An investigation concerning the influence of the emission permit allocation method on the CO_2 pass-through rate was conducted by Wang and Zhou (2017). Nash-Cournot oligopolistic market equilibrium model was employed to find out that the allocation method does affect the rate of CO_2 cost pass-through.

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Research methods

This article presents the research results on the relation between the prices of CO_2 emission allowances and wholesale prices of electricity listed on the Polish Power Exchange (Towarowa Gielda Energii – TGE) in Warsaw. The research period covers the entire 3rd phase of the ETS (2013-2020).

The study covers three daily supply periods characteristic of the energy market, reflected by three different contracts listed on the TGE:

- BASE – 24h energy delivery reflects the average daily energy demand,
- PEAK – deliveries in the so-called peak period, i.e. between 7:00 a.m. and 10:00 p.m., when the demand for energy is the highest,
- OFF-PEAK – deliveries in the off-peak period, i.e. between 10:00 p.m. and 7:00 a.m., when the energy demand is the lowest.

Based on the data from the above types of contracts, three linear regression models were estimated.

Data

Average monthly prices of electricity, hard coal and CO_2 emission allowances from the analysed period were used for the study, which gives the sample size N = 96 (12 months x 8 years in the period of 2013-2020). For each of the examined periods, the average monthly price of electricity from the contract corresponding to the given period of the day (BASE, PEAK, OFF-PEAK), reported by TGE S.A. (operator of the Commodity Power Exchange), was used. Therefore, the sample consisted of N = 96 observations for each of the three estimated models.

Model

In order to find out what part of the cost of carbon allowances was transferred to end customers of energy in Poland in 2013-2020, the following models were estimated:

$$Yt = (Pt - Ft) = \alpha + \beta 1 \cdot CO_2 + \xi \tag{1}$$

where:
Pt – energy price for [MWh],
Ft – hard coal price [MWh],
CO_2 – price of emission allowances,
Yt (Pt – Ft) – dark spread – the price of energy minus the price of fuel, in other words, the price of energy “cleared” by the price of fuel.

The coal price has been converted into MWh and corrected by the average energy efficiency of coal power plants (assuming 0.4).

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CO_2 emission allowance price was corrected by the emissivity of coal power plants (assuming 0.8). Example: the production of 1 MWh of energy emits 800 kg of CO_2, therefore, if the CO_2 emission allowance costs, e.g. EUR 25, then the additional cost of producing 1 MWh of energy in a coal power plant is EUR 20.

The β_1 parameter is the so-called CO_2 cost pass-through rate – which shows part of the costs that are transferred by producers to customers. For example, if it is 0.8, it will mean that producers transfer 80% of the cost of allowances to electricity prices.

The marginal generation unit determines the price of energy on the market. In the Polish power system, it is a hard coal power plant in each period of the day, hence the analysis assumed the energy efficiency and emissivity of such units.

Hypotheses

The research hypothesis assumes that the parameter will be positive ($\beta_1 > 0$) and that it will be statistically significant – it means that the costs of emission allowances were transferred to end customers in the analysed period. Taking into account the structure of electricity generation sources in Poland, it should be expected that the parameter will be close to 1.

An additional hypothesis assumes that the β_1 coefficient will be higher in those periods of the day when the demand for energy is higher (producers have greater bargaining power) and lower in periods of relatively lower demand. In other words, the largest part of the emission allowance cost is transferred by producers to customers between 7.00 a.m. and 10.00 p.m. (PEAK contract) and the least between 10.00 p.m. and 7.00 a.m. (OFF-PEAK contract), ($\beta_{PEAK} > \beta_{OFF\text{-}PEAK}$). Statistical test of the hypothesis: $\beta_{PEAK} = \beta_{OFF\text{-}PEAK}$ was conducted to investigate this.

Results of the research

In the models estimated with the OLS method, there was an autocorrelation of the residuals. Therefore, the models were estimated using the Cochrane – Orcutt method. Detailed model estimation and tables of diagnostic test results are provided in the appendix.

Parameters β_1 next to the CO_2 prices variable turned out to be statistically significant at the level of 0.01 in all examined periods, which confirms the main hypothesis of the study.

- BASE period – the parameter $\beta_{BASE} = 0.996$ and the coefficient $R^2 = 0.78$.

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- PEAK period – the parameter β_{PEAK} = 1.011 and the coefficient R^2 = 0.70.
- OFF-PEAK period – parameter $\beta_{OFF\text{-}PEAK}$ = 0.979 and the coefficient R^2 = 0.92.

Regarding the second hypothesis, the results suggest that during the peak demand period, the cost of energy increases by 1.1% more than it would be presumed from the cost of CO_2 emission allowances. During the off-peak period, a bit less than the entire cost of carbon is passed through, namely 98% of it. As expected, the peak transmission parameter is higher than the off-peak one. Nevertheless, the difference is small and statistically insignificant. Hence the model does not allow for any far-reaching conclusions. P-value for the tested hypothesis is 0.1577.

Table 1. Results of the research – BASE, PEAK, OFF-PEAK periods, 2013-2020

	β	R^2
BASE	0.996	0.78
PEAK	1.011	0.70
OFF-PEAK	0.979	0.92

Discussion/ Limitation and future research

Most of the studies on CO_2 cost pass-through rate have revealed that carbon price impacts electricity price leading to its increase. However, the pass-through rate values estimated in previous studies differ significantly. Depending on the country and period studied, the researchers obtained pass-through rate results both significantly lower than 1 (suggesting only a small inclusion of emission costs in electricity prices) and significantly higher than 1 (suggesting the opposite).

The results of the CO_2 cost pass-through rate from this paper are different from those obtained by Jouvet and Solier for the polish electricity market. However, it should be noted that the period investigated was different, and so were CO_2 allowance prices.

On the other hand, in this paper, likewise in Jouvet and Solier study (2013), CO_2 pass-through rate was higher in PEAK period, when demand was higher, as well as R^2 coefficient was lower for PEAK period indicating that carbon cost in OFF-PEAK period explains a greater part of variability of electricity prices, than in BASE and PEAK periods, when other factors might also play significant role.

Due to the importance of the problem of relation between the prices of CO_2 emission allowances and electricity prices, this issue is worth carrying out further research, especially since the changing structure of generation, new technologies, but also higher prices of allowances may affect the situation in relation to the analysed period.

Conclusions

The conducted study confirmed that electricity producers in Poland transferred virtually the entire additional cost of CO_2 emission on the wholesale electricity price during III ETS phase (2013-2020). In the periods of the greatest demand, the price was even higher than it would appear from the cost of allowances, but it can be assumed that producers could thus compensate for periods of lower demand, when they were not able to transfer all costs on electricity prices. Nevertheless, the difference is small and statistically insignificant, hence the model does not allow for any far-reaching conclusions in this regard.

The research problem is important because the policy of the European Union assumes more and more ambitious goals of reducing greenhouse gas emissions and one of the main tools for its implementation will be the ETS system. Therefore, further increases in the prices of CO_2 emission allowances should be expected. In 2021, the so-called 4th phase of the ETS implementation went into effect, under which i. a. the reduction of the number of allowances in the system has been accelerated. From January to December 2021, the price of allowances increased from about 25 EUR/t to over 80 EUR/t, which puts significant pressure on the increase in electricity prices. The effects will be felt both in the economic sphere (less competitiveness of industry in the EU) and in the social sphere (increasing burden, especially for the poorer part of the society). The most problematic issue occurs in countries like Poland, where most of the electricity is still produced from coal.

If electricity producers transfer the entire cost of allowances to electricity prices, questions may arise both about the effectiveness of the ETS – based policy (what are the incentives to reduce emissions) and about who eventually bears the costs of the energy transformation.

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Appendix A

A.1 Model 1 – price in BASE contracts

Model estimation using the OLS method

OLS estimation, observations used 2013:01-2020:12 (N = 96)

Dependent variable (Y): seasonally adjusted_energy_prices_Y

	Coefficient	standard error	Student's t-distribution	p-value
Const	140.335	4.37801	32.05	2.13e-052 ***
CO_2_prices	0.920399	0.123822	7.433	4.84e-011 ***

Average of dependent variable 177.9228 Standard deviations of dependent variable 34.59021

Sum of squares of residuals 43198.47 Standard error of residuals 21.43731

Determination coefficient R-squared 0.619952 Adjusted R-squared 0.615909

F(1, 94) 55.25272 p-value for the test F 4.84e-11

Logarithm of likelihood −429.4603 Akaike information criterion 862,9206

Bayesian information criterion 868.0493 Hannan-Quinn criterion 864.9937

Autocorrelation of residuals – rho1 0.648682 Durbin-Watson statistic 0.707029

Model estimation using the Cochrane-Orcutt method

Cochrane-Orcutt estimation, observations used 2013:02-2020:12 (N = 95)

Dependent variable (Y): seasonally adjusted_energy_prices

rho = 0.65227

	coefficient	standard error	Student's t-distribution	p-value
const	137.392	8.11901	16.92	3.84e-030 ***
season.adjusted_CO_2_prices	0.996712	0.151589	6.575	2.80e-09 ***

Basic statistics for quasi-differentiated data (rho):

Sum of squares of residuals 25249.08 Standard error of residuals 16.47712

Determination coefficient R-squared 0.777716 Adjusted R-squared 0.775325

F(1, 93) 43.23181 p-value for test F 2.80e-09

Autocorrelation of residuals – rho1 −0.134289 Durbin-Watson statistic 2.238513

Basic statistics for original data:

Average of dependent variable 178.0699 Standard deviation of dependent variable 34.74355

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OLS method				
No.	TEST	H:0	Statistics	p-value
1.	Y variable stationarity (ADF test)	There is a unit root	tau_nc(1) = 0.651253	p = 0.8568
	X variable stationarity (ADF test)	There is a unit root	tau_nc(1) = 2.63412	P = 0.9979
	Stationarity of cointegrating equation residuals (ADF test)	There is a unit root	tau_nc(1) = -2.58612	p = 0.00941
2.	Distribution normality (J-B test)	the distribution is normal	2.31999	0.313488
3.	Model linearity (RESET test)	correct specification	F = 3.249527	p = P(F(2, 92) > 3.24953) = 0.0432878
4.	Parameter stability (CUSUM test)	no change in parameters	t(93) = -4.43198	p = P(t(93) > -4.43198) = 2.55044e-005
5.	ARCH effect (instead of heteroscedasticity test)	ARCH effect does not occur	LM = 18.741	p = P(Chi-square(12)> 18.741) = 0.0949745
6.	Autocorrelation (Durbin – Watson test)	No autocorrelation AR(1)	0.707029	p = 1.05118e-013
7.	Autocorrelation (Breusch – Godfrey test)	No autocorrelation AR(p)	LMF = 65.286405	p = P(F(1, 93) > 65.2864) = 2.31e-012
Cochrane-Orcutt method				
No.	**TEST**	**H:0**	**Statistics**	**p-value**
1.	Residual distribution normality test	random component is normally distributed	Chi-squared(2) = 14.0534	p = 0.000887837
2.	ARCH test	ARCH effect does not occur	LM = 13.009	p = P(Chi-squared(1) > 13.009) = 0.000310006

A.2 Model 2 – price in PEAK contracts

Model estimation using the OLS method

OLS estimation, observations used 2013:01-2020:12 (N = 96)

Dependent variable (Y): seasonally adjusted_energy_prices_Y

	Coefficient	Standard error	t-Student's	p-value	
Constant	158.378	5.91642	26.77	<0.0001	***
CO_2_prices	0.918120	0.147680	6.217	<0.0001	***

Arithmetic mean of the dependent variable	195.8726		Standard deviation of the dependent variable	38.18703
Sum of squares of residuals	68.414.88		Standard error of residuals	26.97810
Determination coefficient R-squared	0.506150		Adjusted R-squared	0.500896
F(1.94)	38.65043		P-value for the F test	1.38e-08
Logarithm of likelihood	−451.5300		Akaike information criterion	907.0599
Bayesian information criterion	912.1886		Hannan-Quinn criterion	909.1331
Autocorrelation of residuals – rho1	0.626098		Durbin-Watson statistic	0.752990

Model estimation using the Cochrane-Orcutt method

Cochrane-Orcutt estimation, observations used 2013:02-2020:12 (N = 95)

Dependent variable (Y): seasonally_adjusted_energy_prices_Y

rho = 0.630521

coefficient standard error Student's t-distribution p-value

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const	154.972	9.89310	15.66	7.97e-028 ***
CO_2_prices	1.01193	0.185773	5.447	4.16e-07 ***

Basic statistics for quasi-differentiated data (rho):

Sum of squares of residuals 42033.34 Standard error of residuals 21.25962

Determination coefficient R-squared 0.696055 Adjusted R-squared 0.692787

F(1, 93) 29.67148 p-value for test F 4.16e-07

Autocorrelation of residuals – rho1 −0.128615 Durbin-Watson statistic 2.223444

Basic statistics for original data:

Mean of dependent variables 196.0782 Standard deviation of dependent variables 38.33617

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OLS method				
No.	**TEST**	**H:0**	**Statistics**	**p-value**
1.	Y variable stationarity (ADF test)	There is a unit root	tau_c(1) = -1.81342	p = 0.3744
	X variable stationarity (ADF test)	There is a unit root	tau_c(1) = 1.14953	p = 0.9977
	Stationarity of cointegrating equation residuals (ADF test)	There is a unit root	tau_nc(1) = -3.32311	p = 0.0008714
2.	Distribution normality (J-B Test)	the distribution is normal	12.0424	0.00242677
3.	Model linearity (RESET test)	correct specification	F(2, 92) = 4.07519	p = P(F(2, 92) > 4.07519) = 0.0201475
4.	Parameter stability (CUSUM test)	no change in parameters	t(93) = -4.04387	P(t(93) > -4.04387) = 0.000108398
5.	ARCH effect (instead of heteroscedasticity test)	ARCH effect does not occur	LM = 4.59527	P(Chi-squared(1) > 4.59527) = 0.0320604
6.	Autocorrelation (Durbin – Watson test)	No autocorrelation AR(1)	0.75299	p = 1.21803e-012
7.	Autocorrelation (Breusch – Godfrey test)	No autocorrelation AR(p)	LMF = 57.971267	P(F(1, 93) > 57.9713) = 2.15e-011
Cochrane-Orcutt method				
No.	**TEST**	**H:0**	**Statistics**	**p-value**
1.	Residual distribution normality test	random component is normally distributed	Chi-squared(2) = 21.0082	p = 2.74235e-005
2.	ARCH test	ARCH effect does not occur	LM = 10.5461	P(Chi-squared(1) > 10.5461) = 0.00116431

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A.3 Model 3 – price in OFF-PEAK contracts

Model estimation using the OLS method

OLS estimation, observations used 2013:01-2020:12 (N = 96)
Dependent variable (Y): seasonally adjusted_energy_prices_Y

	Coefficient	Standard error	t-Student's	p-value	
constant	106.816	2.64355	40.41	<0.0001	***
CO_2_prices	0.922084	0.0936285	9.848	<0.0001	***

Arithmetic mean of the dependent variable	144.4723		Standard deviation of the dependent variable	30.44283
Sum of squares of residuals	17317.17		Standard error of residuals	13.57296
Determination coefficient R-squared	0.803310		Adjusted R-squared	0.801217
F(1, 94)	96.98940		P-value for the F test	3.86e-16
Logarithm of likelihood	−385.5832		Akaike information criterion	775.1663
Bayesian information criterion	780.2950		Hannan-Quinn criterion	777.2394
Autocorrelation of residuals – rho1	0.767498		Durbin-Watson statistic	0.445817

Model estimation using the Cochrane-Orcutt method

Cochrane-Orcutt estimation, observations used 2013:02-2020:12 (N = 95)
Dependent variable (Y): seasonally_adjusted_energy_prices_Y
rho = 0.768605

coefficient standard error Student's t-distribution p-value

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const	103.758	6.10284	17.00	2.76e-030 ***
CO_2_prices	0.979490	0.108141	9.058	2.02e-014 ***

Basic statistics for quasi-differentiated data (rho):

Sum of squares of residuals 6769.239 Standard error of residuals 8.531560
Determination coefficient R-squared 0.923211 Adjusted R-squared 0.922385
F(1, 93) 82.03833 p-value for test F 2.02e-14
Autocorrelation of residuals – rho1 −0.100339 Durbin-Watson statistic 2.185654

Basic statistics for original data:

Average of dependent variable 144.4970 Standard deviation of dependent variable 30.60336

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OLS method				
No.	**TEST**	**H:0**	**statistics**	**p-value**
1.	Y variable stationarity (ADF test)	There is a unit root	tau_c(1) = -0.66652	p = 0.8492
	X variable stationarity (ADF test)	There is a unit root	tau_c(1) = 1.14953	p = 0.9977
	Stationarity of cointegrating equation residuals (ADF test)	There is a unit root	tau_nc(1) = -3.58635	p = 0.0004572
2.	Distribution normality (J-B Test)	the distribution is normal	16.5513	0.000254642
3.	Model linearity (RESET test)	correct specification	F(2, 92) = 0.394645	p = P(F(2, 92) > 0.394645) = 0.675055
4.	Parameter stability (CUSUM test)	no change in parameters	t(93) = -3.69424	P(t(93) > -3.69424) = 0.000372193
5.	ARCH effect (instead of heteroscedasticity test)	ARCH effect does not occur	LM = 34.8987	(Chi-squared(1) > 34.8987) = 3.47305e-009
6.	Autocorrelation (Durbin – Watson test)	No autocorrelation AR(1)	0.445817	p = 0
7.	Autocorrelation (Breusch – Godfrey test)	No autocorrelation AR(p)	LMF = 130.972193	P(F(1, 93) > 130.972) = 1.91e-019

Cochrane-Orcutt method				
No.	**TEST**	**H:0**	**Statistics**	**p-value**
1.	Residual distribution normality test	random component is normally distributed	Chi-squared(2) = 6.53677	p = 0.0380678
2.	ARCH test	ARCH effect does not occur	LM = 1.90805	P(Chi-squared(1) > 1.90805) = 0.167179

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Appendix B

Data statistics

Table 1. Descriptive statistics for observations from the sample 2013:01 – 2020:12 for the energy_price_Y variable for the BASE period (96 correct observations)

Average	Median	Minimum	Maximum
178.12	163.06	131.88	268.34
Standard deviation	Variation coefficient	Skewness	Kurtosis
37.179	0.20873	0.75673	-0.73304
Percentile 5%	Percentile 95%	Range Q3-Q1	Missing observations
134.81	248.08	61.181	0

Table 2. Descriptive statistics for observations from the sample 2013:01 – 2020:12 for the energy_price_Y variable for the PEAK period (96 correct observations)

Average	Median	Minimum	Maximum
196.18	181.71	144.10	302.98
Standard deviation	Variation coefficient	Skewness	Kurtosis
40.880	0.20838	0.69531	-0.71489
Percentile 5%	Percentile 95%	Range Q3-Q1	Missing observations
148.30	272.11	68.555	0

Table 3. Descriptive statistics for observations from the sample 2013:01 – 2020:12 for the energy_price_Y variable for the OFF-PEAK period (96 correct observations)

Average	Median	Minimum	Maximum
144.84	130.67	105.03	233.20
Standard deviation	Variation coefficient	Skewness	Kurtosis
33.254	0.22959	1.0021	-0.41275
Percentile 5%	Percentile 95%	Range Q3-Q1	Missing observations
111.00	210.22	48.033	0

Table 4. Descriptive statistics for the observations from the sample 2013:01 – 2020:12 for the CO_2 emission allowance_prices_X variable (96 correct observations). The price of CO_2 emission allowances is the same for each model

Average	Median	Minimum	Maximum
40.907	24.097	11.838	110.49
Standard deviation	Variation coefficient	Skewness	Kurtosis
29.845	0.72959	0.83948	-0.96281
Percentile 5%	Percentile 95%	Range Q3-Q1	Missing observations
14.595	95.250	54.636	0

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THE REPORTING OF CLIMATE-RELATED INFORMATION BY CSR LEADERS IN POLAND: A CLIMATE-RELATED DISCLOSURES INDEX

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ABSTRACT: The article measures the scope of reporting climate-related information by companies considered CSR leaders in Poland. An original tool is employed for that purpose: a climate-related disclosures index. First, a critical comparative analysis was performed of climate-related disclosure initiatives (regulations, guidelines, standards) to pinpoint the key and commonly required disclosures. Next, an original index of climate-related disclosures was designed. It helped compute index values for 20 companies perceived as Poland's CSR leaders. Non-financial reports available in the public domain were analysed for that purpose. The study showed that virtually all climate-related disclosure initiatives implement, to a greater or lesser extent, the TCFD recommendations, which were also embedded in the developed index covering 18 indicators. The total index value (ranging from 0 to 1) for the analysed companies was 0.51, with a median of 0.42. The index demonstrates that companies named CSR leaders in Poland do not display high awareness of climate change.

KEYWORDS: climate-related disclosures, companies, index, non-financial reporting

Introduction

The latest IPCC Sixth Assessment Report (April 2022) demonstrates that humankind is standing at a crossroads. IPCC Working Group III Co-chair Jim Skea said, "It's now or never if we want to limit global warming to 1.5°C. Without immediate and deep emissions reductions across all sectors, it will be impossible" (Climate Centre, 2022). The increasingly intense negative effects of climate change, just to mention the four-year drought in Somalia coinciding with other disasters and triggering a hunger crisis (Wojcieszek, 2022); heat waves across Europe in the summer of 2022, which all-time heat records (e.g. 40.2°C at London Heathrow Airport) (PAP, 2022) and, unfortunately, the unprecedented number of deaths due to heat (over 1,000 people in Portugal and Spain between 11-17 July 2022 (BNO News, 2022); 1,063 deaths between 7-18 July 2022 in Portugal alone (TVN24, 2022)) are front-page news almost every day, making more and more people aware of the impending climate crisis. According to the Peoples' Climate Vote (the largest survey of public opinion on climate change), of the people who said that climate change is a global emergency, 59% said that the world should do everything necessary and urgently in response (UNDP & University of Oxford, 2021). According to the 2022 Edelman Trust Barometer, the percentage of people who worry about climate change is 75% and has increased by 3 p.p. since 2021 (Edelman, 2022). 72% of the population surveyed by the Pew Research Center is concerned that global climate change will harm them personally at some point in their lifetime (Bell et al., 2021).

Recent events have shown that our infrastructure is not prepared for extreme weather conditions. In the UK, July temperatures in the London Underground system were above the permissible limits for livestock transport; train services were cancelled (bending tracks and falling traction); airport departures and arrivals were suspended (runway surface meltdowns); motorways were closed (surface undulations) (Skarżyński, 2022). Consequently, the negative effects of climate change pose a business risk. As the World Economic Forum reports, climate action failure was identified as the first of the most severe risks on a global scale over the next 10 years, with extreme weather (its major outcome) as the runner-up (World Economic Forum, 2022). Companies need to factor in climate risk not only because it poses a threat to their infrastructure or affects their business operations, which is becoming a more and more crucial point for investors (88% of institutional investors subject ESG[1] to the same scrutiny as operational and finan-

[1] ESG – Environmental, Social, and Governance are performance indicators more and more often used in ratings and non-financial assessments of companies and other organisations.

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cial considerations), but also because they are increasingly expected to display corporate social responsibility (CSR) and, by doing so, participate in solving global problems, not so infrequently caused by their economic activity (47% people strong/mandatory expect CEOs to inform and shape conversations and policy debates about global warming and climate change) (Edelman, 2022). Companies must therefore take action to manage climate change mitigation and adaptation and disclose information on their effort. Practice shows that the interest of businesses in climate action is mounting, which is seen in the emergence of various self-regulation mechanisms (e.g. United Nations' "Race to Zero" campaign, the Business Ambition for 1.5°C coalition, the World Economic Forum's First Movers Coalition or Science Based Target Initiative – SBTi) and an increase in the number of enterprises joining in. The reporting of climate-related information (climate reporting) is also on the rise as part of non-financial reporting (sustainability, ESG, CSR, social reporting), which has now become an inseparable part of financial reporting (as integrated reporting). No mandatory accounting standards are there is place yet for disclosing the bilateral impact of climate change on companies. The EU is working intensively on ESG standards addressing climate issues (see Figure 1).

The first indicators on climate reporting were found in the non-obligatory GRI Sustainable Reporting Guidelines (version G4 was published in 2013; currently binding are the 2016 GRI Standards, partially updated in 2021, and still in consultation). 2014 saw the adoption of the NFRD on disclosure of non-financial and diversity information (including regarding climate: the level of renewable or non-renewable energy use and greenhouse gas performance – GHG) (Directive, 2014). In 2017 non-obligatory EU recommendations on non-financial reporting were published, already provided for in the NFRD. Among the examples of key performance indicators, the recommendations pointed to energy efficiency and GHG emissions, but also addressing climate-related scenarios or individuals responsible for climate policy in organisations (European Commission, 2017).

The most acknowledged and trail-blazing recommendation on climate reporting is the non-obligatory TCFD's climate-related disclosures framework (Task Force on Climate-related Financial Disclosures) published in 2017. It was incorporated into most guidelines and regulations on climate reporting, just to mention the EC supplement on reporting climate-related information (2019/C 209/01), containing non-obligatory reporting guidelines. Up to the TCFD, most companies around the world had used the GRI standards to disclose climate-related information. However, nothing before the TCFD had focused on climate-related risks and opportunities in such an innovative way, which has garnered it widespread recognition and has made it the global benchmark for climate-related disclosures. This initiative has been endorsed by regulators, jurisdictions, and international standard-setters, let alone accounting firms, such as KPMG and Ernst and Young (Demaria & Rigot, 2021). For this reason, the number of TCFD advocates has increased to more than 3,800 companies which have continued to increase their TCFD-aligned reporting (TCFD, 2022). Published in 2019, the Sustainable Finance Disclosure Regulation – SFDR (2019/2088) only concerned the financial services sector. Yet, by requiring transparency from financial market participants and financial advisers with regard to making provisions for sustainability risks in their businesses, it also supports the development of sustainable investment projects, as it requires the disclosure of impact of investment decisions on the domain of sustainability (climate-related issues are not explicitly addressed in this instrument) (Regulation, 2019).

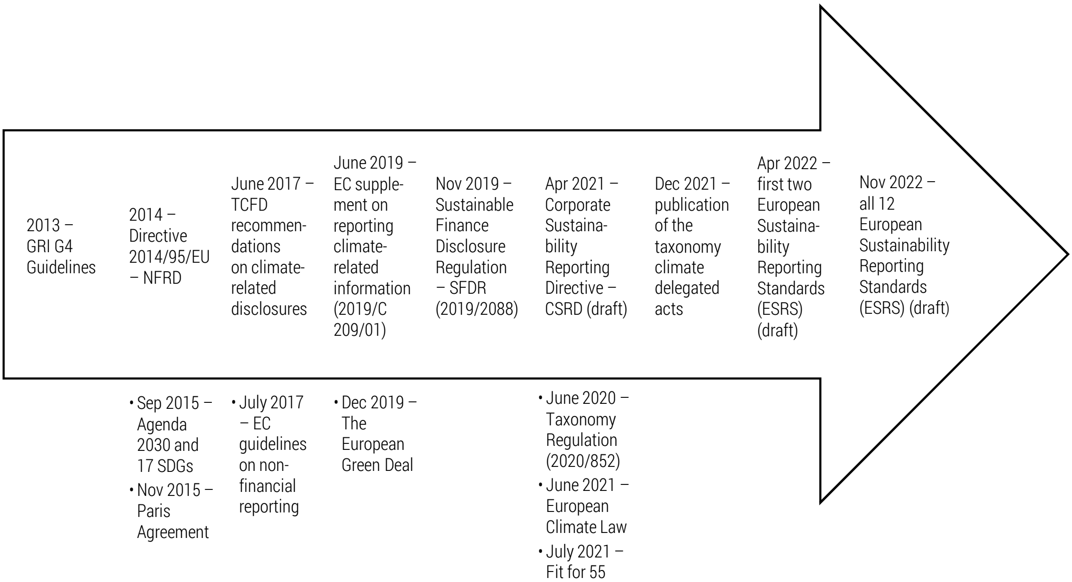

Figure 1. The key climate-related disclosure initiatives, together with instruments supporting the relevant reporting measures

In 2021 the draft Corporate Sustainability Reporting Directive – CSRD (European Commission, 2021) was made public. It imposes the obligation of sustainability reporting on enterprises, however without proposing any specific indicators but only highlighting the need to develop obligatory common reporting standards[2]. At the end of the same year, in accordance with the

[2] 30 June 2022 saw the announcement of the working text of the CSRD in the shape agreed by the EU Council and the European Parliament. It will be further processed and translation into all EU languages.

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Taxonomy Regulation 2020/852 (Regulation, 2020), the first taxonomy delegated acts for two climate goals (Commission Delegated Regulation, 2021) were announced. In April 2022, in accordance with the CSRD, the first draft European Sustainability Reporting Standards (ESRS) were made public, regarding general, strategy, governance, and materiality assessment (ESRS 2) and climate change (ESRS E1). In November 2022, the final set of 12 draft sector-independent standards was published. It was submitted to the European Commission to start working on delegated acts to be completed in mid-2023.

Figure 1 shows the timeline of the key climate disclosure initiatives along with the instruments supporting the relevant reporting measures.

Originally non-obligatory, climate reporting, as provided in the draft CSRD, will become obligatory and will even cover SMEs listed on European regulated markets (European Commission, 2021). Given how fast the relevant requirements are developing, greater importance is attached to the assessment of companies' climate reporting by rating agencies and watchdogs (e.g. Sustainalytics, MSCI ESG, ISS ESG, EcoVadis and CDP), let alone experts and researchers. In Poland, with its coal-based economy and the powerful coal lobby, only several such initiatives have been taken so far among publicly-listed companies. Of interest, however, is how CSR leaders in Poland perform compared with other market players, namely whether they display greater "climate awareness." Therefore, the article attempts to measure the scope of reporting climate-related information by companies considered CSR leaders in Poland. An original tool is employed for that purpose: a climate-related disclosures index. The article relies on a critical analysis of the literature on the subject, primarily research papers from the Scopus database and climate-related disclosure initiatives, as well as on non-financial reports published by companies listed in the index of climate-related disclosures.

An overview of the literature

Climate-related reporting is explicated using stakeholder, legitimacy, and institutional theories. In view of the most discussed one, the theory of legitimacy, a company operating within a society under a social contract makes climate-related disclosures with a view to gaining, managing, and maintaining its legitimacy by demonstrating that it acts within the bounds and norms of that society (Mousa & Hassan, 2015), especially when it's operations in this area are controversial or poorly institutionalised (Perera et al., 2019). In the face of growing public concern about the climate crisis, the company's disclosure of its approach to managing climate risks seems to meet public expectations and helps manifest its climate responsibility. Transparency

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responds to social and regulator pressures as well as projecting the company's image as a good corporate citizen (Kouloukoui et al., 2019b). Seeking to achieve legitimacy may be linked to conveying the impression of doing the right things or not being involved in doing the wrong things when this appearance may have little in common with the company's actual environmental performance (Mousa & Hassan, 2015). In this sense, incomplete climate-related reporting is but a symbolic act undertaken by the company to solve its problems related to legitimisation, which later on makes any comparison between reporting entities almost impossible (Liesen et al., 2015).

To a limited degree, the theory of legitimacy resembles the stakeholder theory. The latter focuses on groups and individuals who are in a position to exert social and political pressures on the company (stakeholders). According to the stakeholder theory, the long-term growth and success of companies depend on stakeholders' acceptance (Freeman, 1984). With that end in view, enterprises respond to stakeholders' expectations by reporting on climate issues. Still, research shows that, given information asymmetry, the non-obligatory character of reporting permits companies to perform incomplete disclosures. Despite this fact, conscious stakeholders keep pressing businesses to reveal reliable and objective environmental indicators in order to be able to validate companies' declarations on a commitment to counteracting climate change (Liesen et al., 2015).

In turn, the institutional theory maintains that the behaviour of companies is affected by the institutional framework (external and internal–organisational) in which they operate, and their reporting practices are under institutional pressures (regulative, normative, or cultural and cognitive). Companies from the same organisational fields pursue similar practices in the process of isomorphism (coercive, mimetic, and normative) (Comyns, 2018), hence the tendency to standardise of the quality of climate-related disclosures.

The question of climate change is a relatively new research field stemming from environmental reporting, a practice developing since the 1970s (Maji & Kalita, 2022). In their studies on the different aspects of climate-related reporting, only a few researchers have focused on the issues of climate change (Demaria & Rigot, 2021). It is evident, however, that exploration of this field has gained momentum for the last ten years or so, and this is true of both theory and practice (Kılıç & Kuzey, 2019). The main driver of strategic corporate change regarding climate was the establishment of the IPCC (1988) and the adoption of the 1997 Kyoto Protocol, which imposed legal caps on GHG emissions in developed countries (Maji & Kalita, 2022). This, in turn, led to the non-obligatory guidelines (such as the GHG Protocol, CDP – Carbon Disclosure Project, or TCFD) and obligatory regulations in, first, sustainable, and next climate-related reporting (particularly in the w UE), getting a firm

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foothold (Comyns, 2018), including under stakeholders' pressure (Kouloukoui et al., 2019a) – among them financial markets (Chen et al., 2022), disappointed with the lack of measurable progress among corporations in reducing GHG emissions (Liesen et al., 2015).

Owing to the said guidelines (soft law) and regulations, climate-related reporting was envisaged to have avoided the errors of environmental reporting, which, especially in its infancy, was mostly incomplete and disconnected from real pro-environment action (Wiseman, 1982; Noci, 2000; Llena et al., 2007), its narrative being essentially qualitative and affirmative (Moneva & Llena, 2000). The application of soft law and/or obligatory regulations results in more and better quality climate-related disclosures among companies (Comyns, 2016; Comyns, 2018; Perera et al., 2019; Demaria & Rigot, 2021; de Grosbois & Fennell, 2022) and their improved performance as regards climate action (Bauckloh et al., 2022; Chen et al., 2022). In contrast, the lack of measurable reporting requirements causes disclosures to be mere declarative statements that are not backed up by actual results (Kumar & Prakash, 2019). Most studies, however, show that the level of climate-related reporting by companies is still substantially low, both with regard to GHG, energy (Liesen et al., 2015; Wedari et al., 2021), and climate risks (Kouloukoui et al., 2019a; Kouloukoui et al., 2019b; Bauckloh et al., 2022; Chen et al., 2022).

1,109 articles can be found in the Scopus database (July 2022) with such keywords as "climate" and "performance," and "climate" and "disclosure". After 2013 the number of publications in the field began to increase each year to exceed 40 papers annually (134 published in 2021 only). With this in mind, the quick literature scan was limited to 835 articles for the years 2013-2022 (also because a completely new version of the GRI G4 Guidelines was released in 2013). The analysed papers focus primarily on GHG emissions by listed companies (e.g. Rodríguez et al., 2022; Demaria & Rigot, 2021; Wedari et al., 2021), often banks (e.g. Kılıç & Kuzey, 2019), in individual countries (e.g. France (Amar et al., 2022), Colombia (Rodríguez et al., 2022), Australia (Wedari et al., 2021)), and on information disclosed in CDP reports. A substantial minority of them share the results of empirical research on corporate climate-related disclosures; only twenty one present various types of indices measuring the level of climate-related disclosures by companies, nine of which focus on GHG emissions (e.g. Asare et al., 2022; Ika et al., 2022; Wedari et al., 2021), five employ the CDP methodology (e.g. de Grosbois & Fennell, 2022; Ika et al., 2022; Charumathi & Rahman, 2019), two resorted to the TCFD methodology (Amar et al., 2022; Demaria & Rigot, 2021). In few cases only, the indices relied upon more than one initiative, e.g. CDP and GRI (de Grosbois & Fennell, 2022). None of the indices covers companies based in Poland.

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In Poland, the Association of Stock Issuers (SEG) made the first attempt to measure companies' awareness of their impact on climate change. In 2018 they published the first Climate Crisis Awareness Study. The study covered 2017, and 2018 annual reports of about 150 Warsaw Stock Exchange (WSE) listed companies. The authors verified whether the companies include climate impact management in their strategy papers; whether they set climate goals and action plans; and whether they report eight indicators on GHG emissions (including under Scope 2) (SEG, 2022).

In 2021 EY published the Climate Risk Disclosure Barometer based on the analysis of fifty-nine reports of the largest WSE-listed companies representing five sectors that are regarded as the most sensitive to climate change. The Barometer was part of a global study carried out in over forty countries and for over 1,100 companies and assessed the disclosure of information in accordance with the TCFD recommendations (EY, 2021).

In 2021 the UNEP/GRID-Warsaw and Go Responsible developed and published the Climate Strategies Benchmark. It was calculated for the WIG20 and mWIG40 companies listed on the WSE. It is the most comprehensive study that looks beyond climate in the strict sense and also addresses risk management, emissions reporting, climate policy, emission benchmarks, global policies (SDGs), climate partnerships, climate goals, the inclusion of RES, energy efficiency, climate governance, sustainability team, TCFD recommendations, strategic management, or sustainable operations (taxonomy) (Go Responsible, 2022).

The studies discussed above focused only on WSE-listed companies due to the growing importance of climate risk for investors. However, no less interesting is whether the market players that are CSR leaders in Poland also lead the way in terms of climate action.

Research methods

The study was phased into two stages. First, a critical comparative analysis was performed of climate-related disclosure initiatives (regulations, guidelines, standards) to identify the key and commonly required disclosures. All climate-related disclosure initiatives shown in Figure 1 were subject to analysis. Selected were those which contained detailed guidelines for such disclosures, i.e. (in chronological order): TCFD Framework, EC Supplement, GRI Guidelines and the draft ESRS (ESRS2, ESRS E1). The analysis focuses on obligatory disclosures that directly refer to/concern climate and not on their explanatory notes. Next, based on that, an original index of climate-related disclosures was designed, which is able to assess the scope of the company's climate-related disclosures using the formula proposed by Zoysa and Takaoka (2020):

$$\text{Climate-related disclosures index} = \sum_{i=1}^{m}(d_i/m). \qquad (1)$$

where:
d_i – climate-related disclosures (1 = makes disclosures, 0 = does not make any),
m – maximum number of disclosures.

The index values fall within the range <0-1>.

In the other stage of the study, the index for CSR leaders in Poland was calculated, namely, twenty companies from the top 10 of the oldest and well-established Polish Ranking of Responsible Companies 2021 (ROF)[3]. They are listed in Table 3. The index calculation was based on analysing the content of the latest non-financial reports available on the Internet (mainly on corporate websites) in early June 2022.

Results of the research

A comparative analysis of selected climate-related disclosure initiatives revealed that all of them (except the currently updated GRI Guidelines) incorporate the TCFD recommendations to a greater or lesser extent (the EC Supplement relies on them entirely). The GRI Guidelines contain the fewest disclosures, which is bound to change when the latest update is released. Table 1 presents the results of the comparative analysis. It divides climate-related disclosures into categories, partly inspired by the TCFD recommendations: corporate governance, business model and strategy, risks, energy efficiency, emissions.

[3] The latest ranking for 2022 was not available before completing this article; it was released later than usual: at the end of June.

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Table 1. Guidelines/recommendations concerning climate-related disclosure in leading initiatives with codes (duplicate entries are in bold type)

Categories/ guidelines	TCFD Framework 2017	EC Supplement 2019	GRI Guidelines 2016/2021	ESRS draft 2021 (ESRS2, ESRS E1)
Governance	**Description of the board's oversight of climate-related risks and opportunities (Governance A).** **Description of management's role in assessing and managing climate-related risks and opportunities (Governance B).**	**Description of the board's oversight of climate-related risks and opportunities (covers TCFD).** **Description of management's role in assessing and managing climate-related risks and opportunities and explain the rationale for the approach (covers TCFD).**		**Roles and responsibilities of the administrative, management and supervisory bodies with regard to sustainability matters [i.e. climate] (2-GOV 1).** Information of administrative, management and supervisory bodies about sustainability matters [i.e. climate] (2-GOV 2). Sustainability matters addressed by the undertaking's administrative, management and supervisory bodies [i.e. climate] (2-GOV 3). Integration of sustainability strategies and performance in incentive schemes (2-GOV 4). Disclosure of general assessment regarding how company embeds the core elements of due diligence in its sustainability statements [i.e. climate] (2-GOV 4).
Business model and strategy	**Description of the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario (Strategy C).** **Description of the targets used by the organization to manage climate-related risks and opportunities and performance against targets (Metrics and Targets C).**	Description of the ways in which the company's business model can impact the climate, both positively and negatively. **Description of the resilience of the company's business model and strategy, taking into consideration different climate-related scenarios over different time horizons, including at least a 2°C or lower scenario and a greater than 2°C scenario (covers TCFD).** **Description of any company policies related to climate, including any climate change mitigation or adaptation policy.** **Description of any climate-related targets the company has set as part of its policies, especially any GHG emissions targets, and How company targets relate to national and international targets and to the Paris Agreement in particular.**		**Interaction of risks and opportunities and the undertaking's strategy and business model (2-SMB 4).** Disclosure of plans to ensure that its business model and strategy are compatible with the transition to a climate-neutral economy and with limiting global warming to 1.5°C in line with the Paris Agreement (E1-1). **Policies implemented to manage climate change mitigation and adaptation (E1-2).** **Measurable targets for climate change mitigation and adaptation (E1-3).** Climate change mitigation and adaptation action plans and resources (E1-4).

Catego-ries/guide-lines	TCFD Framework 2017	EC Supplement 2019	GRI Guidelines 2016/2021	ESRS draft 2021 (ESRS2, ESRS E1)
Business model and strategy		Description of the outcomes of the company's policy on climate change, including the performance of the company against the indicators used and targets set to manage climate-related risks and opportunities (covers TCFD).		
Risks	Description of the climate-related risks and opportunities the organization has identified over the short, medium, and long term (Strategy A). Description of the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning (Strategy B). Description of the organization's processes for identifying and assessing climate-related risks (Risk Management A). Description of the organization's processes for managing climate-related risks (Risk Management B). Description how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management (Risk Management C). Disclosure of the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process (Metrics and Targets A).	Description of the impact of climate-related risks and opportunities on the company's business model, strategy and financial planning (covers TCFD). Description of the principal climate-related risks the company has identified over the short, medium, and long term throughout the value chain, and any assumptions that have been made when identifying these risks (covers TCFD). This description should include the principal risks resulting from any dependencies on natural capitals threatened by climate change, such as water, land, ecosystems or biodiversity. Description of the company's processes for identifying and assessing climate-related risks over the short, medium, and long term and disclose how the company defines short, medium, and long term (covers TCFD). Description of processes for managing climate-related risks (if applicable how they make decisions to mitigate, transfer, accept, or control those risks), and how the company is managing the particular climate-related risks that it has identified (covers TCFD).	Financial implications and other risks and opportunities due to climate change (201-2).	Description of the processes to identify material sustainability impacts, risks and opportunities [including climate-related] (2-IRO 1). Outcome of the undertaking's assessment of material sustainability impacts, risks and opportunities [including climate-related] (2-IRO 2). Potential financial effects from material physical risks (E1-15). Potential financial effects from material transition risks (E1-16). Potential financial effects from climate-related opportunities (E1-17).

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Catego-ries/ guide-lines	TCFD Framework 2017	EC Supplement 2019	GRI Guidelines 2016/2021	ESRS draft 2021 (ESRS2, ESRS E1)
Risks		**Description how processes for identifying, assessing, and managing climate-related risks are integrated into the company's overall risk management (covers TCFD). An important aspect of this description is how the company determines the relative significance of climate-related risks in relation to other risks.** Assets committed in regions likely to become more exposed to acute or chronic physical climate risks.		
Energy efficiency		**Total energy consumption and/or production from renewable and non-renewable sources.** Energy efficiency target. Renewable energy consumption and/or production target.	**Energy consumption within the organization (302-1).** Energy consumption outside of the organization (302-2). Energy intensity (302-3). Reduction of energy consumption (302-4). Reductions in energy requirements of products and services (302-5).	**Energy consumption and mix (E1-5).** Energy consumption associated with activities in high climate impact sectors per net turnover of these activities (E1-6).
Emissions	**Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks (Metrics and Targets B).**	**Description of the development of GHG emissions against the targets set and the related risks over time (covers TCFD).** **EU taxonomy: Percent investment (CapEx) and/or expenditures (OpEx)** or Percent turnover in the reporting year from products or services associated with activities that meet the criteria for substantially contributing to mitigation of or adaptation to climate change as set out in the Regulation on the establishment of a framework to facilitate sustainable investment.	**Direct (Scope 1) GHG emissions (305-1).** **Energy indirect (Scope 2) GHG emissions (305-2).** **Other indirect (Scope 3) GHG emissions (305-3).** GHG emissions intensity (305-4). Reduction of GHG emissions (305-5).	**Scope 1 GHG emissions (E1-7). Scope 2 GHG emissions (E1-8). Scope 3 GHG emissions (E1-9).** Total GHG emissions (E1-10). Total GHG emissions per net turnover (E1-11). GHG removals from own operations and the upstream and downstream value chain (E1-12). GHG emission reductions or removals from climate change mitigation projects outside its value chain it has financed through the purchase of carbon credits (E1-13). Avoided GHG emissions from products and services (E1-14).

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Catego-ries/guide-lines	TCFD Framework 2017	EC Supplement 2019	GRI Guidelines 2016/2021	ESRS draft 2021 (ESRS2, ESRS E1)
Emissions				Taxonomy Disclosure: disclose information on the proportion of the turnover, capital expenditure ('CapEx') and operating expenditure ('OpEx') or on their green asset ratio associated with economic activities that qualify as environmentally sustainable, among others, under the objectives of climate change mitigation and climate change adaptation.

Source: author's work based on European Commission, 2019; EFRAG, 2022a; EFRAG, 2022b; GRI, 2022; TCFD, 2017.

Taking the identified key and most frequently required climate-related disclosures from Table 1 into account (and additionally the taxonomy disclosures effective in the EU as from this year), an original climate-related disclosures index was designed, made up of eighteen disclosures shown in Table 2.

Table 2. Disclosures used in the climate-related disclosures index and initiatives that include them

No.	Disclosure	Initiative
1	Board's oversight of climate-related risks and opportunities.	TCFD, EC supplement, ESRS
2	Management's role in assessing and managing climate-related risks and opportunities.	TCFD, EC supplement, ESRS
3	Resilience of the company's business model and strategy, taking into consideration different climate-related scenarios.	TCFD, EC supplement, ESRS
4	Policies implemented to manage climate change mitigation and adaptation.	EC supplement, ESRS
5	Measurable targets for climate change mitigation and adaptation (targets and indicators).	TCFD, EC supplement, ESRS
6	Outcomes of the company's policy on climate change, including the performance against targets set.	TCFD, EC supplement
7	Climate-related risks and opportunities identified over the short, medium, and long term.	TCFD, EC supplement, ESRS
8	Impact of climate-related risks and opportunities on the company's business model, strategy and financial planning.	TCFD, EC supplement, ESRS

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No.	Disclosure	Initiative
9	Description of the organization's processes for identifying and assessing climate-related risks.	TCFD, EC supplement, ESRS
10	Description of the organization's processes for managing climate-related risks.	TCFD, EC supplement
11	Description of how processes for identifying, assessing, and managing climate--related risks are integrated into the organization's overall risk management.	TCFD, EC supplement
12	Financial implications and other risks and opportunities due to climate change.	GRI, ESRS
13	Total energy consumption.	EC Supplement, GRI, ESRS
14	Energy consumption from renewable sources.	EC supplement
15	Direct GHG emissions (Scope 1).	TCFD, EC supplement, GRI, ESRS
16	Energy indirect GHG emissions (Scope 2).	TCFD, EC supplement, GRI, ESRS
17	Other indirect GHG emissions (if relevant) (Scope 3).	TCFD, EC supplement, GRI, ESRS
18	Taxonomy disclosures.	EC supplement, ESRS

Following the analysis of twenty-four non-financial reports for 2019-2021[4] (including eight integrated reports, six sustainability reports, as well as ESG, social responsibility, climate, and management board reports), both separate and for capital groups, the climate-related disclosures index for twenty CSR leaders in Poland was computed. The total index value for the analysed companies was 0.51 with the median of 0.42. Table 3 shows the index values for individual companies covered by the study.

Table 3. Climate-related disclosures index for Poland's twenty CSR leaders from the top 10 of ROF 2021

Index position	Index value	Company	ROF position
1	1.00	Cemex Polska	7
2	0.94	BNP Paribas Bank Polska	1
3	0.89	Signify Poland	4
4	0.83	Santander Bank Polska	2
5	0.83	Grupa Lotos	6
6	0.78	Orange Polska	2
7	0.78	Sopockie Towarzystwo Ubezpieczeń ERGO Hestia	3

4 The analysis covered all non-financial reports shared by companies with their stakeholders prior to the study: three provided more than one report, hence a greater number of reports than analysed entities.

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Index position	Index value	Company	ROF position
8	0.72	PZU	8
9	0.44	ING Bank Śląski	3
10	0.44	PKN Orlen	8
11	0.39	Coca-Cola HBC Polska	6
12	0.39	Kompania Piwowarska	8
13	0.33	Jeronimo Martins Polska	10
14	0.28	Schenker	5
15	0.28	Polpharma	7
16	0.22	Polskie Sieci Elektroenergetyczne	8
17	0.22	L'Oreal	9
18	0.17	Lidl Polska	7
19	0.17	Capgemini	9
20	0.17	Lyreco	10

The analysis of non-financial reports of twenty selected companies showed that the least frequently reported disclosures are: Disclosure 12. Financial implications and other risks and opportunities due to climate change (two cases); Disclosure 3. Resilience of the company's business model and strategy, taking into consideration different climate-related scenarios (five cases) and Disclosure 18. Taxonomy (five cases). The most frequently reported information was: Disclosure 15. Direct GHG emissions – Scope 1 (nineteen cases) and Disclosure 5. Measurable targets for climate change mitigation and adaptation (targets and indicators) (eighteen cases). It is worth keeping in mind that although this study did not aim to assess the quality of climate-related disclosures, in cases that were indisputable, the analysed companies did not score one point for a disclosure which was of such a low quality that, in fact, was not disclosure at all, although the reporting company listed it in the table of contents. The study also highlighted the fact that the quality of disclosures was extremely varied. For example, only one company presented a fair picture of Disclosure 3. Resilience of the company's business model and strategy, taking into consideration different climate-related scenarios.

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Conclusions

The climate-related disclosures index demonstrates that companies named CSR leaders in Poland do not display high awareness of climate change. This conclusion is proven valid also by other Polish studies on climate-related reporting mentioned elsewhere. In the Climate Crisis Awareness Study carried out by the Association of Stock Issuers, the average result for 2018 was 1.03 points out of 10 and was 0.09 points higher than in 2017. In 2019 the companies collected an average of 1.87 points and 1.79 points in the following year (which may be attributed to alterations to the study methodology: the authors added indicators on risks and opportunities, climate management in the organisational structure, or Scope 3) (SEG, 2022). In contrast, in the Climate Strategies Benchmark published by the UNEP/GRID-Warsaw and Go Responsible in 2021, the average for the analysed entities was not computed, but the top five companies scored 21-14 points out of 23 (Go Responsible, 2022).

The original index largely relies on the TCFD Framework, published back in 2017 and widely incorporated by various climate-related disclosure initiatives. Meanwhile, in Poland only few companies have begun to include TCFD indexes in their reports. This fact also surfaces in the Climate Risk Disclosure Barometer published by EY in 2021: in Poland the average score for compliance with the TCFD recommendations was 57%, which was significantly lower than the average obtained in the global study (70%). The Barometer also tested the quality of disclosures. In this case, the average for Poland (27%) was also below the global figure (42%) (EY, 2021).

The index proposed herein can be extended not only to include more companies from the ROF rating but also other entities publishing non-financial reports. The limitations of the designed index stem from the aforesaid high variability of climate-related disclosure initiatives. This variability manifests itself not only in the growing number of such initiatives but also in rising expectations as to the scope and quality of reported data. For this reason, the index may need to be updated within the following years. Another question to be addressed broadly in the index may be the quality of climate-related disclosures.

The designed index also led to other conclusions. As shown in Figure 1, the development of climate-related disclosure initiatives has greatly accelerated in recent years, and the relevant requirements are also growing rapidly. This is clearly seen in the analysed non-financial reports. Even between 2019 and 2021, there is unquestionable progress in reporting, both the number and quality of climate-related disclosures have changed for the better. Still, it must be noted that non-financial reports do not always reflect the actual

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pro-climate activities undertaken by companies. Some companies boasted climate-related awards in their reports as if to prove their maturity in managing climate change mitigation and adaptation, yet this was not properly substantiated in the content of the reports. This is because many ratings and rankings rely on questionnaires submitted by companies and verified by auditors rather than on non-financial reports available in the public domain. On the one hand, it proves that such reports cannot be fully trusted as reliable and comprehensive sources of information about companies' impact on the environment. On the other hand, the reports are readily available to stakeholders, including investors and clients who want to make informed decisions, and they enhance the corporate image. Another thing is that the information shared by companies with stakeholders happens to be outdated. In some cases, in mid-2022, only non-financial reports from 2019 are made public.

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Elżbieta **LOREK** • Agnieszka **LOREK** • Wiesław **KOCZUR**

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN POLISH INSTITUTIONS OF HIGHER EDUCATION – PRESENT AND FUTURE

IN MEMORY OF PROF. BAZYLI POSKROBKO.

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ABSTRACT: Education for sustainable development is still developing as a broad and comprehensive concept that includes related content on the environment, economy and society. Key issues of sustainable development include, among others, economic issues, production and consumption models, natural resource management, environmental protection, development models, poverty reduction, civic rights, democracy, governance etc. These issues are very diverse and require a holistic approach to teaching. The objective of this article is to diagnose and evaluate the current state of education for sustainable development in Polish higher education institutions, with particular emphasis on the EU in Katowice and to identify the directions of change. This article was written based on the Authors' many years of scientific and teaching experience. It was also supported by a survey conducted in the year 2020/2021 among the students at the University of Economics in Katowice, which allowed them to identify directions for future educational activities.

KEYWORDS: sustainable development, higher education, education for sustainable development

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Introduction

Education for sustainable development has now become one of the most critical challenges of the UN and the EU (UNESCO, 2007; UNESCO, 2009; Leicht et al., 2018; UNESCO, 2020; Geryk, 2018; Nizinska & Kurantowicz, 2019; Alcantud-Diaz, 2021; Leal Filho et al., 2021). The targets to be pursued in this education are to integrate principles, values and practices around sustainable development (SD) in all aspects of education and training.

The implementation of the goals should lead to behavioural changes that create a more sustainable future, consisting of natural integrity, economic vitality and social activity for the needs of present and future generations. Poland is actively involved in the realisation of these objectives through the relevant provisions contained, among other things, in the *2030 National Environmental Policy*. These actions fall into a period of rapid economic changes, especially in recovering from the Covid-19 pandemic.

This period is linked, among other issues, to Poland's involvement in the disbursement of approximately €35.970 billion under The National Recovery Plan (NRP). Hence, the disbursement of funds must be in line with the constitutional principle of sustainable development, favouring an integrated approach to selected projects that seek to improve resource efficiency and environmental quality. Implementing these intentions will require the presence of university graduates in the labour market who are aware of and educated in the area of sustainable development.

Higher education reform is a strategic challenge for the development of the Polish economy, allowing the undertaking of such research directions that may support the search for solutions to economic, ecological, technical and social problems. A prerequisite for the success of this reform is an international cooperation with various entities, as this will support systemic and interdisciplinary solutions that are fundamental instruments for sustainable development.

Despite the tremendous changes that have taken place in Polish universities, the introduction of sustainable development issues into the curriculum is still not an easy matter. At the same time, it should be emphasised that graduates and young PhDs leaving universities are, after all, potential leaders equipped with knowledge and experience of sustainable development who will co-create several institutions and companies active for this development, not only in the Polish economy but also in other countries of the world (Sady et al., 2019). Thus, the question arises as to whether Polish higher education institutions properly prepare their graduates for these tasks. Moreover, does the education on sustainable development provide students with up-to-date knowledge about future directions of innovative actions in managing natural resources and thus countering adverse climate change?

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Therefore, to answer this question, the Authors researched the evaluation of building the foundations of active education for sustainable development at a selected higher education institution, i.e. the University of Economics in Katowice. This article was written based on the Authors' research concerning education for sustainable development (Lorek et al., 2008; Lorek & Słupik, 2010; Lorek & Gierczycka, 2010; Lorek & Sobol, 2010; Lorek, 2011; Lorek, 2013; Lorek & Olszak, 2013) and many years of teaching experience in subjects such as "Environmental Management" and "Economics of Sustainable Development" at the University of Economics in Katowice and Higher Silesian School of Management in Katowice. In addition, a survey was carried out in the year 2020/2021 among the students of this university that made it possible to identify directions for future educational activities in the area of sustainable development.

Evaluation of provisions on education for sustainable development in Polish government documents

The content of Act illustrates the importance of education for sustainable development. 77 of the Act of 27 April 2001 Environmental Protection Law (Journal of Laws 2017, item 519 as amended) indicates that environmental protection and sustainable development issues are included in the core curriculum of general education for all types of schools. The primary government document that contains provisions on education for sustainable development is the *2030 National Environmental Policy*. This policy includes the following conditions regarding the medium-term goals to be achieved in the field of education:

- continuous raising of the environmental awareness of society, to guarantee broad access to information on the environment and its protection,
- increasing the number of people taking conscious consumer decisions, taking into account the need to protect natural resources,
- creating a platform of cooperation with non-governmental ecological organisations by supporting the activities of these organisations.

The indicated policy's directions include supporting education projects for sustainable development carried out by various entities and promoting attitudes based on the idea of development and responsible consumption (Resolution of the Council of Ministers, 2019).

Based on a review of government documents on education for sustainable development, it is evident that there is no single formalised cooperation structure for education for sustainable development. This is considered one of the most significant barriers to its development. The Ministry of Education and Science's guidelines for introducing education for sustainability in higher

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education institutions are very general and only apply to specific fields of study. However, the elements of sustainability should be included in the curricula of all areas of study. There is no current document on education for sustainable development in Poland. All previous records, such as *the National Strategy of Ecological Education* (a strategy from 2001 that has not been updated; there is also no document replacing it), did not take into account the current conditions for sustainable development, especially as regards climate policy and the very related energy policy. In addition, there are no systematic measures to assess the level of education for sustainable development in formal and informal education. Moreover, the Central Statistical Office does not keep statistics on education for SD.

The Core curriculum defines the obligation to introduce SD issues at all levels of education. This document indicates the implementation of curricula using practical methods, experiences, analysis, and problem-solving. At the university level, SD includes courses in environmental studies, tourism, sociology and social policy; at economic studies – courses in macroeconomics, marketing and monetary policy. It should be emphasised here that universities have complete autonomy in curriculum development. In higher education, SD and related issues are mainly found in the natural, agricultural, forestry and veterinary sciences. The only guideline for many years defining the necessity of SD education at the university level is contained in the National Qualifications Framework. This document is general, and education for sustainable development is only present in some fields of study. No nationwide standards specify the necessity of education in SD in all areas of study.

The environmental education provisions in higher education indicate the primary objective of environmental education, i.e. to introduce future graduates of all higher education institutions to ecological issues. Accordingly, environmental knowledge is to be imparted so that graduates acquire basic knowledge in scientific fields such as natural, technical, economic and social sciences. In other words, it should shape graduates' holistic thinking about economic growth, quality of life and environmental protection to implement sustainable development (Von Hauff & Ngujen, 2014; Buchcic, 2016; Korwin-Szymanowska et al., 2016).

Despite the passage of many years since the strategies above were incepted, only a limited number of studies provide comprehensive knowledge of sustainable development. The observed phenomenon brings about a situation wherein graduates of biological and technical studies often take an extreme position in matters of the broadly understood "environment" – either extremely technical or natural/environmental – without understanding the socio-economic conditions.

The article's authors encountered this issue while preparing opinions for prosecution regarding specific irregular waste management in Silesian cities.

From these experiences, it is evident that there is a lack of educated university graduates capable of preparing proper economic analyses in the field of, for example, assessing the eco-efficiency of waste management, consistent with the principles of sustainable development. Therefore, the objectives set out in the *National Strategy of Ecological Education* to ensure that universities educate students comprehensively by the principles of sustainable development are still valid and still not met.

Universities should, therefore, issue and promote textbooks and scientific publications treating environmental protection problems in the philosophy of sustainable development. In this area, such scientists as Professors Bazyli Poskrobko, Bogusław Fiedor, Andrzej Graczyk, Tadeusz Borys, Eugeniusz Kośmicki, Kazimierz Górka, Tomasz Żylicz and others play a leading role in Polish higher education.

Educational activities and challenges for sustainable development in higher education

Education for sustainable development means much more than environmental education. It also includes human rights, conflict resolution, good governance, economics, culture and the arts. It goes beyond formal education systems but should influence them, as reflected in textbooks, curricula and teaching methods (Franco et al., 2018; Sady et al., 2019). Currently, the main fields of higher education in Poland mainly concern:

1) internationalisation – the inclusion of international and inter-cultural issues in educational programs (e.g. using an instrument such as the Bologna Process),
2) research interdisciplinarity – e.g. by implementing research programs under the EU Framework Programs or other,
3) virtualisation – e.g. research and teaching programs implemented using modern information technologies (such as distance learning).

It should be added that the Bologna Process aims to create competitive knowledge communities. To this end, in 1999, 29 European countries signed the so-called 'Bologna Declaration' to achieve a shared space for higher education in Europe. The Bologna Declaration is being extended to non-European areas of higher education and, together with the EU Strategy for Central Asia, focuses on bilateral and regional initiatives, systematic political dialogue and economic, transport, energy, environmental and educational cooperation. Herein, higher education develops international cooperation through:

a) carrying out student exchanges, mainly within the Erasmus program,
b) implementing study programs in cooperation with foreign universities (studies under the Erasmus Mundus program),

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c) participating in international associations, thematic networks, university unions, and multilateral projects.

Among the forms mentioned above of cooperation in undertaking activities for sustainable development, the final form plays a unique role, creating perfect conditions for scientific and educational collaboration (The Copernicus Alliance). Accordingly, the part of university courses is to familiarise students with the existing state of knowledge, with an indication of what we already know and what we do not know, with the communication of for and against, or positive and negative arguments.

Researchers' predictions indicate that sustainable development, especially the economics of sustainable development, will be the leading area of economic research in the third decade of the 21st century. Initially, it will develop in parallel with knowledge of economics to form a new science. Education for sustainability promotes good co-governance, sustainable consumption and production patterns, and the transmission of values and culture, reinforcing institutional sustainability (Barth et al., 2007). Without sustainability, it is challenging to change development goals and weak institutions without the help of education and science. Thus, education is an element of good co-governance because it stimulates public participation, transparency, accountability and political stability.

It is also vital in creating institutional capital and building capacity for institutional change. Education has a variety of functions about the effective functioning of institutions and institutional structures of co-governance and the activity's social, economic and environmental outcomes. It creates skills, knowledge, and human capital, essential factors of production, innovation in production technology and organisational structures. The ability to seek, process and interpret information reduces problems with asymmetric information and creates an understanding of sustainability issues. Education for sustainable development forms the basis for making, assimilation and disseminating knowledge. It facilitates access to institutional structures for co-governance and the full exploitation of the economic and social potential of property rights. Moreover, it enables the enforcement of these rights and the minimisation of adverse environmental externalities.

Realistically looking at educational programs at this level of education, the scenario to provide every student with a set of desirable knowledge in this area seems unworkable. A more down-to-earth method is inspiring lecturers to refer more widely to relevant examples in the implementation of sustainable development in the economies of Western countries, especially European. Compared to other countries, Poland has achievements in this area and its failures and weaknesses. The latter include that education – considering sustainable development issues – is not yet systemic in our country (Lorek & Olszak, 2013).

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Education for sustainable development is based on 'warm' values –empathy, honesty, kindness, respect for dignity, and truth. According to Borys (2010), the main challenges facing education for sustainable development are solving the following problems:

1) unambiguous disclosure of the new development paradigm in the instruction for the sustainable development system,
2) combining education for a sustainable quality of life with education for sustainable development – into an integrated system,
3) the prominence of culture as a link to education for sustainable development,
4) systemic transfer of international initiatives supporting education for sustainable development to the national level, and coordination of Polish activities in the field of education for sustainable development (Borys, 2010).

As indicated above, education for sustainable development has not been systemic in Poland so far; the lack of interest in this global commitment of the political sphere at the national, regional and local levels is also noteworthy. The absence of an action plan enacted in Poland for implementing the Decade of Education for Sustainable Development (2005-2014) contrasts with the actions of other European countries, especially Germany (Borys, 2010; Kędzierska et al., 2013; Von Hauff & Nguyen, 2014).

An example of an organisation working for international cooperation in the EU is the European Environmental Advisory Council (EEAC), tasked with improving Europe's sustainable development strategy. This Council promotes public engagement, interdisciplinary research on sustainable development and transgenic cooperation for future generations.

Initiatives worth mentioning in the context of the practical integration of education for sustainable development into university curricula include the series of conferences: 'Education for Sustainable Development. The most recent was the VII International Conference entitled 'Education for Sustainable Development, which took place in October 2009. This conference was organised by the Jelenia Góra Faculty of the Wrocław University of Economics in cooperation with the Polish-German Network of Scientists for Sustainable Development, the European Association of Environmental Economists – Polish Branch and the State Council for Environmental Protection.

It brought together over 140 representatives from more than 40 scientific centres from all over Poland (universities of economics, agriculture, technical universities), politicians, journalists, minist of ministries, UNESCO, several NGOs, special purpose funds and representatives of German universities. The conferences in this series provided an essential forum for exchanging experiences between individual centres, and it would be worth considering their reactivation. The meeting resulted in a publication entirely devoted

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to the issues of education for sustainable development (Borys, 2010; Poskrobko, 2010a; Brzozowski & Rogala, 2010; Bartniczak & Zaremba-Warnke, 2010).

Education for sustainable development in universities – a literature review

The role and importance of education for sustainable development in higher education institutions are discussed in Polish and foreign literature in many publications, diverse in their character and objective. A unique role and momentous significance, especially in the didactic process, is attributed to textbooks and other compact developments similar in purpose. In the case of Polish publications, the following books on sustainable development and environmental management should be mentioned in particular:

- fundamentals of environmental and natural resource economics, edited by Bogusław Fiedor, Publisher: C.H. Beck, Warsaw 2002,
- sustainable development economics. Theory and practice, by Holger Rogall (Zysk i S-ka Publishing House 2010), or
- economics and management in environmental engineering, by Elżbieta Broniewicz, Joanna Godlewska, Agata Lulewicz-Sas and Rafał Miłaszewski, published by the Publishing House of the Bialystok University of Technology in 2019.

Professor Bazyli Poskrobko's enormous contribution to education for sustainable development (SD) needs to be emphasised. It has been expressed, among other things, in several special publications; in particular, the Environmental monograph management, edited by the Professor in 2007 (by PWE), and the works: Economics of sustainable development: an outline of research problems and didactics (Poskrobko, 2010) and Theoretical aspects of sustainable development economics (Poskrobko, 2011), as well as the work by Bazyli and Tomasz Poskrobko entitled Environment management in Poland, published by the University of Białystok in 2012.

As indicated above, professors such as Tadeusz Borys, Kazimierz Górka, Andrzej Graczyk, Eugeniusz Kośmicki, Tomasz Żylicz have also made significant contributions to education to sustainable development in Poland.

Currently, education for sustainable development is one of the most fundamental challenges for the United Nations and the European Union, emphasised in the above-mentioned Polish publications and foreign literature (e.g. Rosen, 2020; Alcantud-Diaz, 2021; Leal Filho et al., 2021).

Analysing the foreign literature on education for sustainability in higher education, it is noted that, in addition to developments of a textbook and

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guidebook nature (e.g. Barth et al., 2015; SDSN Australia/Pacific, 2017; UNESCO, 2020; SDSN Italia, 2021), the following can also be distinguished:

a) scientific publications generally dedicated to the role and importance of this education, its axiological, social and economic foundations, as well as the outcomes that should be achieved in the process of this education (e.g. Barth et al., 2007; Shephard, 2008; von Hauff & Nguyen, 2014; Owens, 2017; Franco et al., 2018; Leicht et al., 2018; Parricchi, 2018; Finnveden et al., 2020; Alcantud-Diaz, 2021; Blasco et al., 2021),
b) publications devoted to the identification or analysis of the curricular basis of education for sustainable development in universities (e.g. Sady et al., 2019; Leal Filho et al., 2021),
c) publications providing an overview of good practices in this education in different countries (e.g. Aleixo et al., 2016; Calvano, 2017; RUS, 2017; Sonetti et al., 2020), as well as
d) publications containing case studies on the indicated subject based on research carried out in one specific university (e.g. Di Gerio et al., 2020; Calvano, 2021; Chaleta et al., 2021; De Vincenzo & Riggo, 2021).

The latter group includes the present study, prepared based on research on education for sustainable development conducted among students at the University of Economics in Katowice.

Assessment of education for sustainable development in the light of surveys conducted among the students at the University of Economics in Katowice

The direct research concerned students of a higher education institution with an economic profile, namely, the University of Economics in Katowice. The indicated investigation aimed to identify and assess the state of education for sustainable development, with a particular focus on social and environmental issues, as well as ascertaining students' attitudes towards selected problems related to sustainable development. It was carried out in the academic year 2020/2021 as part of the statutory research of the Department of Social and Economic Policy entitled '*Selected social and environmental components of sustainable development of the Silesian agglomeration. Stage 1: The importance of educational policy for implementing the sustainable development strategy under Dr hab's* supervision of dr hab. Agnieszka Lorek, professor at the University of Economics in Katowice.

Based on the previous research of the article's authors (Lorek et al., 2008; Lorek & Słupik, 2010; Lorek, 2013), the following research hypothesis has been formulated: education for sustainable development in the EU Katowice is not comprehensive.

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The survey in the academic year 2020/2021 was addressed to people using the Internet, who filled it out on their own using the survey link that they received. The links were posted on the Google platform. Two hundred undergraduates completed the survey questionnaire, and postgraduate students (full-time and part-time) of the University indicated above.

The survey questionnaire presented to the respondents was divided into three areas: environmental education, social education, and the linking area of sustainable development. The following results were obtained through questionnaire surveys among the students of the University of Economics in Katowice:

1. More than 61% of all respondents perceive the presence of environmental topics in the teaching content (in the 2020/2011 survey, this was 79%). More than 82% of all respondents came into contact with social issues during their studies.
2. 72% of the students participating in the survey in question believe that knowledge of the environmental determinants of economic development is indispensable in the process of education in economics (in the study conducted in the 2010/2011 academic year, the figure was 89%). Similarly, 79.5% consider familiarisation with social problems to be necessary.
3. 57% of the surveyed students state that the information on environmental conditions for economic development provided within the current curriculum is insufficient. At the same time, 49.5% of all respondents consider information on social issues inadequate.
4. The topics that were least discussed during the classes were (in all cases, according to about 50% of the respondents):
   - in the field of the environment: water management and ecosystem services and loss of biodiversity,
   - in the field of social issues: green jobs, inclusive social programs and protection of cultural heritage.
5. Among the topics discussed, according to the respondents, to a sufficient extent, the most frequently indicated cases were: ways of managing natural resources, sustainable development of transport (environmental sphere), social security, active labour market policy (social sphere) with, in these cases, the level of indications varying between 33 and 39% of the respondents.
6. At the same time, the respondents could indicate issues they would like to learn more about. The most frequently mentioned topics were:
   - climate change and its impact on the economy and society,
   - waste management,

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- ways of managing natural resources – this topic was considered one of the best discussed, but the students found it worthy of an even more extensive discussion,
- problems of poverty and social exclusion,
- principles of the functioning of social insurance,
- active labour market policy,
- green-collar workers – a topic considered one of the worst discussed, worth devoting more attention to.

7. Approximately 86% of the students surveyed in the 2020/2021 academic year correctly understand the term “sustainability” (in the 2010/2011 survey, this was as high as 95.8%), and 53% had encountered the time during their studies (in the earlier survey 90.1%).
8. More than half (51.5%) of the respondents believe that a separate subject on sustainability, introduced as a specialised, elective subject, is needed (around 74% of all responses). Most of the students surveyed do not know the availability of literature on sustainability issues.
9. The educational process should also translate into personal action. Among the pro-environmental and pro-social activities undertaken by students, the most frequently mentioned were:
   - segregation of household waste (91.4% of responses),
   - saving water (79.7%),
   - resignation from foil bags (75.1%).

On the other hand, social and civic activities such as volunteering (4.1% of all indications) or participation in social consultations (1%) are relatively unpopular among the respondents.

To sum up – the majority of the surveyed students of the University of Economics in Katowice state that the education process at the university raises awareness of issues related to sustainable development (51.8% of all such statements); at the same time, still there are spheres and topics that, due to the existing challenges of civilisation, should be discussed to a greater extent.

When assessing the curricula of the University of Economics in Katowice about the implementation of education for sustainable development, it should be noted that since 2007, several subjects related to this topic have been eliminated at the faculties of Economics and Management; such issues were also stopped at the Faculty of Finance and Insurance. This has decreased the percentage of students able to interpret the term ‘sustainability’ correctly. Currently, the subject is covered to the greatest extent by the Spatial Management course at the Faculty of Economics. It should be added that in the 2022/2023 academic year, the University of Economics in Katowice is planning to launch a new specialisation, ‘Green management in public economy’, within the Public Management course of study. The field is intended to equip

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graduates with knowledge and skills for solving the complex problems faced by society, the environment and the economy today. The 'Green management in the public economy' specialisation also provides students with a scientific understanding of ecological and social systems applicable to governance or sustainable development policy-making.

Sustainability and green management need to be present in almost all sectors: from the public sector to modern industries, agriculture, energy, and traditional manufacturing. For large enterprises, dealing with this challenge is no longer an alternative but an urgent need for managers who want to use their commitment to an innovation-inspired career.

University courses in green management will provide the tools to handle the change in both the public sector and enterprises, thus contributing to transforming an element of organisational culture into a factor supporting economic objectives. The specialisation is intended to train new managers of green transformation, inspiring executives, professionals and eco-entrepreneurs who want to be the source of new ventures and green start-ups.

Conclusions

In Polish higher education institutions, the implementation of educational activities for sustainable development remains an arduous undertaking. In many countries of the world, mainly European, the main objective is – firstly – to introduce the issue of sustainable development into the national educational systems and educational policies of the countries, and secondly – to raise awareness of the importance of sustainable development assumptions among the various stakeholders of civil society: the media, social and non-governmental organisations, the private sector and education. The European form of achieving the objectives was developing a Strategy on Education for Sustainable Development by the United Nations Economic Commission for Europe (UNECE). This strategy addresses the following issues: human rights, health, cultural diversity, peace, ethics, democracy, social justice, security, the economy, environmental protection and natural resource management.

Our country also participates in this educational program to provide appropriate conditions, creating financial assistance and support programs for education and research. Education for sustainable development forms the basis for making, assimilation and disseminating knowledge. It facilitates access to institutional structures for co-governance and the full exploitation of the economic and social potential of property rights. It enables the enforcement of these rights and the minimisation of adverse environmental externalities. Well-educated graduates should understand sustainability in suffi-

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cient depth to know how to include natural capital in economic analyses and build scenarios with a chance of social acceptance. In-depth sustainability knowledge should be transferred, especially at the third level of education. An increasing number of doctoral and post-doctoral theses include the basic assumptions of sustainable development in their title and content.

In general, this education takes place in many Polish universities. Assuming that the importance of the sustainable development paradigm (as a constitutional principle) is appreciated, the future of economic education should also be related to the inclusion of this subject matter in the curriculum minima. At present, however, it is difficult to find a 'trace' of this concept in the curriculum minima of economic studies. Nonetheless, the subject is included in the curriculum minima of technical and natural science faculties.

Universities are centres for acquiring practical knowledge and experience in sustainable development, thus creating opportunities for meetings and cooperation between students of different faculties and universities and completing the formal side of education for sustainable development. The research shows that there is still a need to remove barriers to existing behaviour in implementing sustainable development. This should be fostered by qualified academic teachers and foreign exchanges with other academic centres. Educated academics, especially members of the Polish and European Association of Environmental and Resource Economists and the international Polish-German Network of Scientists for Sustainable Development, guarantee professional education in sustainable development. The Authors' observations show that at universities where academic teachers are employed – who are also members of the Polish Association of Environmental and Resource Economists – the students' knowledge of the topics mentioned above is very extensive. Yet, it needs to be emphasised that for sustainability education to be effective, monitoring of the effects of sustainability measures is required, as well as the availability of active sustainability education provided by both public and non-public universities (COPERNICUS-CAMPUS, 2022; SDSN Australia/Pacific, 2017).

The contribution of the authors

The article was written in collaboration with all authors.

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STUDIES AND MATERIALS

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ASSESSMENT OF THE POSSIBILITY OF LOCATING ELECTRIC CAR CHARGING STATIONS USING FUZZY AHP AND GIS – THE CASE OF ŁÓDŹ, POLAND

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ABSTRACT: This paper examines the possibility of locating electric vehicle charging stations using multi-criteria decision analysis (MCDA) and GIS. The study presents an integrated approach, which can be helpful in spatial planning. Recent years have witnessed a growing interest in using alternative power sources for motor vehicles. It is stimulated by top-down factors, such as regulations introduced by the European Commission or the introduction of the so-called "clean transport zones" by some local governments, as well as the bottom-up ones, including the increase in the cost of maintaining fossil fuel-powered cars. Local governments can employ the analysis presented in the paper to find a coherent development strategy for using electric vehicles (EVs) in cities. Based on the verified hypothesis, the Łódź city area has diverse suitability for EV charging stations, with predominant unfavourable regions for such investments. The research aims to find the methodology for performing the suitability analysis to locate new infrastructure elements in an urban space.

KEYWORDS: AHP, FAHP, GIS, electromobility, location problem

Introduction

Global warming and its consequences affect various aspects of life and the economy. This phenomenon impacts urban areas in terms of the society's quality of life and the necessity of constant technological progress. Examples of the remedial factors for the problem may include the implementation of a zero-emission fleet in urban transport (Pietrzak & Pietrzak, 2020; Pietrzak & Pietrzak, 2021) or the use of electric freight vehicles in the city space (Quak et al., 2016). Nowadays, electromobility is important in improving living conditions in urbanised areas. On the one hand, it reduces the economy's dependence on oil and supports the development of sustainable urban areas. On the other hand, using EVs requires costly investments in a new type of infrastructure, i.e., charging stations. The choice of their location is one of the most important conditions for increasing the use of this vehicle type and can be seen as a research gap visible in the Polish literature on the subject. The authors of this article are unaware of the study on this subject concerning Łódź – one of the largest cities in Poland. This requires action to fill a specific gap in the context of electromobility in Polish cities. Therefore, the primary goal of the research is to indicate Łódź areas preferred for electric car charging stations. Fuzzy AHP and GIS have been used for this purpose.

The COVID-19 pandemic (Rokicki et al., 2022) and the war in Ukraine did not stop but only slowed down the switch to electric-powered vehicles. According to the report of the Polish Alternative Fuels Association, the share of electric cars in Poland is expected to increase to 14.5% in 2025. At the end of September 2022, the number of battery electric vehicles (BEVs) equalled almost 27,000. This represents approx. half of the country's electric passenger and utility vehicles. From January to September of the year mentioned, 18,000 new electric vehicles (PHEV+BEV) were registered (Polskie Stowarzyszenie Paliw Alternatywnych, 2022a). Furthermore, the forecasts for the development of electromobility in Europe show that the demand for BEV will increase to around 50% in 2030 and to around 70% in 2040 (Polskie Stowarzyszenie Paliw Alternatywnych, 2022b).

The development of charging infrastructure available in Poland is disproportionate to the increase in the number of electric cars. At the time of the research, there were 2,460 publicly accessible charging stations, equalling 4,738 charging points. Unfortunately, as many as 72% of them are slow alternating current (AC) chargers with power less than or equal to 22 kW (Polskie Stowarzyszenie Paliw Alternatywnych, 2022b). Besides, they form a very distributed network. A further increase in the number of electric cars would necessitate an adequate infrastructure upgrade. Consequently, the topic should be investigated further.

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The article has five parts. First, it presents an overview of criteria and methods supporting the decision-making process for the location of a BEV charging station. Next, FAHP and GIS methods are characterised. Then, the criteria are presented for determining the charging station locations in the city of Łódź. These criteria were assessed using a five-point scale built of fuzzy triangular numbers. The fourth part presents the calculation results using combined FAHP and GIS for assessing the attractiveness of the Łódź area in terms of the location problem. Finally, a comprehensive summary of the results is presented.

Literature Overview regarding Electric Vehicle Charging Stations (EVCS)

The literature review on the topic shows various articles concerning the problem of the use of MCDA methods to research electromobility. Some of them consider GIS as an element of the analysis. The examples of research in the field include those based on the following:

- mixed integer programming related to the planning problem of plug-in hybrid charging infrastructure (Dashora et al., 2010),
- TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) in the fuzzy variant to find the optimal electric vehicle charging station sites (Guo & Zhao, 2015),
- GRA-VICOR (Grey Relation Analysis – Vlsekriterijumska Optimizacijia I Kompromisno Resenje) method to provide a comprehensive approach for optimal siting of EVCS and as a way to improve the aggregating function of the fuzzy VIKOR method (Zhao & Li, 2016),
- genetic algorithms for the creation of a model for the location of PHEV charging stations (Zhu et al., 2016),
- PROMETHEE (Preference Ranking Organisation Method for Enrichment Evaluations) method combined with a cloud model for the EVCS site selection (Wu et al., 2016),
- Fuzzy AHP (Analytic Hierarchy Process) and combined to indicate the location of charging stations in Istanbul (Guler & Yomralioglu, 2020). The use of results received by these authors is described further in the paper.

Choosing the criteria supporting the decision-making process connected with the location of electric vehicle charging stations is a subject rarely mentioned in the Polish literature. The problem of assessing the location has been analysed, e.g., for Poznań (Szymańska & Szczur, 2019). The authors of this article pointed out that the analysis requires considering many criteria simultaneously. They applied an approach considering a set of criteria belonging to six categories, including construction costs, the share of high-power chargers, spatial availability, population density, areas with commer-

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cial development and integration with public transport. However, some of the adopted criteria raise doubts. Since then, construction costs have increased significantly, which can be connected with the overall large increase in the prices of building materials and labour.

Use of MCDA and GIS in the Electromobility Analysis

The very nature of the decision problem often implies its multi-criteria character, as planning requires considering at least several decision variants, each influenced by many factors determining its acceptability. The multi-criteria decision support methods evaluate decision variants that usually belong to a finite set of feasible solutions. The Analytic Hierarchy Process (AHP) has been chosen as a methodological starting point. The method, developed by Thomas L. Saaty in 1977, assists complex decision-making and is considered universal. The highly flexible method is used to solve decision problems with a hierarchical structure. It is especially useful with some qualitative evaluation criteria. Assessments of decision variants are usually subjective, so the final result depends on the decision-maker's goals and preferences.

The AHP method is strongly based on a hierarchy of factors. In the simplest case, this structure consists of the goal, criteria and (the lowest) decision variants, although it is possible to introduce subsequent levels containing additional sub-criteria. Each structure element has an appropriate weight assigned, considering expert knowledge concerning the problem. Generating weights necessitates setting adequate preferences that reflect the criterion's significance (Trzaskalik, 2014).

The AHP method consists of the following steps:

- building a hierarchical model,
- assessing the pairwise comparisons,
- determining global and local preferences,
- verifying the compliance of the assessments resulting from pairwise comparisons,
- classifying the decision variants.

Typically, people assign many possible values to one evaluation. A decision-maker often has to average the assessment and place it between extreme values, e.g., between a significant and a large advantage, which leads to ambiguity in determining preferences. During the decision-making process, it is difficult to precisely express preferences concerning the pairwise comparison of the objects due to the need to switch from linguistically formulated judgments to numerical values. This shows the necessity to introduce fuzzy numbers to the procedure. The fuzzy AHP was chosen as it reduced this preference's ambiguity.

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There are many ways to refer to the FAHP (Fuzzy AHP) problem. The most popular approaches were presented by Chang (1996) and Mikhailov (2003), where all stages of the classic AHP method have been retained. Differences appear when determining the matrix of pairwise comparisons, local and global weights, and examining the consistency of assessments. Some authors (Krejčí et al., 2017) propose the concept of bounded fuzzy arithmetic if there is an interaction between fuzzy numbers.

In Chang's approach (used in this work), the first stage of the analysis is the same as in the classic AHP method. Also is the second stage, i.e., creating a pairwise comparison matrix, although the assessments are in the form of fuzzy numbers. Therefore, the comparison matrix has the following form:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix}, \tag{1}$$

where:

$$\tilde{a}_{ji} = \frac{1}{\tilde{a}_{ij}} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}\right). \tag{2}$$

In the third step of the AHP algorithm, global and local preferences are determined based on the pairwise comparison matrix from the previous phase.

The following steps need to be considered in Chang's approach:

Normalising the elements of the pairwise comparison matrix. In the beginning, all the elements in a given row of the comparison matrix $\tilde{a}$ are summed up in pairs. Then, the matrix elements are normalised according to the following formula:

$$\tilde{Q}_i = (l_i, m_i, u_i) = \sum_{j=1}^{k}(l_{ij}, m_{ij}, u_{ij}) \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{n}(l_{ij}, m_{ij}, u_{ij})\right]^{-1}. \tag{3}$$

Calculating the degree of exceeding the number $\tilde{Q_i}$ over $\tilde{Q_j}$ using the formula:

$$V(\tilde{Q}_i \geq \tilde{Q}_j) = \begin{cases} 1, & \text{for} \quad m_i \geq m_j \\ 0 & \text{for} \quad l_j \geq u_i \\ \frac{l_j - u_i}{(m_i - u_i) - (m_j - l_j)}, & \text{for} \quad other\ cases \end{cases}. \tag{4}$$

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Determining the degree of exceeding the number $\tilde{Q_1}$ over the remaining numbers in the row using the formula:

$$V\left(\tilde{Q}_i \geq \tilde{Q}_j | j = 1, \ldots, n; i \neq j\right) = \min_{j=1,\ldots,n; i\neq j} V\left(\tilde{Q}_i \geq \tilde{Q}_j\right). \tag{5}$$

Determining individual indexes of preferences (weights) following the formula:

$$w_i^{(k)} = \frac{V\left(\tilde{Q}_i \geq \tilde{Q}_j \middle| j=1,\ldots,n ; i\neq j\right)}{\sum_{h=1}^{n} V\left(\tilde{Q}_h \geq \tilde{Q}_j \middle| j=1,\ldots,k ; h\neq j\right)}, \tag{6}$$

where k is the number of the factor for which the weight was determined.

Suitability Analysis for Locating Car Charging Stations in Łódź

The analysis was performed using FAHP and GIS. The multi-criteria method established a set of weights for the considered criteria. GIS was used to assess areas within the administrative boundaries of Łódź city for attractiveness in locating electric car charging stations. The ArcGIS package, i.e., ArcMap and ArcScene, was the chosen software. The calculations for the FAHP method were made using the FuzzyAHP package launched in the R environment.

While determining the location suitability of BEV charging stations, it becomes important to select the appropriate criteria and restrictions that directly impact project implementation. These criteria may vary depending on the objectives to be achieved, the information available and the planners' experience. At the same time, it should be noted that the criteria selection process depends on the availability of data and the nature of the research area. The set of criteria can be considered universal for urban analyses as some of the infrastructure elements are the same as everyday functioning problems. Therefore, the criteria found in studies on the location of charging stations are at least partially repeated. The examples may include such criteria as population density, location of shopping centres, road network (at least two lanes), population income rate, the presence of public transport stops, locations of parks and other green zones, land slope or land value (Guler & Yomralioglu, 2020). It is worth noting the different nature of all criteria.

Following the studied literature (Dashora et al., 2010; Guler & Yomralioglu, 2020; Guo & Zhao, 2015; Pietrzak & Pietrzak, 2021; Szymańska & Szczur, 2019), the chosen set of criteria is based on infrastructure and demography.

It has been decided that the construction cost of BEV charging stations is a factor too uncertain to estimate due to continuously growing material prices and inflation. Furthermore, the criterion considering the power of the charging stations is constantly evolving. Two years ago, charging stations were considered fast if they had the power of at least 22 kW, while a year ago, it was 50 kW, and now, 100 kW is expected. This makes the two criteria unusable.

The following set of criteria has been chosen:

- distance from petrol stations (C1),
- distance from shopping centres and supermarkets (C2),
- population density (C3),
- distance from car parks (C4),
- location in relation to parks (C5),
- location in relation to already existing charging stations (C6),
- distance from the main roads running through the city (up to the level of voivodeship roads) (C7).

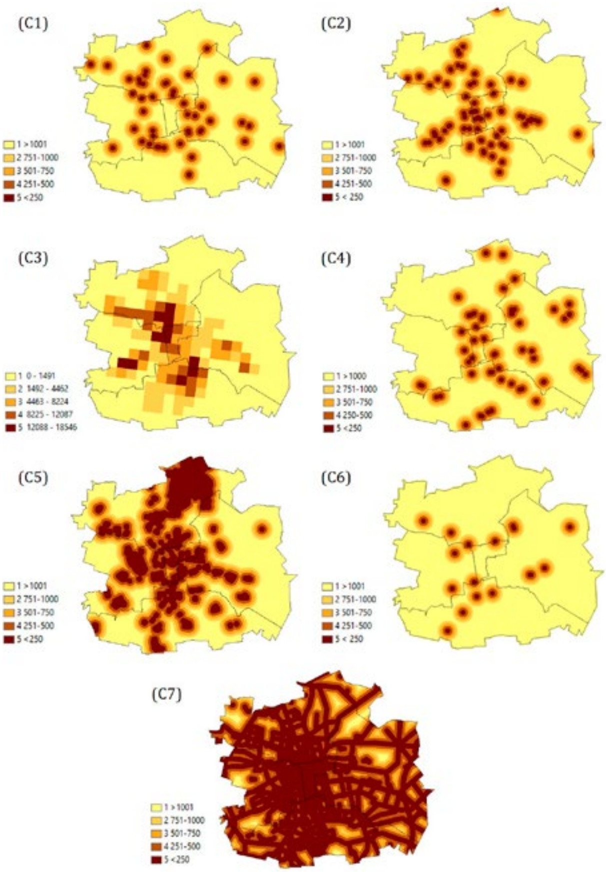

Figure 1. Reclassified raster layers for the criteria maps

Source: author's work based on ArcMap.

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Maps for the criteria have been reclassified to diversify the city's area into five suitability classes (1 – most unsuitable; 5 – the most suitable). The reclassification process refers to resuming the classification process and is one of the important stages in the cycle of determining the suitability of the location. Reclassification tools use appropriate methods to convert the original raster cell value to an alternative one. The process becomes useful in situations where the values of a given input raster are to be divided into specific ranges according to the individual preferences of a decision-maker or considering restrictions resulting from, e.g., laws or other normative acts.

The analysis of the reclassification effects presented in Figure 1 shows that most of the criteria are clearly concentrated in particular districts. The least concentrated criterion is C7 – distance from main roads. Several national and provincial roads pass through Łódź, from the north to the south and from the east to the west.

For the next step of performing the suitability analysis, all criteria were presented as a pairwise comparison matrix. It was assumed that the criteria comparisons and the coherence assessment would be made based on a five-point descriptive scale in the acute version. The basic matrix was transformed by introducing triangular fuzzy numbers. This is consistent with the considerations of other authors in this field of research. In the article by Liu et al. (2017), a list of various consistency measures can be found, from which the CR index has been chosen.

Table 1. Pairwise comparison matrix for ratings in the form of a five-point verbal scale

	C1	C2	C3	C4	C5	C6	C7
C1	1	1	1	1/3	1	1	1/5
C2	1	1	1	1/3	1	1	1/3
C3	1	1	1	1/5	1	1/3	1/5
C4	3	3	5	1	5	3	1
C5	1	1	1	1/5	1	1/3	1/7
C6	1	1	3	1/3	3	1	1/3
C7	5	3	5	1	7	3	1

The basic comparison matrix was characterised by the CR index at the level of 0.11, which is on the verge of acceptability. Therefore, a procedure described by Jarek (2016) has been used to improve the matrix consistency. It is based on selected numerical properties of AHP and consists of multiplying the pairwise comparison matrix by the inverted vector of preference

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weights. Implementing the procedure resulted in improving the CR index to 0.03. The improved pairwise comparison matrix is shown in Table 1. It is worth noting that for three criteria (distance from shopping centres and supermarkets, population density, and distance from main roads), Guler and Yomralioglu (2020) preferences have been used. Own preference assessment was proposed for the remainder. A study by Csutora and Buckley (2001) proved that if a sharp matrix is consistent, the fuzzy one will also be consistent.

When the form of the pairwise comparison matrix is known, the sharp scores can be replaced with their fuzzy counterparts. The research made a comparison of two very different approaches. Variant A used the scale proposed by Guler and Yomralioglu (2020). It has the peculiarity that the triangular fuzzy number of the form (1, 1, 1) is used only when comparing the same factors. Equivalent factors already have numbers with different values (Table 2). Variant B is based on the classically understood fuzzy scale, in which the comparison of equivalent factors corresponds to the fuzzy number of (1, 1, 1) (Kutlu & Ekmekçioğlu, 2012). Thus, two calculation scenarios that differ in the comparison scale type were created.

Table 2. Scales of comparison for fuzzy numbers

Verbal preference assessment	Triangular fuzzy scale	
	Variant A	Variant B
Comparison of the same factors	(1, 1, 1)	
The compared factors are equivalent (1)	(1/2, 1, 3/2)	(1, 1, 1)
A slight advantage of one factor over another (3)	(1, 3/2, 2)	(1, 1, 3/2)
A great advantage of one factor over another (5)	(3/2, 2, 5/2)	(1, 3/2, 2)
A significantly greater advantage of one factor over another (7)	(2, 5/2, 3)	(3/2, 2, 5/2)
A huge advantage of one factor over another (9)	(5/2, 3, 7/2)	(2, 5/2, 3)

Source: Guler and Yomralioglu, 2020; Kutlu and Ekmekçioğlu, 2012.

Calculations in the fuzzy AHP method were performed according to the procedure described by Chang (1996). ArcGIS requires the weights to be sharp, not fuzzy. Therefore, the defuzzification process has been carried out as also recommended by Chang (Table 3). In scenario A, the most important factors are the location in relation to parks and the population density. The weights of other criteria are not very different from each other. In scenario B, the same criteria are still the most important but with much higher weights. Moreover, greater differentiation of the weight values was observed in this scenario.

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Table 3. Weights after defuzzification [%] for scenarios A and B

Criterion	Scenario A	Scenario B
C1	12.16	9.77
C2	12.16	10.74
C3	19.32	22.37
C4	13.65	14.72
C5	20.74	26.6
C6	10.85	8.96
C7	11.12	6.83

Analysis of the Results

The combination of FAHP and GIS allowed creating a five-point scale assessing the suitability of areas within the Łódź city's administrative boundaries for locating BEV charging stations. A five-point scale has been adapted for the result maps, where (1) means the lowest attractiveness for locating electric car charging stations, and (5) is the highest. Figures 2 and 3 show the share of areas belonging to a given class in the Łódź area. The results are broken down into individual districts.

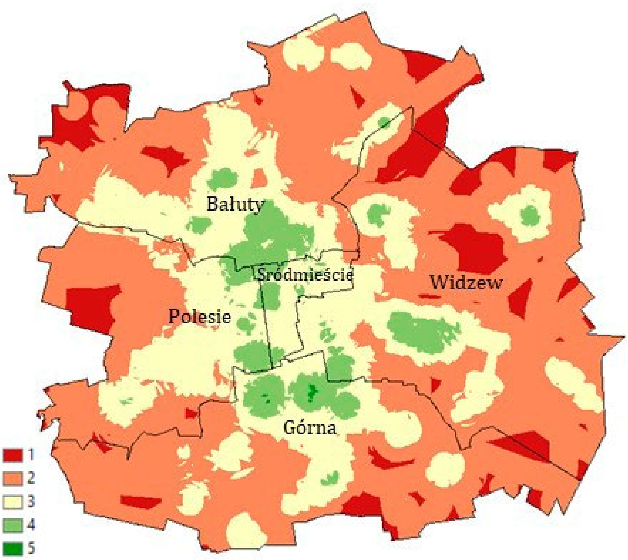

Figure 2. Suitability analysis for scenario A

Source: author's work based on ArcMap.

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Table 4. Shares and areas of individual suitability classes in scenario A

Class	Łódź	Górna		Polesie		Śródmieście		Widzew		Bałuty	
	Share [%]	Share [%]	Area [km²]	Share [%]	Area [km²]	Share [%]	Area [km²]	Share [%]	Area [km²]	Share [%]	Area [km²]
1	7.91	5.33	3.83	6.03	2.78	0.00	0.00	10.84	9.93	8.68	6.94
2	55.44	61.36	45.37	51.23	25.08	3.04	0.35	58.12	53.56	54.15	43.96
3	29.99	26.41	17.82	37.04	15.62	72.00	4.79	25.87	22.81	30.11	22.57
4	6.61	6.70	4.75	5.70	2.53	24.96	1.66	5.17	4.50	7.06	5.43
5	0.05	0.20	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

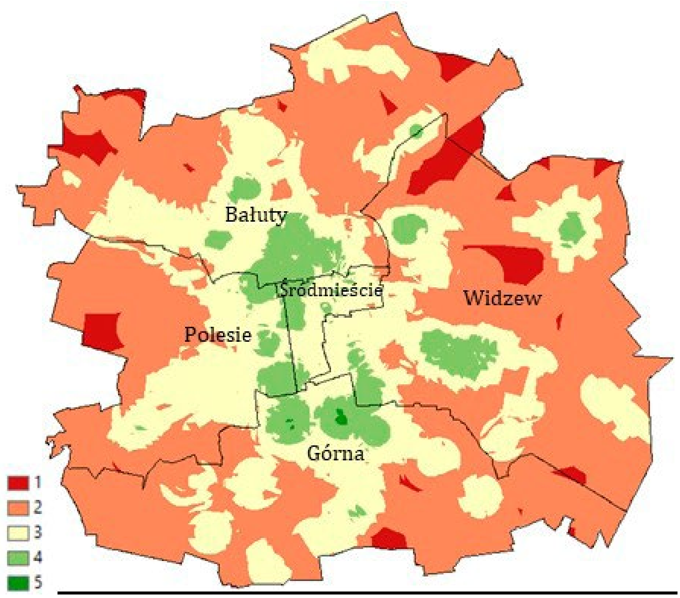

Figure 3. Suitability analysis for scenario B

Source: author's work based on ArcMap.

The Łódź analysis of shows that class (2) has the largest share in the city's area (over 50% in both scenarios). It means that these parts are not attractive as the locations of the charging stations. About 33% of the city's area is assigned to class (3). Classes (4) and (5) cover only about 7–8% of the analysed area. The first general conclusion is, therefore, that Łódź has few sites worth considering for BEV charging stations.

Figures 2 and 3 show that attractive areas are concentrated in the city centre and along the main roads.

Table 5. Shares and areas of individual suitability classes in scenario B

Class	Łódź	Górna		Polesie		Śródmieście		Widzew		Bałuty	
	Share [%]	Share [%]	Area [km²]	Share [%]	Area [km²]	Share [%]	Area [km²]	Share [%]	Area [km²]	Share [%]	Area [km²]
1	3.77	1.36	3.83	3.20	2.78	0.00	0.00	5.28	9.93	4.91	6.94
2	55.23	58.99	45.37	52.43	25.08	2.80	0.35	57.94	53.56	55.04	43.96
3	33.54	32.51	17.82	37.84	15.62	69.90	4.79	30.19	22.81	32.57	22.57
4	7.39	6.87	4.75	6.53	2.53	27.30	1.66	6.59	4.50	7.48	5.43
5	0.07	0.26	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The analysis at the district level shows that class (5) is present in small numbers only in the Górna district. The Śródmieście district is centrally located in the area of interest and seems to be the most attractive due to the largest share of class (4) among all districts. It also has a very high share of class (3) in its total area and almost absent classes (1) and (2). Over 90% of this district can be seen as worth considering for a charging station. In the remaining districts, however, the areas classified as class 2 prevail. Only the areas of large housing estates were rated as members of at least class (3).

The authors' attention was drawn to the uneven distribution of individual classes between Łódź districts, raising the question of whether a given class is concentrated in selected districts. To verify the question, the Gini coefficient was calculated (Table 6). A very strong concentration for class 5 occurred in both scenarios, but this could be expected from earlier results. In scenario A, classes 1–4 are characterised by moderately high to high concentrations, probably because the weights for this scenario are less different from each other. For the second scenario, classes 1–4 showed low to moderate concentration.

Table 6. Values of the GINI coefficient

Class	Scenario A	Scenario B
1	0.6329	0.449
2	0.6617	0.3051
3	0.6119	0.2174
4	0.66	0.2057
5	0.8	0.7941

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Treating the equivalent factors with different variants of fuzzy numbers is important in terms of class concentration. The assumption that equivalence is connected with some, even small preference, can be connected with an increase in the Gini coefficient's value.

Conclusions

The MCDA and GIS integration enabled the identification of areas in individual Łódź districts for building charging stations first. Łódź is not very attractive for such infrastructure investments. Considering the administrative boundaries of the city, classes (1) and (2) occupied more than 60% of the area, regardless of the scenario. Classes 4–5 accounted for about 7% of the city's area, which will encounter serious competition for potential investors.

The most attractive (classes 3–5) areas for the construction of charging stations are concentrated along the most important communication routes of the city (national roads) and in the Śródmieście district. In general, the outskirts of Łódź were rated as classes (1) and (2) according to the adopted scale and therefore are unattractive. This is important considering the city's recently announced plans to limit car entry into the city centre, which could provoke owners to leave their vehicles on the city outskirts.

Incorporating the FAHP-obtained weights into GIS results in a useful and flexible method for evaluating an area from the point of view of the adopted criteria. The authors believe that the case of Łódź is no exception. Many other Polish cities require a similar analysis due to common problems with the availability of charging stations in Poland (cf. PSPA reports). The authors believe that the methods and criteria proposed in the research can be successfully used in analyses of cities of various sizes. However, although FAHP has a wide range of advantages, it also has some shortcomings. First, it lacks a single method for assessing the consistency of pairwise comparisons. Second, the necessity for weight defuzzification, which has several available methods. Besides, the calculation results depend on the criteria selection. However, the authors tried to eliminate this disadvantage by choosing criteria that were general enough to be used in other studies.

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The contribution of the authors

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Izabela **DZIADUCH**

WROCŁAW PUBLIC TRANSPORT PASSENGERS' SATISFACTION SURVEY BY MEANS OF CSI AND IPA

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ABSTRACT: This paper aims to assess the satisfaction level of passengers who use public transport services in Wrocław and to identify the quality characteristics that the service provider needs to improve if it wants to increase the overall quality of its services. The passenger satisfaction survey was conducted according to the stages of a procedure outlined in the article. In pursuit of the stated goal, CSI and IPA were used. The main measurement tool used was a survey questionnaire. The survey was conducted on a sample of 500 respondents, which allows us to trust the results at 95%, assuming an "estimation error" of ±5%. A total of 14 quality characteristics were selected to evaluate the level of satisfaction of passengers that use services provided by MPK Wrocław. Quality characteristics that each respondent rated were: spatial accessibility, frequency of connections, regularity of departures, directness of travel, speed of travel, punctuality of departures, reliability of travel, travel time, safety, accessibility of information, travel cost, travel comfort, travel integration and investment cost. Statistical data analysis was carried out using Statistica 13.3 software, as well as functions and commands available in Microsoft Excel. The results allowed the authors to conduct a detailed analysis related to the service quality of Wrocław's public transport. Urban transport organisers and operators should use these results to shape their transport offerings, primarily in terms of increasing the quality of transport services. This is very important since it is, among other things, the quality of public mass transport that determines the quality of life of residents, as well as the conditions for the economic development of the transport network.

KEYWORDS: sustainable development, public mass transport, services quality, Customer Satisfaction Index (CSI), Importance-Performance Analysis (IPA)

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Introduction

The negative impact of transport on the environment and human health is well known. However, when comparing the environmental costs of public transport and individual automobile transport, it should be objectively stated that greater ecological damage is caused by the latter, with which residents have to cope regardless of their transport choices. If, in addition to air pollution and noise generation, other effects are added, such as the development of urban heat islands or the problem of secondary dust emission, the vision of a "clean" city cannot materialise without introducing measures to reduce road traffic in the city (Trako Projekty Transportowe, 2019). Solving the problem of congestion in the city, caused by the increasing number of cars owned by city residents as well as a large influx of vehicles from outside the city, is one of the goals-both environmental and social-arising from the assumptions of sustainable development of public mass transport in agglomerations (Zawieska & Skotak, 2015).

In order for this goal to be achievable, public mass transit offerings must be competitive with individual transport and therefore must be of high quality. The quality of public mass transit services is determined by the degree to which transport demands made by residents (i.e. passengers – the users of mass transit and potential users of such means of transport who previously used their vehicles) are anticipated and fulfilled. Transport demands are requirements related to meeting the mobility needs of residents (Kauf et al., 2018) made on the public service providers (carrier and/or organiser). In other words, these are quality determinants (characteristics, criteria) that define the level of utility value of[1] public mass transit service (Babis, 1986). The number and types of transport demands are virtually unlimited and constantly changing. They largely depend on the currently experienced traffic conditions, the automotive status of the traveller, as well as the level and lifestyle of the cities. A lot of empirical research and theoretical deductions have been devoted to establishing a list of transport demands. While there is considerable overlap between most of them, there are some discrepancies too. They concern the following (Wyszomirski, 2007):

- combining specific demands into a synthetic one,
- passing over specific demands as less important,
- including rare or even particular demands.

Although the identification of transport demands does not cause significant problems (travel duration, convenience, cost, and travel safety are usually mentioned) (Ciesielski et al., 1994; Wyszomirski, 2007), prioritising

[1] The value in the use of a public mass transit services is the movement of people in space and time.

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their importance is relatively difficult; determined sometimes by transport conditions present in the local market (Kauf et al., 2018). Knowing the rank of each transport demand is of fundamental importance, as it determines which elements of the transport offer should be improved first. The results of a study conducted in 18 cities to prioritise transport demands indicate that the most important are the following: directness of travel, timeliness of departures, frequency of connections, spatial accessibility, cost and convenience of travel, speed and reliability of travel, the rhythmicity of departures and accessibility of information (Wyszomirski, 2008).

The starting point in improving the quality of public mass transit services is the passengers' experience. The quality of public mass transit services as perceived (experienced or felt) by passengers has a direct impact on their satisfaction with the service. In order to determine the level of happiness, it is necessary to carry out marketing surveys to find out the passengers' opinions on the importance of transport demands and the degree to which they are fulfilled. The importance of a criterion determines its relevance in public mass transport services. In other words, the respondent determines how vital each service quality characteristic is to them. The level of performance, on the other hand, is the level of fulfilment of a given characteristic by the service provider. Passenger satisfaction is measured primarily by methods used to measure service quality. Among the most commonly mentioned in the literature and used in practice are the Servqual method and its variations, i.e. CSI and IPA.

The literature on measuring the quality of services of various means of public mass transit (e.g. public transport, passenger rail transport) is numerous. However, it should be emphasised that, apart from a few exceptions, there is still a lack of research works in the field of measuring how satisfied passengers are with the quality of public mass transit services that comprehensively analyse this problem (Sembiring et al., 2018; Justitia et al., 2019). Therefore, the paper's main objective is to develop a procedure for studying the level of passenger satisfaction when using public mass transit services, taking into account the use of CSI and IPA. In addition, a specific objective has been defined, which is to assess the level of satisfaction of passengers using public transport services in Wrocław and to identify transport postulates that require immediate improvement on the part of the service provider, which will give them a chance to quickly improve the quality of services. The subject of research is passenger transport services on streetcar and bus lines of public transport in the area of operation of MPK Sp. z o.o., based in Wrocław. It is worth pointing out that no research papers have been found in the literature on the study of passenger satisfaction using the CSI and IPA for passengers of the Wrocław public transport. There are only papers in which the authors present the structure of the respondent's answers to questions

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related to evaluating the quality of Wrocław public transport services, so their cognitive value is limited (Adamiczka & Adamiczka, 2015; Rada Miejska Wrocławia, 2016). This research gap has inspired the author to investigate this area.

The results presented in this paper are part of the INTERCON project financed under the programme launched by the Minister of Science and Higher Education, i.e. "Regional Initiative of Excellence", between 2019 and 2022, entitled "Structural modelling in the study of the quality of public mass transit services, on the example of MPK Sp. z o.o. in Wrocław. A Passenger's Perspective." The project aims to develop a concept for a structural model, which can be used to analyse the quality of public mass transit services, understood as a public utility, from the passenger's point of view. The model can be later used as a tool for developing the services and improving the quality of life of Wrocław residents.

Research method

The survey of satisfaction levels among passengers who use public mass transit consists of nine stages (Figure 1). The procedure is relatively simple and can be easily carried out in various service areas. The results obtained are quantitative in nature, allowing conclusions to be drawn and comparisons to be made between services.

In stage one of the procedure, the quality characteristics of the transport service should be defined. The set of features to be included in the questionnaire (stage three) can be determined using, among other things, expert knowledge or individual and/or group interviews conducted on purposively selected samples of respondents (Śmiatacz, 2012; Snarski, 2012). The number of characteristics is not strictly defined. As they point out (Wolniak & Skotnicka-Zasadzień, 2008), the use of eight to ten quality characteristics that describe a service is sufficient.

The selection of the research sample (stage two) consists in extracting from the population a certain number of representatives on whom the survey will be conducted. As (Miszczak & Walasek, 2013) points out, the sampling procedure should be preceded by defining the population using public transport services, determining the scope of sampling, selecting the sampling technique, determining the sample size, and selecting the sample elements.

Stage three is the development of the survey questionnaire, with which the satisfaction of passengers using public mass transit will be measured. The questionnaire should consist of three main parts, i.e. the introduction, the central part or questions, and the metric. The introduction should include, among others, the title of the survey, information about the person or company conducting the survey, the purpose of the survey, and the approximate

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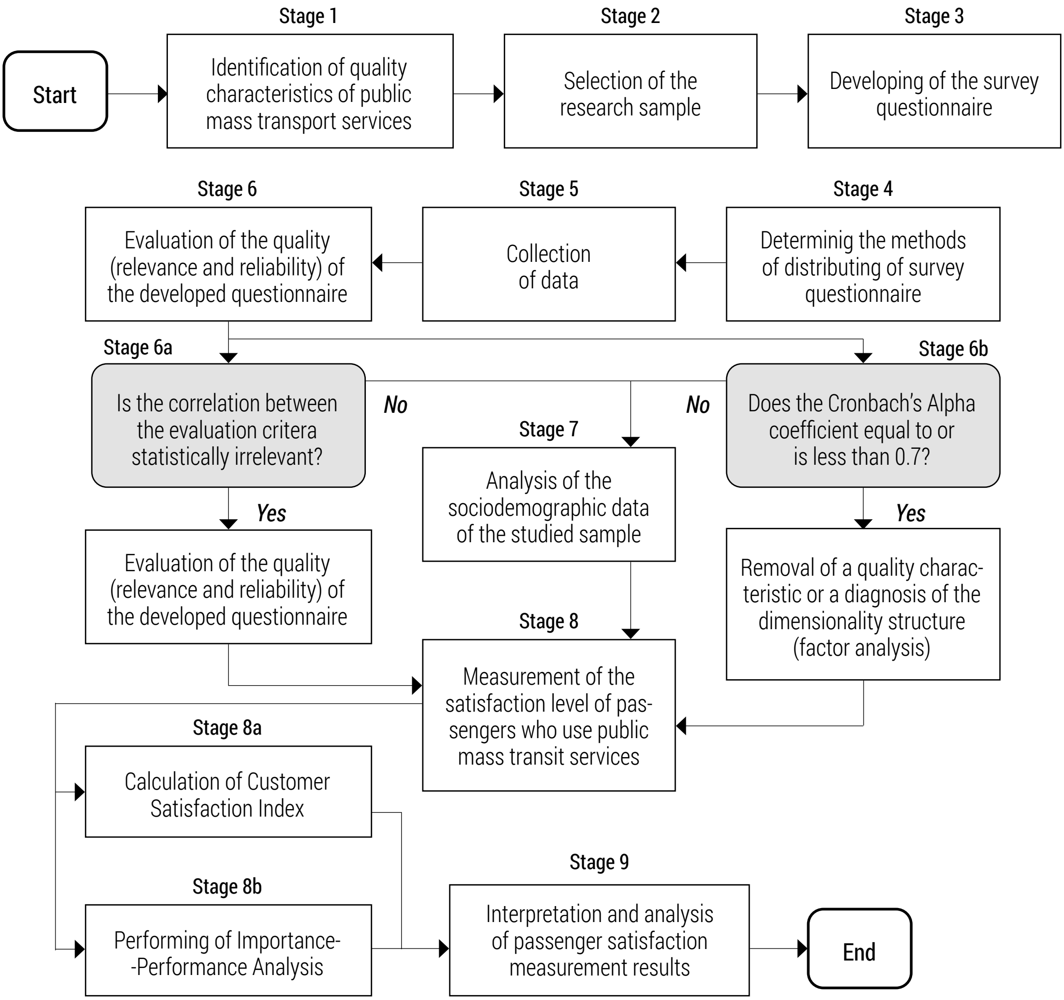

Figure 1. Stages of the procedure for surveying the level of satisfaction of passengers who use public transport services

time of completion. The main part of the questionnaire consists of a set of quality characteristics of the service, as defined in stage one. The correctness of the results obtained is determined by the comprehensibility of the definitions of quality characteristics; therefore, it is worth including them in the questionnaire. Each quality characteristic is evaluated in two aspects, i.e. the importance and the level of its performance. A bipolar ordinal scale, such as the five-point Likert scale, can be used to assess the importance and the level of performance of each characteristic in the questionnaire. The concept of the main part of the questionnaire is provided in Table 1. Furthermore, in the

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main section of the survey questionnaire, additional questions related to the purpose or topic of the study can be included. These questions may include the frequency of the use of transport services, the reasons for undertaking urban travels, car ownership, or public transport entitlements. The final part of the questionnaire contains metric questions, i.e. the questions relating to the respondent's demographic and social affiliation, i.e. gender, age, or occupational status.

Table 1. Sample questionnaire for measuring the quality of public transport services

No.	Service quality characteristic	Definition of service quality characteristic	Mark with "X"	
			The level of performance of the characteristic by the mass transit provider 1 pt – Very low 2 pt – Low 3 pt – Medium 4 pt – High 5 pt – Very high	How important is the criterion for you? 1 pt – Not important 2 pt – Of little importance 3 pt – No matter 4 pt – Important 5 pt – Very important
1.	....	....	1 2 3 4 5	1 2 3 4 5
...	....	....	1 2 3 4 5	1 2 3 4 5
C.	....	....	1 2 3 4 5	1 2 3 4 5

Stage four should indicate how the survey questionnaire will be delivered to respondents. Methods of distributing surveys have been described in detail in the works (Szyjewski, 2018; Kauf & Tłuczak, 2013), among others.

The fifth stage is the collection of qualitative and quantitative data on the level of performance and importance of the characteristics determining the quality of the services as well as relating to the demographic and social affiliation of the sample, or additional questions. The collected data will be analysed in the seventh and eighth stage.

Before analysing the data, it is necessary to determine the relevance and reliability of the created survey questionnaire (stage six). An assessment of relevance will ensure that the service quality characteristics adopted in the questionnaire accurately, or not, describe the passenger's perceived and expected quality under study. For this purpose, correlation coefficient can be used between the two examined variables quality characteristics), i.e. Pearson's linear correlation coefficient (Greń, 1982):

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})\cdot(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2\cdot\sum_{i=1}^{n}(y_i-\bar{y})^2}}, \tag{1}$$

where:

x_i – variable value (quality characteristic) X,
y_i – variable value (quality characteristic) Y,
x – arithmetic mean variable,
y – arithmetic mean of variable,
n – number of respondents, where $i = 1, ..., n$.

Pearson's coefficient takes values in the range (-1; 1). The value of the coefficient determines the strength of the correlation between the variables (service quality characteristics), while the sign of the coefficient indicates its direction. By comparing different ranges of absolute values of the coefficient, used to interpret the results obtained, it can be seen that with data from the area of social sciences, the strength of the correlation is determined as follows (Moore et al., 2013):

- $|r|<0.3$ – no or very weak correlation,
- $0.3\leq|r|<0.5$ – weak correlation,
- $0.5\leq|r|<0.7$ – moderate (medium) correlation,
- $|r|>0.7$ – strong correlation.

To estimate the interscale correspondence of individual quality characteristics, it is necessary to determine the correlation matrix between these characteristics. According to (Justitia et al., 2019), the value $r \geqslant 0.3$ can be taken as a criterion for a satisfactory level of consistency. It is worth noting that the interpretation of the correlation's strength and direction is less important than the information on whether the correlation is statistically relevant. To verify the significance of the correlation coefficient, the hypothesis that X and Y variables are not correlated should be checked, i.e. null hypothesis H_0: $r = 0$, against the alternative hypothesis H_1: $r \neq 0$. Student's t-distribution for the predetermined α significance level and for $D - 2$ degrees of freedom shows t_α critical value, so that $P\{|t| \geqslant t_\alpha\} = \alpha$. If the comparison of value calculated based on formula 2, i.e.:

$$t_{(\alpha,n-2)} = \frac{r}{\sqrt{1-r^2}} \cdot \sqrt{D-2}, \quad (2)$$

with t_α critical value results in $|t| \geqslant t_\alpha$ inequality, then H_0 hypothesis about the absence of correlation between the variables has to be rejected. However, when the $|t| < t_\alpha$, there are no grounds to reject H_0 hypothesis, that and variables are uncorrelated.

However, by performing a reliability analysis of a survey questionnaire, the internal consistency of the tool is determined. More specifically, a reliable survey questionnaire is one that, when used twice, will yield similar results.

To determine the reliability of the tool's measurement, Cronbach's Alpha coefficient (Cronbach, 1971) can be used, the basis of which is the assumption that a person's responses to each question should be similar. This coefficient is, therefore, a measure of the consistency of a set of scales[2]. Cronbach's alpha coefficient (formula 3) estimates the proportion of the variance of the actual score that stemming from the questions given by comparing the sum of the variance of the questions to the variance of the sum scale (Parkitna, 2020):

$$\propto_C = \frac{K}{K-1} \cdot \left(1 - \frac{\sum_{k=1}^{K} s_k{}^2}{s_{sum}{}^2}\right), \tag{3}$$

where:
α_C – the function of Cronbach's Alpha coefficient,
s_i^2 – variance of individual items (questions),
$s_{sum}{}^2$ – variance of the sum of all items,
K – number of items in the questionnaire, where $k = 1, ..., K$.

Cronbach's Alpha coefficient takes values from 0 to 1, although it can sometimes be negative (the presence of negative correlations between items). Cronbach's Alpha values approaching 1 indicate high reliability of the scale. According to J.C. Nunnally's criterion, scale is considered reliable if the value α_C is higher than 0.7 (Nunnally, 1970).

If, when assessing accuracy, the correlation between the scale items is statistically irrelevant, and/or when assessing reliability, Cronbach's alpha coefficient is not satisfactory, then a decision should be made to remove such items from the scale or to identify the variable's coefficient structure.

The seventh stage includes the characteristics of the research sample on which the research was conducted. According to the APA standard (American Psychological Association, 2019), these characteristics should include basic demographic data, such as the age, gender, education, or social and economic status, as well as other important sample-specific data related to the subject of the survey.

Measurement of the level of satisfaction of passengers who use public mass transit services is carried out in the eighth stage. Calculation of CSI values is carried out in four stages (Sembiring et al., 2018; Utomo et al., 2013)[3], i.e.:

Determination of the average importance of the quality characteristics studied (formula 4) and the average level of their performance (formula 5):

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2 Individual questions from the survey are called scale items.

3 In the works of (Hall, 2013; Raposo et al., 2008), other ways of calculating CSI can be found, which is related, among others, to the different perception of customer satisfaction in different countries (CSI models) (Skowron, 2010; Rajendran & Arun, 2019).

$$\overline{I_c} = \frac{1}{n} \cdot \sum_{i=1}^{n} I_c^n \ , \tag{4}$$

$$\overline{P_c} = \frac{1}{n} \cdot \sum_{i=1}^{n} P_c^n, \tag{5}$$

where:
I_c – average importance of service quality characteristic c for respondents,
P_c – the average level of performance of service quality characteristics c by the transport company,
n – number of respondents, where $i = 1, ..., n$,
I_c^n – weights assigned by respondents to service quality characteristic c,
P_c^n – levels of performance assigned by respondents to service quality characteristic c.

Calculation of the weighting factors for each quality characteristic (IF_c):

$$IF_c = \frac{\overline{I_c}}{\sum_{c=1}^{C} \overline{I_c}}\, , \tag{6}$$

where:
c – number of the next characteristic under study,
C – number of quality characteristics included in the analysis, where $c = 1, ..., C$.

Calculation of the overall weighted score on passenger satisfaction evaluation (IS):

$$IS = \sum_{c=1}^{C} \overline{P_c} \cdot IF_c, \tag{7}$$

Calculation of the overall CSI:

$$CSI = \frac{IS}{HS}, \tag{8}$$

where:

$$HS = \sum_{c=1}^{C} P_c^{max} \cdot IF_c\, , \tag{9}$$

where:
HS – maximum overall weighted score relating to the passenger satisfaction rating,
P_c^{max} – the maximum number of points a respondent could assign to the level of performance of service quality characteristic c.

CSI takes values from 0 to 1. Table 2 includes ranges of CSI values that will facilitate the interpretation of the level of satisfaction of passengers using the company's transport services. It is worth noting that the ranges presented

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are not universal[4] and, in certain cases, should be changed depending on the specifics of a particular industry or organisation (Wolniak & Skotnicka-Zasadzień, 2008).

Table 2. Interpretation of CSI

Range of values	Interpretation of CSI
CSI ≤ 0.40	The passenger is extremely dissatisfied with the service provided.
0.40 < CSI ≤ 0.60	The passenger is dissatisfied with the service provided.
0.60 < CSI ≤ 0.75	The passenger is moderately satisfied with the service provided.
0.75 < CSI ≤ 0.90	The passenger is satisfied with the service provided.
0.90 < CSI ≤ 1.00	The passenger is extremely satisfied with the service provided.

Source: author's work based on Wolniak and Skotnicka-Zasadzień (2008).

Importance-Performance Analysis (IPA) comes down to the construction of a two-dimensional graph, referred to as an IPA graph[5]. To construct the chart, the following should be performed (Niemiec, 2015; Tucki et al., 2018):

Determination of the division points of the graph using the following formulas:

$$\bar{\bar{I}} = \frac{1}{C} \cdot \sum_{c=1}^{C} \overline{I_c}, \tag{10}$$

$$\bar{\bar{P}} = \frac{1}{C} \cdot \sum_{c=1}^{C} \overline{P_c}, \tag{11}$$

where:

$\bar{\bar{I}}$ – the average of the average weights assigned to service quality characteristic *c*,

$\bar{\bar{P}}$ – the average of the average levels of performance assigned to service quality characteristic *c*.

The value of is placed on the abscissae axis, while the on the ordinate axis. At these points, lines are drawn to divide the graph into 4 areas (quadrants, decision boxes).

Determination of the coordinates for each quality characteristic, taking into account the values of the average relevance and the values of the average level of performance, using formula (4) and formula (5), respectively.

[4] In the literature, different interpretations of the CSI value can be found, *inter alia*, in the works: (Justitia et al., 2019; Sembiring et al., 2018; Utomo et al., 2013.

[5] Other names can also be found in the literature, such as IPA matrix (Biesok et al., 2016), quality map (Woźniak & Zimon, 2016), or IPA model (Rodzeń & Stoma, 2018).

Application of the coordinate points of each quality characteristic to the graph.

Each of the quality characteristics analysed is qualified into one of the four areas (Figure 2). This makes it possible to propose appropriate approaches for each of the identified areas (Rogala, 2020).

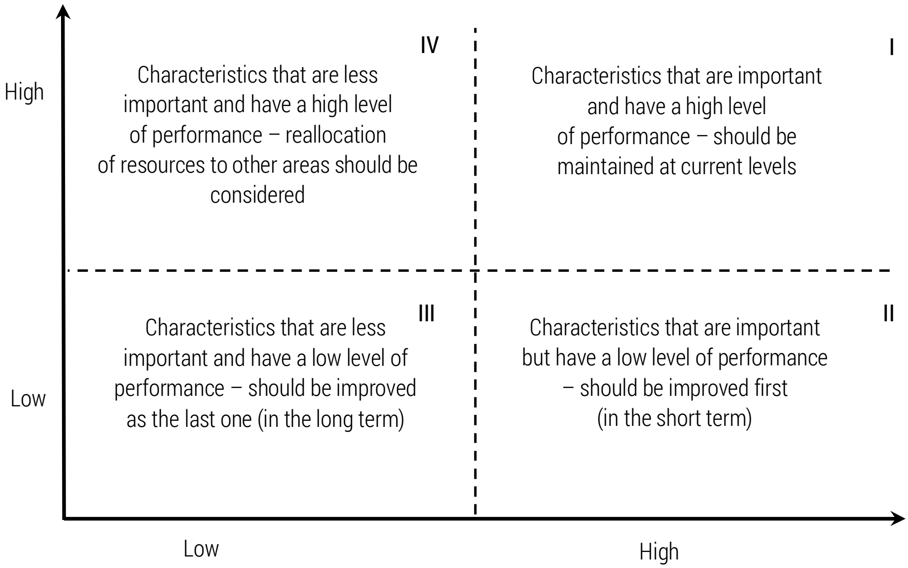

Figure 2. Interpretation of four decision areas placed on the IPA chart

Source: author's work based on Rogala (2020); Wolniak and Skotnicka-Zasadzień (2008).

In the final stage of the survey procedure (ninth stage), the passenger satisfaction survey results should be interpreted and analysed.

Results of the research

Based on the analysis of the literature on the subject, a set of 14 quality characteristics, typical for Wrocław's public transport services, was identified (Table 3). Passengers rated the relevance (importance) of each quality characteristic and the degree to which MPK Wrocław performed them.

Setting the maximum margin of statistical error at 1% (for a confidence level of $\alpha = 0.99$, response distribution of 0.5, and population size of 642,700[6]), it was calculated that the survey sample should consist of 25,975 people. It is

6 According to the Statistics Poland, it is the number of inhabitants of Wrocław as at 31 December 2021 https://wroclaw.stat.gov.pl/zakladka2/

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virtually impossible to implement the survey for such a large sample due to its cost. In addition, to determine the importance of characteristics to the passenger and the level of their performance by the service provider, adopting such a low error value and such a high level of confidence is not necessary, given the frequent change in the views of public transport passengers. In the end, the survey was conducted on a sample of 500 respondents, which allows us to trust the results at 95%, assuming an "estimation error" of ±5%. Sampling was quota-targeted with an algorithm for drawing panellists meeting two criteria, i.e. the respondent had to be a resident of Wrocław and had to have used public transport in Wrocław at least once since the beginning of 2022.

Table 3. Quality characteristics of public transport services with interpretation

No. (a)	Quality characteristic (ca)	Definition of quality characteristic	Publication in which quality characteristic was used
1.	Accessibility	Distance to get to a stop in order to use a given transport network (temporal and spatial).	Wyszomirski and Grzelec (1998); PKN (2004); Mężyk and Zamkowska (2004); Starowicz (2007); Mikulska and Starowicz (2015).
2.	Frequency	The number of rides made on the same line within a specified time interval.	Wyszomirski and Grzelec (1998); Starowicz (2007); Mikulska and Starowicz (2015).
3.	Regularity	Equal intervals between consecutive departures on the same line.	Wyszomirski and Grzelec (1998).
4.	Directness	Connection without the need to transfer.	Wyszomirski and Grzelec (1998); Mężyk and Zamkowska (2004); Starowicz (2007); Mikulska and Starowicz (2015).
5.	Speed	Driving time including stopping at stops.	Wyszomirski and Grzelec (1998); Starowicz (2007).
6.	Punctuality	Compliance of departures with the timetable.	Wyszomirski and Grzelec (1998); Starowicz (2007); Mikulska and Starowicz (2015).
7.	Reliability	Getting to a particular destination at the appointed time.	Wyszomirski and Grzelec (1998); Mężyk and Zamkowska (2004); Starowicz (2007); Mikulska and Starowicz (2015).
8.	Travel time	Time to get to the stop + time to wait for the arrival of the means of transport + transit time + time of any transfers + time to reach the destination.	PKN (2004); Mężyk and Zamkowska (2004); Mikulska and Starowicz (2015).
9.	Safety	Safety while waiting at the bus stop and during transit (e.g. monitoring system in vehicles, monitoring system and lighting of bus stops, proper technical condition of vehicles, experience and skills of drivers, separated lanes for public transport vehicles).	PKN (2004); Mężyk and Zamkowska (2004); Starowicz (2007); Mikulska and Starowicz (2015).

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No. (a)	Quality characteristic (ca)	Definition of quality characteristic	Publication in which quality characteristic was used
10.	Information	Availability and communication of information related to travel route planning (e.g. schedules, fare tariffs, ticket outlets, announcements about changes in the transport network), and travel route signage (visual or audio information at stops or inside vehicles).	Wyszomirski and Grzelec (1998); PKN (2004); Mężyk and Zamkowska (2004); Starowicz (2007); Mikulska and Starowicz (2015).
11.	Travel cost	Fare + any additional fees (e.g. for carrying luggage, pets).	Wyszomirski and Grzelec (1998); Mężyk and Zamkowska (2004); Starowicz (2007); Mikulska and Starowicz (2015).
12.	Comfort	Conditions of waiting at the stop and staying in the vehicle, e.g. cleanliness, seating, degree of congestion, ergonomics.	Wyszomirski and Grzelec (1998); PKN (2004); Mężyk and Zamkowska (2004); Starowicz (2007); Mikulska and Starowicz (2015).
13.	Integration	Synchronisation of fares and schedules of different transport lines on common sections.	Solecka (2013).
14.	Investment cost	The cost associated with the construction, expansion, reconstruction of nodal infrastructure (e.g. bus stops, transfer nodes), line infrastructure (roads), and the purchase of rolling stock.	Solecka (2013).

Source: author's work based on Wyszomirski and Grzelec (1998); PKN (2004); Mężyk and Zamkowska (2004); Starowicz (2007); Solecka (2013); Mikulska and Starowicz (2015).

The survey questionnaire consisted of the following:

1) Introduction – stating the purpose of the survey.
2) The main part, included three closed questions which the respondent answered by choosing a pre-prepared answer. The first two required questions in the passenger satisfaction survey were designed to determine the respondents' level of satisfaction with the performance level of 14 quality characteristics displayed by the transport company that provides public transport services and the importance (relevance) of these 14 characteristics to the respondent. Both questions were rated by respondents on a scale from 1 to 5. These two questions in the questionnaire are presented in a table, according to the example provided in Table 1. This part of the survey questionnaire also asked how frequently the MPK Wrocław transport services were used.
3) The respondent's metrics, through which primary socio-demographic data was collected, i.e. gender, age, and occupational status.

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The survey was conducted from 1 to 2 June 2022 on the Norstat.pl online panel. It is worth noting that a failure to answer all questions in the survey prevented its completion.

The correlation analysis showed that most of the correlations between the respondents' answers to the question on how well MPK Wrocław performs on the 14 quality characteristics (Table 4) and the respondents' evaluation of the relevance of these characteristics (Table 5) are statistically relevant (for $\alpha = 0.05$), which proves the relevance of the questionnaire as a tool for measuring the perceived and expected service quality.

Table 4. Pearson's correlation coefficients between the respondents' answers to the question on the evaluation of 14 characteristics describing the perceived quality of services

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
C_1	1.00	0.41	0.46	0.38	0.42	0.34	0.40	0.34	0.43	0.45	0.12	0.37	0.43	0.22
C_2	0.41	1.00	0.56	0.47	0.48	0.51	0.51	0.44	0.41	0.44	0.12	0.45	0.53	0.28
C_3	0.46	0.56	1.00	0.46	0.53	0.62	0.60	0.45	0.45	0.47	0.15	0.49	0.56	0.28
C_4	0.38	0.47	0.46	1.00	0.45	0.33	0.37	0.38	0.35	0.37	**0.08***	0.35	0.49	0.22
C_5	0.42	0.48	0.53	0.45	1.00	0.54	0.56	0.43	0.41	0.37	0.10	0.46	0.50	0.20
C_6	0.34	0.51	0.62	0.33	0.54	1.00	0.67	0.37	0.41	0.36	0.20	0.48	0.48	0.20
C_7	0.40	0.51	0.60	0.37	0.56	0.67	1.00	0.47	0.43	0.41	0.09	0.47	0.48	0.24
C_8	0.34	0.44	0.45	0.38	0.43	0.37	0.47	1.00	0.28	0.29	0.10	0.40	0.38	0.15
C_9	0.43	0.41	0.45	0.35	0.41	0.41	0.43	0.28	1.00	0.41	0.13	0.55	0.38	0.24
C_{10}	0.45	0.44	0.47	0.37	0.37	0.36	0.41	0.29	0.41	1.00	**0.06***	0.40	0.41	0.24
C_{11}	0.12	0.12	0.15	**0.08***	0.10	0.20	0.09	0.10	0.13	**0.06***	1.00	0.15	0.14	0.22
C_{12}	0.37	0.45	0.49	0.35	0.46	0.48	0.47	0.40	0.55	0.40	0.15	1.00	0.43	0.28
C_{13}	0.43	0.53	0.56	0.49	0.50	0.48	0.48	0.38	0.38	0.41	0.14	0.43	1.00	0.24
C_{14}	0.22	0.28	0.28	0.22	0.20	0.20	0.24	0.15	0.24	0.24	0.22	0.28	0.24	1.00

* The value of the correlation coefficient *r* in bold indicates a statistically irrelevant correlation (for $\alpha = 0.05$)

Source: author's work based on Norstat.pl.

The level of Cronbach's Alpha for the set of questions diagnosing the perceived quality of services was 0.89, while for the expected quality of services was 0.88, which means very high reliability of the scales used in the questionnaire and allows for the further analysis of the data.

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Table 5. Pearson's correlation coefficients between the respondents' answers to the question on the evaluation of 14 characteristics describing the expected quality of services

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}
C_1	1.00	0.48	0.53	0.48	0.44	0.43	0.43	0.47	0.37	0.38	0.29	0.42	0.35	0.22
C_2	0.48	1.00	0.58	0.40	0.44	0.43	0.44	0.48	0.39	0.34	0.26	0.37	0.42	0.15
C_3	0.53	0.58	1.00	0.41	0.37	0.44	0.42	0.46	0.40	0.33	0.29	0.39	0.46	0.24
C_4	0.48	0.40	0.41	1.00	0.39	0.40	0.42	0.45	0.29	0.38	0.26	0.41	0.38	**0.08***
C_5	0.44	0.44	0.37	0.39	1.00	0.37	0.38	0.44	0.33	0.37	0.25	0.39	0.35	0.24
C_6	0.43	0.43	0.44	0.40	0.37	1.00	0.58	0.52	0.41	0.31	0.33	0.33	0.33	**0.06***
C_7	0.43	0.44	0.42	0.42	0.38	0.58	1.00	0.44	0.37	0.33	0.23	0.34	0.36	**0.09***
C_8	0.47	0.48	0.46	0.45	0.44	0.52	0.44	1.00	0.38	0.29	0.35	0.46	0.38	0.15
C_9	0.37	0.39	0.40	0.29	0.33	0.41	0.37	0.38	1.00	0.36	0.30	0.50	0.35	0.25
C_{10}	0.38	0.34	0.33	0.38	0.37	0.31	0.33	0.29	0.36	1.00	0.31	0.36	0.37	0.20
C_{11}	0.29	0.26	0.29	0.26	0.25	0.33	0.23	0.35	0.30	0.31	1.00	0.32	0.24	0.20
C_{12}	0.42	0.37	0.39	0.41	0.39	0.33	0.34	0.46	0.50	0.36	0.32	1.00	0.33	0.21
C_{13}	0.35	0.42	0.46	0.38	0.35	0.33	0.36	0.38	0.35	0.37	0.24	0.33	1.00	0.29
C_{14}	0.22	0.15	0.24	**0.08***	0.24	**0.06***	**0.09***	0.15	0.25	0.20	0.20	0.21	0.29	1.00

* The value of the correlation coefficient r in bold indicates a statistically irrelevant correlation (for α = 0,05)

Source: author's work based on Norstat.pl.

Table 6. Sociodemographic characteristics of the studied sample

Variable	Subgroup	n	%
Gender	Woman	294	58.8%
	Man	206	41.2%
Age	≤ 18	5	1.0%
	19-26	104	20.8%
	27-39	208	41.6%
	40-59	138	27.6%
	≥ 60	45	9.0%
Occupational status	Student	69	13.8%
	Working person	364	72.8%
	Unemployed	29	5.8%
	Pensioner	38	7.6%

Source: author's work based on Norstat.pl.

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A total of 500 people took part in the passenger satisfaction survey of public transport services provided by MPK Wrocław, including 294 women (58.8%) and 206 men (41.2%) between 16 and 77 years of age. The largest percentage of respondents were employed individuals (72.8%). Detailed sociodemographic characteristics of the sample are shown in Table 6. It is worth noting that the survey included people who use public transport relatively frequently (32.8% of respondents travel by public transport several times a week, while 28.8% of respondents travel daily).

Based on the respondent's answers, the average relevance/importance of each quality characteristic and the average level of their performance by MPK Wrocław were determined, as shown in Figure 3.

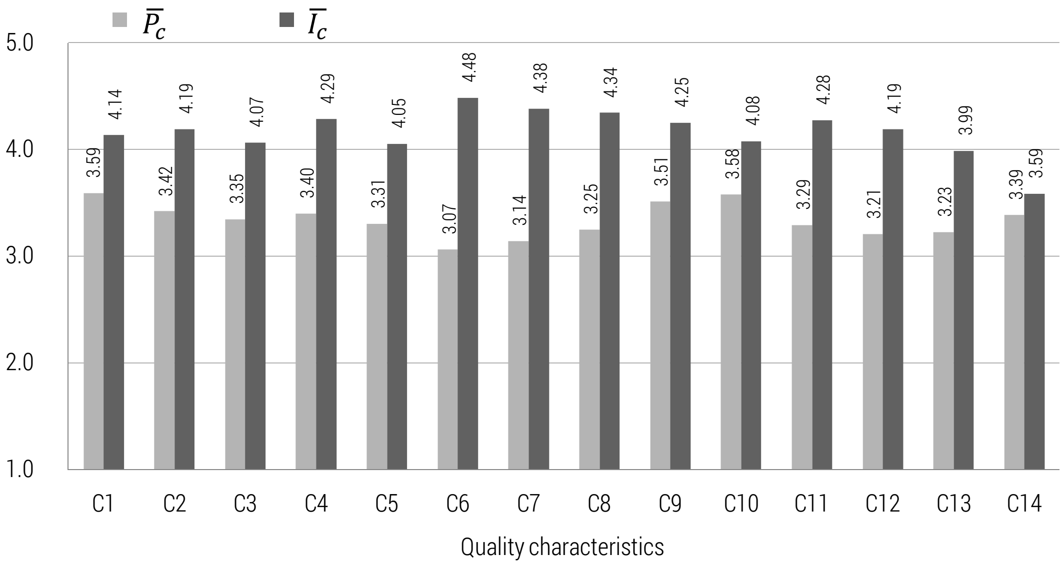

Figure 3. Average importance of the studied quality characteristics and the average level of their performance by MPK Wrocław from the passenger's perspective

Source: author's work based on Norstat.pl.

These values formed the basis for calculating CSI for individual characteristics and overall CSI of public transport services (Figure 4).

The calculated values of $\overline{P_c}$ and $\overline{I_c}$ also provided the basis for linking them to the IPA chart. The location of each point on the graph was determined by determining the size of the (3.34) and (4.17). Determining these quantities allowed us to lay out the boundaries of the separate quadrants (Figure 5).

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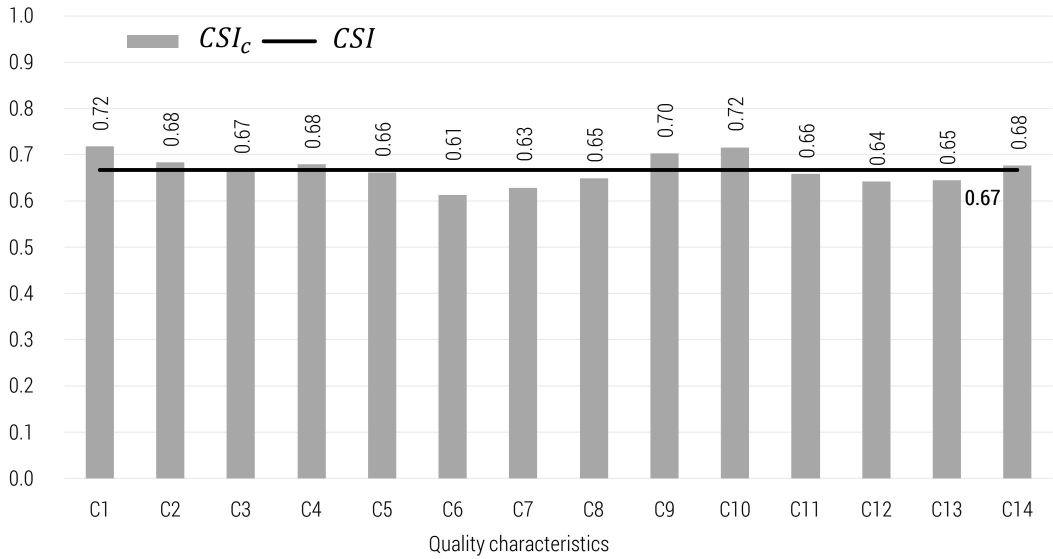

Figure 4. CSI values for individual characteristics and the value of the overall CSI for the transport services provided by MPK Wrocław

Source: author's work based on Norstat.pl.

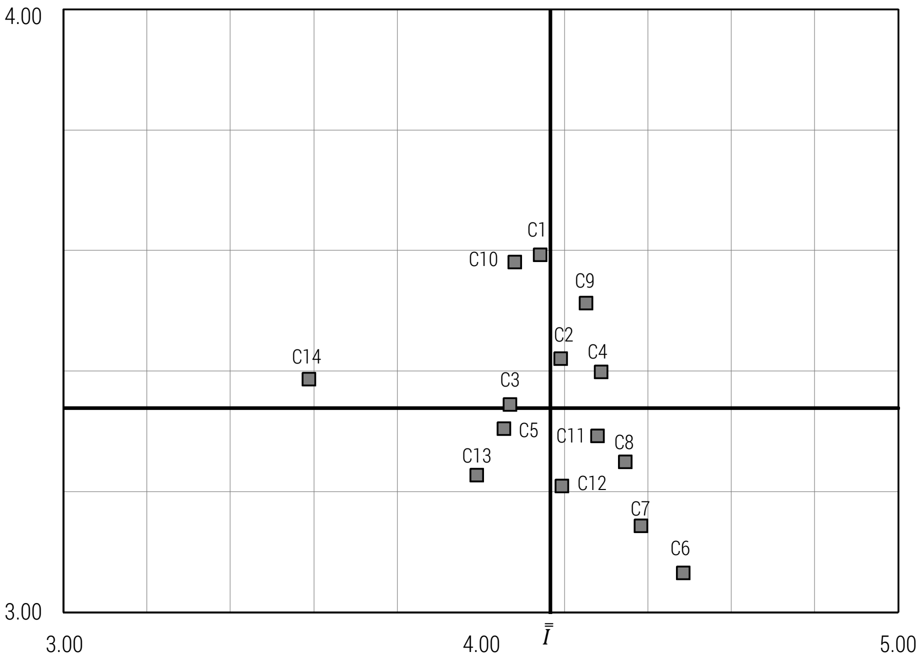

Figure 5. IPA chart for service quality characteristics of Wrocław public transport

Source: author's work based on Norstat.pl.

The survey shows that passenger expectations for all quality criteria are higher than their performance level (Figure 3). The highest measurement difference is seen in the case of C_6 – punctuality (-1.42) or C_7 – reliability (-1.24), and C_8 – travel time (-1.09). In contrast, the lowest gap size occurs with C_{14} – investment costs (-0.20), so this criterion is the least likely to reduce the overall quality of Wrocław's public transport services.

Negative gap sizes, which indicate passenger dissatisfaction with the service, translate directly into the size of the CSI. Based on the CSI ranges in Table 2, the calculated size of the overall CSI (0.67) indicates that passengers are, on average, satisfied with the transport services that MPK Wrocław provides. Analysing the CSI sizes for individual quality characteristics, it can be seen that passengers, using the MPK Wrocław services, are most satisfied with the spatial accessibility of stops (CSI_1 = 0.72) and information accessibility (CSI_{10} = 0.72), while they are least satisfied with punctuality (CSI_6 = 0.61) and reliability (CSI_7 = 0.63) of Wrocław's public transport.

Negative gap sizes with all quality characteristics indicate that MPK Wrocław should take certain measures to increase its level of performance. However, in order to achieve improvement in the overall quality of its services, MPK Wrocław does not have to improve all characteristics of a given service but only focus on those that are important to its passengers. The analysis of the data in the IPA chart (Figure 5) shows that C_6 – punctuality, C_7 – reliability, C_8 – travel time, C_{11} – cost of travel, and C_{12} – comfort require immediate intervention by the service provider (to increase the level of their performance), while C_2 – frequency of travels, C_4 – immediacy of travel, and C_9 – safety are characteristics for which the carrier does not need to take any special measures, only those that are necessary to maintain their current level of performance. In addition, as resources become available, MPK Wrocław, wishing to improve the overall quality of its services, should shorten driving times

(C_6) and better synchronise the fares and timetables of various transport lines on common sections (C_{12}). The level of performance of the criteria – spatial accessibility of stops, C_3 – the regularity of rides, C_{10} – information availability, and C_{14} – investment costs are the closest to passengers' expectations, so MPK Wrocław does not need to take any measures to increase their level of performance. In summary, the overall level of service quality will increase if MPK Wrocław increases the level of performance of the characteristics placed in the area 2 and 3 of the IPA chart (Figure 5), and provided that the level of performance of other characteristics is maintained at the current level.

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Conclusions

Road traffic in cities is constantly increasing, causing more and more congestion and negatively affecting the standard of living of city residents. One solution to reduce the use of personal cars is to encourage traffic participants to use public mass transit. Public mass transport services should, therefore, have characteristics attractive to traffic participants in order to lead to a lasting change in their transport preferences. To correctly identify the directions for the development of public mass transport, thus guaranteeing the demand for transport services, it is necessary to know the requirements for meeting mobility demands of the residents. The discrepancy (gap) that will arise between the expected (required, preferred) and perceived (received, sensed) quality of services expresses the level of passenger satisfaction with the services of a given provider.

The purpose of this article was to assess the level of satisfaction of passengers who use public transport services in Wrocław and to identify quality characteristics that require immediate improvement on the part of the service provider. This evaluation was carried out in accordance with the procedural stages presented in the article for surveying the level of satisfaction of passengers who use public mass transport services, taking into account the use of CSI and IPA.

The article presents the results of a survey conducted in June 2022 on a sample of 500 people. The evaluation of the relevance and reliability of the developed questionnaire showed that it is an appropriate tool for studying the satisfaction of passengers who use public transport services. A total of 14 service quality characteristics were selected for the satisfaction evaluation. CSI was used to determine passenger satisfaction. The overall CSI was 0.67, which means that passengers are, on average, satisfied with the services provided by MPK Wrocław. The average degree of performance of quality characteristics ranged from 3.07 to 3.59. Passengers considered spatial accessibility the best performing quality characteristic, while they rated the punctuality of public transport vehicle departures the lowest However, the ratings assigned by respondents to the relevance/importance of the quality characteristics indicate that the performance of 12 out of 14 characteristics is important (the average importance rating is greater than 4 points). The average importance of the quality characteristics ranged from 3.59 to 4.48. The most important characteristics of the services quality from the point of view of passengers are the punctuality of public transport vehicles departures (executed according to the timetable) and, rated as the least important, the cost of investments associated with the construction, expansion, or reconstruction of nodal infrastructure (e.g. stops, transfer nodes), line infrastruc-

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ture (roads), and the purchase of rolling stock. The survey also shows that passengers' expectations for all quality characteristics are higher than their performance level. The largest quality gap was recorded for the punctuality of public transport departures (-1.42), while the smallest was for the cost of investment (-0.20). The IPA analysis indicated that if the overall quality of the MPK Wrocław's services is to improve, the company should first increase the level of performance of five characteristics, i.e. punctuality, reliability, time, cost, and travel comfort.

Changes in the level of services provided and in the residents' transport preferences should be identified through systematic marketing surveys. The information provided by such surveys is a hint for the organiser and operator of urban transport about the actions they must take in order to create an optimal transport offer, primarily in terms of achieving the desired quality of transport services. It should be noted that the pursuit of better performance of the indicated characteristics may encounter a number of impediments (financial capabilities of the organiser and/or technical capabilities of the operator). Furthermore, it is beyond dispute that raising the quality of public transport rides involves an increase in fare prices, which are the most important element of public transport services. All these conditions make it very difficult to meet the expectations of low fares for the use of public transport services.

The results of the research presented in the article will be used to identify the "hidden" dimensions (categories) of the evaluation of the quality of public mass transport services using factor analysis. This task represents the next phase of the INTERECON project financed under the programme launched by the Minister of Science and Higher Education, i.e. "Regional Initiative of Excellence", between 2019 and 2022, entitled, "Structural modelling in the study of the quality of public mass transit services, on the example of MPK Sp. z o.o. in Wrocław. A Passenger's Perspective."

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RETURNABLE PACKING IN E-COMMERCE FROM THE SOCIO-ECONOMIC PERSPECTIVE – RESEARCH RESULTS

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ABSTRACT: Growth in online sales results in an increase in the number of containers remaining in economic circulation, causing both economic (increased costs of container production, storage and disposal) and environmental effects. One way to reduce the scale of this problem would be to introduce reusable packaging, which enterprises could use as part of their e-commerce solutions. The question remains, however, whether the customers are ready for this. What is their opinion on implementing such a solution? Would they be willing to pay a deposit for using such containers? This paper aims to suggest individual returnable packaging solutions that can be used in e-commerce to manifest corporate social responsibility and reflect customer attitudes towards them. The paper is empirical, with the empirical part presenting the results of the author's study.

KEYWORDS: e-commerce, corporate social responsibility, returnable packing

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Introduction

Between 2020 and 2022, global online sales have increased significantly. The sector that has become the greatest beneficiary of the pandemic is the fashion industry (clothes, accessories, footwear), which in 2021 reached a global market value of USD 759.5 billion (leader in e-commerce sales), and whose forecast for 2025 reaches 1 trillion USD (COMMON THREAD, 2021), thereby elevating the number of containers used. This is becoming a significant environmental problem, posing an economic and ecological challenge for enterprises. By recalling the essence of corporate social responsibility (understood by the European Commission as „voluntarily taking into account the social and environmental dimension in its economic activities and relations with all stakeholders" (Lewicka-Strzelecka, 2008)), one can indicate that placing the packaging „in the centre of attention" becomes a justified necessity. It is important to note that the material from which a container is made (environmental aspect) may affect both the cost of the offer (economic part), customer convenience (marketing aspect) and storage and transport options (logistical aspect). In every company, stakeholders should co-create the idea of socially responsible packaging and be in charge of its implementation and operation.

This paper aims to indicate individual returnable containers that can be used in e-commerce as a manifestation of corporate social responsibility and the customers' attitudes towards this solution. The empirical part presents the results of the author's study, which will allow us to answer the following research questions:

- What is the respondents' opinion (considering their age) towards the possible introduction of reusable, returnable packaging into the market?
- What is the respondents' attitude (considering their age) towards implementing a deposit for (potential) reusable, returnable containers?

This study is empirical in nature.

Reusable, returnable packaging as an expression of corporate social responsibility: research methods

In 2011, the International Organization for Standardization, in their ISO 26000 standard, defined corporate social responsibility as „the responsibility of an organisation for the impact of its decisions and activities (products, services, processes) on society and the environment, through transparent and ethical behaviour that:

- contributes to the sustainable development, health and welfare of society,
- takes into account the expectations of stakeholders,

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- complies with applicable law and is consistent with international standards of behaviour,
- is consistent with the organisation and practically applied in its relations" (Adamczyk & Nitkiewicz, 2007; CSRinfo, 2022; Sadziewska, 2010).

This approach shows the necessity of adopting sustainable development on many levels, not only in terms of the product offered, but also in the packaging used for transporting goods purchased online. This can be associated with the growing ecological awareness of our society (which is shaped under the influence of changing social norms, information, formal and informal education, as well as state actions) or – more broadly – to the social awareness (understood as the state of knowledge about the methods and instruments of controlling the use and protection of the environment (Poskrobko, 2001)). Ecological awareness also pertains to our attitude towards the natural environment (a set of information and beliefs about it) and the system of values a person follows in their behaviour (Małachowski, 2007; Nycz-Wróbel, 2012). The Ipsos MORI report for DS Smith (2022) shows that 32% of respondents in Europe and 39% in Poland believe that „solving the problem of the waste we generate" is one of the three main issues related to environmental protection. The respondents expect, among others:

- buying optimally packaged products (85%),
- the smallest possible packaging (29%),
- packaging made of recyclable materials (26%),
- packaging manufactured using technologies with low environmental impact (22%),
- packaging made with the use of ecological materials (20%),
- packaging that is not made of plastic (24%),
- hygienic packaging (22%).

Only 15% of European respondents were aware of „circular packaging" (DS Smith, 2022). In Poland, 74% of respondents (above the European average) declare awareness of the existence of recyclable packaging, and only 18% the awareness of the presence of reusable packaging (that is why it is necessary to popularise the idea of sustainable development). This paper's research part presents references to this aspect of the study.

When discussing containers the use of which is environmentally friendly, one can refer to three aspects (Global Web Index, 2022):

- packaging material: containers manufactured from 100% biodegradable materials or materials obtained from recycling,
- production method: selection and use of solutions that minimise, among others, water consumption and carbon footprint,
- reusability: designing containers that can be reused (not necessarily in the same form) and extending their life cycle (e.g. returnable packaging – reusable packaging that could be used in online shopping).

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A manifestation of corporate social responsibility in the field of packaging is manifesting its strong connection to ecology and the practical implementation of the 3×R (reduce, reuse, recycle) principle, which includes:

- reduction of the amount of waste and raw materials used,
- extending the life of raw materials (e.g. by reusing or repairing them),
- recycling.

An example of such a solution is paper packaging (paper cups, ecological bags, paper bags, etc.), which is not only a way to reduce the amount of waste generated, but also significantly improve the identification of the company, thanks to additional personalisation. Another example is introducing reusable, returnable packaging that the market leader – the fashion industry – could use in online sales. This industry is interested in using reusable packaging for e-commerce, which undoubtedly corresponds with the idea of corporate social responsibility (more: Yusuf et al., 2017; Akabane et al., 2018; Coelho et al., 2020). Nevertheless, in addition to the benefits of a possible reduction in the number of containers and a better perception of the company by customers, there are several challenges. They could be as follows:

- the costs of purchasing such packaging (more: Granato et al., 2022),
- reusability – from the point of view of the durability of the packaging (more: Radhakrishnan, 2015),
- reverse logistics related to the method of returning the container or requirements regarding hygiene (more: Demajorovic et al., 2019),
- customer attitudes towards a new market solution (this issue is analysed in the empirical part of this paper).

Results of the research

In the Department of Logistics and Innovation, the University of Lodz, extensive research has been carried out. It was undertaken as part of this publication and was financed based on cooperation with ARVATO Polska Sp. z o. o. company: an operator of comprehensive services for the e-commerce sector in Poland and worldwide. Activities related to the „Development of ecological reusable packaging for use in e-commerce logistics services" were carried out. The research contributed significantly to transferring knowledge in the interregional system between the sectors of enterprises, academia, and science and research. The undertaken study was related to the possibility of implementing ecological returnable packaging; one that is reusable and could be used in e-commerce. This article presents the results pertaining to the following questions:

1. What is the respondents' opinion (considering their age) towards the possible introduction of reusable, returnable packaging into the market?

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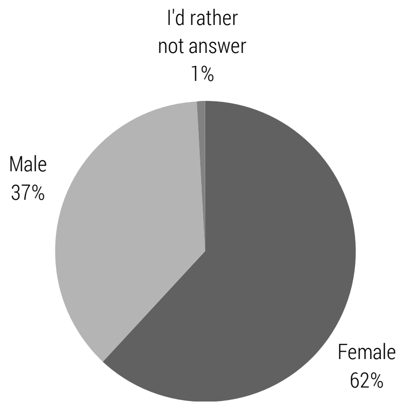
2. What is the respondents' attitude (considering their age) towards implementing a deposit for (a potential) reusable, returnable containers?

In the period between May 4, 2021, and June 26, 2021, an online survey (CAWI) was conducted, in which the respondents answered the questions on their own. The questionnaire was distributed nationally. The study was anonymous, and the sample selection was non-random (the snowball method was used). Due to the sampling method, the study is not representative, so the results cannot be generalised to the entire population of Poland. Therefore, all conclusions will relate to the studied sample, i.e. the respondents who participated in the study.

Gender	Age
Size of the place of residence 24% Countryside 14% City up to 50 thousand inhabitants 11% City between 51 and 150 thousand inhabitants 7% City between 151 and 500 thousand inhabitants 44% City with over 500 thousand inhabitants	Type of residence 43% single-family house 7% multi-family house 48% apartment building/skyscraper 2% other
Education 1.5% Lower 42.4% Secondary 56.1% Higher	Professional status 44% Student 53% Employed 2% Retired or pensioner 1% Unemployed



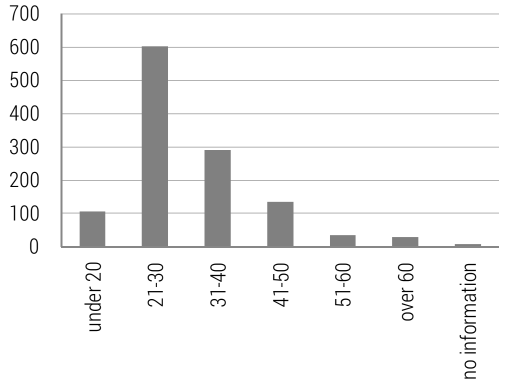


Figure 1. The characteristics of the surveyed respondents

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The survey questionnaire contained an individual data part, which allowed us to verify the gender (62% of respondents were women, 37% – were men, and 1% of the respondents did not specify their gender), age (it should be noted that about 1% of the respondents did not indicate their age; however, this incompleteness did not have a negative impact on the data analysis), size of the place of residence, type of residence (the type of building), education and professional status of the respondents. 1213 respondents (details in Figure 1) aged 17 to 79 participated in the study. The most significant number, as many as 600 (which accounted for nearly 50% of the total), were people aged 21-30. Moreover, about 9% of the respondents were under the age of 20, 24% – were aged 31-40, 11% – were aged 41-50, 3% – were aged 51-60 and 2% – were over 60 years old. The age factor has become a classifier for the answers given by the respondents.

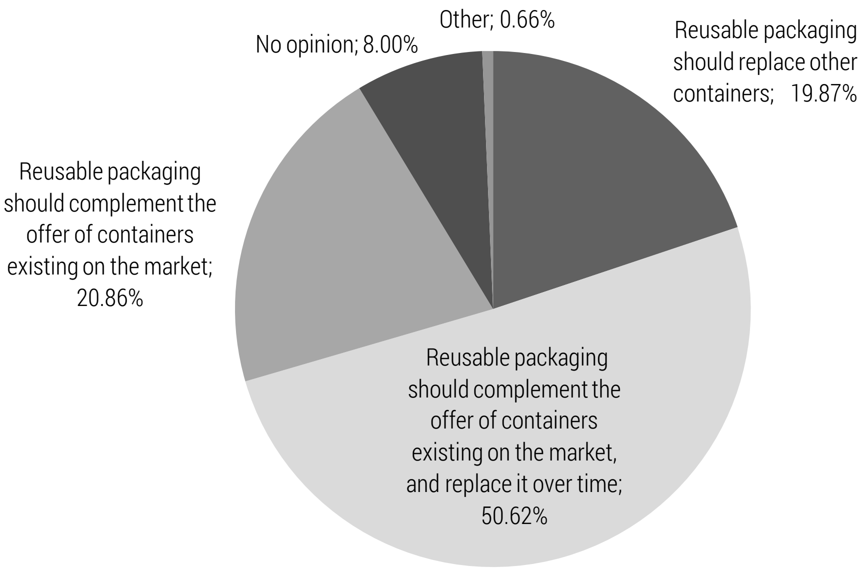

Figure 2. The existence of a potential returnable, reusable packaging for online purchases

Introducing new returnable packaging solutions involves the elimination of standard packaging or the simultaneous coexistence of both solutions. Figure 2 shows the distribution of respondents' replies pertaining to this issue. More than half of the respondents indicated that reusable packaging should complement the offer of existing containers on the market and should replace it over time. Almost 20% of respondents say that reusable returnable packaging should replace other containers, and 21.9% – say that reusable packaging should complement the offer of containers already existing on the market.

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Table 1 shows the relationship between the opinion on how potential returnable packaging should function on the market, as part of online shopping, in relation to the age of respondents.

Table 1. Opinion on how potential returnable packaging should function in the market as part of online shopping according to the age of respondents [%]

Opinion / Age group	Under 20	21-30	31-40	41-50	51-60	Over 60
No opinion	10.3	8.0	7.9	5.9	5.6	10.0
Reusable packaging should complement the offer of containers existing on the market	15.9	20.2	20.5	25.2	16.7	26.7
Reusable packaging should complement the offer of containers existing on the market, and replace it over time	55.1	53.9	46.2	45.9	52.8	43.3
Reusable packaging should replace other containers	18.7	17.6	24.0	23.0	22.2	16.7
Other	0.0	0.3	1.4	0.0	2.8	3.3

All respondents see the legitimacy of introducing reusable packaging into economic circulation. When interpreting the data in the table, the following patterns can be noticed:

- the awareness of the assessment among the respondents about the existence of returnable packaging increases with age (according to the study, up to 60 years of age; the answer „No opinion" was given almost twice as often by respondents under 20 than by people aged 51-60),
- respondents who are more afraid of introducing returnable packaging are people over 60 years of age (as many as 26.7% of respondents propose that reusable packaging should complement the offer of other containers on the market, for comparison, this opinion is expressed only by 15.9% of people under the age of 20),
- respondents aged 31-50 showed the greatest approval rate for innovative solutions (as many as 47% of respondents at this age indicate that reusable packaging should replace other containers),
- slightly more often, respondents aged under 30 and aged 51-60 say that reusable packaging should complement the offer of containers existing on the market and replace it over time.

In general, most of the respondents showed interest in the new solution. To deepen the analysis, the responses were compared in the context of environmental awareness (defined in the first part of this paper) and the existence of returnable packaging (see Table 2). On this basis, we can conclude

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that the most hesitant and uncertain group of respondents indicated that their knowledge of ecology is at a very low level, which may signal that society needs to be educated about the benefits of implementing closed-loop packaging.

Table 2. Environmental awareness of the respondents (on a scale from 1 – very poor to 5 – very good) and the introduction of returnable packaging [response frequency in %]

Introducing returnable packaging / Environmental awareness	1	2	3	4	5
No opinion	33.3	10.8	11.0	5.2	6.6
Reusable packaging should complement the offer of containers existing on the market	22.2	32.3	20.7	20.2	18.2
Reusable packaging should complement the offer of containers existing on the market, and replace it over time	11.1	46.2	51.2	52.0	47.1
Reusable packaging should replace the offer of containers existing on the market	33.3	9.2	16.5	22.0	27.3
Other	0.0	1.5	0.7	0.5	0.8

In summary, the majority of respondents see the possibility of introducing reusable returnable packaging into the market: 1/5 sees a chance for it to complement the offer of containers already existing on the market (the highest percentage among people 41-50 years old), and others, for it to replace the previously used containers: immediately (most indications in the group of people aged 31-60), or after some time (most indications in the group of people under 30).

Another issue that was the subject of this analysis is the attitude of the respondents towards introducing a deposit for returnable packaging. Taking into account the age of the respondents (Table 3), one can indicate that the willingness to purchase a product in returnable packaging (when a deposit is required in the store) increases with up to about 50 years of age. Most undecided respondents were people over 60 and under 20 years of age.

In summary, over 40% of respondents in each age group (and even over 50% in the group of 31-60 years of age) said „yes" when it comes to the necessity of paying a deposit for packaging. Additionally, the respondents who expressed their approval to use returnable packaging were asked about the amount of money they would be willing to pay for it (see Figure 3). Slightly over 40% of respondents estimated the amount of the deposit for returnable packaging to be in the range of PLN 0.50-5.00, and 11.9% – of PLN 5.01-10.00.

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Table 3. Willingness to purchase a product in returnable packaging and paying a deposit in an online store sorted by the respondents' age groups [%]

Age group / Willingness to purchase	Definitely yes	Rather yes	Yes	I don't know	Rather not	Definitely not
under 20	12.1	27.1	1.9	36.4	21.5	0.9
21-30	10.3	33.3	4.3	33.5	13.6	5.0
31-40	11.6	34.9	7.2	28.8	13.0	4.5
41-50	14.1	32.6	5.2	27.4	15.6	5.2
51-60	13.9	33.3	11.1	16.7	19.4	5.6
over 60	10.0	20.0	10.0	46.7	10.0	3.3

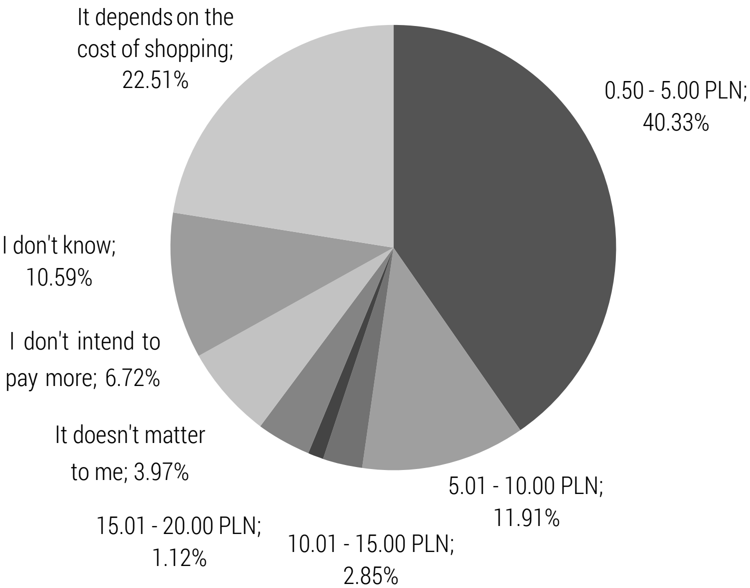

Figure 3. Deposit amount for potential returnable packaging when shopping online

This means the respondents do not want to incur higher costs related to the returnable deposit for the packaging they will receive as part of online purchases. It should be noted that as many as 22.5% of the respondents indicated that, according to them, the deposit amount depends on the purchase cost. Some of the respondents replied that they did not intend to pay more (6.7%), did not have an opinion on this subject (4.0%), and 10.6% of them did not know the amount of the deposit (they have not thought about it

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before, therefore it was difficult for them to estimate). Based on this analysis, one can indicate that most respondents are ready to cover the additional amount of the deposit, provided that it will later be returned.

Table 4. Deposit amounts and the willingness to purchase the product in returnable packaging [share of the response frequency in %]

Willingness to purchase the product in returnable packaging / Deposit amount	I don't know	Rather yes	Yes	Definitely yes
0.50-5.00 PLN	33.5	45.3	46.0	42.3
5.01-10.00 PLN	3.6	18.9	11.1	15.3
10.01-15.00 PLN	1.3	3.5	3.2	5.1
15.01-20.00 PLN	0.8	1.3	0.0	2.2
I don't care	1.8	4.0	3.2	10.2
I don't know	22.9	2.5	3.2	2.9
I don't intend to pay more	14.8	1.0	6.3	0.7
It depends on the cost of shopping	21.3	23.4	27.0	21.2

Table 4. lists the respondents' responses regarding the propensity to purchase products (answers „yes", „rather yes", „definitely yes", and „I don't know" were taken into account) in returnable containers along with the amount they are willing to pay for a deposit. It should be noted that people who are hesitant to use returnable packaging often do not know what amount they would be willing to pay, or do not intend to pay more for returnable containers. People who indicated that they are rather convinced to use returnable packaging, are open to the amount of the deposit required for it. Respondents who showed the highest approval of the idea of returnable packaging often indicated that they did not care about the deposit's amount. Within this relationship, all surveyed respondents are most likely to cover the lowest possible amount of the returnable deposit.

Conclusions

In the constantly growing online sales environment, a comprehensive evaluation of the company's offer cannot be limited to the product itself. As people pay more and more attention to transport packaging, those attitudes become an indispensable part of corporate social responsibility.

Packaging in e-commerce should be socially acceptable ecologically (e.g., considering the materials it is made of) and economically (cost). It should protect the product from damage and allow it to reach the customer unchanged, and – in the case of returnable packaging – it should reach customers in its unchanged form several times. Returnable packaging should not only be made of recycled materials, reducing the consumption of raw and processed materials (although one is not able to "escape" a dedicated production process), but it should become an integral part of responsible production processes and be subject to ecological disposal. It is necessary to maintain the packaging's shape (size parameters) that enables storage and transport in standard forms (e.g. palleting). An important issue about reusable packaging is the possibility of cleaning/disinfecting the packaging, so its material should be resistant (both physically and chemically) to such processes.

The decision regarding the choice of a specific material used for the production of the packaging will be in the hands of technologists/chemists who –by changing the proportions of ingredients/manufacturing conditions – may affect the wear time/strength/brittleness/ flexibility of the material the container will be made of. The number of use cycles of reusable packaging will also be influenced by the activities of people involved in circling such containers. While the diligent work of employees packing the goods will instead (undoubtedly?) be maintained, the quality of work of subcontractors – such as couriers – may significantly impact maintaining proper packaging parameters. Similarly, the consumer's behaviour towards the packaging (throwing away, using it at home, careless storage before return) will affect its life expectancy in e-commerce. The study shows that online buyers are open to the marketing of (reusable) ecological returnable packaging and are willing to pay a deposit.

The contribution of the authors

Agnieszka Bukowska-Piestrzyńska – 50% (conception, literature review, acquisition of data, analysis and interpretation of data).

Joanna Górniak – 50% (conception, literature review, acquisition of data, analysis and interpretation of data).

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THE QUALITY OF WELL WATERS IN POLAND – A STUDY CASE

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ABSTRACT: The aim of this study was to analyse the quality and compare the functional value of water from traditionally dug and drilled wells located in western Poland. Basic physicochemical and microbiological (Escherichia coli in 100 ml, coliform bacteria in 100 ml, enterococci in 100 ml, total number of bacteria in 1 ml grown at 22°C, total number of bacteria in 1 ml grown at 36°C) were determined for the water samples. Additionally, some water samples were analysed for the presence of heavy metals, TN (total nitrogen), TOC (total organic carbon) and NPOC (dissolved organic carbon). The conducted research has indicated that mineral and microbiological contamination occurs in the waters collected from the wells. This confirms that the wells were not sufficiently protected and that penetration of pollutants into the water occurs from their immediate surroundings, geological layers with which underground water resources come into contact.

KEYWORDS: drilled well, dug well, water quality, water pollutants, quality of water

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Introduction

Groundwater is a very valuable water resource all over the world, including in Poland. It results from the penetration of surface water, mainly rainwater, through the soil layers. During ground filtration, the rainwater encounters impermeable layers such as clay or loam. This causes the voids to be filled with water, thus creating saturation zones (the so-called aquifers) at different depths. After penetration through the ground layers, water becomes purified as the physicochemical and bacteriological pollutants are eliminated to some extent. The quality of the water is determined by the depth at which the aquifer is situated. In terms of sanitation and geology, groundwater aquifers have been divided into shallow, ground, principal, and deep.

Shallow groundwater aquifers are located in shallow ground and are often referred to as near-surface waters. Their depth of deposition varies from a few to several dozen centimetres, more rarely to several meters, e.g. in depressions of the terrain. They are separated from the land surface by a layer of soil and ground characterised by small thickness, and they mainly result from precipitation. These waters are usually used by plant root systems. Due to their short contact with the ground layers during filtration, these waters are not sufficiently purified and are susceptible to daily temperature fluctuations. Due to the low quality of these waters it is not possible to use them for drinking or in water supply systems.

Groundwater at the ground level occurs above the first impermeable layer and lies at a depth of up to several meters. The groundwater level is related to, inter alia, the type of soil, its porosity and hydrological conditions. In sandy soils, the groundwater level is lower than in soils with high water absorption. Precipitation is the main source of groundwater supply. Therefore, it can often be said that groundwater is filtered rainwater. These types of water are usually highly purified, have a constant temperature, and can be used for consumption, but it is necessary to monitor their quality.

Principal groundwater aquifers occur under hydrostatic pressure and are usually located at depths below several meters, between two impermeable layers. They are characterised by very stable parameters, such as temperature and physicochemical composition. In most cases, well water can be used for drinking purposes, provided that the chemical composition meets the sanitary requirements (Cierniak et al., 2020; Hermanowicz et al., 1999; Rodrigues-Narvaez et al., 2017; Romero et al., 2014; Jha et al., 2020; El Baba et al., 2020; Mohamed et al., 2019; Kapembo et al., 2022; Abbasnia et al., 2019).

Deep waters are the deepest water resources from ancient geological layers. They are highly mineralised and occur deeply between impermeable layers of soil. They are also referred to as relict waters. They are non-renew-

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able. They are often heated by the heat from the Earth's interior and form the so-called thermal water.

Groundwater resources can also be divided into natural, artificial, variable, static, dynamic and operational. According to the literature, exploitable resources include some static or dynamic resources, the exploitation of which does not yield negative effects (Sadurski et al., 2016). According to the data of the Central Statistical Office, exploitation resources of groundwater in Poland in 2020 amounted to 18,439.5 hm^3, and the second place in the country in terms of groundwater exploitation belonged to the Greater Poland Voivodship (in west Poland) (Figure 1). In this area, exploitation resources amounted to 1724.9 hm^3, which constituted 9.40% of Poland's resources (GUS, 2020a; GUS, 2020b; Ober et al., 2021).

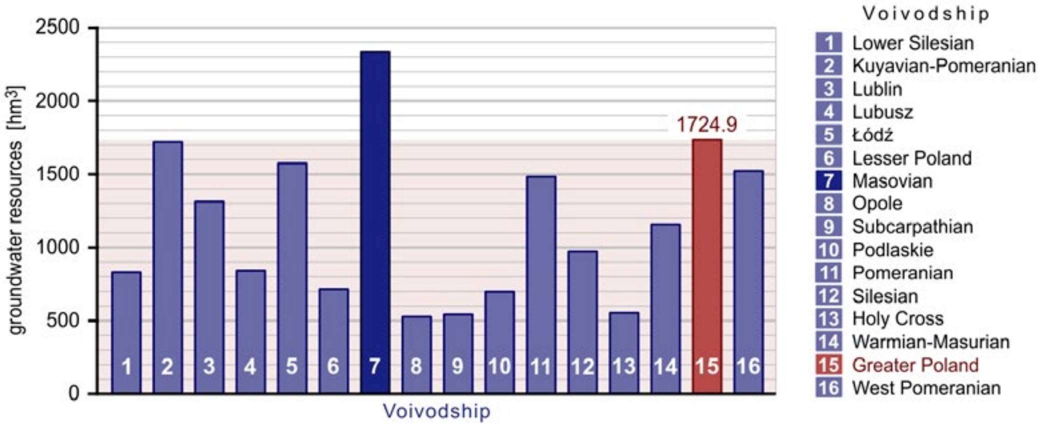

Figure 1. Exploitable groundwater resources in Poland in 2020

Source: GUS (2021).

In Greater Poland Voivodship, usable groundwater occurs in the Quaternary, Tertiary, Cretaceous and older formations. The distribution of exploitation resources in geological formations is as follows:

The example of a bulleted list:

- Quaternary – 1031.3 hm^3, which accounts for 59.80% of all Greater Poland Voivodship resources,
- Tertiary – 428.9 hm^3, which accounts for 24.87% of all Greater Poland Voivodship resources,
- Cretaceous – 235.4 hm^3, which accounts for 13.65% of all Greater Poland Voivodship resources,
- older formations – 29.4 hm^3, which accounts for 1.70% of all Greater Poland Voivodship resources (GUS, 2021).

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The data indicates that the waters taken for exploitation in Greater Poland Voivodship mainly originate from Quaternary deposits. There are four main groundwater reservoirs in the vicinity of Poznań (Figure 2):

- GZWP 144 – The Greater Poland fossil valley in the Quaternary formations,
- GZWP 143 – Inowrocław Sub-reservoir – Gniezno in older works,
- GZWP 145 – The Szamotuły fossil valley – Duszniki in the Quaternary formations,
- GZWP 150 – Warsaw – Berlin Urstromtal in Quaternary works (Olejniczak et al., 2021).

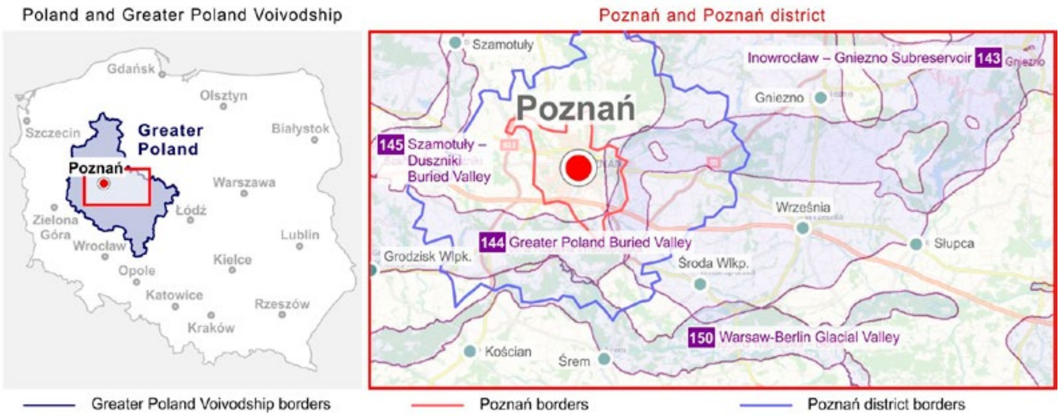

Figure 2. Location of the main groundwater reservoirs in the Poznań district
Source: PSH (2021).

According to the data of the Central Statistical Office in the Poznań district, 96.1% of the population used the water supply network in 2020. Furthermore, 96.7% of the urban population drew water from the water supply system. In the case of rural residents, this percentage was equal to 95.8% (GUS, 2020a; GUS, 2020b). This indicates that 3.3% of the urban population and 4.2% of the rural population did not use the water supply system.

Despite the constant development of water supply systems, a part of society has limited access to this infrastructure. The inability to use the water supply system is associated with the need to build a personal water intake. Sometimes the desire to possess a personal water intake is dictated by other reasons, e.g. economic or independence from system solutions (MacDonald Gibson & Pieper, 2017).

Domestic water intakes include driven, dug or drilled wells. Selection of the proper well for a plot of land depends on the depth of the aquifer, geological conditions and construction costs (Jha et al., 2020; El Baba et al., 2020;

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Mohamed et al., 2019; Kapembo et al., 2022; Abbasnia et al., 2019; Michałkiewicz et al., 2014).

An Abyssinian well is an example of a well with a punch-in filter. It is designed to collect water from the shallowest aquifer. Usually, its depth is in the range of 3-7 m. The diameter of the driven well does not exceed 50 mm. It is used in sandy soil by driving a pipe with a filter ended with a cone. The well also consists of a concrete ring and a pump with a lowered plunger (usually with a hand lever). The water is extracted from the well while pumping with a hand lever. This causes the piston to move, and hence, the lifting of the water column occurs. The wells with appropriate filters can also be equipped with electric pumps. The Abyssinian well has a low capacity and is not able to provide water for a household. It is most often used for supplying the garden with water (Piekarek, 2006).

Dug (shaft) wells are created by lowering the shaft vertically and then extracting the ground from its interior. These types of wells are most often used for shallow aquifers. It should be noted that the first aquifers are usually not covered with impermeable layers. This has a large impact on the quality of well water, as it is exposed to anthropogenic pollution. The depth of the dug wells ranges from 5 to 20 m. In order to construct the well, in most cases, concrete and reinforced concrete rings with a height of 0.6-1.0 m are used, which should be tightly connected (Piekarek, 2006; Betonbest, 2022). On the other hand, the internal diameters are 0.80-1.2 m. However, it is recommended to build wells with a diameter that exceeds 1.0 m because its capacity and efficiency increase. This also facilitates construction works (Przewłocki et al., 1966). Shaft wells consist of an underground and an above-ground part. The underground part consists of a filter, an impermeable wall and a bottom which can be tight or open. Traditional dug wells include gravel or a perforated mesh at the bottom. On the other hand, the above-ground part is formed by the body of the well and the cover with the hatch that closes it. In this type of wells, the last circle is usually above ground level. It should be noted that the above-ground part must be protected against the inflow of rainwater. Water can enter the well through openings in the side wall or through the bottom (Gabryszewski & Wieczysty, 1985). Water from the dug well is collected by means of a winch, crane, suction pump and hydrophore or by means of a column pump located on the cover (Piekarek, 2006).

Drilled (deep, tubular) wells are a borehole that allows to extract water from aquifers. For technical reasons, the casing is required. These types of wells capture water from greater depths than dug or well-filtered wells. However, for financial reasons, drilled wells with a depth not exceeding 30 meters are the most common (Gabryszewski & Wieczysty, 1985). The water-bearing layers lie under the impermeable layers of the ground, which improves the water quality. Drilled wells may possess small diameters, con-

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ventionally up to 0.3 m, and more rarely larger, exceeding 0.5 m. Filter and non-filter wells can be distinguished. In the case of filter wells, they are formed by casing columns (casing pipe) and a filter column. The casing column consists of joined steel pipes whose main purpose is to protect the walls of the borehole. In addition, it can also form a maintenance column for draining water.

Drilled wells, similar to dug wells, can draw water through the side walls and through the bottom. The construction of a well depends, e.g. on the method of drilling, depth, purpose, hydrogeological conditions and the method of drawing water (Gabryszewski & Wieczysty, 1985). In most cases, a submersible pressure pump or pumps submerged below the water level are installed at the bottom of the well to draw water. It is also worth noting that they are currently the best solution for households (Piekarek, 2006).

Research methods

In order to assess the quality of water from individual water intakes, 10 dug and drilled wells located in urban and rural areas of the Greater Poland Voivodship were tested. Basic physicochemical (colour, turbidity, content of ammonium nitrogen, nitrite nitrogen, nitrate nitrogen, iron, manganese, orthophosphates, P-general, sulphates, pH, conductivity, alkalinity towards methyl orange, hardness, calcium, chlorides) and microbiological (*Escherichia coli* in 100 ml, coliform bacteria in 100 ml, enterococci in 100 ml, total number of bacteria in 1 ml grown at 22 °C, total number of bacteria in 1 ml grown at 36°C) determinations were carried out for the collected water samples. Additionally, some waters samples were analysed in terms of the presence of heavy metals (chromium, zinc, cadmium, copper, nickel, lead), TN (total nitrogen), TOC (total organic carbon) and NPOC (dissolved organic carbon). The collection of water samples as well as the physic-chemical and microbiological analysis were carried out in accordance with the applicable methodology according to the guidelines of Standard Methods and Polish Standards (Regulation, 2017). Heavy metals were determined using the AA-7000 Shimadzu atomic absorption spectrometer, and the TOC/TN 3100 multi Analytik Jena analyser was used for carbon and nitrogen determinations. The catalytic oxidation via the combustion process is used for the determination of TOC/TN. This method enables the efficient oxidation of recalcitrant organic compounds with low molecular weight but also high-molecular, insoluble and difficult-to-decompose compounds. Nitrogen adapter – TN – enables total nitrogen determination due to thermal decomposition and chemiluminescence.

The characteristics of the studied wells are summarised in Table 1.

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Table 1. List of studied wells

Well number	Location	Well type	Deep	Method of use	
				watering the garden	to drink
1	Municipality Kuślin	drilled. deep	80.0 m	yes	yes
2	Poznań	drilled	6.0 m	yes	yes
3	Kostrzyn Wlkp.	dug	4.0 m	yes	yes/no
4	Paczkowo	dug	3.5 m	yes	yes/no
5	Rogalin	dug	8.5 m	yes	yes/no
6	Jaryszki	drilled	7.5 m	yes	yes
7	Zborowo	dug	6.5 m	yes	yes/no
8	Borowo	drilled	26.0 m	yes	yes/no
9	Puszczykowo	drilled	17.0 m	yes	yes
10	Kórnik	dug	5.5 m	yes	yes/no

Results of the research

Table 2. Results of physicochemical and bacteriological tests of water from wells No. 1-10

Water parameter	Unit	Well number										Limit value
		1	2	3	4	5	6	7	8	9	10	
physicochemical tests												
Colour	mg Pt/l	10	15	5	10	10	3	5	30	3	4	accept. to 15
Turbidity	NTU	1.26	5.84	1.67	3.56	2.69	1.00	0.25	15	1.00	1.20	accept. to 1
pH	—	6.93	6.61	7.04	7.15	7.13	8.20	7.75	7.14	7.01	6.97	6.5÷9.5
Electrical conductivity (EC)	μS/cm	1145	1253	1594	809	1528	676	573	680	662	483	2500
Ammonium nitrogen	mg NH_4/l	0.348	0.888	0.315	0.287	0.464	0.140	0.001	1.220	0.232	0.106	0.5
Nitrite nitrogen	mg NO_2/l	0	0.098	0.011	0	0	0.024	0.011	0.013	0.019	0	0.5
Nitrate nitrogen	mg NO_3/l	0.032	3.042	2.348	5.010	0.044	0.127	0.111	0.431	0.324	0.166	50
Iron	mg Fe/l	0.021	0.091	0.009	0.032	2.207	0.090	0.140	2.452	0.072	0.198	0.2
Manganese	mg Mn/l	0.273	1.474	0	0	0.423	0	0	0.008	0	0.070	0.05
Orthophosphates	mg P/l	0	0.502	0.492	0.081	0.098	0.065	0.124	NS	0.058	0.164	—
P-general	mg P/l	0.091	0.917	0.746	0.142	0.247	0.120	0.180	NS	0.124	0.197	—
Sulphates	mg SO_4/l	215.16	96.68	70.35	83.92	102.43	87.92	182.22	104.76	NS	127.13	250
Methyl orange alkalinity	mval/l	5.10	7.95	8.30	5.85	6.50	7.30	8.00	8.50	7.00	4.70	—
Total hardness	mg $CaCO_3$/l	607.0	606.0	439.0	488.5	760.5	455.5	310.5	341.0	421.5	241.0	60÷500
Calcium	mg Ca/l	173.91	175.13	117.58	138.67	224.45	127.23	67.91	92.92	132.24	80.77	—
Magnesium	mg Mg/l	42.03	40.98	35.33	34.55	48.68	33.46	34.33	26.51	22.17	9.56	7÷125
Chlorides	mg Cl/l	103.5	133.0	210.0	32.0	63.0	76.0	44.0	40.0	85.0	17.0	250
bacteriological tests												
Escherichia coli	jtk/100 ml	0	0	6	5	0	0	50	0	0	0	0
Coliforms bacteria	jtk/100 ml	47	6	36	34	13	0	200	0	0	16	0
Enterococci	jtk/100 ml	0	0	16	31	1	0	12	0	0	0	0
Bacteria grown at 22°C	jtk/1 ml	42	620	6400	3200	3900	12	11	45	2	310	100 NA
Bacteria grown at 36°C	jtk/1 ml	16	105	5650	300	1850	5	65	12	3	10	—

limit values exceeded

wells that meet all the requirements contained in the Regulation of the Minister of Health (Dz. U. 2017. poz. 2294)

accept. - *acceptable*
NS - *not studied*
NA - *no abnormal changes*

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The results of physicochemical and bacteriological testing of water and the permissible values of individual parameters in accordance with the Regulation of the Minister of Health on the quality of water intended for human consumption, which is in force in Poland (Regulation, 2017) were presented in Table 2. Moreover, the results of heavy metals, TOC, TN and NPOC determinations in selected wells were presented in Table 3.

Table 3. Results of heavy metals, TOC, TN and NPOC determinations in selected wells

Water Parameter	Unit	Well number				Limit value
		1	2	3	4	
Chromium	mg Cr/l	0.0955	0.1121	0.1427	0.1546	0.05
Zinc	mg Zn/l	0	0.0500	0.0574	0.1090	—
Cadmium	mg Cd/l	0.0032	0.0046	0.0065	0.0082	0.005
Copper	mg Cu/l	0.0070	0.0111	0.0145	0.0193	2.0
Nickel	mg Ni/l	0.0128	0.0098	0.0098	0.0118	0.02
Lead	mg Pb/l	0.0253	0.0678	0.0578	0.0632	0.01
TOC	mg C/l	0	0	0	0	—
TN	mg N/l	0.6304	5.3	12.87	10.84	—
NPOC	mg C/l	2.92	7.04	4.89	3.17	—

limit values exceeded

Discussion

The quality of water from individual intakes is often not subjected to periodic monitoring, as is the case with waterworks. As a consequence, inadequately treated and disinfected water can be dangerous to human health and even life. Moreover, numerous physicochemical and microbiological contaminants in the water render it impossible to use, e.g. for drinking purposes (MacDonald Gibson & Pieper, 2017; Kowalski et al., 2017; Mahmoud et al., 2022; Ximenes et al., 2018).

Excessive turbidity of water collected from most wells may be associated with the presence of suspensions of mineral or organic origin (Kiedryńska et al., 2006). In addition, water hardness can also cause turbidity due to the precipitation of calcium and magnesium carbonate (Water Engineering, 2022). In three wells, the water was very hard (+500 mg $CaCO_3$/l) and exceeded the permissible values specified in the Regulation of the Minister of Health. The high hardness of the analysed well waters indicates the presence of dissolved substances, mainly calcium and magnesium salts (Water Engineering, 2022). Calcium had a significant contribution to the observed hardness, as its concentrations ranged from 67.91 to 224.45 mg Ca/l, while the magnesium concentrations remained at the lower levels, from 9.56 to 48.68 mg Mg/l. Water samples from four wells (no. 1, 2, 5, 10) were characterised

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by exceeding the manganese content. This may indicate the penetration of this element into groundwater from plant debris or soil, leaching from the ground, and contamination with wastewater (Kiedryńska et al., 2006). The situation was notably better in terms of the presence of iron in the water because the permissible value of this element was exceeded only in two wells.

After analysing the bacteriological status of the well water, it can be concluded that typical indicator bacteria (*Escherichia coli*, coliform bacteria or enterococci) were not detected only in three wells, while the number of bacteria grown at 22°C in five wells was low (below 100 CFU/1 ml). In four wells, the number of bacteria grown at 36°C exceeded 100 CFU/1 ml. The content of mesophilic bacteria in water (cultivation at 36°C) may result from pollutants such as sewage, soil and vegetation, and psychrophilic bacteria (cultivation at 22°C) from the presence of organic substances in water. The presence of coliforms, *Escherichia coli* and enterococci in water is particularly dangerous for human health, as it indicates contamination of the wells with human or animal faeces, and thus the potential possibility of the presence of other but pathogenic bacteria, e.g. *Salmonella, Shigella, Klebsiella, Clostridium, Campylobacter* (Ciślak & Michałkiewicz, 2021). It can be assumed that the microbiological contamination of well water results from the improper location of the wells in the field and failure to comply with the requirements of the Minister of Infrastructure (Regulation, 2019).

In accordance with the regulations in force in Poland, contained in the Journal of Laws 2019, item 1065, the distance of the well-supplying water intended for human consumption should be – from the axis of the well – at least: 5 m to the plot border, 7.5 m to the axis of the roadside ditch, 15 m to livestock buildings and related airtight silos, waste collection tanks, compost and similar sealed devices, 30 m to the nearest drainage conduit of an individual sewage system, if biologically treated sewage is discharged into it to the extent specified in the provisions on water protection, 70 m to unpaved enclosures for livestock, to the nearest infiltration pipe of the local sewage system without biological sewage treatment devices and to the border of the filtration field. In addition, the area surrounding the dug well and the drilled well pipe, in a strip at least 1 m wide, counting from the outer casing of the well, should be covered with a hardened surface with a 2% slope towards the outside. In the case of the analysed wells, it was found that the above regulations are often not followed.

Analysis of the results of heavy metal determinations indicated that the permissible values of chromium, cadmium and lead were exceeded. Excessive concentrations of chromium in water samples may indicate water contamination with wastewater that may contain chromium compounds. On the other hand, increased cadmium content indicates that the water had contact with industrial sewage or soil fertilised with phosphorus fertilisers. The

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presence of lead in groundwater can originate from the leaching of soil containing lead compounds, from pollutants supplied with industrial wastewater, or it can be introduced into the water due to corrosion of lead pipes or tanks coated with lead compounds and from car exhaust fumes. The highest lead content was found in water from a drilled well located in Poznań. It should be remembered that the vast majority of heavy metals are toxic substances that act as carcinogens and have a negative impact on human health (Ciślak & Michałkiewicz, 2021).

The elevated content of ammonia nitrogen in groundwater may indicate that the water is contaminated with domestic or industrial wastewater. The concentrations of ammonia nitrogen in the tested water samples varied, but in wells 2 and 8, they exceeded the permissible concentration (0.5 mg NH_4/l), reaching the values of 0.888 mg/l (well 2) and 1.220 mg/l (well 8). Taking into account the concentration of nitrite nitrogen, it should be remembered that it is the most unfavourable form of nitrogen compound in groundwater, as it is highly toxic to living organisms. The high content of these compounds indicates that very intense nitrogen transformations occur, most often in hypoxic or anaerobic conditions, i.e. under conditions unfavourable for aerobic organisms (including humans). The concentration of nitrite nitrogen in the waters taken from the selected wells ranged from 0.000 to 0.098 mg/l (in well number 2), and the permissible concentration of 0.5 mg/l was not exceeded in any case. A similar situation was observed when determining the concentration of nitrates (V); the values were not exceeded in all wells.

The results of the TOC tests confirmed that the analysed water samples did not contain any organic substances. This can be explained by the fact that the concentration of organic matter in groundwater decreases significantly over time. This phenomenon is caused by the process of mineralisation of organic compounds, i.e. chemical and biological degradation to carbon dioxide, which can occur due to both aerobic and anaerobic processes. On the other hand, the presence of nitrogen compounds in groundwater is the result of geochemical changes occurring in the aquifer and may also be the result of the presence of anthropogenic pollutants (well 3, TN concentration – 12.87 mg N/l). The main sources of nitrogen compounds, in this case, are probably easily soluble inorganic nitrogen salts, which enter groundwater from improperly secured septic tanks.

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Conclusions

On the basis of the obtained results of water tests from dug and bored wells, it can be stated that the quality of groundwater, both shallow and deeper, is not satisfactory. Among the deeper wells (over 10 m deep), only the water from well no. 9 meets all the requirements specified in the Regulation of the Minister of Health on the quality of water intended for human consumption, while among the shallow wells (up to 10 m deep) only well no. 6 meets the criteria. In water samples from other wells, it was noted that the physicochemical or bacteriological parameters were exceeded. Therefore, in order to fully use these waters, it is necessary to apply the processes of their treatment and disinfection.

For water treatment in domestic installations, one can use filters with filter cartridges, iron removal, manganese removal and water softening. In order to improve microbiological parameters, one can periodically chlorinate the water in the well or install UV lamps immediately before water intake in a given room (e.g. in the kitchen under the sink). The cost of the investment ranges from 2,000 to 3,000 EUR depending on the devices used. However, if it is not possible to use municipal water supplied by a water company that meets all the criteria contained in the Regulation of the Minister of Health on the quality of water intended for human consumption, such an investment is profitable and gives us a guarantee that we will have a home drinking water.

The periodic water quality control should be very important information for the users of the wells, both in terms of physicochemical and microbiological parameters. In addition, sanitary regulations should be taken into account during the construction of the well, which indicates the location of the wells at appropriate distances from potential sources of contamination (septic tanks, absorbent pits, manure landfills, etc.). Unfortunately, many people who use well water on a daily basis have never commissioned a water test to assess its suitability for consumption. On the other hand, people who use water from the well only for watering the garden most often believe that such a test is unnecessary, which is a misconception, since watering plants with contaminated water, especially in microbiological terms, may result in the transmission of pathogenic microorganisms to the human body.

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The contribution of the authors

Conceptualization, M.M., I.K. and D.G.K.; literature review, M.Ć, P.M. and W.G.; methodology, M.M.; formal analysis, M.M., I.K., D.G.K. and W.G; writing, M.M., P.M., W.G. and I.K.; conclusions and discussion, M.M., I.K., D.G.K. and M.Ć. Authors have read and agreed to the published version of the manuscript.

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PERCEPTION OF ECOSYSTEM SERVICES PROVIDED BY CARP PONDS IN PASŁĘK, POLAND

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ABSTRACT: An assessment of perceptions of fishpond ecosystem services was conducted in Pasłek, a town located in northeastern Poland. Ninety-four expert interviews were conducted with non-fishermen. The survey included a list of 28 possible ecosystem services provided by fishponds. Environmental benefits were considered the most important, followed by social and productive services. Respondents rated the ponds' function as a place for fish spawning and reproduction highest, followed by their role as fire reservoirs and as a place for recreation and leisure. A comparison with other surveys showed that perceptions of ecosystem services in local surveys could be influenced by a number of conditions, including, among others, the nature and location of fish ponds. The survey showed that people not involved in fisheries and fish farming are aware of the wide range of ecosystem services fishponds provide. This is a positive social recommendation for European fisheries policy, which aims to develop aquaculture without deteriorating the environment, creating a balanced relationship between producers and consumers of production and non-production aquaculture products.

KEYWORDS: ecosystem services, multifunctionality, fishponds

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Introduction

Poland has the largest area of carp ponds in the European Union countries; estimated at about 87,000 hectares (GUS, 2021). Annual domestic carp production varies between 16,000 and 20,000 tons (Eurostat, 2022). Poland is the leading European market for fresh carp, with stable consumption exceeding 21,000 mt (Lasner et al., 2020). Carp farming retains its traditional character, with the low intensification of production (up to 1,500 kg/ha) and a high share of natural food from the pond in the fish's diet (Raftowicz & Le Gallic, 2020). In carp farming, multi-species stocks (polycultures) are usually used. The share of other fish species, mainly amur, silverfish, carp, tench, pikeperch, sturgeon, pike and trout, is about 13% (Lirski et al., 2022).

Pond carp farming is part of aquaculture, generally understood as the rearing, breeding and cultivation of aquatic organisms (FAO, 2022). It represents the world's fastest-growing food production sector (FAO, 2021). There are two main divisions of aquaculture in Poland: traditional, semi-intensive carp farming in earthen ponds and intensive trout farming in various production facilities, including concrete ponds and plastic tanks (Turkowski, 2018). In the case of intensive trout farming, as in most intensive forms of aquaculture worldwide, the ecosystem approach is primarily to minimise their negative environmental impacts. This impact is different in the case of traditional pond carp farming, which has been developing for centuries in Poland and other European countries (Adámek et al., 2012; Mathé & Rey-Valette, 2015).

The EU's Blue economy strategy identifies aquaculture as a high-potential sector that can boost economic growth and bring social benefits through new jobs (European Commission, 2022). Non-productive aspects of aquaculture are also important, especially in an ecosystem approach for aquaculture, which is defined as a strategy for integrating the activity into the broader ecosystem (Soto et al., 2008). The European Maritime and Fisheries Fund includes financial support to accelerate aquaculture development, thus providing ecosystem services (Regulation, 2014). The problem is that there is still little knowledge of fishpond ecosystem services, especially among people not professionally involved in fisheries.

Ecosystem services

The concept of ecosystem services emerged as early as 1981 as a joint initiative of economists and environmentalists. They stressed that valuing nature's services in economic decisions could correct the misjudgment of the relationship between humans and nature. The universal definition of ecosystem services was proposed by Costanza et al. (1997): "the benefits humanity

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derives directly or indirectly from ecosystem services." In Poland, research on mapping and assessing ecosystems and their services was also undertaken relatively quickly. Following Lupa and Stępniewska (2019), it is worth mentioning here the early studies by Ryszkowski (Bunce et al., 1993), and Żylicz (2000).

Initially, ecosystem services were attributed only to natural ecosystems. However, it was recognised fairly quickly that, in addition to producing food, feed and raw materials, agriculture could also provide ecosystem services just like natural ecosystems.

As defined by the Ramsar Convention (1971), earthen fish ponds are classified as wetlands and provide ecosystem services similar to those generated by natural wetlands and shallow lakes (Dobrowolski, 1995; Cižkova et al., 2013; Nyman, 2011). However, unlike natural water bodies, water and trophic conditions in ponds are controlled and modified by fish farmers. Therefore, the services mentioned above correspond more closely to the concept of non-productive values in multifunctional aquaculture (Békefi & Váradi, 2007; Popp et al., 2018). Given the widespread use of the term "ecosystem services" in the aquaculture literature (Mathé & Rey-Valette, 2015; Wietzman, 2019; Willot et al., 2019), as well as in Regulation (2014), this article also uses the term "ecosystem services".

The article aims to identify and assess perceptions of ecosystem services provided by fishponds located on the outskirts of the city of Pasłęk in the Warmian-Masurian Province. The data used in the study came from surveys conducted with people who are not fish farmers, but owners and residents of properties near the ponds.

Material and methods

Study area

The survey was conducted among residents of Pasłęk, a small town (about 12,000 residents) in the Warmian-Masurian Voivodeship. The province is dominated by agricultural land (54%) and forests (32%). The Warmian-Masurian Voivodeship has the largest total area in the country of 115,361 hectares of inland waters (mainly lakes) and the lowest population density (59 people against the national average of 123 people per 1 km^2). In Warmia-Mazury, there are 16 zones under area protection (national parks, nature reserves) and 44 special zones belonging to the Natura 2000 network. Commercial breeding ponds in the province cover a relatively small area of a total of 1850 ha. An additional 1,000 hectares are estimated for the remaining small ponds and other small water reservoirs used on farms for amateur fish farming and breeding.

38 hectares of fish ponds are located in the northeastern part of the town (Figure 1). The ponds are used for an incomplete breeding cycle to raise stocking material, mainly carp fry. The ponds are irrigated from the Wąska River. Two similar 14 hectares of recreational ponds are located on the other side of the ecological park and are irrigated from the same river (Figure 1).

Data collection and analysis

The survey was conducted in July and August 2019 among 94 people (Table 1) living near the ponds located in Pasłęk (Figure 1). The structure of the random sample of respondents did not differ from that of the general population of the township, except for the much higher university education and the much lower primary education, which averaged 9.5% and 30%, respectively, for the whole town (Polska w liczbach, 2022).

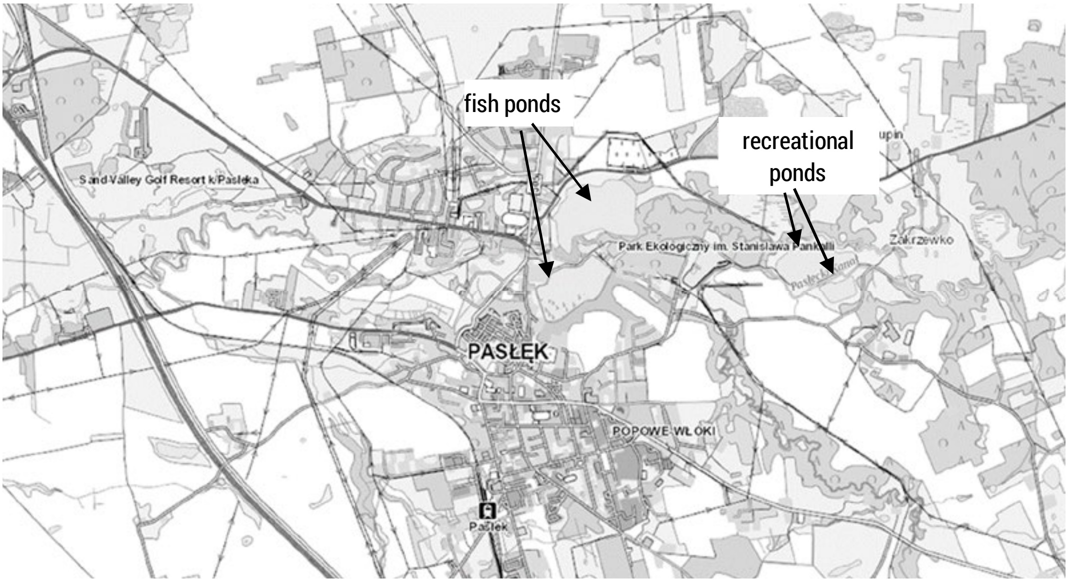

Figure 1. Location of earthen carp-type ponds in Pasłęk

Source: authors' work based on Geoportal (2022).

The interviews were conducted face-to-face. They began with a brief general description of the study and its objectives. On average, the interview lasted about 45 minutes and was based on closed-ended questions aimed at revealing preferences in ranking selected potential pond ecosystem services.

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Table 1. Characteristics of respondents

Specification	Number of people	%
Gender		
woman	40	43
man	54	57
Age		
18-30	6	7
31-40	18	19
41-50	21	22
51-60	20	21
61 and more	29	31
Education		
primary	3	3
basic vocational	23	25
secondary	36	38
higher	32	34

The study used a list of 28 possible ecosystem services presented alphabetically, including 6 productive services, 13 environmental services and 9 social services. They corresponded in principle to the classification of pond ecosystem services used by Mathé and Rey-Valette (2015). However, due to the fact that Pasłęk ponds are located practically in an urban area, the social functions were complemented by the function of the ponds as a fire reservoir and a source of spiritual inspiration.

Respondents rated the importance of each service, assigning points from 1 (not important) to 5 (very important). The results were presented in percentage terms.

Results

Ponds as places of fish spawning and reproduction were seen as the most important pond services (74%). Fewer indications, by two percentage points, were given for the function of the ponds as a fire reservoir (72%). Fish and other aquatic organism production services were ranked only sixth with a score of 56% (Figure 2).

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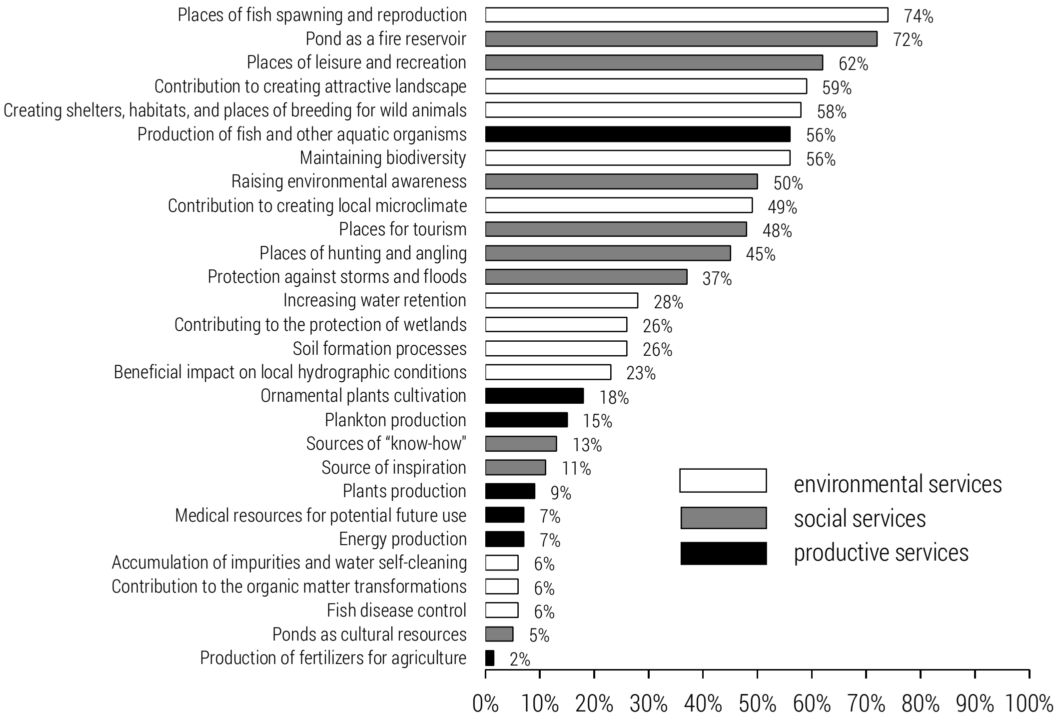

Figure 2. Preferences of ecosystem services of ponds in Pasłęk

In general, environmental services were indicated as the most important (48%), social services received slightly fewer indications (39%) and productive services were mentioned much less frequently (13%).

In addition to the dominant service of ponds as a place for fish spawning and breeding, among environmental services, the contribution of ponds to the creation of an attractive landscape (59%), shelter, residence and breeding sites for wildlife (58%), maintenance of biodiversity (56%) and creation of a local microclimate (49%) were considered important. The other environmental services: increasing water retention (28%), contribution to the protection of wetlands (26%), beneficial impact on local hydrographic conditions (23%) and soil formation processes (23%), were generally thought to be of little importance, whereas contribution to organic matter transformation, accumulation of impurities and water self-cleaning, as well as fish disease control (all 6% each) were considered less relevant (Figure 3).

Among social services (Figures 2 and 4), the pond's role as a fire reservoir got the highest rate of 72%. Other social services, such as ponds as a place of leisure and recreation (62%), source of raising environmental

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awareness (50%), and place for tourism (49%), as well as hunting and angling (48%), received slightly lower ratings, as did the role of ponds in protection against storms and floods, which was perceived as also somewhat important (32%). Ponds as a source of "know-how" (13%) and a source of inspiration (11%) were assessed significantly lower. The lack of historical devices was probably the main reason for the poor assessment of ponds as cultural resources (5%).

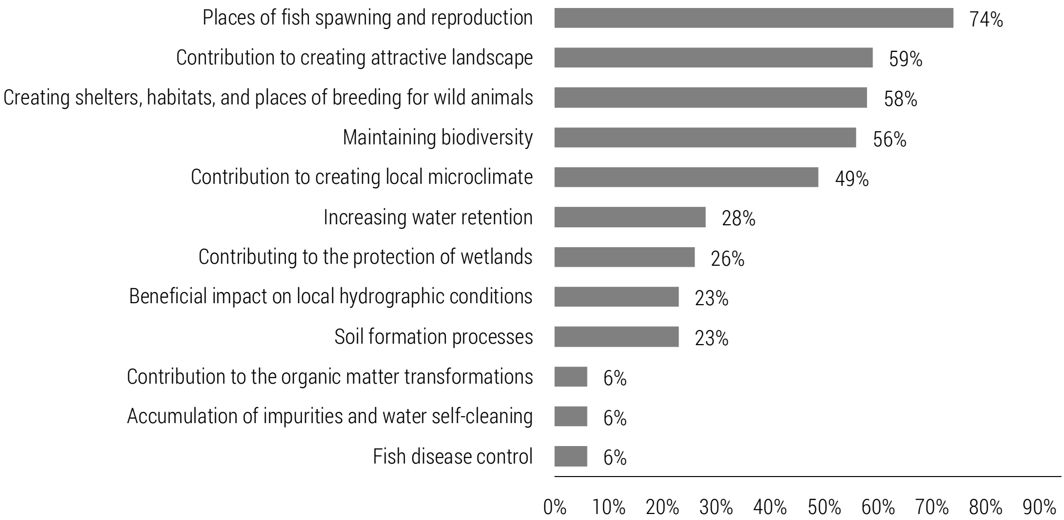

Figure 3. Preferences for environmental ecosystem services of ponds in Pasłęk

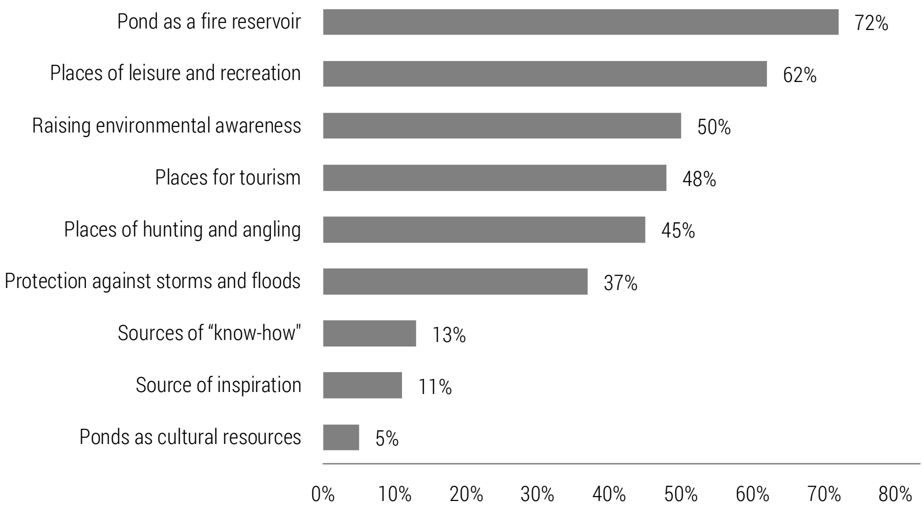

Figure 4. Preferences of social ecosystem services of ponds in Pasłęk

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As has already been mentioned, fish and other aquatic organism production were rated the highest (56%). Other productive services, including ornamental plants cultivation (18%) and plankton production (15%), were generally thought to be of little importance, whereas medical resources for potential future use (e.g., medicinal plants) (7%), production of energy (7%) and of fertilisers for agriculture (2%) were regarded as irrelevant (Figure 5).

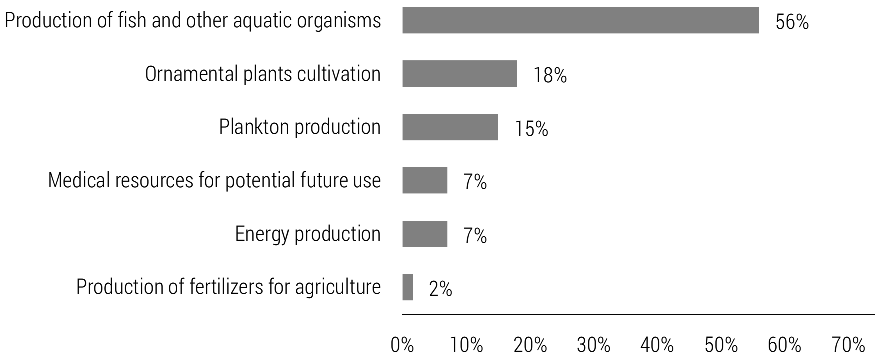

Figure 5. Preferences of productive ecosystem services of ponds in Pasłęk

Discussion

In the ichthyological literature, the non-productive benefits provided by fishery-used carp ponds received attention in Poland as early as the 1970s (Leopold, 1983). In this and later studies (Guziur, 2000; Guziur, 2018; Turkowski & Lirski, 2011), the issues are presented from the point of view of knowledge and experience of experts involved in fisheries as a scientific discipline. On the other hand, the first studies of the perception of ecosystem services by fish farmers themselves were conducted in 2019 (Turkowski, 2021a; Turkowski, 2021b). However, from the point of view of identifying and economically capturing ecosystem services, more important is their perception and evaluation by their beneficiaries, including owners of properties near ponds, tourists, nature lovers and others who are not fish farmers.

This article presents the results of a pilot study conducted for the first time in Poland among people not professionally involved in fisheries and fish farming. Previously, similar studies in Europe were conducted only in France. The study also aimed to address perceptions of ecosystem services of carp-type ponds by people outside fisheries. However, they focused on two large clusters of ponds of 7,000 hectares and 8,800 hectares each, located in undeveloped, ecologically valuable areas (Mathé & Rey-Valette, 2015). The size of

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the ponds and, above all, their location did not fail to influence the results. Nevertheless, it is worth comparing them with the results obtained in Pasłęk, taking into account the above differences.

In both surveys, the order in which the main types of ecosystem services were evaluated was the same. Environmental services were indicated as the most important, followed by social and productive services.

However, there were already significant differences within service groups. Among ecological functions, French respondents placed far greater importance on the contribution of ponds to sustaining biodiversity (90% of indications vs 56% in Pasłęk), creating shelter, habitat and breeding sites for wild animals (71% vs 58%), their role in shaping local water relations (58% vs 23%), and in the accumulation of pollutants and self-purification of water (47% vs 6%), as well as the contribution of ponds to wetland protection (58% vs 26%), soil-forming processes (31% vs 23%), and the transformation of organic matter (22% vs 6%). The French survey (Mathé & Rey-Valette, 2015) also highlighted the positive impact of the presence of ponds on the control of fish diseases (39% vs 6%). In contrast, respondents from Pasłęk gave more importance to the role of ponds in creating spawning sites and fish reproduction (71% vs 46%), creation of attractive landscapes (59% vs 36%), and local microclimate (49% vs 32%). The retention functions of the ponds were rated at the same level of 23% in both studies.

In the French study, two social services of ponds were by far the most dominant: cultural, related to tradition, and the recognition of ponds as national heritage (59%), and the role of ponds as a source of specific traditional knowledge (know-how) (37%) (Mathé & Rey-Valette, 2015). Respondents in Pasłęk did not place much importance on these functions, rating them at 5% and 13%, respectively. In this case, the difference seems obvious. In France, fishponds were built next to monasteries as early as the Middle Ages. This was associated with the religious custom of eating fish on Good Friday. Until the French Revolution, the aristocracy and clergy owned 90% of the country's ponds (Mathé & Rey-Valette, 2015). The ponds in Pasłęk, which were put into operation in 1985, do not have such a long history. Their location near the Pasłęk castle was not a significantly contributing factor. On the other hand, their function as fire reservoirs was highly rated (72%). In the case of French ponds, located in extensive wetlands, the question of the possibility of the above role was completely unfounded and was not even asked.

In both studies, similar indications were given for services related to the implementation of hunting and fishing in ponds, as well as the contribution of ponds to stormwater and flood protection. In contrast, the possibility of leisure and recreation based on ponds was rated significantly higher in Pasłęk (62% vs 31% in the French study).

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Significant differences emerged when assessing ponds as a place for the production of fish and other organisms, which was rated at a very high level of 90% in the French study. Only the contribution of ponds to maintaining biodiversity was rated as high (Mathé & Rey-Valette, 2015). In Pasłęk, this function was rated relatively lower, at 56%. Such a result may have been due to the fact that during the study period, the Pasłęk ponds, unlike the French ponds, mainly grew stocking material, and the fish farm did not operate a fish store or fish bar.

It is worth noting that in both countries, carp is subject to political odium. Carp in France was identified with the aristocracy and the clergy, and after the French Revolution, the tradition of eating this fish at Christmas disappeared. In Poland, on the other hand, where the tradition is still strong, the Christmas consumption of carp is often attributed to the communist time (Kowalski, 2022), forgetting the centuries-old tradition.

Conclusions

The non-productive values of carp fish ponds have already been recognised by ecologists (Dobrowolski, 1995), fisheries experts (Leopold, 1983) and fishermen (Turkowski, 2021a). The presented pilot research suggests that people not involved in fish farming are also fully aware of the importance of the ecosystem services of the ponds.

Environmental services were identified as the most important, followed by social services and productive services. The most important environmental services of fishponds were considered to be the function of ponds as a spawning and breeding ground for fish, their contribution to the creation of an attractive landscape, but also their function as a place of shelter, residence and reproduction of wild animals, and their contribution to the maintenance of biodiversity. Among the most important social services of fishponds were their function as fire reservoirs, a place for rest and recreation, and their role in raising environmental awareness. The production of fish and other aquatic organisms has been identified as the most important productive service of fishponds.

A number of conditions can cause differences in the perception of ecosystem services in local studies. Their evaluation depends on the knowledge and needs of the various stakeholders, the mutual and dynamic relationship between them and the services, but also on the nature and location of the fishponds. The reasons for differences in the perception of ecosystem services of Pasłek's and French fishponds should be sought in their different sizes and locations rather than in the attitudes and characteristics of the respondent groups surveyed.

The results, both presented and cited in the discussion, showed that non-fishermen are aware of the wide range of ecosystem services provided by fishponds. This can be taken as a positive social recommendation for a European fisheries policy that aims to develop aquaculture without deteriorating the environment, creating a sustainable relationship between producers and broader consumers of production and non-production aquaculture products. The research was a pilot study, and the broader application of the results requires further research. In practice, it may contribute to correcting the water-environmental compensation paid to fishpond users for ecosystem services, which is currently discretionary in nature and not supported by adequate research. Another aspect concerns water-environmental permits for fishponds. Permit decisions consider only the production aspects of the ponds, completely ignoring the ecosystem services they provide.

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The contribution of the authors

Konrad Turkowski – development of survey template, data analysis, literature review, preparation of article content – 50%.

Michał Dubrowski – development of survey template, data collection, data analysis, preparation of article content – 50%.

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SHARE OF MECHANICAL-BIOLOGICAL INSTALLATION OF WASTE PROCESSING (MBP) IN THE LEVEL OF RECYCLING AND PREPARATION FOR RE-USE OF PAPER, METALS, PLASTICS, AND GLASS ACHIEVED BY MUNICIPALITIES

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ABSTRACT: The article aims to determine the share of mechanical-biological installation of waste processing (MBP) in the levels of recycling and preparation for the reuse of paper, metals, plastics, and glass (PMPG) achieved by municipalities. Two MBP installations were taken for the analysis – with the highest and the lowest share of municipalities in the Podlaskie Voivodship (Poland), which reached the recycling level required in 2019. In order to determine the share of MBP installations in the level of recycling achieved by communes, the share of the mass of recycled PMPG waste segregated from mixed municipal waste was calculated: in the total mass of generated PMPG waste and in the total mass of recycled PMPG waste from the municipal waste stream. On the basis of the conducted analyses, it should be stated that the MBP installation may have an impact on the achievement by municipalities of the recycling level required by law.

KEYWORDS: recycling rate, waste, waste treatment facility

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Introduction

According to the Act of September 13, 1996, on maintaining cleanliness and order in municipalities, from 2012-2020, municipalities were obliged to achieve a level of recycling and prepare for the re-use of paper, metals, plastics, and glass (PMPG) (Act, 1996). The levels mentioned above for individual years were specified in the Regulation of the Minister of the Environment of December 14, 2016, on the levels of recycling, preparation for re-use, and recovery by other methods of specific fractions of municipal waste (Regulation, 2016). For failure to achieve the required level in a given year, the municipality was subject to a financial penalty calculated as the product of the unit rate of the fee for placing unsorted (mixed) municipal waste at the landfill, specified in the regulations issued under Art. 290 sec. 2 of the Act of April 27, 2001, Environmental Protection Law and the missing mass of municipal waste expressed in Mg, required to achieve an appropriate level of recycling and preparation for re-use of PMPG (Act, 1996).

When calculating the level of recycling and preparation for re-use of PMPG, municipalities considered the waste of four of the fractions mentioned above with specific codes following the regulation mentioned above (Regulation, 2016), both from the selective collection of municipal waste collected from inhabited and uninhabited properties where municipal waste is generated, waste collected at municipal selective municipal waste collection points (PSZOK), but also waste sorted from unsorted (mixed) municipal waste in a mechanical-biological installation municipal waste processing (MBP installations). Thus, the level of recycling and preparation for re-use of PMPG achieved by municipalities was influenced not only by the amount of waste collected and collected as sorted but also by the amount of waste of the four fractions mentioned above sorted from mixed municipal waste (in MBP installations).

The available scientific studies do not provide information on the impact of MBP installations on the level of recycling and preparation for re-use achieved by municipalities. There is a lack of analysis on how secondary raw materials segregated from mixed municipal waste in MBP installations affect the level of recycling and preparation for reuse achieved by municipalities. Currently, the impact of MBP installations on the achieved level of recycling is not monitored in any way. On the other hand, the share of secondary raw materials separated from mixed municipal waste added when calculating the recycling rate may determine the achievement of the level required by law. Pursuant to the provisions of the Act (1996), the levels of preparation for the reuse and recycling of municipal waste increase annually, reaching the level of 65% in 2035. Therefore, it can be expected that municipalities will have

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more and more problems with achieving the required levels of recycling, which will entail financial penalties. Directing mixed municipal waste to MBP installations, which have the highest share of recycled secondary raw materials segregated from mixed municipal waste, may increase the chances of the municipality achieving the level of recycling and preparation for re-use.

According to the best knowledge of the authors, current information on the impact of segregated secondary raw materials from mixed municipal waste on the recycling levels achieved by municipalities is not analysed and made public. Monitoring and spread of knowledge in this area could contribute to the fact that entities managing MBP installations would focus more on activities resulting in increasing the number of recycled materials separated from mixed municipal waste.

A novelty of this work is the assessment of the impact of MBP installations on the level of recycling achieved by municipalities. The aim of the article is to determine the share of MBP installations in the levels of recycling and preparation for the reuse of PMPG achieved by municipalities. The article determines the impact of the amount of PMPG recycled raw materials separated from mixed municipal waste in the MBP installation on the PMPG recycling rate obtained by municipalities. The above studies may also be an introduction to broader analyses concerning assessing the efficiency of MBP installations.

An overview of the literature

Performing a literature review, we find a number of articles on issues involving recycling rates for specific types of municipal waste. These include studies on the recycling of plastic waste (Antonopoulos et al., 2021; Thoden van Velzen et al., 2017; Huysman et al., 2015), metals (Fizaine, 2020; Das et al., 2006), or paper (Tatoutchoup, 2016; Schenk et al., 2008), among others.

The existing literature also includes analyses of the dependence of achieved waste recycling rates on various factors (Abbot et al., 2011; Cerqueira et al., 2022; Dijkgraaf et al., 2017; Zhang et al., 2021; Muñoz et al., 2004).

The quality of waste recycling is influenced by the existing collection system and product design (Eriksen et al., 2019) but also by the design and operation of materials recovery facilities (MRFs) (WRAP, 2014). Despite this, there are few studies in the available literature with primary data on the recovery and cleanliness rates of MRFs and recycling plants in the EU (Antonopoulos et al., 2021). Available studies on recovery rates at materials recovery facilities refer to mixed packaging waste and the post-consumer plastic waste being processed (Mastellone et al., 2017; Brouwer et al., 2018; Antonopoulos et al., 2021), as well as mixed municipal waste (Cimpan et al., 2015). However, they do not show the contribution to municipalities' recycling rates

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of recyclables separated from mixed municipal waste at an MBP facility. Hence, the purpose of the article is to fill the research gap that exists in this area.

Research methods

The analysis covers the level of recycling and preparation for re-use of PMPG (hereinafter referred to as the recycling level) achieved by municipalities from the Podlaskie Voivodeship (Poland) in 2019. The municipalities and the recycling levels they achieved were grouped according to MBP installations, to which unsorted (mixed) municipal waste collected from the municipal area was directed.

Two MBP installations were adopted for the analysis – with the highest (Installation A) and the lowest (Installation B) share of municipalities in Podlaskie Voivodeship, which achieved the recycling level of 40% required in 2019.

In 2019, both MBP installations processed a comparable amount of unsorted (mixed) municipal waste (25.93 thousand Mg and 25.98 thousand Mg, respectively), with Installation A servicing 19 municipalities and Installation B serving 26 municipalities. For the performed calculations, the data contained in the annual reports on the implementation of tasks in the field of municipal waste management, prepared by the municipality head, mayor, or president, submitted via the Database on products and packaging and waste management were used (Act, 1996) and data obtained from the managers of Installation A and B. The recycling level obtained by individual municipalities in 2019 was calculated following the Regulation (2016), according to the formula:

$$\mathrm{Ppmts} = \frac{\mathrm{Mrpmts}}{\mathrm{Mwpmts}}, \tag{1}$$

where:

Ppmts – level of recycling and preparation for re-use of PMPG, expressed in %,

Mrpmts – total weight of recycled and prepared for re-use PMPG waste from the municipal waste stream from households and other municipal waste producers, expressed in Mg. These are recycled and prepared for re-use waste coming from both selective collection of municipal waste collected from residential and uninhabited properties where municipal waste is generated, waste collected at separate municipal waste collection points (PSZOK), as well as waste sorted from unsorted (mixed) municipal waste in the MBP installation,

Mwpmts – total mass of PMPG waste generated from the municipal waste stream from households and other municipal waste producers, expressed in Mg.

To determine the share of MBP installations in the level of recycling achieved by municipalities, the following were calculated:

- U1MBP – share of recycled and prepared for re-use PMPG waste sorted from unsorted (mixed) municipal waste in the total weight of PMPG waste generated from the municipal waste stream from households and other municipal waste producers and
- U2MBP – share by weight of recycled and prepared for re-use PMPG waste sorted from unsorted (mixed) municipal waste in the total amount of recycled and prepared for re-use PMPG waste from the municipal waste stream from households and other municipal waste producers.

The U1MBP value was calculated according to the formula:

$$\text{U1MBP} = \frac{\text{Mw200301}}{\text{Mwpmts}}, \tag{2}$$

where:

Mw200301 – the total weight of recycled PMPG waste prepared for re-use sorted in the MBP installation from unsorted (mixed) municipal waste, calculated for individual municipalities from Installation A according to the formula:

$$\text{Mw200301} = \text{Mp200301 x } \frac{\text{Mw200301 MBP}}{\text{Mp200301 MBP}}, \tag{3}$$

where:

Mp200301 – a mass of unsorted (mixed) municipal waste from a given municipality, processed in Installation A,

Mw200301 MBP – the total mass of PMPG waste, recycled and prepared for re-use, sorted in the MBP installation from the total mass of unsorted (mixed) municipal waste processed in Installation A, calculated as the sum of the masses of individual waste codes included in the level of recycling and preparation for re-use following the Regulation (2016) sorted from mixed (unsorted) municipal waste separately for the first and second half of the year,

Mp200301 MBP – total mass of unsorted (mixed) municipal waste processed in Installation A.

In the case of Installation B, the Mw200301 value was determined individually for each of the municipalities, while information about its amount was obtained from the Installation manager.

The size of U2MBP was calculated for individual municipalities from Installations A and B according to the formula:

$$\text{U2MBP} = \frac{\text{Mw200301}}{\text{Mrpmts}}. \tag{4}$$

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The obtained results were subjected to fundamental statistical analysis and presented in a tabular and graphical manner using an Excel spreadsheet.

Results of research

Table 1 summarises the essential statistical data on the weight of waste and the level of recycling in municipalities directing unsorted municipal waste to Installation A.

Table 1. Primary data on waste masses and the level of recycling achieved in municipalities sending unsorted (mixed) municipal waste to Installation A in 2019

Parameter	Mwpmts [Mg]	Mrpmts [Mg]	Ppmts [%]	Mw200301 [Mg]	U1MBP [%]	U2MBP [%]
Minimum	154	48	31	12	6	13
Maximum	2 946	1 319	61	443	28	50
Average	637	295	48	82	12	25
Standard dev.	638	280	7	108	5	10

Source: author's work based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation A.

The value of the total mass of PMPG waste generated from the municipal waste stream from households and other municipal waste producers (Mwpmts) ranges from 154 Mg to 2,946 Mg, with an average of 637 Mg. The recycling level in the analysed 19 municipalities ranges from 31% to 61% (48% on average).

The share of the weight of recycled waste, sorted from municipal waste in the total weight of the waste mentioned above (U1MBP) ranges from 6% to 28%, with an average value of 12%. The share of recycled waste sorted from municipal waste in the total weight of the waste mentioned above (U2MBP) ranges from 13% to 50%, which gives an average of 25%.

The high value of the standard deviation of the Mwpmts, Mrpmts, and Mw200301 masses indicates a large dispersion of the results in individual municipalities.

Figure 1 shows the achieved recycling levels in municipalities sending mixed municipal waste to Installation A and the share of sorted waste in the MBP installation in 2019.

The achieved recycling levels ranged from 31% in the A19 municipality to 61% in the A1 municipality. In both of the above municipalities, the share of MBP in the obtained recycling level was comparable and amounted to 8%

and 9%, respectively. Two of the 19 municipalities failed to achieve the required 40% recycling rate.

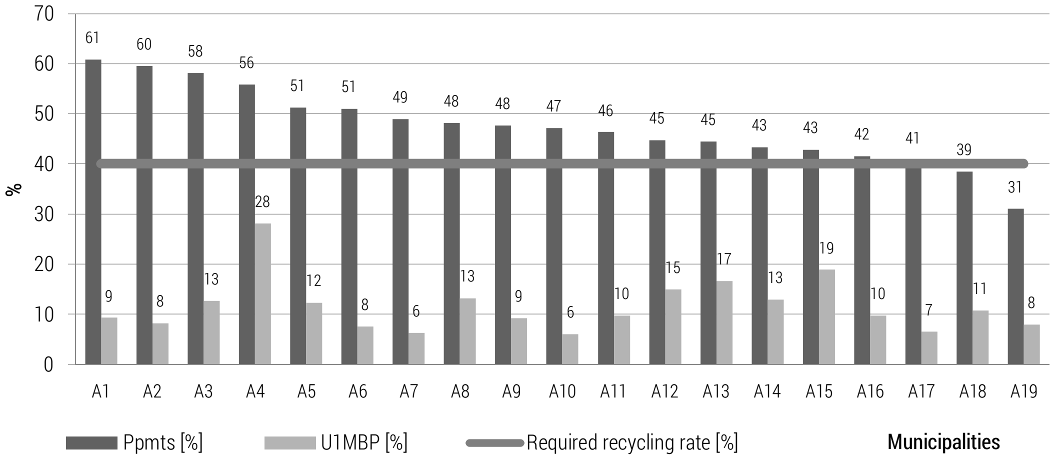

Figure 1. The level of recycling (Ppmts) and the share of MBP installations (U1MBP) in it achieved in individual municipalities, directing unsorted (mixed) municipal waste to Installation A

Source: author's work is based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation A.

The share of MBP installations in the achieved recycling level ranged from 6% in the A7 and A10 municipalities to 28% in the A4 municipalities. There was no clear relationship between the recycling level achieved by individual municipalities and the share of MBP installations in it. The required level of recycling was achieved by the A4 municipality, where the highest MBP share was recorded, amounting to 28%, and the A7 and A10 municipalities, with the lowest MBP share of 6%.

Figure 2 shows the level of recycling in individual municipalities directing unsorted (mixed) municipal waste to Installation A, calculated without considering the weight of waste sorted from mixed municipal waste in the MBP installation.

The presented data show that without the participation of MBP installations, the levels of recycling in municipalities would range from 23% in the A19 municipality to 52% in the A1 municipality. The number of municipalities with a 40% level of recycling achieved without the share of MBP, compared to the level with the share of MBP, decreased from 17 (89.5% of municipalities) to 6 (31.6% of municipalities). The analyses show that even a small share (less than 10%) of MBP installations at the recycling level may affect municipalities' achievement of the required 40% recycling rate. It is espe-

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cially true in the case of municipalities where the achieved recycling rate is just above 40%. The share of the fractions of PMPG sorted in Installation A ensured that 11 out of 19 municipalities (57.9% of municipalities) achieved the level of recycling that would not be achieved without the waste sorted in the plant.

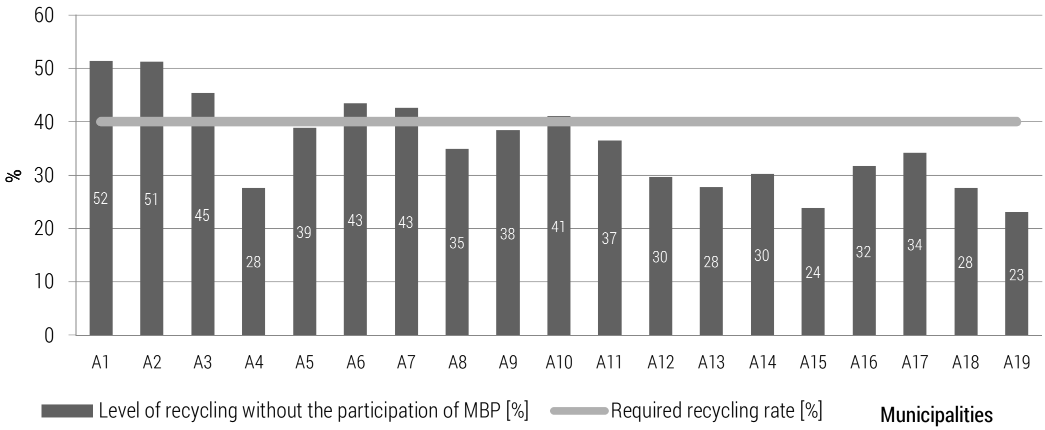

Figure 2. The level of recycling in individual municipalities directing unsorted (mixed) municipal waste to Installation A, without the participation of MBP installations in it

Source: author's work is based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation A.

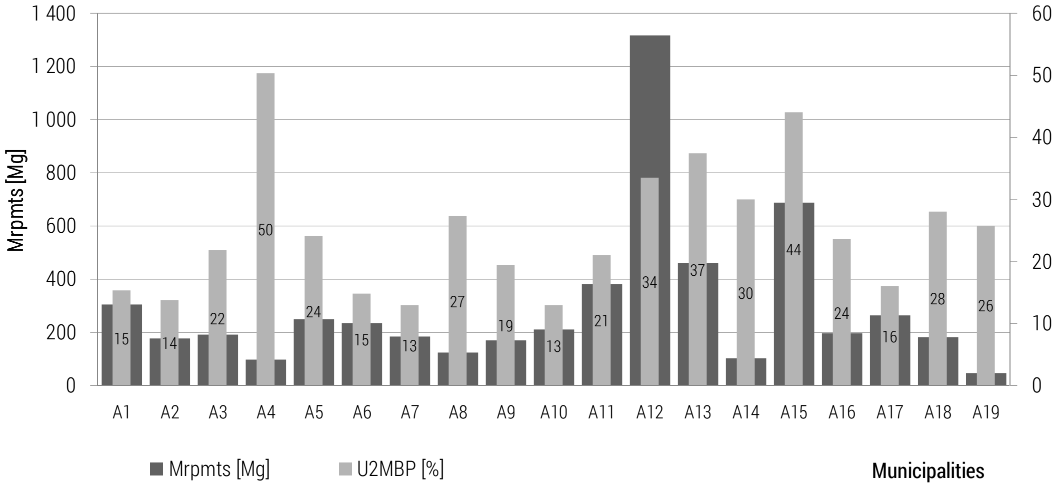

Figure 3. The total weight of recycled waste and the share of recycled waste sorted in the MBP installation in municipalities directing unsorted (mixed) municipal waste to Installation A

Source: author's work is based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation A.

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Figure 3 shows the weight of recycled and prepared for re-use waste PMPG (Mrpmts) and the share of the waste mentioned above. Waste is sorted in the MBP (U2MBP) for individual municipalities, directing mixed waste to Installation A.

The total weight of recycled waste in individual municipalities ranges from 48 Mg in the A19 municipality (with an MBP share of 26%) to 1,319 Mg in the A12 municipality (with an MBP share of 34%). The share of the weight of sorted waste in the MBP installation ranged from 13% in the municipalities of A7 and A10 (with the weight of recycled waste amounting to 185 and 212 Mg, respectively) to 50% in the A4 municipality (with the weight of recycled waste equal to 98 Mg).

The municipalities of A18 and A19, which did not achieve the required level of recycling in 2019, had a high (above the average of 25%) share of the weight of recycled waste sorted from mixed municipal waste in the total weight of recycled waste (equal to 28% and 26%, respectively). Therefore, the high share of MBP in the mass of recycled waste did not determine the required recycling level by all municipalities. Its achievement depended on the total weight of recycled waste sorted from mixed municipal waste in the MBP installation and the weight of recycled waste from selective "at source" collection and collected in PSZOK.

The municipalities with the highest and the lowest mass of recycled waste achieved a similar index of MBP share, equal to 34% and 26%, respectively.

Table 2 presents the minimum and maximum values, the average and the standard deviation calculated for the values of individual waste masses, the level of recycling, and the share of U1MBP and U2MBP achieved by individual municipalities directing mixed municipal waste to Installation B.

Table 2. Primary data on waste masses and the level of recycling achieved in municipalities sending unsorted (mixed) municipal waste to Installation B in 2019

Parameter	Mwpmts [Mg]	Mrpmts [Mg]	Ppmts [%]	Mw_{200301} [Mg]	U1MBP [%]	U2MBP [Mg]
Minimum	144	58	26.3	0	0.2	0.4
Maximum	2 191	2 229	101.7	72	24.3	70.6
Average	486	239	40.6	21	6.1	17.1
Standard dev.	445	415	13.4	25	8.2	23.1

Source: author's work based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation B.

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The total mass of PMPG waste generated for the 26 analysed municipalities ranges from 144 to 2,191 Mg, with an average of 486 Mg. The recycling rate ranges from 26.3% to 101.7%, with an average of 40.6%.

The share of recycled waste sorted from municipal waste in the total weight of the above-mentioned generated waste (U1MBP) ranges from 0.2% to 24.3%, with an average of 6.1% and a standard deviation of 8.2%. The share of recycled waste sorted from municipal waste in the total weight of the waste mentioned above (U2MBP) ranges from 0.4% to 70.6%, on average, 17.1%.

The high value of the standard deviation of the Mwpmts, Mrpmts, and Mw200301 masses, the level of recycling, and the share of U1MBP and U2MBP indicate a large variability of the results in individual municipalities.

Figure 4 shows the recycling levels achieved by individual municipalities directing mixed municipal waste to Installation B and the share of sorted waste in the MBP installation in 2019.

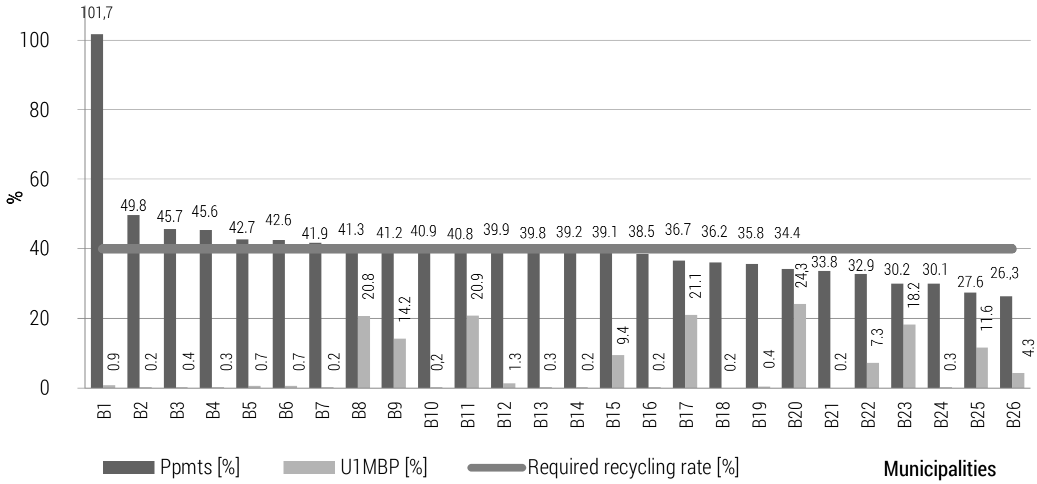

Figure 4. The level of recycling (Ppmts) and the share of MBP installations (U1MBP) in it achieved in individual municipalities directing unsorted (mixed) municipal waste to Installation B

Source: author's work is based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation B.

The recycling rate achieved by individual municipalities ranged from 26.3% (with a share of MBP amounting to 4.3%) in municipality B26 to 101.7% (with a share of MBP 0.9%) in municipality B1. The required 40% recycling rate was achieved by 11 out of 26 municipalities.

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The value of the share in the level of recycling of MBP installations ranged from 0.2% in the municipalities B2, B7, B10, B14, B16, B18, and B21 (with the recycling level from 33.8% to 49.8%) to 24.3% in the municipality B20 (at a recycling rate of 34.4%). There was no correlation between the level of recycling achieved by individual municipalities and the share of MBP installations. Some municipalities achieved the required 40% level of recycling with the lowest MBP share of 0.2%, as well as municipalities with one of the highest MBP shares, over 20% (B8 and B11 municipalities). The share of MBP in the level of recycling of municipalities that did not achieve the required level reaches both the minimum (0.2%) and maximum (24.3%) values recorded for this indicator.

In 15 out of 26 municipalities, the share of MBP installations in the achieved recycling level is less than 1%, while in 4 municipalities, it is higher than 20%. The lower the share of PMPG waste sorted from mixed municipal waste in the MBP installation at the recycling level, the higher the share of those mentioned above. Waste from other sources, i.e., waste collection from real estate in the municipality and waste collected in PSZOK. In most municipalities sending mixed municipal waste to Installation B, the share of sorted waste in the MBP installation was negligible. The achieved recycling level was achieved thanks to waste from the collection of selectively collected waste “at source” and collected at the PSZOK.

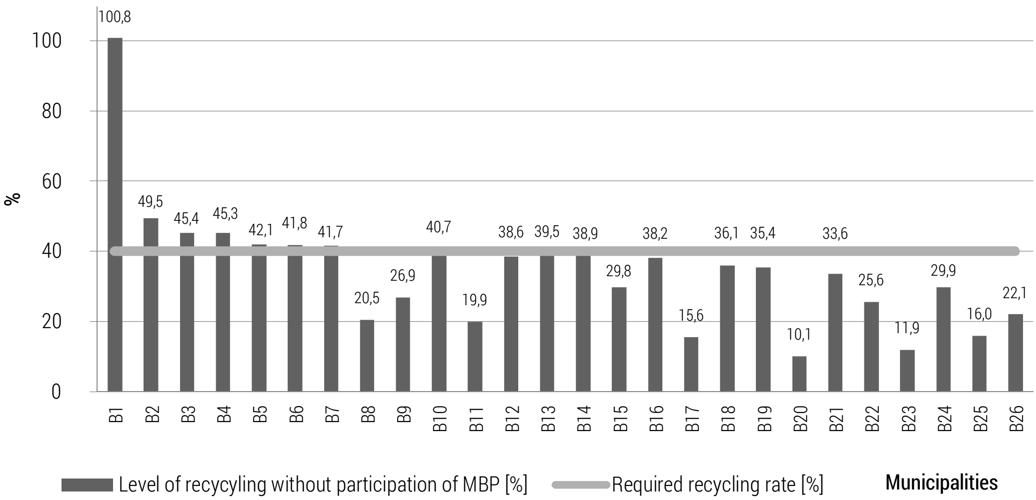

Figure 5. The level of recycling in individual municipalities directing unsorted (mixed) municipal waste to Installation B, without the participation of MBP installations in it

Source: author’s work is based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation B.

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Figure 5 shows the level of recycling in individual municipalities directing unsorted (mixed) municipal waste to Installation B, calculated without considering the weight of PMPG waste sorted from mixed municipal waste in the MBP installation.

The recycling level achieved without considering the weight of sorted waste from mixed municipal waste in Installation B ranges from 10.1% (municipality B20) to 100.8% (municipality B1). The number of municipalities with the legally required level of recycling without the share of MBP, compared to the level including the share of MBP, decreased from 11 (42.3% of municipalities) to 8 (30.8% of municipalities).

The share of PMPG waste sorted from mixed municipal waste in Installation B ensured that 3 out of 26 municipalities (11.5% of municipalities) achieved the level of recycling that would not be achieved without waste sorted in the installation. In these municipalities (B8, B9, and B11), the share of MBP ranged from 14.2% to 20.9%. In the case of 8 municipalities that would obtain the required level of recycling without considering the mass of waste sorted in the MBP installation, its share was so low (from 0.2% to 0.9%) that it did not significantly affect the achieved result.

Figure 6 shows the weight of recycled and waste PMPG prepared for re-use (Mrpmts) and the share of those mentioned above. Waste is sorted in municipalities' MBP (U2MBP), directing unsorted municipal waste to Installation B.

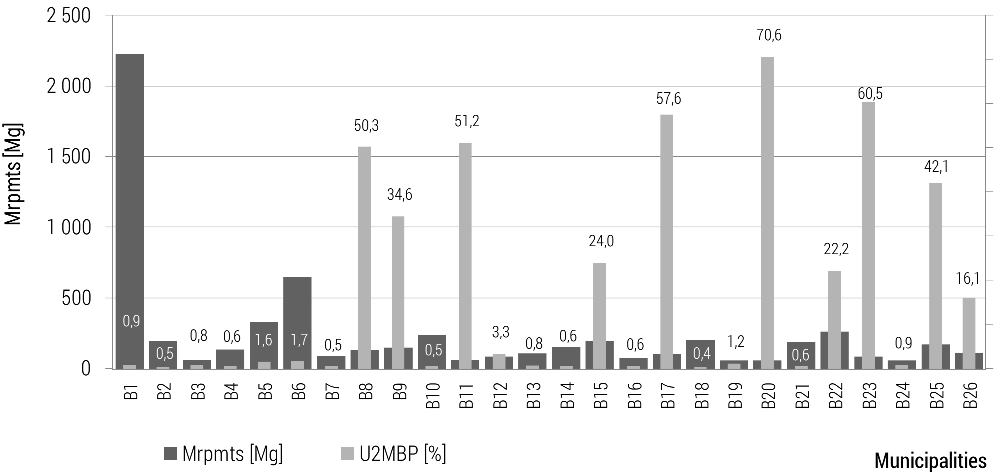

Figure 6. The total weight of recycled waste and the share of recycled waste sorted in the MBP installation in municipalities directing unsorted (mixed) municipal waste to Installation B

Source: author's work is based on data from annual reports on the implementation of tasks in the field of municipal waste management for 2019 and data from the manager of Installation B.

The total mass of PMPG waste recycled and prepared for re-use in individual municipalities ranges from 58 Mg (B19 and B24 municipalities) with an MBP share of 1.2% and 0.9%, respectively, to 2,229 Mg (municipality B1) with the MBP share value of 0.9%. The share of MBP in the total weight of recycled waste ranges from 0.4% (municipality B18) with a mass of recycled waste of 205 Mg to 70.6% (municipality B20) with 60 Mg. In 12 municipalities, the share of sorted waste from mixed municipal waste in the MBP installation in the total weight of recycled waste is less than 1%. In comparison, in 5 municipalities, it is higher than 50%.

In municipalities that did not achieve the required recycling level (from B12 to B26), the share of the weight of sorted waste from mixed municipal waste in Installation B in the weight of those mentioned above of total recycled waste reached the lowest values and the highest recorded for the ratio (from 0.4% to 70.6%). However, in the municipality with the highest recycling level (B1), it was 0.9%. It was observed that the low share of recycled waste sorted in the MBP installation does not mean that the municipality will not achieve the recycling level, and a high percentage does not guarantee its achievement. Obtaining the level of recycling required by law depends on the total weight of recycled waste sorted from mixed municipal waste in the MBP installation and the weight of recycled waste from the selective waste collection "at source," and the weight of waste collected in PSZOK.

Limitations and future research

During the review of the literature, no research on the share of MBP installations in the level of PMPG recycling achieved by municipalities was found. In the present study, in accordance with formulas (2 and 4), the share of the MBP installation in the recycling level achieved by municipalities was calculated as the share of the mass of PMPG recycled and prepared for reuse, separated from mixed municipal waste in the MBP installation, respectively in relation to the total mass of generated waste PMPG (U1MBP) and in the total weight of PMPG waste (U2MBP), recycled and prepared for reuse, coming from the municipal waste stream from households and from other municipal waste producers. To the best of the authors' knowledge, there are no data from similar studies in the available literature.

As pointed out by Cimpan et al. (2015), there is also a lack of detailed data on the efficiency of processes in MBT plants in terms of, e.g. sorting efficiency. Available information concerns the recovery efficiency of Mechanical-Biological Treatment (MBT) installations (defined as the weight percentage of waste in a wet state to the weight of recovered input) in relation to individual waste fractions (i.e. paper and cardboard, metals, glass, plastic films), PET,

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HDPE, beverage cartons, mixed plastics (PVC, PP, PS)) and total recovery as a per cent of total residual MSW input. For example, for the MBT Ecoparc 4 plant in Barcelona, the above-mentioned value of total recovery was set at 10.5% (Navarotto et al., 2012), while for the 8 MBT plants in Castilla y León (Spain) – an average of 7% (from 2.5% to 13%) (Montejo et al., 2013). In addition, for some MBT and MRF plants, the total input waste recovered as output products were determined; for example, for secondary raw materials at the MBT plant in Larnaca (Cyprus) was 20% (Wellacher, 2011) and at the MRF plant in California (USA) – 22% (SWANA, 2013). However, according to the results presented by Wiśniewska et al. (2018), the amount of secondary raw materials segregated from mixed municipal waste at the MBP plant in Poświętne (Poland) was less than 4%. Nevertheless, the authors of the above-mentioned works did not specify what share in the achievement of the recycling level by the communes had the recycled waste, which was segregated in the above-mentioned installations.

There are also few studies that have compared the quality of recyclable materials recovered through separate collection with the quality of materials separated by central sorting of mixed municipal waste (Cimpan et al., 2015). This topic was dealt with by Schmalbein et al. (2011), Wellacher (2011), and Van Velzen et al. (2013).

According to Cimpan et al. (2015), the main role of sorting mixed municipal waste is to supplement the systems of „at source" segregation and selective collection in areas where its efficiency is lower (e.g. in urban areas). The above statement is in line with the assumptions of the municipal waste management system regulated by law in Poland. The Act (1996) requires both selective collection of waste as well as directing mixed municipal waste to MBP installations. The legal provision constructed in this way is aimed at maximising the amount of secondary raw materials that will be sent for recycling, with the priority action being a selective collection of waste (both „at source" and in PSZOK). On the other hand, waste constituting secondary raw materials, which as a result of incorrectly conducted selective waste collection, will end up in mixed municipal waste, should be recovered by sorting it in the MBP installation.

Cimpan (2015) points to the particularly important role of central sorting of residual waste where source segregation is difficult (i.e. cities), concluding that the recovery of secondary raw materials for recycling from waste mixed in installations can be a supplement to segregation „at source" or a separate substitute collection of certain wastes, e.g. plastics and metals. He also maintains that in the context of the recycling levels that the EU Member States are obliged to achieve, the expansion of the MBT installation with the additional recovery of secondary raw materials may contribute to achieving the above-mentioned targets.

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The above conclusions are consistent with the obtained research results, which indicate the significant role of MBP installations in achieving the level of recycling required by the law by municipalities. According to the calculations obtained in the MBP installation with the highest share of municipalities that achieved the required recycling level, equal to 89.5% (Installation A), PMPG waste segregated from mixed municipal waste ensured that as many as 57.9% of municipalities achieved the level required by law. At the same time, the high share of the mass of secondary raw materials separated from mixed municipal waste in the total weight of recycled waste did not determine the achievement of the required level of recycling by municipalities. The conducted research indicates that the achievement of the required level of recycling was determined by the total mass of PMPG waste recycled, both from the selective collection and segregated from mixed municipal waste in the MBP installation.

This research, apart from filling the existing research gap in this area, may have practical significance for municipal governments obliged to achieve the levels of recycling and preparation for re-use required by law. Although from 2021, there is no longer an obligation in Polish law to achieve the level of recycling and preparation for re-use of PMPG, municipalities face the challenge of achieving in individual years the level of preparation for re-use and recycling of municipal waste, calculated as the ratio of the mass of the total (including PMPG) municipal waste prepared for re-use and recycled to the mass of municipal waste generated, excluding other than hazardous construction and demolition waste constituting municipal waste (Act, 1996). The conducted research indicates that the MBP installation may have an impact on the achievement of the recycling level required by the regulations. According to the Act (1996), the levels of preparation for re-use and recycling of municipal waste that municipalities must achieve are increasing every year (reaching 55% in 2025, reaching up to 65% in 2035). Therefore, it is likely that municipalities will increasingly not achieve the required recycling levels and incur associated financial penalties. The dissemination of this information may show the role of MBP installations in achieving the levels needed by municipalities. This, in turn, on the one hand, may enable municipalities to take appropriate steps to direct mixed municipal waste to MBP installations achieving the largest amounts of waste (secondary raw materials) separated from mixed municipal waste (e.g. by defining appropriate requirements or criteria in tenders for the management of mixed municipal waste). On the other hand, it can motivate entities managing MBP installations to be more mobilised in order to segregate as many secondary raw materials as possible from mixed municipal waste, which will be directed for recycling, which will allow municipalities to achieve higher recycling rates.

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Of course, it should be borne in mind that the amount of secondary raw materials that can be segregated from mixed municipal waste in the MBP installation also depends on the devices the plant is equipped with and on the properties of the waste being treated (Wiśniewska et al., 2018), including its content in mixed municipal waste, and thus on the effectiveness of the municipal waste segregation carried out by property owners „at source". Thus, their amount may vary depending on the efficiency of the segregation, whereby, according to the observed patterns, a higher amount of raw materials can be expected in mixed municipal waste in urban agglomeration areas, where waste segregation „at source" is difficult (Cimpan et al., 2015). However, with regard to the quality of secondary raw materials contained in mixed municipal waste and the possibility of recycling it, it should be pointed out that, according to the available literature, the quality of potentially recyclable secondary raw materials separated from mixed municipal waste is mainly influenced by cross-contamination, which depends primarily on the time of collection and storage of waste. Therefore, the high degree of moisture content of the waste may not be of great importance in the case of plastics. However, in the case of paper and board contained in mixed municipal waste, due to their high moisture absorption capacity, combined with the presence of fine particles, the degree of moisture is crucial in their contamination (Schmalbein et al., 2011) and thus their continued recyclability.

In order to achieve more analytical results, the research should be continued. The research work can be extended to other MBP installations in the Podlaskie Voivodeship. In addition, the share of MBP installations in the level of recycling and preparation for re-use of PMPG in 2020, as well as the above-mentioned share in the level of preparation for re-use and recycling of the municipal waste in subsequent years, can be examined, checking whether the same regularities will be recorded as in the year 2019 under review.

Conclusions

Based on the conducted analyses, it should be stated that the MBP installation may have an impact on the achievement by municipalities of the recycling level required by law. In the MBP installation with the highest percentage of municipalities that achieved the required level of recycling, equal to 89.5% (Installation A), PMPG waste segregated from mixed municipal waste ensured that as many as 57.9% of municipalities achieved the level required by law. On the other hand, in the case of MBP installations with the lowest percentage of municipalities that achieved the required recycling level of 42.3% (Installation B), the share of MBP installations ensured that only 11.5% of municipalities achieved the above-mentioned level. It follows that

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without the participation of MBP installations (i.e. without including PMPG waste segregated from mixed municipal waste in each municipality's recycling rate), the required level of recycling would have been achieved by a similar percentage of municipalities, i.e. 31.66% in the case of municipalities directing mixed municipal waste to Installation A, and 30.8% in the case of municipalities directing the above-mentioned waste to Installation B. Calculations made on the data of municipalities directing waste from both installations A and B indicate that the high share of the weight of recycled municipal waste separated from mixed municipal waste in the weight of recycled waste did not determine the achievement of the required level of recycling by all municipalities. The low share of recycled waste sorted in MBP did not mean that municipalities did not achieve the recycling level. Achieving the required level of recycling depended on the total mass of PMPG waste recycled, i.e. segregated from mixed municipal waste in the MBP installation and the weight of recycled waste from the selective collection (collected from residents as selectively collected waste "at source" and collected in PSZOK).

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The contribution of the authors

A. Krysztopik – conception, acquisition of data, analysis and interpretation of data – 70%.

I.A. Tałałaj – conception, analysis and interpretation of data – 20%.

P. Biedka – literature review – 10%.

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DEVELOPMENT BARRIERS OF AGRICULTURAL BIOGAS PLANTS IN POLAND

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ABSTRACT: The article aims to identify barriers related to developing agricultural biogas plants in Poland. The secondary data was supplemented by primary data from a questionnaire conducted among employees of an enterprise whose biogas production is one of the elements of the circular economy. The results of the research revealed that the majority of respondents indicated external, systemic and developmental obstacles. The largest percentage of responses concerned the lack of stable legal regulations in the scope of renewable energy sources, including biogas plants, and the lack of programs financing the construction of agricultural biogas plants. Moreover, the respondents pointed to the proposals that could improve the development of agricultural biogas plants in the future. The respondents considered updating and ensuring the profitability of investments in the situation of significantly higher expenditures, growing costs of business and debt servicing through the reference price as a significant motivator, as well as inclusion in the support system of tariffs guaranteeing a stable income for at least 15 years. Barriers to developing agricultural biogas plants in Poland remain unchanged, and the awareness of the positive impact of agricultural biogas plants on many levels is still very low.

KEYWORDS: barriers, development, agricultural biogas plants, Poland

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Introduction

The world of biogas installations is particularly developed in the United States, where biomethane is primarily used for the production of electricity. China is also a big producer of bioenergy production, where the main idea of the existing installations is the production of energy for heating purposes. Europe currently produces 3 billion m^3 of biogas and biomethane in total, which corresponds to the total gas demand of Belgium. By 2030, it is estimated that Europe can produce 35 billion m^3 of biogas, which is 10% of the total gas demand in the European Union. By 2050, the combined production of biogas and biomethane could reach 95 billion m^3, which in turn could cover 30-40% of the total gas demand in 2050 (European Biogas Association, 2022). In terms of the number of installations, Germany is the leader, but the biogas market is also developing successfully in the UK, Italy, France, the Czech Republic, and Denmark, which is possible thanks to the pro-ecological economy conducted there (Eurobserv'er, 2020; Gostomczyk, 2017).

Agricultural biogas plants are not only installations that are part of the energy sector operating in the renewable energy sources sub-sector (Nikiciuk, 2019) but also an underestimated element of the agricultural sector. The use of agricultural biomass for the production of energy, liquid and gaseous fuels can be considered to be one of the most promising directions for the development of renewable energy sources (RES) (Ignaciuk & Sulewski, 2021; Kisiel et al., 2006).

The potential of biogas production in Poland is still underestimated (Biomass Media Group, 2020). Estimated at several billion m^3 annually, it is comparable to the potential of our western neighbours. In Poland, annually, about 120 million tons of manure and slurry and at least 8 million tons of straw from cereals and rape are produced, which translates into a relatively high energy potential of the agri-food sector itself (Ustawa, 2015) in terms of agricultural biogas production, which could even exceed 7.8 billion m^3 annually (Ministerstwo Aktywów Państwowych, 2019). Table 1 presents a list of the most popular raw materials used for the production of agricultural biogas in 2020. Agricultural biogas plants operating in a sustainable manner are those that produce agricultural biogas from substrates that cannot be used in any other way (e.g. as feed, as a fertiliser ingredient, etc.). We are talking here primarily about waste and residues from agricultural activity, waste from agricultural and food processing, and other by-products of agricultural origin. These substrates can be used in an optimal way, preferably as part of a circular economy.

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Table 1. List of the most popular raw materials used for the production of agricultural biogas in 2020

Type of raw material	Amount [thousand t]
Distillery decoction	914.5
Slurry	764.4
Residues from fruits and vegetables	679.6
Maize silage	497.6
Food processing waste	346.6
Technological sludge from the agricultural and food industry	225.3
Beet pulp	210.4
Waste from the dairy industry	131.5
Expired food	117.2
Manure	91.7
Waste plant mass	87.5
Slaughterhouse waste	83.1
Green mass	38.2
Fruits and vegetables	35.9
Fowl manure	27.7
Grass and grain silage	26.7
Fats	25.6
Waste from the production of vegetable oil	11.8
Straw	7.7
Protein and fat waste	3
Digestate	1.6
Catering waste	1.5

Source: Magazyn Biomasa (2022a).

Unfortunately, according to the Institute of Fuel and Energy Technology, there are only over 340 biogas plants in Poland, including 137 agricultural biogas plants (Lajnert, 2022; Energy Regulatory Office, 2022; Krajowy Ośrodek Wsparcia Rolnictwa, 2022b).

The institution keeping the register of agricultural biogas producers in Poland is the General Director of the National Center for Agricultural Support (KOWR) (Act, 2015). KOWR is a state legal entity that supports the development of renewable energy sources in rural areas, both through information

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and promotion campaigns contributing to the dissemination of knowledge (Krajowy Ośrodek Wsparcia Rolnictwa, 2022a), as well as through participation in green energy development projects for agricultural biogas plants (Krajowy Ośrodek Wsparcia Rolnictwa, 2020). According to the register of agricultural biogas producers, as of November 11, 2022, there are 117 entities in Poland (Krajowy Ośrodek Wsparcia Rolnictwa, 2022b) whose annual capacity of the agricultural biogas production plant is 563 163 631m^3, with a total installed electrical capacity of 138,218 MW_e (Krajowy Ośrodek Wsparcia Rolnictwa, 2022b).

Table 2. Range of installed electrical capacity of agricultural biogas plants in Poland by power and voivodships in 2022

Voivodship	Power [kW]					Total	
	< 100	>100 i < 500	> 500 i < 999	> 999 i < 2.000	> 2.000	Amount	Power [kW]
Dolnośląskie	-	1	4	5	-	10	11 111
Kujawsko-Pomorskie	1	-	-	4	1	6	9 073
Lubelskie	1	-	5	1	2	9	10 794
Lubuskie	-	3	3	1	-	7	5 288
Łódzkie	-	1	4	3	-	8	7 932
Małopolskie	-	1	1	-	-	2	1 148
Mazowieckie	1	5	5	1	1	13	11 307
Opolskie	-	-	1	1	-	2	2 199
Podkarpackie	-	4	2	1	-	7	4 994
Podlaskie	1	-	8	2	-	11	9 273
Pomorskie	-	2	5	3	2	12	14 144
Śląskie	-	1	1	-	-	2	1 495
Świętokrzyskie	-	-	1	-	-	1	800
Warmińsko-Mazurskie	-	5	7	5	-	17	15 342
Wielkopolskie	-	5	6	4	2	17	19 150
Zachodniopomorskie	-	2	9	4	-	15	14 168
Total	4	30	62	35	8	139	138 218
Power [kW]	264	13 288	56 013	49 209	19 444		

Source: authors' work based on Krajowy Ośrodek Wsparcia Rolnictwa (2022b).

The agricultural biogas plant in Zbiersk, in the Wielkopolskie voivodship (10,120,000 m^3/year and 3,500 MW_e, respectively) has the highest annual efficiency among all agricultural biogas plants in the country. In total, 53% of

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the installed capacity belongs to Goodvalley, which was the first in Poland who had built an agricultural biogas plant in Pawłówko (Przechlewo commune, Człuchów district) in 2005. Table 2 presents the range of installed electrical capacity of agricultural biogas plants in Poland by power and voivodeships.

Biogas plants with a capacity of nearly 1 MW (37 installations) and nearly 0.5 MW (22 installations) are the most used. This is due to the fact that units with a capacity of up to 1MW are covered by the support system in the form of guaranteed prices (the so-called FIP without the need to participate in the auction). However, for units with a capacity below 0.5 MW, it is not necessary to carry out an environmental impact assessment. Most of the installations are located in the Wielkopolskie Voivodship (over 19 MW – 17 biogas plants) and Warmińsko-Wazurskie Voivodship (over 15 MW – 17 installations). However, one agricultural biogas plant in Świętokrzyskie has very low power produced (800 kW), despite favourable substrate possibilities (agricultural land constitutes over 60% of the area, while the number of cattle is approx. 156 thousand heads, pigs approx. 196 thousand heads, and chicken poultry 6,035 thousand heads) (Statistics Poland, 2021). Among the registered biogas plants, one does not produce energy, and biogas is intended for sale to another producer (Lubelskie Voivodship). On the other hand, two biogas plants partly sell biogas to third parties, and three biogas plants partly burn biogas in a boiler, including one in a feed material dryer.

One of the motivators for the development of the biogas sector in Poland is the assumptions of the European Green Deal and the implementation of the European Union (EU) strategy to reduce CH4 and the plan to reduce CO_2 emissions by 55% by 2030 (European Parliament resolution, 2021). Additionally, it may also be the so-called methane tax (on cows and sheep) or a scale for assessing the carbon footprint of goods in commercial circulation in the EU.

A limitation related to the development of the agricultural biogas sector in Poland is the strong dependence on the support system (Ignaciuk & Sulewski, 2021), without which, with relatively high investment and operating costs, biogas projects cannot exist, especially if compared to wind projects or PV installations. Moreover, organisational and legal barriers should also be considered important (Klepacka, 2019; Powałka et al., 2013).

The objective of the agricultural strategy “from farm to fork” adopted in May 2020 is to guarantee food security while reducing the negative impact of agriculture on the environment. An agricultural biogas plant should be a natural complement to the production cycle for each breeding of animals with a size greater than 100 LU. Closing the circulation in agriculture by using an agricultural biogas plant for the recycling of natural fertilisers enables the effective management of biogenic elements, thus reducing their losses and reducing the negative impact of a farm on the natural environment (Ceny rolnicze, 2022). The justification for taking up the topic of barriers to the development of agricultural biogas plants in Poland were two key issues. Firstly, rising electricity and gas prices and the spectre of gas shortage on the European market due to the geopolitical situation, i.e. the armed conflict in Ukraine. In the current situation, independence from external gas suppliers is an opportunity for the development of domestic agricultural biogas production. Secondly, the proposed legislative changes as part of the amendment to the RES Act (Ceny rolnicze, 2022), mainly in the field of the biogas and biomethane market, which is also a consequence of the signing of the "Agreement on cooperation for the development of the biogas and biomethane sector" (gramwzielone.pl, 2022) on the initiative of the Minister of Climate and Environment (Climate and Environment Ministry, 2021).

An overview of the literature

Agricultural biogas plants operating worldwide (Igliński et al., 2020; Yousuf et al., 2016), and their history, depending on the sources, dates back to the 10th century BC or slightly later (Bond & Templetion, 2011; Chasnyk et al., 2015). functioning of agricultural biogas plants is associated with both opportunities and barriers, which are classified according to various typologies.

The research gap that the article fills in the literature on the subject indicates the use of a typology of barriers to local development. The purpose of the study, which is to identify barriers related to the development of agricultural biogas plants, fits in that gap.

Earlier studies present barriers to the functioning of agricultural biogas plants without any particular use of the typology (Pawlak, 2013; Mateescu et al., 2008). Other studies indicate the following barriers: political, economic, social, and technological (Situmeang et al., 2022; Igliński et al., 2020) supplemented with market barriers (Monjurul et al., 2022; Nevzorova & Kutcherov, 2019). At the same time, the literature points out the following issues applied to barriers to biogas technologies in rural areas: financial and economic; market; social and cultural; regulatory and institutional; technological and infrastructural, as well as information (Mittal et al., 2018).

Research methods

The descriptive method was used to achieve the goal of this article. The sources of materials were the literature on the subject, legal acts, industry literature and materials provided by the company that first "appeared" with agricultural biogas plants on the Polish market. The secondary data is supplemented with primary data obtained based on a questionnaire conducted among employees of the company, whose biogas production is one of the assets of the circular economy.

The survey questionnaire consisted of two parts: descriptions of respondents (e.g. gender, age, education, position, work experience, and place for a living) and 3 questions concerning barriers to the development of agricultural biogas plants. The first question concerned the respondent's request to assign an obstacle/barrier to its typologies (Table 1). Barriers were assigned a typology according to four criteria (Sekuła, 2005) (Table 1):

1. Sources of formation:
   - internal obstacles that occur at the local level,
   - external obstacles caused by regional, national and even global environments.
2. Probability of overcoming:
   - relative barriers that can be removed with the use of additional economic, legal and organisational measures,
   - absolute barriers, the overcoming of which is unprofitable from the perspective of the costs incurred, obtained profits and time involved.
3. Universality of occurrence (universality of impact):
   - systemic barriers, which are a limitation for all territorial units and do not result from irrational management, lack of competence of local authorities or unfavourable characteristics of the area,
   - local barriers that occur when the impact range is narrowed to a certain area, and the impact force has a local dimension.

Types of impact on development:
   - hindering or preventing development,
   - slowing down development processes,
   - preventing the initiation and sustainment of development processes.

The second question was to indicate the importance of these barriers on a scale from 1 to 5 (1 – not important, 5 – very important). The third question concerned broadening the scope of the barriers and making them valid on a scale from 1 to 5 as well.

Results of the research

Barriers to the development of agricultural biogas plants according to the typology used in the opinion of the respondents

28 people participated in the survey, and out of them, 43% were women. The average age of the respondents was 42, including the average age of women at 38. 40% of respondents (including 35% of women) declared a managerial position or specialist position. The remaining persons (of which

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11% were women) declared the position of director (3%), operator (7%) and office worker (10%). Among the respondents, less than 30% (7% were women) are employed in biogas plants or collaborate with the biogas department. The total average work experience for all respondents was 10 years, including the average 6 years of work experience of people closely related to biogas plants. 60% of the respondents live in rural and urban-rural areas. Besides, 79% of the respondents declared higher education (including incomplete higher education).

In the first question, the respondents were asked to assign barriers to the development of agricultural biogas in the typology used. The results are presented in Table 1.

Table 3. Assignment of barriers to the development of agricultural biogas in the typology used in the opinion of the respondents

Barrier type/typology	Internal obstacles	External obstacles	Relative barrier	Absolute barrier	Systemic barrier	Local barrier	Development obstacles
	[%]						
Lack of stable legal regulations in the field of renewable energy sources, including biogas plants	7	75	11	14	75	11	50
Lack of consistency in implementing positive changes, programs, plans	39	32	39	7	39	18	57
High investment outlays/costs	46	32	31	29	7	4	57
Lack of programs financing the construction of agricultural biogas plants	0	50	14	11	61	0	39
Planning constraints (local development plan, study of the conditions and directions of spatial development in the commune)	43	36	21	0	32	57	32
Location and size of an agricultural biogas plant	46	14	32	4	32	54	7
Problems with obtaining connection to the power grid	11	46	29	11	43	25	39
No justification for special cases of biogas purification	25	21	21	32	29	4	18
Defining digestate1 – fertilizer or waste?	14	50	29	4	61	4	29
Proper operation of biogas plants and high operating costs	50	21	32	14	32	7	21

1 digestate (post-fermentation mass) – solid-liquid by-product (Cecchi et al., 1988; Schievano et al., 2009).

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Barrier type/typology	Internal obstacles	External obstacles	Relative barrier	Absolute barrier	Systemic barrier	Local barrier	Development obstacles
	[%]						
Public and legal burdens (mainly local taxes and fees)	29	50	21	18	50	21	21
Local protests mainly due to the lack of knowledge about the functioning of agricultural biogas plants	57	25	18	7	14	39	36

The results of the research indicated that the vast majority of respondents indicated external, systemic and developmental obstacles. The largest percentage of responses concerned the lack of stable legal regulations in the field of renewable energy sources, including biogas plants (75%, 75%, and 50%, respectively) and the lack of programs financing the construction of agricultural biogas plants (50%, 61%, and 39% respectively). In addition, an important issue related to the definition of digestate (50%, 61%, and 29% respectively) and problems with obtaining the conditions for connection to the power grid (46%, 43%, and 39% respectively). In responses to the second question concerning the importance of barriers on a scale from 1 to 5, the respondents rated the highest importance of the barriers, apart from the lack of stability of the law on renewable energy, which was assessed as a very important barrier (89%), indicated high investment expenditure (75%) and the correct operation of the biogas plant and high operating costs (71%). Moreover, the respondents pointed to the proposals (also rated on a scale from 1 to 5) that could improve the development of agricultural biogas plants in the future. The respondents considered it very important to update and guarantee the profitability of investments in the situation of much higher expenditures, growing operating costs, and debt servicing through the reference price, as well as including in the support system tariffs that guarantee stable income for at least 15 years (50% of respondents' answers respectively). Among the important factors, 75% of respondents indicated the introduction of facilities in the purchase of land with an area of more than 1 ha for the construction of biogas plants, and 68% of respondents emphasized the significance of the competencies of administrative bodies and the timeliness of the procedure.

In the further part of the work, a list of barriers was used according to their weight in % share in the typology of assignment in the opinion of the respondents.

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External obstacle, systemic and development barrier. Lack of stable legal regulations in the field of renewable energy sources, including biogas plants

The Act on Renewable Energy Sources (RES) of 2015 was amended 32 times, including 20 times in 2019-2021. Despite this, the key requirements set out in the Market and by the RED II Directive have not been implemented so far (Teraz Środowisko, 2022).

Until the act on renewable energy sources is passed in February 2015, all issues related to the operation of agricultural biogas plants were regulated in the Act of April 10, 1997 – Energy Law (hereinafter referred to as the Energy Law), which imposed an obligation on agricultural biogas plants to have a license to generate electricity. Since 2010, companies using agricultural biogas plants have been exempt from this obligation. Act of January 8, 2010 amending the Act – Energy Law and amending certain other acts, a definition of agricultural biogas was introduced, and pursuant to Art. 9 p.2 and 3, biogas plants were entered into the register of enterprises producing electricity from agricultural biogas kept by the Agricultural Market Agency, whose duties were taken over by the National Center for Agricultural Support.

In accordance with the energy law and later the RES Act, agricultural biogas plants received support for energy produced from renewable energy sources in the form of the so-called "Green certificates" in the RES Property Rights market, operating since December 28, 2008 (TGE, 2022a). As a result of a long-lasting sharp decline in the prices of green certificates, which have fallen more than twice (TGE, 2022b) since the beginning of their existence with the next amendment to the RES Act, on 1 July 2016, the obligation to present certificates of origin for energy from renewable sources (green certificates) for redemption has changed (Act, 2016; Palusiński, 2016). The 15% obligation was reduced in the second half of 2016 to 14.35% in order to distinguish a dedicated level of the obligation to redeem certificates of origin confirming energy production from agricultural biogas, the so-called blue certificates, which amounted to 0.65%.

The prices of green certificates in recent years have been much lower than the prices of blue certificates, which were slightly higher than the level of the substitution fee, i.e. about PLN 300/MWh. The comparison of certificate prices in the years 2016-2022 is presented in Figure 1.

The instability of the legal regulations concerned not only the renewable energy support system, but also related to the produced energy support system in cogeneration. Cogeneration means combined energy production, which is the production of electricity and heat in one technological process as a result of the combustion of e.g. gas or biogas, including agricultural. The so-called "Yellow certificates" were a significant support not only for agricultural biogas plants – the prices of yellow certificates were at the level of the

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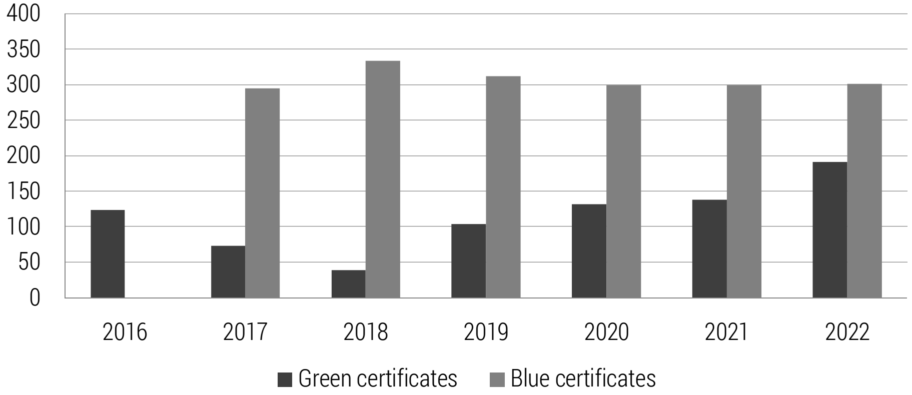
substitution fee, so they amounted to approx. PLN 100-125/MWh (WNP, 2014).



Note: 1 EURO=4.6858 PLN (Narodowy Bank Polski, 2022)

Figure 1. Average prices of certificates in 2016-2022 [PLN/MWh]

Source: authors' work based on TGE, 2022b.

However, due to the lack of enactment of the regulation on the amount of the obligation to obtain and submit for redemption certificates of origin for energy from cogeneration, energy entrepreneurs selling energy to end users were not obliged to purchase yellow certificates and fulfill the statutory obligation. This was, along with the sharp drop in green certificate prices, one of the main causes of the crisis in which the biogas industry in Poland plunged in 2013. Due to this situation, many biogas projects were suspended or even abandonment. The existing biogas plants, began to bring losses so severe that many of them faced bankruptcy (Krzemiński, 2014).

The yellow certificate system was reintroduced in April 2014, but the obligation to redeem certificates was limited only to the year in which the cogeneration energy was produced. An important issue in the period of the lack of yellow certificates was the possibility of applying for the so-called purple certificates, i.e. certificates of origin for energy from a methane-fired unit introduced in 2010, the amendment to the Energy Law Act, the price of which oscillated around PLN 60/MWh (Energy Regulatory Office, 2018). The system of yellow and purple certificates was in force until the end of the 2018, with the settlement obligation until June 30, 2019. It was replaced by the Act of December 14, 2018 on the promotion of electricity from high-efficiency cogeneration, which made it impossible to combine support systems, which consequently meant that agricultural biogas plants receiving support

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in the form of blue certificates cannot benefit from the support system for high-efficiency cogeneration.

For new agricultural biogas plants (under the feed-in tariff system, the so-called FIT, FIP or auctions), the inability to use the support for energy production in high-efficiency cogeneration was compensated by the differentiation of reference prices for electricity produced from agricultural biogas or from agricultural biogas from high-efficiency cogeneration (110 PLN/MWh price difference) (Regulation of the Minister of Climate and Environment, 2021).

Subsequent changes took place on July 14, 2018, when the provisions of the Act of June 7, 2018 amending the Act on renewable energy sources and certain other acts (Journal of Laws of 2018, item 1276) came into force, introducing inter alia new forms of support for electricity generation from renewable energy sources – the so-called feed-in-tariff system of feed-in tariffs (Energy Regulatory Office, 2018).

In accordance with the adopted regulations, renewable energy installations with a capacity of less than 500 kW may join the FIT system (Szwarc, 2021). After obtaining a certificate from the President of the ERO about the possibility of using the FIT system, the generator sells the generated electricity, the so-called obligated sellers (appointed by the President of the ERO based on the highest volume of sales to end users connected to the distribution network in a given area) at prices equal to 95% of the reference price applicable on the date of submission of the FIT, less public investment aid, if applicable.

The system of additional payment to the market price (FIP) may be used by installations with a total installed electrical capacity of not less than 0.5 MW and not more than 1 MW (Szwarc, 2021). Under this system, they can obtain the right to cover 90% of the negative balance, i.e. the difference between the reference price and the average electricity prices on the Polish Power Exchange. These prices are subject to annual indexation with the average annual total consumer price index for the previous calendar year published by the President of the Central Statistical Office. In the case of the FIP support system, similarly to the FIT system, the reference price should be reduced by the public investment aid obtained, if any. In November 2021, the reference price level in the FIT system, for which investors could sell electricity from agricultural biogas, produced in high-efficiency cogeneration, was PLN 722/MWh (95% of PLN 760/MWh) (Szkwarek, 2021). In the FIP system, the reference price for electricity generated from agricultural biogas in high-efficiency cogeneration is PLN 700/MWh, which means that an agricultural biogas plant may receive support at the level of PLN 630/MWh (90% of PLN 700/MWh) (Regulation of the Minister of Climate and Environment, 2021).

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On October 30, 2021, further amendments to the act were introduced under the Act of September 17 amending the Act on renewable energy sources and certain other acts (Journal of Laws 2021, item 1873), allowing participation in the FIT/FIP system for 24 additional months for renewable energy installations that received certificates of origin for a minimum period of 5 years. Therefore, the additional 24 months in the FIT/FIP system can be used by installations that are in the process of using the certificates of origin system and installations for which the maximum 15-year period of using the certificates of origin system has already expired. The total duration of using the support system may not exceed 17 years (Szwarc, 2021). Contrary to the simple FIT/FIP system, the auction system for installations with a capacity above 1 MW is a challenging mechanism, as it requires an obligation to supply energy under the pain of high penalties, for the price proposed in the auction, which, after winning, is reduced by public investment aid. Settlement of the energy volumes declared in the auction takes place in three-year periods.

In 2014, a guarantee of origin system started operating in Poland, which was implemented as part of the implementation of selected assumptions of the 2009 EU RES Directive. The role of the guarantee of the origin of electricity is to certify the end user of the generation of electricity in RES and the related environmental values resulting from the avoided emission of greenhouse gases. No property rights arise from guarantees of origin, and their current market value is at the level of a few PLN.

The barrier related to the lack of stable legal regulations concerns primarily the frequency of changes and their impact on the functioning of the industry. The Renewable Energy Sources Act of 2015 was amended thirty-two times, including 20 times in 2019-2021. And still does not contain key provisions of the so-called Market Directive, the implementation of which has a huge impact on the development and operation of agricultural biogas plants in Poland. Changes in regulations and their adaptation to changing market realities take too long, which results in a lack of trust in the legal system in its broadest sense and is often the decisive factor in not implementing biogas investments.

Development barrier, internal barrier, relative barrier, systemic barrier. Lack of consistency in implementing positive changes, programs, plans

In 2010, the government adopted the program “Directions for the development of agricultural biogas plants in Poland in 2010-2020”, which was to stimulate the economy of Polish countryside, make it partially energy-independent and help achieve the targets for the share of energy from renewable sources (gramwzielone.pl, 2013; NIK, 2018). The Polish countryside was

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about to change. The ambitious plan provided for the construction of an average of one biogas plant with a capacity of approx. 1 MW in each municipality that had the conditions to do so. In practice, this meant about 2,000 such installations, the total capacity of which was to be 2,000 MW. The Ministry of Economy estimated that biogas plants will produce biogas corresponding to 10% of the national consumption of natural gas. The plan was never implemented. On the contrary, the interest in agricultural biogas plants has been gradually decreasing since 2012 due to changes in legal regulations and the unfavourable situation on the green certificates market. If the plan were implemented, about 2,000 agricultural biogas plants in Poland would have been built; it would have given the power system a distributed and fully controllable source of energy with a capacity and production volume compared to the commissioning of the planned nuclear power plant (Grzybek et al., 2020). The costs of the nuclear power plant are at least several billion PLN higher than the construction of an agricultural biogas plant, and the first effects could be achieved just one year after inception.

In addition, it would improve the energy infrastructure and increase the competitiveness of Polish agriculture and would stimulate the development of local entrepreneurship (Ministerstwo Gospodarki, 2010). The implementation of the assumptions of the "Directions for the development of agricultural biogas plants in Poland in the years 2010-2020" would also contribute to the achievement of the objectives indicated, among others, in the Energy Policy of Poland until 2040, which assume: optimal use of own energy resources, expansion of production infrastructure, development of energy markets, renewable energy sources, heating and cogeneration, as well as to improve the energy efficiency of the economy, and thus to improve energy security. Due to the location of the agricultural biogas plant, local documents and plans are also important, such as low-emission economy plans, which set goals and directions in terms of improving air quality, energy efficiency, reducing pollutant emissions, including greenhouse gases, local development plans, which formulate objectives and describe strategies aimed at achieving social, economic and spatial development, or plans for the supply of heat, electricity and gaseous fuels, which define and specify the commune's energy policy. Regionally, this is prepared in the strategies of voivodships.

Development barrier, internal obstacle. High investment outlays

Agricultural biogas plants are complex installations, which consist of many elements, such as buildings: technical building with a CHP module and pump building, tanks: for components, preliminary, mixing, fermentation, post-fermentation, electrical installations and networks with a transformer station, water supply networks, sanitary, technological networks with a

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pump system and component networks, e.g. with a moving floor, biogas treatment network with a desulphurisation tank, heat network with boiler room technology, separator, automation and control, component yards, roads, etc.

Such complexity of the installations means that the investment outlays for this type of project are much higher than the outlays for photovoltaic installations or wind turbines, which, compared to agricultural biogas plants, may deem to be rather basic. In 2010-2012, the amount of expenditure on an agricultural biogas plant with a capacity of 1 MW ranged from PLN 13 to 16 million. Currently, it is estimated that the construction of a 1 MW installation requires an investment of over PLN 20 million.

Table 4. Investment outlays for biogas plants with three different plant capacities – calculation as of December 31, 2021*

Year of construction	Biogas plant with installation capacity (kWel / kWt)		
	625/690	1 063/1 088	2 126/2 206
	2010	2011	2009
Investment outlays for construction [PLN]	9 500 000	13 000 000	15 300 000
Total investment outlays [PLN]	10 000 000	15 000 000	21 500 000
Electricity production [MWh]	5 200	8 500	17 000
Production efficiency [%]	94.98%	91.28%	91.28%
Thermal energy production [GJ]	22 300	38 500	55 000
Heat surplus (to be used) [GJ]	5 800	15 000	16 300
Number of animals [JPD]	12 300	1 200	9 300
Share of electricity from biogas plants in the energy used for energy production [%]	17.69%	19.29%	18.82%
Amount of energy used for energy production [MWh/year]	920	1 640	3 200
Share of electricity from biogas plants in the energy used on the farm [%]	6.92%	8,59%	34,12%
The amount of energy consumed on the farm [MWh/year]	360	730	5 800
Share of electricity from biogas plants in the energy used in other / remote farms [%]	11.63%	15.92%	14.55%
Amount of energy used in other/remote farms [MWh/year]	2 593	6 130	8 000
Substrate costs [PLN/year]	1 700 000	2 200 000	6 200 000
Total direct costs other than the cost of the substrate [PLN/year]	1 400 000	1 700 000	3 000 000

Note: 1 EURO=4.6858 PLN (Narodowy Bank Polski, 2022).
* The costs increased significantly by about 30-40% after February 24, 2022.

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The analyses carried out in the literature show that at the assumed level of costs and outlays, investments in agricultural biogas plants do not provide, in most of the analysed cases, a return on the invested money (Sulewski et al., 2016). As an example, Table 2 presents the investment outlays for biogas plants with different plant capacities.

The cost of the substrate is the largest cost driver in the case of agricultural biogas plants, mainly in those using corn silage as a substrate, the price of which depends on the market price of corn grain. The use of silage should therefore be limited to silage from part of the green maize. Agricultural biogas plants should mostly use second-generation raw materials, e.g. waste straw or other by-products of agricultural origin, which have no other possibility of use and are cheap. Corn silage should only be a supplementary raw material, especially where the technology of the biogas plant was adapted to a specific substrate – only then it makes economic sense.

It is also noteworthy the barriers that appear at the design stage and during the technological start-up, which is not without significance during operation. The basic problem at the design stage is the wrong assumption as to the power and size of the biogas plant, which often results from administrative and legislative reasons and not from functional and technical aspects, e.g. a biogas plant up to 0.5 MW does not require an environmental impact assessment. An undersized biogas plant may struggle with such problems as insufficient amount of heat necessary in the fermentation process, especially thermophilic, inflexible technology in terms of raw materials, e.g. too small tanks, inefficient mixers, etc. At the start-up stage, it is very important to carry out the fermentation correctly, so proper feeding of the bacteria. Disturbance of fermentation at any stage may cause the biogas plant to work unstable, and thus it will not achieve the intended efficiency. This problem also applies to the exploitation stage. It is not without significance for the proper functioning of the biogas plant is the service and technological supervision, including properly carried out inspections and servicing of installations, as well as controlling the basic parameters of the biogas plant.

Systemic barrier, external obstacle, development barrier. Lack of programs financing the construction of agricultural biogas plants

The construction of a biogas plant requires the involvement of large capital, and investors most often do not have the funds that would allow the project to be implemented without external support (Filipiak, 2020). When deciding on a biogas investment, consideration needs to be taken regarding the financing formula and possibilities offered by: banks, leasing companies, as well as other institutions that offer dedicated support programs in the form of grants and loans.

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Among the investment financing formulas, three proposals should be mentioned: financing on the investor's balance sheet (corporate finance) or off-balance sheet (project finance). It is also possible to combine the forms of financing: use the form of balance sheet financing as a limited liability company for the time of construction, and after the technical acceptance of the project, create a special purpose company and continue its operation under the project finance, refinancing it with a long-term loan. As a result, the risk for lenders is reduced (which leads to lower costs of the loan at the construction stage and the refinancing loan), and it is easier to start an investment while maintaining the benefits of using the project finance formula at the stage of operation of the installation.

It is also possible to combine the forms of financing: use the form of balance sheet financing as a limited liability company for the time of construction, and after the technical acceptance of the project, create a special purpose and continue its operation under project finance, refinancing it with a long-term loan.

Unfortunately, there are only a few possibilities for obtaining financing. It is difficult to find a standardised offer dedicated to biogas plants in the banks offer. However, the National Fund for Environmental Protection and Water Management offered only two active programs offering subsidies and preferential loans for biogas plants. The first is Energia Plus (a program offering subsidies up to 50% of eligible costs) and loans (up to 85% of eligible costs, loan amounts from PLN 0.5 to 300 million). The second is Agroenergia, in which the form of support is a subsidy (up to 50% of eligible costs, but not more than PLN 1.8 million for sources up to 150 kW; PLN 2.2 million for sources with a capacity of 150-300 kW, but not more than 2, PLN 5 million, if the investor applies for support for the construction of an installation with a capacity of 300-500 kW) and loans up to 100% of eligible costs.

Provincial Funds for Environmental Protection and Water Management also have preferential loans for ecological investments usable for biogas plants. For agricultural activity, the Agency for Restructuring and Modernization of Agriculture offered its help, after an individual assessment of the project, under the Rural Development Program for 2014-2020. Moreover, it is possible to obtain the support after an individual assessment of a given project, e.g. as part of PFR investment funds, ARP loans, loans granted by BGK and loans from commercial banks secured with BGK guarantees (de minimis or Biznesmax with subsidy). However, when making financial commitments, it should be remembered that the main obstacle for both financing entities and investors themselves is the high risk of biogas projects, which do not always take into account the responses to potential threats at the stage of investment implementation and operation of a biogas plant (Filipiak, 2020).

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It is worth mentioning that on June 1, 2022, the European Commission approved the National Plan for Reconstruction and Increasing Immunity (KPO), under which Poland should obtain approximately EUR 36 billion (ACCREO, 2022). The funds were broken down into non-repayable instruments, such as grants, with € 23.850 billion, and repayable instruments, with € 12.11 billion. Among the five main thematic components, there is also "Green energy and reduction of energy intensity (around EUR 14.3 billion). The objectives of the subsidy include, inter alia, the construction of waste storage and management facilities, as well as sewage treatment plants and biogas plants.

Local barriers, internal obstacle. Planning constraints

According to the Supreme Audit Office, "Documents specifying the spatial policy of communes are often outdated and incomplete, which significantly limits their role in the spatial management system" (NIK, 2017). In Poland, the most important decisions regarding the destination and development of land are taken by municipalities. One of the basic factors that are taken into account when looking for real estate for investment purposes, including biogas plants, is information about whether the plot is covered by a local spatial development plan (Local Development Plan) and what are the provisions of this plan. The energy use of biogas plant products means that it should be included in the draft assumptions for the plan for supplying the commune with heat, electricity and gas. It should be ensured that the planned biogas plant is included in other local documents, such as the study of the conditions and directions of the spatial development of the commune, environmental protection program, low-emission economy plan, draft assumptions for the heat, electricity and gas fuel supply plan, to which the head of the commune, mayor, or president is obligated, under the Energy Law, etc.

In addition, when planning an investment in a biogas plant, ambiguous interpretation of the provisions determining the investment process needs to be taken into account, e.g. regulations in the field of construction law, real estate management, and protection of agricultural and forest land. Therefore, questions arise: Does the land for an agricultural biogas plant need to be de-agriculturalized? Is the biogas plant an agricultural structure? Is the biogas plant built for agricultural purposes?

Depending on the answer provided by the authorities participating in the investment process – the procedure may be completely different, as there are no standardised approaches to this type of project in Poland, and most importantly, there are no legal provisions that would prevent freedom of interpretation. It should also be remembered that the exclusion from the production of agricultural land produced from soils of mineral and organic ori-

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gin, classified as classes I, II, III, IIIa, IIIb, and agricultural land of classes IV, IVa, IVb, V and VI produced from soils of organic origin, and also the land referred to in article 1. 2 clause 1 items 2-10 of the Act on the protection of agricultural land and forest land intended for non-agricultural and non-forest purposes, may take place after the issuance of a decision authorising such an exemption.

Referring to the possibility of recognising an agricultural biogas plant as an agricultural goal in itself, it should be ruled out that the biogas plant is an industrial activity within the meaning of Art. 4 pts 26 of the Act on the Protection of Agricultural Land and Art. 3 point 12 of the Energy Law (Act, 1997).

The location and size of the biogas plant is not adapted to local conditions

When considering the construction of a biogas plant, the type of feedstock, its quantity and quality, and specifying its availability on the local market need to be determined at the start. The most commonly used raw material in an agricultural biogas plant is slurry, stillage and various types of silage. Straw, which is a by-product of plant production, is also becoming more and more popular (Ginalski). The availability of the listed substrates and other raw materials that meet the statutory definition of agricultural biogas has a decisive impact on the location of an agricultural biogas plant. Transport of substrates, mainly those with a high water content, such as slurry, is expensive and reduces the efficiency of energy production, and is also inadvisable from the point of view of environmental protection. The most optimal and appropriate solution is to build an agricultural biogas plant in the immediate vicinity of the raw material supplier, e.g. in the vicinity of a farm, so that slurry can be delivered via a pipeline directly to the biogas plant, without affecting the environment and the immediate surroundings.

In Poland, there are many cases where the location or size is not adapted to local conditions. We are talking primarily about such installations in the case of which the feedstock is not in the immediate vicinity or on the local market, but is transported from considerable distances, which is neither economically nor environmentally justified. Biogas plants should develop where there is a supply of waste from agricultural production and the agri-food industry, as well as agricultural raw materials of the second category. The most optimal solution for an agricultural biogas plant is its operation within an integrated farm. The location far from the place of sale of the feedstock to the biogas plant increases the risk of insufficient feedstock for biogas production or an increase in costs in this regard to levels that do not allow to ensure financial liquidity. It is even riskier if a given installation participates in the auction system and has to meet the obligation to sell the amount of electricity declared during the auction. The stability of a biogas plant depends mainly

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on the stability of the fermentation process, and without a stable supply of raw material, it is impossible to achieve and may indicate oversizing of the installation. It is also important to undersize the biogas plant in the case when a certain amount of substrate is provided. An example is a situation in which a small agricultural biogas plant operates in the immediate vicinity of a large pig farm, but due to its size and power, it is not able to produce waste heat sufficient to carry out the fermentation process and heat the livestock buildings. An important issue, both in terms of location and size, is to ensure the appropriate area of land for fertilisation with an organic fertiliser in the form of digestate, remembering to limit nitrogen application to 170 kg/ha.

An important issue that directly concerns the location barrier is that agricultural biogas plants operate at a considerable distance from potential heat recipients, which significantly reduces the economy of biogas plants and is a kind of waste in the case of biogas plants producing energy in cogeneration because unused heat goes to the cooler. The size of the biogas plant must therefore be adapted to the local raw material resources, to the local demand for thermal energy, as well as to the needs of the biogas plant itself, which in thermophilic fermentation requires a large amount of heat in the technological process.

In the case of new investments, potential electricity consumers in the immediate vicinity may also be important from the point of view of problems with obtaining connection conditions to the power grid.

External obstacle, systemic barrier. Problems with obtaining a connection to the power grid

The development of renewable energy sources in Poland will not accelerate without decisive investments in power grids and without changing the way they are managed (Act, 1997). In Poland, the operator of the electricity transmission system is Polskie Sieci Elektroenergetyczne S.A. (PSE). PSE cooperates with energy companies/operators who distribute gaseous fuels or energy. These enterprises are required to conclude a grid connection agreement with entities applying for it. In the first instance, connections include the installation of a renewable energy source, if technical and economic conditions meet the conditions for connection to the network and reception. Refusals to conclude a grid connection agreement or to connect a renewable energy source installation are, unfortunately, quite common.

According to the data published by the energy regulatory office, the number of connection refusals in 2021 increased by 70% compared to 2020 and amounted to 3,751 cases. These were mainly PV micro-installations. In 2015-2021, over 6,000 applications to connect to the grid were rejected for installations with a total capacity of approximately 30 GW. This is almost 50% of the currently installed capacity in all types of energy sources in Poland as of May 2022. This is a result close to the total capacity of coal-powered and lignite-powered units in 2021. Refusals to connect the highest RES capacity were in 2021, and it was as much as 15 GW (Globenergia, 2022). An unconnected or shut-down installation does not generate electricity, so self-consumption also does not occur. The solution could be energy storage and changes in the capacity market, including the release of the capacity blocked by wind and solar installations in favour of stable generation sources, which could supplement this capacity in periods of low efficiency. Unfortunately, this type of action requires systemic changes.

Absolute barrier. The need for biogas treatment

Biogas can be used for energy purposes locally by coupling the generated fuel with a biogas combustion unit or, after purification, introduced into the gas network and, after transmission, further used for energy purposes (PIGEOR, 2015). Despite the fact that, in accordance with the legal status in force, it has been possible to introduce purified agricultural biogas to the gas distribution network for several years, so far, no installation of this type has started operating in the country (NIK, 2018). For producers of agricultural biogas injected into the network, which is not subject to the concession obligation (Ustawa, 2003), there was no indication in the regulations of the competent authority which should participate in the process of testing the so-called "Incentive effect" (Act, 2017). Another form of biogas use can be bio-LNG, i.e. liquefied biomethane, which, due to the density of the stored energy and, therefore, the small volume of fuel, is an excellent solution for transport. It can be a solution for the energy and heating sectors, wherever there are no gas networks or they are located at considerable distances from the generation site.

A significant limitation is also the high expenditure on installations for biogas purification to network parameters and/or condensation.

At the moment, there is no installation producing bio-LNG in Poland, mainly due to high investment outlays and all the barriers referred to in this study. However, due to the current geopolitical situation and high prices of natural gas and energy, bio-LNG may, under certain conditions, be competitive with natural gas. The interest in this product is growing, mainly among enterprises pursuing decarbonisation goals in accordance with their own policy of implementing ESG non-financial reporting objectives (Environmental, Social Responsibility and Governance). Moreover, it is popular among enterprises operating on the fuel market obliged to meet the indicative targets set out in relevant legal regulations, such as the Act of 25 August 2006 on biocomponents and liquid biofuels (NCW – the indicative national target,

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which for 2023 is 8.9%) and the Act of August 25, 2006, on the Fuel Quality Monitoring and Control System (NCR – National Reduction Rate, which is 6%) (Magazyn Biomasa, 2022b). Examples of installations for the production of bioLNG operate in Europe, e.g. in Germany or the Netherlands.

Biogas as a product can be injected into local gas networks without increasing its quality parameters and without the necessity to incur huge expenditures on biogas purification installations. A biogas plant can be built on the outskirts of a municipality with a district heating network with its own gas-fired boiler houses, to which a gas pipeline supplying biogas to the boiler room can be built. However, this is justified only where the local gas network is not integrated with the natural gas network.

System barrier, external obstacle. Defining digestate – fertiliser or waste?

In the light of the law in force, the digestate may or may not be considered waste. Pursuant to Art. 2 point 6c of the Act of 14 December 2012 on waste, it is stated that "the provisions of the Act do not apply to (...) other, non-hazardous, natural substances derived from agricultural or forestry production used in agriculture, forestry or for the production of energy from such biomass by means of processes or methods that are neither harmful to the environment nor endanger human life and health. " The definition of waste states that "any substance or object which the holder discards intend or is required to discard" allows the digestate to be treated as waste or as a by-product subject to trade. In order for the digestate to be considered a by-product, the procedure presented in Art. 11 of the Act on Fertilizers and Fertilization, i.e. "producer of the object or substance referred to in Art. 10, is obliged to submit to the voivodeship marshal (...) the notification of recognition of the object or substance as a by-product.

On the farm without biogas plant, animal manure in the form of slurry can be used in arable fields as fertiliser without the need to conduct microbiological tests. In the case of a biogas plant and slurry processing in a biogas plant, tests are mandatory and result from legal regulations. According to the veterinary requirements, the animal by-product after processing by a biogas plant is still an animal by-product, even though it is registered as an organic fertiliser, which means that the buyer of such fertiliser must have appropriate permits for the use and transport of this fertiliser. An individual farmer without support from the administration has a difficult path to obtaining such a permit. What's more, if it were to be sold, the carrier and the buyer must have a veterinary identification number (WNI), which is associated with the registration of the means of transport by the carrier and confirmation of the purchase of the fertiliser by the buyer. Such interpretative duality

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is quite a significant barrier affecting for the operation of both planned and existing biogas plants.

Internal obstruction. High operating costs

In addition to the selection of appropriate devices and components for a biogas plant already at the design stage, it is equally important to strictly control their technical condition during operation, which has a significant impact on the functioning of the biogas plant and its efficiency. This is associated with high operating costs, which are also influenced by payroll costs, as biogas plants are not maintenance-free installations. An average biogas plant with a capacity of 1 MW requires constant service and therefore employs a minimum of 5 people. A large part of the operating costs is also the cost of the raw material in the form of silage or straw, the price of which increases every year. With the current prices of raw materials, services and all other components, the average technical cost of generating 1 MWh of energy ranges from PLN 800-1000/MWh.

External obstacle, system barrier. Public and legal burdens (mainly local taxes and fees)

Another barrier to the operation of biogas plants is the issue of their taxation (Aromiński, 2017). In the opinion of entities operating biogas plants only as part of agricultural activity (i.e. energy is not sold outside), the installation should be taxed with agricultural tax and not with the real estate tax because it serves agriculture and is used only for the purposes of agricultural activity, and is not strictly an economic activity. In the opinion of the tax authorities, the objects consisting of a biogas plant (buildings and structures) are related to economic activity, and at the same time, the agricultural land on which the biogas plant facilities are located is therefore occupied for economic activity, which results in charging real estate tax, which for the owner of an agricultural biogas plant is a much higher burden compared to agricultural tax (from PLN 100,000 to PLN 200,000 per year).

Moreover, there is often a twofold interpretation of the regulations in the context of tanks that meet the statutory definition of a building. In some communes, administrative employees recognise the tanks as structures (taxed with real estate tax in the amount of 2% of their value) (Ustawa, 1991); in others, they are treated as buildings (taxed on the area). From the taxpayer's point of view, it is more advantageous to tax tanks as buildings, where the tax burden may be twice lower than in the case of taxing tanks as structures, due to the fact that the book value of the tanks, which is the tax base, amounts to several million PLN.

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Internal obstacle, local barrier. Local protests mainly due to the lack of knowledge about the functioning of agricultural biogas plants

Investments in the construction of agricultural biogas plants also encounter social resistance, most often caused by the fear of the emission of noxious odours among local communities (Ceny rolnicze, 2022). In addition, local communities indicate, inter alia, unfavourable factors related to the functioning of biogas plants, such as water and soil contamination for monoculture crops; negative impact on the health of residents; a significant drop in land prices in the area; reducing the chances of agritourism development, increasing the nuisance of road traffic, as well as their destruction by vehicles delivering feedstock (Wawer, 2016).

A distorted image of the real social support for RES investments, through loud actions of a small group of opponents, may suggest that the majority of residents are against this type of investment. As a result, policymakers are under pressure and changing their attitude toward biogas investments.

Discussion/Limitation and future research

The research carried out by Igliński et al. (2020), who used the barrier typology according to the PEST method (political, economic, social, technological), indicating the lack of social awareness of the production and use of biogas, lack of knowledge transfer related to investment risk in biogas plants, as well as limited availability and capacity of the electricity network in rural areas. The last element, problems with obtaining connection conditions to the power grid, despite a different typology of barriers, was also indicated by the respondents whose opinions are described in the article. It should be emphasised that in the case of both studies, knowledge from specialists dealing with the subject of agricultural biogas was used, directly or indirectly, mainly due to their place of employment.

The issue of the functioning of agricultural biogas plants should be considered from more than just the perspective of barriers. The positive aspects of its operation should also be indicated, which may be the basis for further research on developing agricultural biogas plants in Poland. The opportunities include calculating the carbon footprint for biogas plants and calculating the emissions avoided thanks to agricultural biogas. An additional opportunity for the development of agricultural biogas plants is their operation within cluster structures, the development of the concept of a “green gas card”, as well as local distribution networks.

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Conclusions

Agricultural biogas plants undoubtedly deserve a distinction because they operate in rural areas based on a circular economy with the participation of numerous stakeholders. Despite the fact that agricultural biogas plants have been operating in Poland for over 17 years, barriers to the development of agricultural biogas plants in Poland remain unchanged, and the awareness of the positive impact of agricultural biogas plants on many levels is still very low.

The survey results indicated that most respondents pointed to external, systemic and developmental obstacles. The highest percentage of responses concerned the lack of stable legal regulations in renewable energy sources, including biogas plants, and the lack of financing programs for constructing agricultural biogas plants. In addition, an important issue related to the definition of digestate and problems with obtaining connection conditions to the power grid. Apart from the lack of stability of the law on renewable energy sources, the most important barriers among the respondents indicated high investment expenditures, proper operation of biogas plants and high operating costs. This theme also appeared in elements that could improve the development of agricultural biogas plants in the future. The respondents considered it very important to update and guarantee the profitability of investments in the situation of significantly higher expenditures, growing costs of business and debt servicing through the reference price, as well as inclusion in the support system of tariffs guaranteeing a stable income for at least 15 years. In addition, among the important factors, the respondents pointed to the introduction of facilitations in the purchase of land with an area of more than 1 ha for the construction of a biogas plant and the importance of the competence of administrative bodies and the timeliness of the procedure.

The impact of biogas plants on the local community is also significant through the creation of new and interesting jobs and the development of modern technologies that, thanks to a cogeneration unit, generate heat consumed locally for heating or technological purposes, especially by the agri-food industry. This subject may become of future research because it is worth remembering that this way of operating makes biogas plants favour local entrepreneurship not only in the field of energy biomass production but, above all, in the field of agrotechnical and technical services and favour new ventures based on constant access to energy, especially thermal energy (dryers, greenhouses, distilleries, farms).

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Conception – AMK (50%) and AB (50%); literature review – AMK (50%) and AB (50%); acquisition of data – AMK (50%) and AB (50%); analysis and interpretation of data – AMK (50%) and AB (50%); writing – original draft AMK (50%) and AB (50%); writing – review & editing – AMK (33%), AB (33%), AS (33%). The authors have read and agreed to the published version of the manuscript.

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CHANGES IN THE POLISH MARKET FOR AGRICULTURAL ORGANIC PRODUCTS

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ABSTRACT: This paper attempts to identify changes in the factors influencing the functioning and evolution of the Polish market for organic agricultural products. It brings together the results of surveys of farmers (carried out in 2011, 2019, and 2021), distributors (carried out in 2019 and 2021), and consumers (carried out in 2009 and 2021). Initially, farmers believed that the greatest opportunities for market development lay in demand factors, including in particular consumer environmental awareness. In 2021, their opinions worsened in this regard, which means that they had difficulties in reaching consumers. Another opportunity that was less popular than before was the EU subsidies. This is due to administrative and bureaucratic burdens, which, along with high production costs and weak links between farmers and distributors, were considered to be the biggest barriers to market development. For distributors, the survey produced similar conclusions. According to consumers, the greatest opportunities for market development result from increasing environmental awareness increased diversity of products and better promotion. The barriers they highlighted include high prices, limited environmental education, lack of adequate state support, and insufficient information about the offer.

KEYWORDS: sustainable agriculture; organic farming; ecological products markets, opportunities and limitations of development

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Introduction

The organic food market is growing rapidly in the European Union (EU). In 2020, the area of organic crops accounted for 9.2% of the total agricultural area, and sales amounted to EUR 44.8 billion (Trávníček et al., 2022). Germany and France recorded the highest organic food sales (EUR 15.0 billion and EUR 12.7 billion respectively). The highest market shares for organic products were achieved in Denmark (13.0%), Austria (11.3%), Luxembourg (9.1%), and Sweden (8.7%) (Willer et al., 2022). The development of organic farming is an important element of the European Green Deal. According to the farm-to-fork strategy, organic food is expected to account for 25% of the EU's cultivated area by 2030 (European Commission, 2020).

In Poland, in the period from accession to the EU in 2004 to 2013, there was a dynamic increase in the number of farms (by 24.8 thousand, i.e. 617% more than in 2004) (Kociszewski & Graczyk, 2021) and the cultivated area (by 587 thousand ha, i.e. 710% more than the baseline). Between 2013 and 2020, there was a decrease in the number of farms (by 24%, i.e. to 19.2 thousand) and in the cultivated area (by 27%, i.e. to 509 thousand ha, which accounts for 3.5% of the total agricultural area). Between 2004 and 2020, the number of operators involved in the preparation of organic agricultural products increased from 55 to 1,104. In 2020, there were 668 organic processors and 218 operators involved in the preparation and packaging of organic products. Other operators were not engaged in organic product activities (Żakowska-Biemans, 2022). The value of sales in Poland is still relatively much lower than in the EU. In 2019, it accounted for EUR 300 million (at gross retail prices). In 2020, there was a 20% increase and the value of sales accounted for a 0.45% share of the total food sales value. This compares to 4% for the EU as a whole (Kociszewski & Graczyk, 2021). The organic food market will grow by 9.4% each year and will reach around EUR 600 million by 2026 (Żakowska-Biemans, 2022).

It is worth determining the factors that influence these processes based on the analysis of the attitudes and expectations of producers and consumers. The aim of this paper is to identify changes in the factors influencing the functioning of the Polish market for organic products of agricultural origin and the factors affecting the future development of the market. The paper brings together 2009, 2011, 2019, and 2021 survey results to show how market development factors changed over time. The survey was conducted in parallel on the supply side (conventional farms, 2011 and 2019; certified organic farms, 2011, 2019, and 2021) and on the demand side (consumers, 2009 and 2021). In 2019 and 2021, the survey was extended to include distributors. The survey gathered the opinions of farmers, distributors, and con-

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sumers on the opportunities for and barriers to the development of the organic food market. The results are checked against selected references from literature and secondary sources. The final part provides recommendations for actions to support further development of sales of organic farming products.

Literature overview

Previous studies concerning the supply side of organic farming mainly focused on the development of production potential in terms of the number and area of farms on a global and macroeconomic scale (Runowski, 2012; Łuczka-Bakuła, 2007) and the interplay of economic (Torres et al., 2016), ecological, and social aspects (Zaher et al., 2016; Tuomisto et al., 2012; MacRae et al., 2007; Seufert et al., 2012). Studies conducted during the impeded development of organic food production mainly focused on the functioning and efficiency of organic farm production (Komorowska, 2013; Brodzińska, 2014; Nachtman, 2015; Gil, 2016). They indicate that there were barriers exacerbating the decreasing level of public support for farm development and the formation of producer groups. Other barriers, as indicated by farmers who acted as producers or considered the conversion of their farms towards organic production, included the difficulties of sale of organic products, weak involvement of state institutions, lack of strong organisations representing the political and economic interests of organic farming actors, the reluctance of farmers to cooperate, and excessive bureaucratic burdens. Furthermore, the production activity is burdened by a significant risk of weather changes and the need to maintain a stable raw material base. The latter entails the need to develop a model of cooperation with suppliers (Żakowska-Biemans et al., 2020). Another weakness of organic farming in Poland is the problem with the transfer of knowledge to agricultural practice, including the lack of a sufficient number of advisors specialising in organic farming (Sołtysiak, 2021).

Organic food processing was hardly examined in Poland and other countries in terms of market environment except for several studies (Łuczka, 2016a; Smoluk-Sikorska et al., 2017). The weak point of the organic food market was the relationship with market participants, suppliers, and customers. The number of organic food processing enterprises was insufficient in relation to the number of organic farms, and their production structure was unfavourable in terms of demand. The supply was dominated by cereal products as well as fruit and vegetable products, while consumers were largely interested in dairy and meat (Łuczka, 2016b). Another barrier was the unfavourable production structure in organic farms, including the low

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share of farms with animals in the organic farming system, adversely affecting the sustainability of production (Sołtysiak, 2021).

Producers and processors declared their willingness to cooperate and the need to organise local and regional distribution channels, but the cooperation was limited in practice. There was also a lack of adequate communication between the food processing sector and producers. In this respect, barriers to the development of the organic food market included the lack of market organisation, the lack of cooperation at the producer, processor, and trade levels, and the lack of trust in partners. The development of the Polish market for organic food is hampered by disproportionately high prices of final products in relation to the prices of agricultural products resulting from low supply and high margins charged by intermediaries (Grzybowska-Brzezińska & Gorlowa, 2019). Average margins are 40% in specialist and grocery shops and 20% in retail networks (Smoluk-Sikorska, 2017).

The distribution of organic food in Poland has a number of weaknesses due to low and irregular supplies and the dispersion of producers and intermediaries. The main distribution channel was sales to small retail outlets, followed by wholesale. More than half of the processors surveyed sold their products abroad, but these were low-processed products (Smoluk-Sikorska, 2019). There are at least 850 shops specialising in the sale of organic food, with an average sales area of 60 m^2 (Żakowska-Biemans, 2022). Sales of organic processed food and fresh produce are expanding, but the supply of fresh domestic produce, especially seasonal fruit and vegetables, does not fully meet demand. As a result, these products are imported from other EU member states and third countries. In 2020, there was a 23.2% increase in imports compared to 2019 (Żakowska-Biemans, 2022). From the point of view of the development of domestic production by Polish producers and processors, this is an unfavourable process. On the other hand, the development of organic food sales in large-format shops and discount shops increases consumer interest in organic food. The development of the distribution of organic food via online shops is also accelerating, especially in the era of the COVID-19 pandemic. Smaller producers sell their products directly at local fairs, bazaars, and marketplaces. Developing direct sales and shortening supply chains is one of the key priorities of national rural and agricultural development policy (Żakowska-Biemans, 2022).

Most of the weaknesses in the development of Polish organic farming correspond with those identified in the Framework Action Plan for Organic Food and Farming in Poland for 2021–2027 (Ministerstwo Rolnictwa i Rozwoju Wsi, 2021). The plan also draws attention to the low interest of farmers in carrying out organic livestock production due to, among others, the low supply of organic reproductive material and the lack of development of its production.

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In presenting the literature review on the market for organic agricultural products, reference should also be made to the results of research on the demand side and consumer behaviour in the market. Research has sought to identify various factors influencing organic food purchase intention and consumption using value theory and rational choice theory (Knowledge-Attitude-Behaviour Model, Theory of Reasoned Action, Theory of Plan Behaviour) and ethical and normative models (Norm Activation Model, Value-Beliefs-Norm Model). Studies have examined various factors of consumer behaviour in the market for organic agricultural products, including individual factors (demographic variables, life values, environmental and health concerns, animal welfare, ethical beliefs, attitudes, and lifestyles) and socio-cultural factors that affect individual factors (social norms, media influence, cultural values) (Golob et al., 2018; Pham et al., 2019; Nosi et al., 2020; Katt & Meixner, 2020).

Another area of research to date identifies factors limiting the consumption of organic agricultural products, such as price and financial barriers, distrust of organic certification and labelling, habits (buying conventional food products), unavailability of products, and insufficient differentiation (Hughner et al., 2007; Kushwah et al., 2019; Bryła, 2016; Van Doorn & Verhoef, 2015). The barriers to market development also involve mental and marketing barriers (Grzybowska-Brzezińska, 2013), including the little extent to which organic market players benefit from the experience of companies implementing modern marketing concepts (Pilarczyk & Nestorowicz, 2010).

In this case, price is affected by the transition from the post-Engel phase (Engel's law no longer applies as the increase in income does not affect the level of expenditure on food) to a phase with a relative increase in expenditure on food under conditions of increased income. This is due to an increase in expenditure on organic food, which is relatively more expensive than non-certified organic food (Kieżel, 2010).

The literature also emphasises the role of environmental awareness as a key factor motivating consumers to behave in an environmentally friendly manner. Environmental awareness is shaped in a complex process influenced by factors of different natures, such as social norms, state regulations, and market communication channels (Poskrobko, 2007; Nycz-Wróbel, 2012). A higher level of environmental awareness translates into greater involvement in the purchase of organic products.

On the other hand, although consumers often express positive attitudes towards sustainability and organic products and feel concerned about the state of the environment, this does not always translate into their purchasing behaviour (Bray et al., 2011). This is evidenced by research findings on consumer behaviour from various countries, including the UK, Belgium, and

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Sweden (Tanner & Kast, 2003; Vermeir & Verbeke, 2008; Vermeir & Verbeke, 2006; Hughner et al., 2007). This shows that consumers sometimes exhibit “contradictory behaviour in green purchasing;” there is a gap between positive attitudes towards the environment and ecology and the actual behaviour in purchasing organic products.

Furthermore, with regard to the state of research on food, including organic food, the hierarchy of life values is incompatible with the food attributes valued by consumers and their behaviour. Although consumers see health as the overriding value in their lives, they often seek mainly pleasure in food consumption. This reflects the conflict between incommensurable value scales in relation to food (Gutkowska, 2007).

Equally importantly, the literature indicates that the impact and importance of the drivers and barriers to the consumption of organic farm products vary depending on the category of farm product and the level of socio-economic development of the country (Nguyen et al., 2021).

The demand side and the supply side of the market are usually considered separately; there are no studies presenting the dependencies and relations between them concerning the mechanisms of market functioning in light of the supply chain. The current state of research defined above indicates a research gap in analysing the perspectives (opportunities and barriers) of market development based on the connections between the links in the value chain and the challenges resulting from the contemporary policy of the European Union and changes in the global food market. Therefore, the drivers and barriers to demand and supply growth, as well as relations between farmers, distribution areas, and consumer expectations towards organic products, should be investigated. Furthermore, an attempt should be made to determine how to reduce these barriers and strengthen these drivers so as to contribute to increasing the degree of utilisation of the domestic agricultural production potential. The research problem that needs to be addressed is what changes have taken place in the development of the Polish organic food market on the demand and supply side in terms of its opportunities and barriers. The aim of this paper is to identify changes in the factors influencing the functioning and development of the Polish market of organic products of agricultural origin.

Research methods

Supply-side surveys were conducted in three stages (in 2011, 2019, and 2021) by specialised external companies using CATI and CAWI methods based on questionnaires prepared by the project authors. The selected nationally representative sample of farmers reflects the area structure of organic and conventional farmers and the distribution of the number of farms between voivodships. In 2011, the size of the survey sample was 420 farms (n = 420) with an agricultural area of more than 1 ha, including 350 conventional farms (n = 350) and 70 organic farms certified for organic farming (n = 70). In 2019, the total sample size was n = 325, including farmers using organic farming methods (n = 65) and farmers officially not using organic farming methods (n = 260). The 2021 survey was carried out only among farmers certified for organic production (N = 120). The distributor survey was conducted in 2019 with a sample of 75 organic distributors. In 2021, the sample size in this group was 120 (N = 120).

Demand-side survey sample sizes were as follows: 1,002 respondents in 2009 (including 300 consumers who purchase certified organic products and 702 respondents who do not) and 1032 respondents in 2021 (including 509 respondents who purchased an organic product in the last 3 months and 523 respondents who did not).

As the individual groups of respondents in supply-side surveys were defined differently and the individual responses were obtained in a different manner, the responses were aggregated where possible. The responses were obtained from conventional and organic farmers using a nominal scale (in 2011 and 2019) and from organic farmers using an ordinal scale (in 2021). For the purposes of this study (to compare the results from the three years), the responses in the latter group were converted from an ordinal scale to a nominal scale. These responses, as well as the responses obtained from conventional farmers in 2011 and 2019, were analysed based on the frequency of responses. The factor analysis was only applied to the 2021 survey of organic farmers and to the 2019 and 2021 survey of distributors allowing a comparison between 2019 and 2021 in the latter group. The aim of the factor analysis was to determine the structure of the latent factors (opportunities and barriers to the development of the market for organic agricultural products).

On the demand side, material collected in consumer surveys from 2009 and 2021 was used to analyse what are the drivers and barriers to the development of demand for organic agricultural products. The analysis of the frequency of responses (for the 2009 data) and the exploratory factor analysis (for the 2021 data) was used separately for opportunities and barriers.

The exploratory factor analysis was used to identify the latent factor structure of opportunities and main barriers to the development of organic production according to supply-side actors. The responses regarding opportunities and barriers to development varied in the surveys of organic distributors and farmers in 2019 and 2021 (different factors and different numbers of factors were used). Therefore, the factor analysis was carried out separately for opportunities and barriers and for the responses obtained from

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farmers and distributors in 2019 and 2021. The factors (opportunities and barriers) were assessed by the respondents on a 7-point scale (1 – very insignificant, 7 – very significant). The same scale can be used to compare the average assessments of the respondents. The validity of the use of the factor analysis is each time evidenced by (i) a high value of the Kaiser-Meyer-Olsen test (with KMO usually exceeding 0.7), proving the that the correlation matrix is adequate to the assumptions of the factor analysis, and (ii) a statistically significant result of the Bartlett's Test of Sphericity (), confirming that the correlation matrix as a whole contains significant correlation coefficients. The exploratory factor analysis was performed using the principal component analysis with Varimax rotation (with Kaiser normalisation). The Varimax rotation minimises the number of variables used to explain the common factor. The scree plot criterion was used to determine the number of components and explain at least 70% of the common variance. Four components were usually extracted (three in one case). The extracted common factors together explain between 71.4% and 78.9% of the variance, which should be considered quite high. All factors (opportunities and barriers) were included in the dimensional reduction procedure. The variables for which the Wilcoxon signed-rank test confirmed the significance of the barrier and the mean significance score was greater than 4 were only included in the 2021 responses of organic farmers and distributors regarding barriers. The reliability and high consistency of the scale used, with the number of variables defined in this way, is evidenced each time by a high value of Cronbach's alpha statistics (higher than 0.75).

The demand side of the organic food products market was analysed in a similar way. Again, the factors (opportunities and barriers) were assessed by the respondents on a 7-point scale (1 – very insignificant, 7 – very significant). The exploratory factor analysis was performed using the principal component analysis with Varimax rotation (with Kaiser normalisation). The Varimax rotation minimises the number of variables used to explain the common factor. The scree plot criterion was used to determine the number of components and explain at least 70% of the common variance. Three or four components were extracted. The extracted common factors together explain more than 75% of the variance, which should be considered high. All factors (opportunities and barriers) were included in the dimensional reduction procedure. In each case, the Wilcoxon signed-rank test confirmed the significance of the opportunity and the barrier, and the mean significance scores were greater than 4.6. The reliability and high consistency of the scale used, with the number of variables defined in this way, is evidenced each time by a very high value of Cronbach's alpha statistics (higher than 0.9). The values of Cronbach's alpha after removing individual questions are not higher than the

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statistics calculated for the initial number of variables together, which means that there are no grounds for reducing the set of factors in the analysis.

Opportunities for the development of organic production according to farmers

In the opinion of farmers (both conventional and organic), in both 2011 and 2019 survey, the opportunity for the development of organic production lies in the growing environmental awareness of consumers, which is the most frequent response (19.7% and 22.1% of responses in 2011 and 2019 respectively). EU subsidies (18.1% and 14.8%) and growing demand (15.4% and 15.9%) are the second and third most frequent responses (Figure 1). Organic farmers also indicated the growing environmental awareness of consumers, followed by the growing demand and the popularity of ecological consumption patterns (in 2019 and 2021). In organic farms, these responses were more frequent than in conventional farms. In conventional farms, the popularity of ecological consumption patterns was in decline in the next years (7.8% of responses in 2019 compared to 15.0% in 2011). Organic farmers were least likely to indicate a favourable policy of Polish authorities (16.4% of responses in 2011 and 5.4% in 2019). In 2021, this improved (an increase to 16.0%) but was still one of the less frequent responses.

The exploratory factor analysis using the principal component analysis with Varimax rotation was applied to the survey of organic farmers from 2021, identifying three components regarding the opportunities for the development of production and increased sales in Polish organic farming from the perspective of farmers in 2021. The first common factor is a leading factor explaining 35.6% of the common variance.

It takes into account six variables (opportunities) with high factor loadings indicating a rather strong association with the common factor, i.e. increased cooperation between organic distributors (0.848), increased cooperation between organic distributors and farmers (0.821), increased cooperation between farmers (0.767), the relevant policy of Polish state institutions supporting organic farms (0.755), EU subsidies (0.712), and implementation of innovation by Polish agri-food companies producing organic products (0.650). This component determines the conditions for good functioning and cooperation of agricultural producers as well as support from micro and macro environment entities, shaping the institutional dimension of the development of organic agriculture.

The second common factor explains 23.3% of the common variance and is strongly associated with three variables, i.e. the growing demand for organic products (0.882), the growing environmental awareness of consum-

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ers (0.849), and the popularity of ecological consumption patterns (0.746). It reflects environmentally friendly consumer behaviour. The third component (13.8% of the variance) is formed by two factors: lower quality of conventional food compared to organic food (0.896) and better distribution (0.637). Due to the very high first factor loading, the component identifies the quality of organic food.

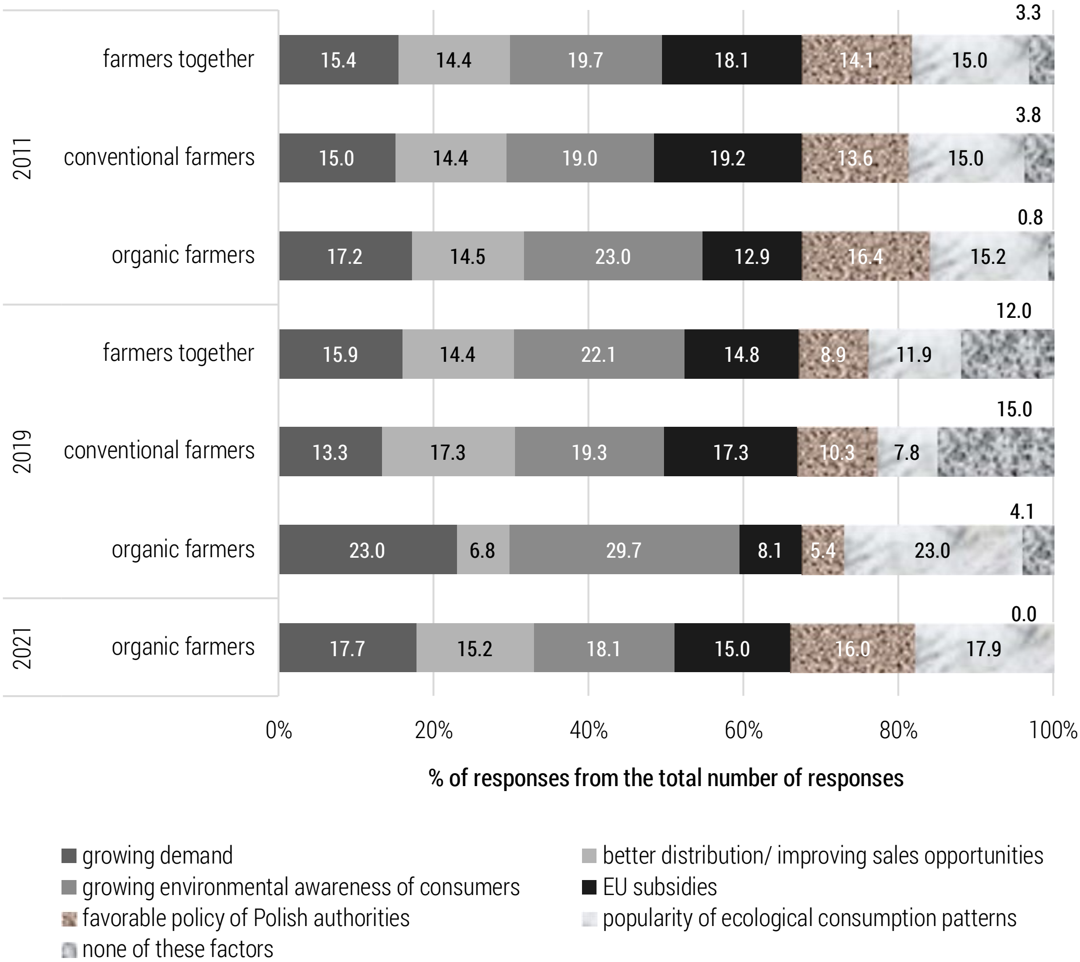

Figure 1. Opportunities for the development of organic production in 2011, 2019, and 2021. Distribution of farmers' responses

Opportunities for market development according to distributors

In 2019, in the opinion of distributors, the greatest opportunities for the development of sales of organic farming products in Poland lay in the growing environmental awareness of consumers (mean score of 5.88), the growing demand (5.79), and the increased diversity of organic farming products (5.37).

Table 1. Factor loadings of components[1] were obtained using the principal component analysis with Varimax rotation with Kaiser normalisation. Opportunities for the development of sales of organic farming products according to distributors in 2019 and 2021

Factor	Sales development opportunities 2019	Loading	Factor	Sales development opportunities 2021	Loading
1	Increased cooperation between organic distributors	0.830	1	Growing demand for organic products	0.868
	Increased competition between organic distributors	0.778		Popularity of ecological consumption patterns	0.833
	Increased competition between farmers	0.770		Growing environmental awareness of consumers	0.828
	Increased cooperation between farmers	0.530			
2	Growing demand	0.842	2	EU subsidies	0.851
	Increased diversity of organic farming products	0.731		Relevant policy of Polish state institutions	0.749
	Increasing environmental awareness of consumers	0.618		Implementation of innovation by Polish agri-food companies producing organic products	0.600
3	EU subsidies	0.868	3	Better distribution	0.826
				Increased cooperation between farmers	0.652
	Relevant state policy	0.839		Increased cooperation between organic distributors and farmers	0.639
4	Better promotion	0.895	4	Lower quality of conventional food compared to organic food	0.876
	Better distribution	0.805			

Notes: [1] The rotation reached convergence in 6 iterations (2019) and 8 iterations (2021).
Source: own calculations in IBM SPSS Statistics 28.0.

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In 2021, the first two factors were still popular, although slightly less compared to the 2019 survey (5.75 and 5.53 respectively). Another highly rated factor is the popularity of ecological consumption patterns (5.34).

The results of the exploratory factor analysis for the development opportunities according to organic distributors are presented in Table 1. Four common factors were extracted in 2019. The first component is loaded by four variables (the factor loadings of three of them are high). This factor covers 21.1% of the common variance. This component determines the conditions for the functioning of distributors and farmers on the market. The second component (explaining 17.3% of the variance) is loaded by three variables (the factor loadings of two of them are high). It reflects environmentally friendly consumer behaviour. The third component is formed by two factors (EU subsidies and relevant state policy). It explains 16.8% of the common variance and determines external financial and legal support. The fourth component concerns access to organic food. It is formed by two factors (better promotion and better access). Their high loadings prove a strong association with the component. This factor is equivalent to the third component in terms of explaining common variance (16.3%). In 2021, four components were also extracted.

The first component is made up of three variables with high factor loadings and explains 25.5% of the variance. It reflects environmentally friendly consumer behaviour. The second component is loaded by three factors (the factor loadings of two of them are high, explaining 23.9% of the variance). It determines external legal and financial support. The third component explains 18.7% of the variance. It is formed by three factors, of which “better distribution” is the most strongly correlated with the component. It determines the conditions for the functioning of distributors and farmers on the market. The fourth component identifies the quality of organic products. It takes into account only one factor with a high loading (0.876, explaining 10.8% of the common variance). Note that similar common factors were obtained in the subsequent research periods despite different opportunity specifications. Two of them (environmentally friendly consumer behaviour and financial and legal support) became more important as sales development opportunities over time.

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Opportunities for the development of organic production according to consumers

Table 2. Factor loadings of components[1] obtained using the principal component analysis with Varimax rotation with Kaiser normalisation. Opportunities for the development of sales of organic farming products according to consumers in 2021 (N = 1032)

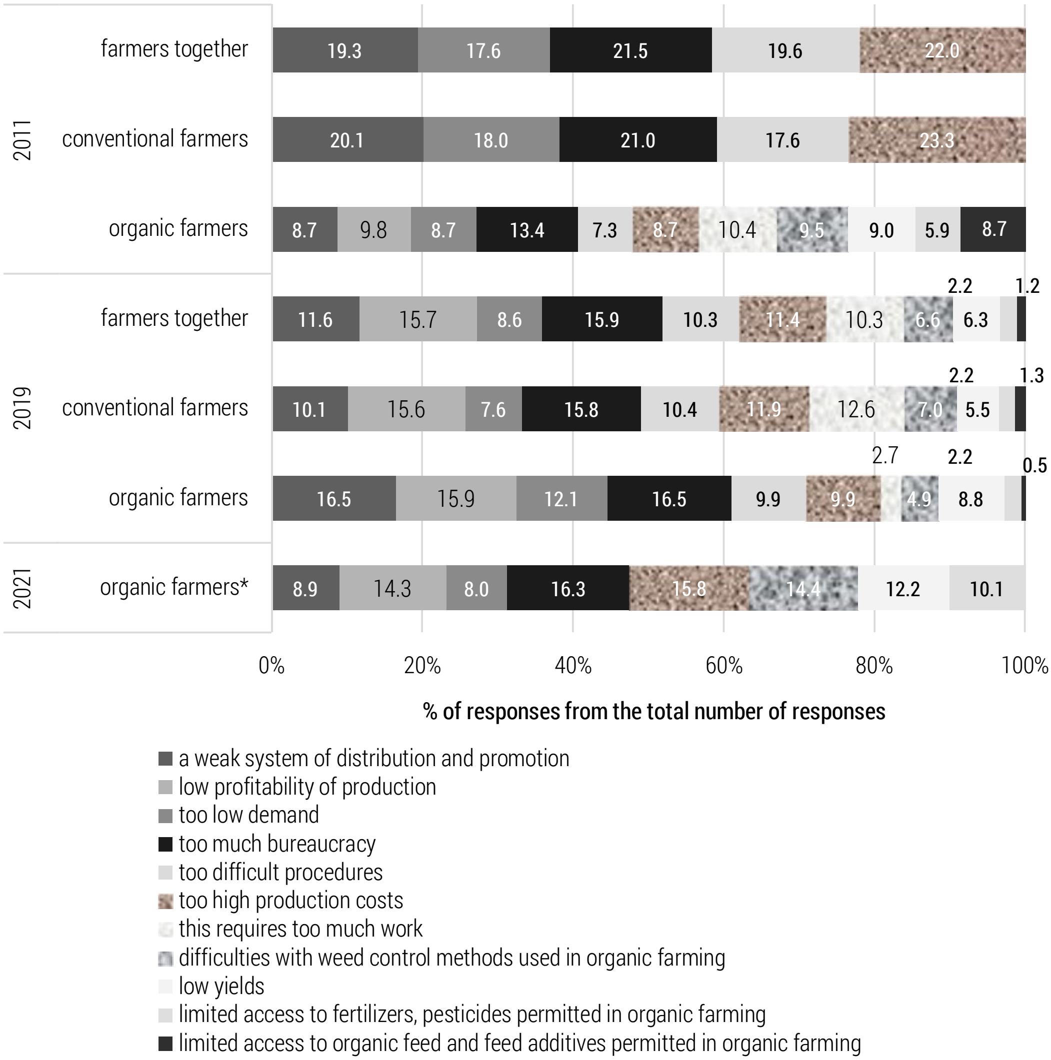
Factor	Opportunity	Loading
1	Growing demand for organic products	0.798
	Better distribution	0.746
	Growing environmental awareness of consumers	0.739
	Increased diversity of organic products	0.715
	Better promotion	0.683
	Increased cooperation between organic producers	0.666
	Increased cooperation between organic distributors	0.661
2	Increased competition between organic producers	0.858
	Increased competition between organic distributors	0.804
3	EU subsidies	0.808
	Relevant state policy	0.750

Notes: [1] The rotation reached convergence in 6 iterations.
Source: own calculations using IBM SPSS Statistics 28.0.

The analysis of the consumer opinions expressed in 2021 shows that consumers see the greatest opportunities for the development of sales of organic farming products in Poland in growing environmental awareness (mean score of 5.17), increased diversity of organic products (5.14), better promotion (5.11), and growing demand for organic products (5.06). The results of the exploratory factor analysis for the opportunities for the development of sales of organic products according to consumers are presented in Table 2. Three common factors were extracted. The first component is loaded by six variables (the factor loadings of four of them are high, exceeding 0.7). This common factor is a leading factor covering 37.1% of the common variance. This component expresses environmentally friendly consumer behaviour related to better availability and promotion as well as cooperation between producers and organic distributors. The second component (explaining 20.6% of the variance) is loaded by two variables with high factor loadings. This component refers to the increased competition between producers and between distributors. The third component is formed by two factors (EU subsidies and relevant state policy). It explains 17.9% of the common variance and determines external financial and legal support.

Barriers to the development of organic production according to farmers

As the lists of obstacles presented to respondents were different in the subsequent surveys, the possibilities to compare the results in the subsequent years are limited.



Notes: * Barriers from the 2019 survey are included.

Figure 2. Barriers to the development of organic production in 2011, 2019, and 2021 – distribution of farmers' responses

In the opinion of all surveyed farmers, excessive bureaucracy (too much bureaucracy) and the weak system of distribution and promotion are key factors that make organic farming difficult (Figure 2). They were indicated in 2011 more frequently than in 2019 by all groups of farmers. In the subsequent years, the increasingly significant barriers for organic farmers included excessively high production costs, low yields, low agricultural profitability ("low profitability of production"), and a poor distribution system. These barriers were indicated more frequently in 2019 than in 2011 and less frequently in 2021 than in 2019. In the subsequent years, excessive labour input ("this requires too much work") and limited access to organic feed and feed additives permitted in organic farming were factors less frequently regarded as a difficulty.

The exploratory factor analysis allowed the identification of four components of barriers to the development of production and increased sales in Polish organic farming from the perspective of organic farmers in 2021. Three common factors have a similar percentage of variance explanation (21.6%, 19.4%, and 18.1%), while the fourth component explains 15.2% of the common variance. The first component is loaded by four factors, i.e. low yields (0.800), difficulties in applying organic farming methods (0.781), excessively high costs of organic production (0.613), and low agricultural profitability (0.589).

It identifies a barrier resulting from the specific character of organic farming. The second common factor is linked to bureaucratic and administrative difficulties (0.846) and the lack of state support (0.776). It relates to organisational and legal barriers. The third component contains two factors: an insufficient number of processing facilities (0.783) and excessively low prices of agricultural produce (0.705). It defines the barriers to organic food processing. The last component loads two factors: an inclination towards conventionally produced food (0.799) and low consumer awareness (0.737). It identifies barriers resulting from conventional consumer attitudes.

Barriers to market development, according to distributors

In 2019, in the opinion of distributors, the most significant barriers to the sales of organic products included the high price of organic products (mean score of 5.68), customers' inclination towards conventionally produced food (4.63) and the lack of adequate support from the state (4.41). In 2021, the most significant sales barriers included excessively high costs of organic production (mean score 5.02), bureaucratic and administrative difficulties for organic farms (5.00) and the lack of adequate state support for organic farming (4.90). The results of the exploratory factor analysis for barriers to development according to organic distributors are presented in Table 3.

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Table 3. Factor loadings of components[1] were obtained using the principal component analysis with Varimax rotation with Kaiser normalisation. Barriers to sales of organic farming products, according to distributors in 2019 and 2021

Factor	Barriers to the sales of organic farming products 2019	Loading	Factor	Barriers to the production development and increased sales 2021	Loading
1	Insufficient consumer awareness of environmental issues	0.859	1	Bureaucratic and administrative difficulties faced by organic farms	0.878
	Customer inclination towards conventionally produced food	0.711		Lack of adequate state support for organic farming	0.731
	Underdeveloped distribution network	0.648			
2	Low awareness of organic farming certification	0.833	2	Difficulties in applying organic farming methods on farms	0.871
	Insufficient information about the offer	0.785		Excessively high costs of organic production	0.795
3	Lack of adequate state support	0.870	3	Little opportunity to sell organic products (too little demand)	0.844
	Lack of confidence in the ability to solve global environmental issues	0.747		Low profitability of organic farming	0.682
4	Unavailability of some products	0.875	4	Excessive high prices of organic food making consumers discouraged	0.867
	High prices of organic products	0.621		Insufficient environmental awareness of consumers	0.668
				Customer inclination towards conventionally produced food	0.517

Notes: [1] The rotation reached convergence in 6 iterations (2019) and 5 iterations (2021).
Source: own calculations in IBM SPSS Statistics 28.0.

The four components extracted in 2019 explain, respectively: 23.0%, 17.6%, 16.6%, and 14.2% of the common variance. The first common factor is formed by the following: insufficient consumer awareness of environmental issues, inclination towards conventionally produced food, and an underdeveloped distribution network. These factors determine consumer awareness and attitudes towards environmental issues. The second component, comprising two factors with high loadings, identifies (insufficient) knowledge and information regarding organic agricultural products. The third common factor describes the difficulties in obtaining external financial aid as

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well as organisational and legal support for environmental activities. The fourth component, loading two factors (one with a high loading), identifies access to organic products.

In 2021, the shares of variance of the four components were similar: 18.7%, 18.5%, 18.5%, and 17.7%. The first common factor comprises bureaucratic and administrative difficulties (0.878) and the lack of state support (0.731). It relates to organisational and legal barriers.

The second component is loaded by the following: difficulties in applying organic farming methods and high production costs. It identifies a barrier resulting from the specific character of organic farming. The third common factor takes into account two variables, one of which (too little demand) has a strong correlation with the component. It is referred to as the demand income factor. The fourth component, loading three factors (with "excessively high prices of organic food" having a high loading), reflects traditional consumer attitudes.

Barriers to the development of organic production according to consumers

The 2021 survey of consumers regarding barriers to the development of the sales of organic farming products reveals that the main barriers include the high price (mean score of 5.52), insufficient consumer awareness of environmental matters (4.86), the lack of adequate state support (4.80), insufficient information about the offer (4.78), and unavailability of some products (4.76). The results of the exploratory factor analysis regarding barriers to the development of sales of organic products (Table 4) show that the first common factor (formed by four variables) is the leading factor for explaining the common variance (27.0%). It determines barriers to the availability of organic products. The second component, comprising two factors (21.3% of the variance), describes the difficulties in obtaining external organisational and legal support. The third common factor, related to the two variables, reflects barriers resulting from the underestimation of the role of environmental matters. It explains 17.1% of the variance.

The fourth component, identifying the price barriers to organic products, takes into account one variable with a high loading (0.846). It explains 12.5% of the common variance.

The 2009 consumer survey regarding barriers to the development of sales of organic products revealed three barriers: high price (26%), habits and customs (18%), and poor distribution network (14%) (Figure 3).

Table 4. Factor loadings of components[1] were obtained using the principal component analysis with Varimax rotation with Kaiser normalisation. Barriers to the development of sales of organic farming products according to consumers in 2021 (N = 1032)

Factor	Barrier	Loading
1	Unavailability of some products	0.782
	Insufficient information about the offer	0.689
	Underdeveloped distribution network	0.620
	Low awareness of certification	0.604
2	Lack of adequate state support	0.828
	Insufficient consumer awareness of environmental issues	0.671
3	Lack of confidence in the ability to solve global environmental issues	0.832
	Customer inclination towards conventionally produced goods	0.604
4	High prices of products	0.846

Notes: [1] The rotation reached convergence in 9 iterations.
Source: own calculations using IBM SPSS Statistics 28.0.

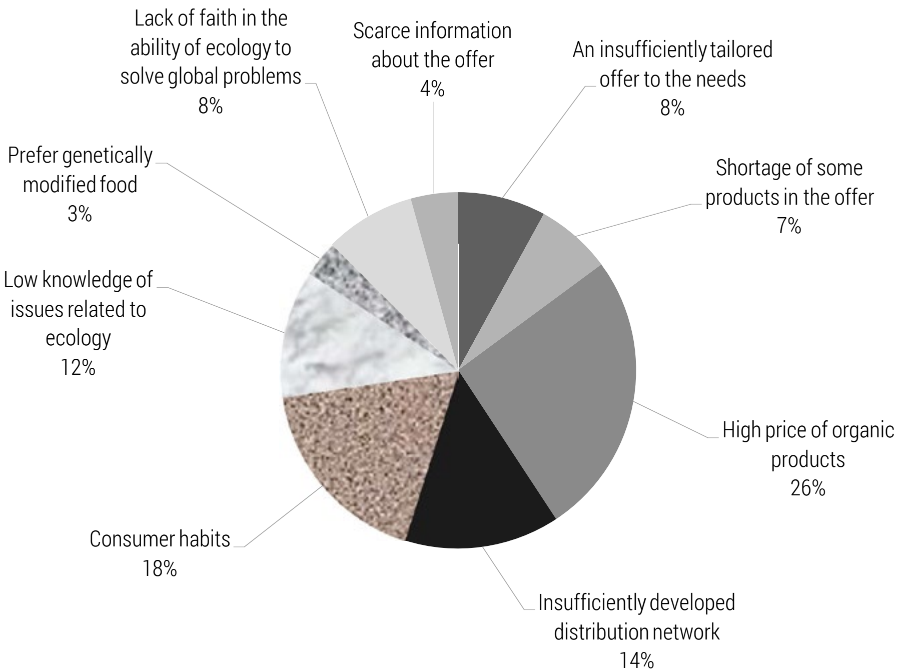

Figure 3. Barriers to organic food purchases in 2009 – distribution of consumer responses.
Source: own calculations in IBM SPSS Statistics 28.0.

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Discussion and conclusions

The results of farmer surveys show that the factor considered to be the greatest opportunity for market development ("environmental awareness of consumers") gained importance between 2011 and 2019. This factor has also become more popular among organic farmers over time. Organic farmers considered it the greatest opportunity for development in all three survey stages. In 2021 and 2019, they tended to choose this response more frequently than in 2011 (however, in 2021, the percentage was slightly lower than in 2019). Between 2011 and 2019, growing demand and environmentally friendly consumer behaviour were factors becoming more popular among organic farmers. These factors were ranked second and third in terms of the frequency of responses. However, in 2021, fewer respondents (by more than 5 percentage points) recognised them as opportunities. This may indicate that farmers find it more difficult than before to reach end customers. EU subsidies are also in decline due to the way Polish organisations involved in paying subsidies operate. In 2011, 16.4% of organic farmers identified friendly state policy as an opportunity for development, which was the third most frequently chosen factor. In 2019, this factor was in last place (5.4%)[1]. This decline may indicate the negative impact of the agricultural policy of Polish institutions on the development of organic farming. The incoherent and chaotic policy was one of the key reasons for the decline in the number of organic farms and acreage since 2013, as presented in the introduction (Kociszewski, 2022). This is also confirmed by the report of the Supreme Chamber of Control (NIK, 2019). According to the survey results, in 2021, significantly more farmers, compared to 2019, indicated the state policy as an opportunity for development (Figure 1). This may mean that farmers who have not abandoned organic production have had to adapt to the functioning of the subsidy system in recent years, which may have affected their opinion.

The results of the factor analysis based on the 2021 organic farmer survey (Table 1) shows that the institutional dimension of the development of organic farming (35.6% of the common variance) is the key component of development opportunities out of the three identified. This mainly refers to the cooperation between actors involved in the organic food market (both among farmers and between farmers and distributors). The variables associated with this cooperation had high factor loadings indicating a strong association with the common factor. "Relevant policy of Polish state institutions supporting organic farms" and "EU subsidies" had lower factor loadings,

[1] In the section containing part of the 2019 organic farmer survey results (Kociszewski, 2022), the percentages were higher due to the use of a different point of reference for calculation (i.e. the number of respondents and not the number of total responses).

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implying a weaker association. The second component extracted regarding development opportunities reflects environmentally friendly consumer behaviour. The survey results (23.3% of the common variance) show that organic farmers find it less important for the development of this segment than institutional aspects (35.6%). They correspond well with the previously discussed decline in the assessment of environmentally friendly consumer behaviour in relation to 2019. The results may be due to a limited flow of demand impulses from consumers to farmers. Consumers buy increasingly more organic food, but much of it is imported. This is also related to the result obtained for the third component, i.e. organic food quality (13.8% of the variance). Of all three components, it is least important for market development. "Better distribution" is one of the variables of this component (0.637). It does not provide an effective link between the supply of Polish organic agricultural produce and the final consumer so far.

According to the 2019 and 2021 distributor surveys, the biggest opportunities for the development of organic farming lie in demand factors related to environmentally friendly consumer attitudes. These factors (as variables) load the component "environmentally friendly consumer behaviour" in the factor analysis (Table 1). The importance of these factors as development opportunities increased in 2021 compared to 2019. The assessment of factors related to the relationships between actors involved in the links of the organic food supply chain (including between distributors and farmers) declined – the component "conditions for the functioning of distributors and farmers on the market" (21.1% of the common variance in 2019 and 18.7% in 2021). Vendors perceive a growing demand for organic food, but, as previously indicated, they meet the demand to a limited extent using final goods from Polish agricultural produce. One of the reasons for this is the weakness of relationships between key actors in the organic food supply chain.

In the opinion of all farmers, the key obstacle to the development of organic farming is bureaucratic difficulties (Figure 2). This confirms the negative impact of the way Polish organisations associated with farm support policies operate, as previously demonstrated. The literature also addresses these aspects (Komorowska, 2013; Brodzińska, 2014; Nachtman, 2015; Gil, 2016). The importance of these factors increased between 2011 and 2019. Weak distribution and promotion system is the second barrier. This corresponds with the unfavourable assessment of relationships between farmers and vendors as a development opportunity. This is also evident from the opinions of organic farmers. Again, there is a correspondence with the findings of other authors (Łuczka, 2016a; Smoluk-Sikorska et al., 2017). Factors limiting the profitability of production (excessively high production costs and low yields) were also considered increasingly significant barriers by organic farmers. This may lead to the conclusion that it would be advisable to

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increase the compensating subsidy rates for organic farms. The policy of Polish organisations involved in the distribution of payments to farms should also be sorted out and stabilised. The policy should shape a predictable support framework allowing for medium to long-term planning of organic product development. Organic farmers considered traditional consumer attitudes as the least important barrier to development. This corresponds with the results for environmental awareness of opportunities for market development and environmentally friendly consumer attitudes.

The results of the survey of organic food distributors for obstacles to market development show that they perceive legal and organisational constraints related to the domestic agricultural policy as an increasing difficulty and see consumer attitudes related to consumer inclination towards conventionally produced food as a lower barrier. High prices and the associated high costs of production are still strong barriers. However, note that some authors conclude that the factor that hinders the development of the market is the high margins charged by intermediaries (Grzybowska-Brzezińska & Gorlowa, 2019; Smoluk-Sikorska, 2017).

There is correspondence between distributors and farmers as regards changes in their assessments of barriers. Similar conclusions can be drawn from the factor analysis. The 2019 results show that consumer awareness and attitudes towards environmental issues (23.0% of the common variance) and insufficient knowledge and information on organic agricultural products (17.6%) were key barriers to development; out of the four components identified the component defining external financial as well as organisational and legal support for organic activities and access to organic products was slightly less significant (16.6% and 14.2% respectively). In 2021, legal and organisational constraints, a factor associated with the policy of state organisations, proved to be the most significant barrier (18.7%). Distributors regarded barriers arising from the specific character of organic farming, including high costs of production, as more important than in the previous survey (18.5%). Demand aspects related to consumer attitudes lost importance as a barrier to market development (third and fourth components, 18.5% and 17.7%, respectively). However, note that different specifications and types of barriers to development led to different common factors (different types and structures of common factors). The product knowledge factor, identified in 2019, had no counterpart in 2021, and the demand-income factor, identified in 2021, had no similar counterpart in 2019. The high price factor (high prices of organic products in 2019, excessively high prices of organic food products in 2021) reflected access to organic products in 2019 and traditional consumer attitudes in 2021.

To summarise the analysis of the demand side of the market, the factors that allow a greater correspondence between consumer-declared attitudes

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towards organic food and their purchasing behaviour on the organic food market should be emphasised, i.e. knowledge and environmental orientation of consumers. Significant interaction effects between these factors are also evident. This means that consumers with an environmental orientation will tend to express more consistent attitudes and purchase behaviour if they know more about organic food, as opposed to consumers with a health or hedonic orientation (Hidalgo-Baz et al., 2017).

Therefore, efforts are needed to raise public awareness of organic food through various forms of education provided by organic food industry companies and associations and governmental actors. In particular, the relevant knowledge should be actively distributed and popularised using all communication channels, especially via the Internet and social media, as well as television, newspapers, and other media channels. Adapting the messages to the channels used and customer segment facilitates the promotion and public understanding of the advantages of organic food over conventional food.

Furthermore, in order to encourage consumers to choose organic products, companies should communicate with consumers by demonstrating more clearly utilitarian and hedonic benefits from the products and, more importantly, core ethical values. Consumer confidence in organic products should also be increased. This requires not only the dissemination of knowledge on food safety but also more exposed organic labels and high-quality food labels. Greater recognition of the labels will translate into more frequently chosen organic food and increased purchasing.

Therefore, companies that want to differentiate their offerings and achieve a competitive advantage based on their organic products must invest in certifications, environmentally friendly technologies and packaging, clear product labels, and credible spokespeople. Furthermore, they should take care to provide consistent messages about their commitment to sustainability (Connelly et al., 2011). The image of an organic food company also plays an important role in shaping consumer behaviour. Research shows that an image based on corporate social responsibility principles has a positive impact on consumer behaviour, particularly in the organic food market (Weiping et al., 2021), enhancing consumer confidence in companies and their products.

An effective form of communication to increase the company's credibility in the eyes of customers and shorten the distance between consumers and organic food producers is to take additional special activities, including organising events that allow consumers to visit production facilities and learn about the production process of the food and launching ecotourism programmes, especially in large production enterprises, to promote organic food (Liu & Zheng, 2019). Furthermore, enterprises, in cooperation with organic food industry associations and local government bodies, should

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undertake other projects, such as organic food promotion programmes and regular organic food fairs to increase the availability of organic food and raise environmental awareness among the public.

Referring to price as a barrier to the consumption of organic food, the high price image should be mitigated by, among others, clearly identifying the features that distinguish organic products from conventional food (Aschemann-Witzel & Aagaard, 2014). In addition, producers should make efforts to improve the cost-to-value ratio. To this end, they should shape consumer perceived value, improve product quality, and lower organic costs (Baum, 2018).

The factor of organic food availability deserves special attention. While Polish consumers perceive positive changes regarding the availability of organic food, this is not the case for all product groups. The support from governmental bodies and other institutions, including the Agency for Restructuring and Modernisation of Agriculture, for the diversification of distribution channels, as expected by consumers, especially in relation to direct sales, is also needed (Nestorowicz et al., 2019). Supporting short distribution chains for organic food is a response to the needs of organic food consumers, who often prefer to buy food directly from organic farmers.

Also, note that Internet technology plays a significant role in overcoming the barrier to food accessibility. Polish consumers surveyed bought organic food most often in supermarkets (24.1% of responses), hypermarkets (17.9%), and small neighbourhood shops (14.7%). However, due to the trend of Internet sales of organic products observed in the world, which, due to the COVID-19 pandemic, has increased significantly over the past two years, the sale of organic food in Internet shops is expected to increase in Poland as well. This will make organic food more accessible to different groups of consumers.

Finally, the need to break the Poles' consumption habits and customs should be emphasised. This requires a profound cultural transformation of society based on the implementation of the idea of the environmental perception of the world. The transformation is already underway but concerns only more educated, better-off groups of society who appreciate the health and environmental benefits of organic products. Therefore, integrating countries into the so-called green revolution requires launching environmental projects, also implemented by market actors, at different levels of education, from primary education through the subsequent levels. Most of the challenges for further development identified in the paper, both on the demand and supply side, correspond with those identified in the Framework Action Plan for Organic Food and Farming in Poland for 2021–2027 (Ministerstwo Rolnictwa i Rozwoju Wsi, 2021) and with the list of challenges from the

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report “Organic Food in Poland. Report 2021” (Koalicja na rzecz BIO & NielsenIQ, 2021).

The assessment of factors affecting the future development of the organic food market should involve new aspects influencing market development, including the increase in energy costs (which will increase the price of fertilisers and the transport of conventional food), the disruption of food supply chains, the impoverishment of consumers forcing a change in the consumption profile (especially the reduction of the supply of cereals), and the production of meat products, highly processed goods, and imported goods. These aspects seem to be an opportunity for the development of organic farming, the development of producer groups, the development of local distribution and sales networks and, consequently, a change in the food consumption profile towards organic agricultural products produced locally and adapted to changing consumer preferences.

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The contribution of the authors

The article is a collaboration between the authors without specifying the detailed contribution of each.

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DEVELOPMENT VS EFFICIENCY OF POLISH FARMS – TRADE-OFF OR SYNERGY EFFECTS?

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ABSTRACT: The article aims to determine the nature of the relationship between farm development and its technical efficiency understood from the perspective of data envelopment analysis (DEA). The time scope of the analysis refers to the period 2004-2019. The empirical part of the article is based on the individual unpublished data for Polish farms conducting agricultural accounting according to Farm Accountancy Data Network (FADN). We employed a super-efficiency slack-based DEA model with variable returns to scale. This model enables us to compare and rank efficient farms as well as investigate the sources of farm (in)efficiency. We did not identify the substitution (trade-off) effect between farms` sustainability and efficiency. For mixed farms, there is some evidence for synergy effect since sustainable farms exhibit higher level of technical efficiency and these differences were statistically significant. The main policy recommendation that can be derived from these results is that agricultural policy should support both efficiency improvements and progress toward higher sustainability.

KEYWORDS: farms, slack-based model (SBM), technical efficiency, sustainability, FADN

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Introduction

Farm development has various facets. Currently, it is most often put together with the term “sustainable.” This concept is not clearly defined in terms of definition (Figiel, 2022), as well as semantics (Śleszyński, 2016). Consequently, there are very many definitions of the term, as well as there are very many proposals for the quantification of sustainable development at the farm level (Gaviglio et al., 2017; Valenti et al., 2018; Steinke et al., 2019). In the article, development is identified with the simultaneous realisation by the farm of selected assumptions (cf. methodological part) from the economic, environmental and social areas. Thus, it can be equated with sustainable development, although we are aware of some simplifications in this regard due to data limitations. The question may arise whether this type of development favours or limits farm efficiency?

In the literature on the subject, this problem is still not clearly resolved (Grzelak et al., 2022; Briner et al., 2013; Czekaj et al., 2020). The question is even more relevant because, on the one hand, the reduction of environmental pressures by farms is currently being promoted, and on the other hand, there is a need to maintain food security both at the national and global levels. This issue is related to the problem of complexity, which is particularly important for agriculture (Grzelak, 2015). The latter context is related to the war in Ukraine, as well as the growing demand for food in the world. From this point of view, the concept of sustainable intensification in agriculture seems interesting. As pointed out by Baulcombe et al. (2009), the idea is to increase agricultural productivity without increasing environmental pressure. In turn, A. Buckwell’s team defined sustainable intensification as increasing production efficiency while improving the environmental management of agricultural land (Buckwell et al., 2014). On the path of sustainable intensification, it is possible to increase agricultural production with limited pressure on the environment, which is particularly important for less developed countries (Pretty et al., 2011). As Staniszewski (2018) notes, for the EU15 member states, the concept of sustainable intensification primarily means increasing the environmental productivity of agriculture without reducing economic productivity. In contrast, in the new member states, the process has been more directed toward increasing economic efficiency. Our article, therefore, attempts to fill the research gap on whether it is possible in a country with a medium level of agricultural development (such as Poland) to focus on realising the social and environmental functions of agriculture with simultaneous improvements in technical efficiency.

The article aims to determine the nature of the relationship between farm development and farm efficiency understood from a data envelopment

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analysis (DEA) perspective. Its implementation was carried out by answering the research problems:

- Are farm sustainability and technical efficiency complementary or substitutable to each other?
- What are the sources of (in) efficiency of farms?

The time scope of the analysis refers to the period 2004-2019 and concerns, in the empirical part, farms from Poland. Our approach to the title question differs from the earlier ones in that we use a panel of farms 2,299 farms with continuous agricultural accounting in the period 2004-2019. In addition, we employed a super-efficiency slack-based DEA model with variable returns to scale, which enables us to compare and rank efficient farms. This model is of non-radial nature and makes it further possible to identify the so-called slacks – the room for potential improvement in the reduction of agricultural inputs and expansion of outputs. To the best of our knowledge, such an approach has not been previously used regarding the polish FADN panel.

The rest of the article is organised as follows. In the next section, we review the literature on links between sustainability and the efficiency of farms. In the third section, we provide a detailed methodology of this research. The fourth section is devoted to the analysis of results together with discussion, while the last part concludes.

Literature review

The analysed issues correspond in practical terms currently with a set of initiatives of the European Commission to achieve climate neutrality in Europe, the so-called European Green Deal (Dobbs et al., 2021). On the other hand, the need to ensure food security in a situation of war in Ukraine, broken supply chains, as well as growing global demand for food create pressure to increase food production. Thus the idea is to reduce the pressure from farms on the environment while not worsening the productivity of the used resources (Czyżewski et al., 2019). However, the support instruments of the CAP (Common Agricultural Policy) increasingly stimulate pro-environmental measures and limited productivity. Indeed, economic efficiency cannot be the only criterion for evaluating EU budget spending on agricultural policy due to the peculiarities of the land factor and the role that rural areas are supposed to play in society (Czyżewski & Polcyn, 2016; McDonagh et al., 2017). As indicated by studies conducted by (van Grinsven et al., 2019), agri-environmental subsidies contribute to the sustainable development of agriculture, and the increase in capital expenditures favours higher economic efficiency in agriculture. The research on the impact of factor intensity on sus-

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tainability and efficiency is dominated by the view that an increase in capital inputs favours high economic efficiency (Van Passel et al., 2007). However, there is fear that stimulating capital equipment under the CAP favours industrial agriculture and may lead to overinvestment (Van Passel et al., 2009).

At the farm level, not worsening the productivity of resources while reducing the pressure on the environment means that the relationship between sustainable development and efficiency should be strengthened. In practice, however, the objectives of farmers that are linked to economic and environmental spheres can be contradictory. Thus growing farm income is accompanied by greater pressure on the environment or increasing stratification of incomes and assets among farmers. For example, (Briner et al., 2013; Jaklič et al., 2014) affirmed the interchangeability between environmental and economic dimensions in the functioning of farms. (Ripoll-Bosch et al., 2012) underlined a clear trade-off between the economic and environmental goals based on investigating sheep farms (in different farming systems) in north-eastern Spain. The higher the economic sustainability, the lower the environmental sustainability. In turn, in Grzelak's (2020) study, the relationships between economic and environmental objectives on farms in Poland were found to be statistically insignificant. On the other hand, however, there was a cluster of farms in which these objectives were simultaneously highly ranked by respondents. This indicates the complexity of the phenomena studied. Špička et al. (2020), based on the experience of farms in the Czech Republic, underline that there is a trade-off between environmental sustainability and economic performance. Moreover, (Gomez-Limon & Sanchez-Fernandez, 2010; Picazo-Tadeo et. al., 2011; Bonfiglio et al., 2017) indicate that a balance between these dimensions is possible, and the relationship between economic and environmental objectives is positive. Different studies stress that larger units, and therefore those with more income, have a better chance of having a positive relationship between the economic and environmental spheres (Haileslassie et al., 2016; Grzelak, 2022b).

The problem of the relationship between efficiency (in the sense of DEA) and environmental sustainability is presented in the work of Guth et al. (2022). Based on the study of small-scale farms in Poland, Lithuania, Romania, Serbia, and Moldova stated that they are rather weak economically but environmentally friendly. Other conclusions come from the work of Gomes et al. (2009). They highlight, based on the performance of farms in Brazil, that the majority of the farmers increased their efficiency, which may support the existence of sustainability. Also, Czekaj et al. (2020) underline, based on the surveys of farms in Poland and Latvia, that economically strong individuals are more able to guarantee social and environmental sustainability. Grzelak et al. (2022) came to similar conclusions based on a survey of farms in Poland. They conclude that significant and positive relationships between the eco-

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nomic, social, and environmental dimensions could create synergies between them.

Methodology of research

In the analyses, the individual unpublished data for Polish farms conducting agricultural accounting according to Farm Accountancy Data Network (FADN) principles continuously during the period 2004–2019 were used. The data was deflated using price indices for products purchased or sold by farmers. In the analysed group, there were 2,299 farms of individuals.

FADN methodology for Poland distinguishes seven main types of farms. In Table 1, we provide the number of farms belonging to the given farm type in each year of analysis. Some farms have changed their type during the research period. The largest number of polish FADN farms can be classified as mixed, followed by field crops and dairy farms.

Table 1. Number of FADN farms in different types of farming in 2004-2019

Year	Fieldcrops	Horticul-ture	Permanent crops	Dairy	Grazing livestock	Granivores	Mixed	Total
2004	412	42	61	166	272	311	1032	2296
2005	419	42	60	190	285	338	964	2298
2006	404	61	57	181	308	377	911	2299
2007	413	64	66	187	309	360	900	2299
2008	456	63	71	199	345	306	856	2296
2009	471	64	74	204	352	312	817	2294
2010	342	75	67	533	85	359	814	2275
2011	368	69	66	540	100	347	803	2293
2012	390	71	70	535	116	337	763	2282
2013	534	63	68	525	62	194	832	2278
2014	556	61	70	519	66	198	787	2257
2015	578	58	69	482	61	189	770	2207
2016	616	59	70	536	90	187	723	2281
2017	643	61	71	535	88	171	708	2277
2018	672	58	73	502	95	167	686	2253
2019	727	61	70	516	119	156	621	2270
Total	8001	972	1083	6350	2753	4309	12987	36455
Unique units	923	84	92	705	660	524	1529	2299*

Source: author's work based on unpublished FADN data.

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Delimitation of farms into groups regarding sustainability farms was done based on economic, environmental, and social dimensions. The economic dimension was determined by estimating farm income per one full-time employed member of the farm family. If the level of these incomes exceeded the average level of net wages in the economy in Poland, then the farm met the condition of sustainability in the economic dimension. This was calculated for the surveyed farms based on the mean for the years 2004-2019. A similar approach was also used to estimate environmental and social sustainability.

Environmental sustainability was defined based on two sub-measures: the share of cereals in the crop structure and livestock density per 1 ha UAA. The choice of these measures was based on the fact that, in their case, it was possible to determine threshold values, which then set the critical values for the given sustainability areas (Wrzaszcz, 2013). In the case of the share of cereals in the sowing structure, the measure should not exceed 66%, while for animal stocking density, values in the range of 0.5–1.5 so-called large livestock units per 1 ha UAA are desirable, which is conducive to maintaining correct fertiliser management on the farm (Baum, 2011; Harasim, 2013). These two proposed metrics represent both agricultural production biodiversity and environmental pressure issues. It was assumed that sustainability in the environmental dimension takes place when the farm achieves it in each of these two sub-metrics.

Due to the microeconomic nature of the data, as well as the level of analysis, social sustainability was determined by the education and age of the farm manager. If the farm manager had at least a secondary agricultural education and was under 45 years old for the year under study, then the social sustainability condition was met. This results from the fact that in Poland, the age of 40 was adopted in the definition of a young farmer. It enables potential beneficiaries to benefit from additional forms of support under the CAP, e.g. the "Young farmer". However, such units would be very few among the studied farms because we use the average age of a farmer running a farm in the years 2004-2019. Therefore, the age of 45 was assumed. In the case of education, having at least a secondary education provides an adequate level of knowledge, which enables the farm's development. Younger farmers have a longer planning horizon and are less averse to risk than older farmers; they adopt new technology more readily and purchase newer equipment more often (Gale, 1994). Such an understanding of the social dimension, with some simplification, can also be applied to human capital.

In the second step of the study, the technical efficiency of the farms was calculated. There are two main approaches for efficiency calculation, namely DEA and stochastic frontier analysis (SFA). The key difference between these two is that the former provides higher flexibility in the structure of the pro-

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duction function while the latter enables noise separation (Bogetoft & Otto, 2011). In this research, the DEA-based model was chosen mainly because we deal with different farm types so the model flexibility is a big advantage. An important drawback of basic DEA models was, however, that they were radial so they assumed that inputs decrease or outputs expansion has to be proportional, while in reality, the potential to change the inputs (or outputs) level is very often not equal (Chen & Jia, 2017). This leads us to the use of the non-radial slack-based measure (SBM) model, first proposed by Tone (2001). In this model, one can assume that all inputs and outputs may change independently. The results of the model calculation show which inputs (or outputs) and in what proportion should be reduced (or increased). Furthermore, we prefer variable (VRS) rather than constant (CRS) returns to scale assumption because agriculture is recognised as a scale-sensitivity economic activity.

An important problem regarding basic DEA-based models, in particular with VRS assumption, is that they have weak discriminating power. In practice, it means that a large many decision-making units (DMUs) are usually found to be efficient (efficiency scores equal to 1) because they are situated on the efficiency frontier. However, it does not mean that these DMUs have exactly the same performance. To overcome this drawback, we use the super-efficiency model, first proposed by Andersen and Petersen (1993). In this approach for each of the efficient DMU an artificial frontier without a given DMU is designated and the distance between this DMU and a new frontier is calculated. The higher the distance the better positioned is the DMU and the higher efficiency score it obtains. Thanks to this approach, the comparison of efficient units becomes possible. From the perspective of this article, an advantage of the presented approach is that it enables to calculate median efficiencies more accurately.

Since 2004 polish farms have been subject of the EU common agricultural policy. The main feature of the policy from the farm perspective is that farmers receive subsidies for their current operations. However, the value of payments received is to large extent beyond the farmer's control. On the other hand, these subsidies create the economic environment for farming activities. Therefore, we include subsidies for current operations in the model as an uncontrollable input (Yang & Pollitt, 2009).

The super-efficiency SBM-DEA model is indicated as follows. Let the observed input data matrix be $X \in R_{+}^{m \times n}$, where n and m are the numbers of DMUs and inputs, respectively. The output data matrix is $Y^{g} \in R_{+}^{s \times n}$ where s is the number of good outputs.

For the specific DMU $(x_0, y_0) \in P$ the linear programming of the super-efficiency SBM-DEA model is described as follows:

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$$min \frac{1-\frac{1}{m}\sum_{i=1}^{M}\frac{s_i^-}{x_{ik}}}{1+\frac{1}{s}\sum_{r=1}^{S}\frac{s_r^+}{y_{rk}}}. \quad (1)$$

Subject to:

$$\sum_{j=1,\neq k}^{n} x_{ij}\,\lambda_j - s_i^- \leq x_{ik},\ i = 1,2,\ldots,m, \quad (2)$$

$$\sum_{j=1,\neq k}^{n} x_{ij}\,\lambda_j + s_i^+ \geq x_{ik},\ r = 1,2,\ldots,s, \quad (3)$$

$$\sum \lambda_j = 1\ , j = 1,2,\ldots,n\ (j \neq k), s_i^- \geq 0, s_i^+ \geq 0,\ \lambda \geq 0,$$

where $\sum \lambda_j$ means that we assume variable returns to scale and $s_i^- \geq 0, s_i^+ \geq 0,$ are the slack values for inputs, and outputs respectively. The slacks are defined as the DMU's potential to decrease of the input use or increase the level of output. Technically, the value of slack shows how much a given DMU should change its inputs or outputs level to become fully efficient (in the sense of strong efficiency).

The input/output mix differs between different farm types. In Table 2 we present mean values together with standard deviations for inputs and outputs used for the analysis for all seven farm types. If the value for the specific variable is not displayed, it means that this variable was not used or it was merged with another category. For example, a field crops farm can still have some livestock but the spending on feed is marginal, so this is included in the "other cost" category. Data in Table 2 shows that sample farms are highly diversified between main farm types but they also vary to a large extent within a given farm type (as demonstrated by standard deviations). Differences in the average level of inputs result from farm type specificity. When it comes to the level of production, it can be said that mixed farms, permanent crop and grazing livestock farms are, on average, smaller in economic terms in comparison to the other farm types. The highest level of current subsidies was noticed among field crops farms since the majority of support is organised in the form of direct payments related to farm areas.

Once efficiency scores are calculated for each farm every year, we calculate median scores for farms belonging to the given farm type and distinguish between 'sustainable' and 'unsustainable' farms, following the criteria described above. Since efficiency scores are not normally distributed we employ a non-parametric Wilcoxon rank sum-test to answer whether median efficiency scores for sustainable and unsustainable farms are significantly different.

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Table. 2. Mean values and standard deviation of variables used for technical efficiency analysis

Variable	Field crops		Horticulture		Permanent crops		Dairy		Grazing livestock		Granivores		Mixed farms	
	Av.	SD	Av.	SD	Av.	SD	Av.	SD	Av.	SD	Av.	SD	Av.	SD
production [PLN 1000]	229.5	257.1	379.6	422.2	168.1	183.7								
crop production [PLN 1000]							35.7	44.3	30.3	31.8	90.6	102.6	80.0	109.8
livestock production [PLN 1000]							212.8	270.5	124.5	135.2	358.9	576.5	89.4	115.7
labour [hrs/year]	4376	3063	8594	7644	6572	4725	4694	1570	4325	1385	4639	2642	4170	1689
Land [ha]	50	53	8	9	14	14	30	21	29	20	33	31	30	28
Livestock units							37	32	33	26	95	118	26	27
fertilizers [PLN 1000]	42.4	55.7	21.0	27.6	8.3	11.8								
pesticides [PLN 1000]	19.9	28.7	7.8	11.8	15.3	18.7								
Fertilizers & pesticides [PLN 1000]													23.3	36.3
Feed [PLN 1000]							58.6	89.4	34.6	40.7	223.4	355.1	49.1	67.7
Energy [PLN 1000]	22.1	25.5	71.2	109.0	13.6	17.3	18.4	20.5	12.0	10.8	21.5	27.3	13.4	16.2
depreciation [PLN 1000]	35.6	42.4	43.3	51.5	39.9	36.7	31.5	34.1	21.6	18.6	33.8	39.2	22.2	24.6
External costs [PLN 1000]					24.2	39.4								
other costs [PLN 1000]	66.3	85.4	148.1	233.9	22.5	40.2	72.1	82.7	47.8	50.3	85.6	112.1	32.8	48.7
Current subsidies [PLN 1000]	59.5	64.8	9.2	17.3	15.0	22.6	39.3	28.7	32.1	27.1	36.4	38.2	35.1	35.0

Source: author's work based on unpublished FADN data.

Results and discussion

To answer the first of our research questions, namely whether the sustainability and a higher level of efficiency can be treated as complementary or substitute objectives of the farm, the median efficiency scores for each farm type were calculated (cf. Table 3), distinguishing between sustainable (regarding given dimension) and unsustainable farms.

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Table 3. Median efficiency of sustainable and unsustainable farms under study in different types of farming

Sustainability dimension		Fieldcrops	Horticulture	Permanent crops	Dairy	Grazing livestock	Granivores	Mixed
Environmental	*Yes*	0.514	0.840	**0.735**	**0.688**	0.773	0.817	**0.649**
	No	*0.525*	0.840	0.678	0.679	*0.784*	*0.819*	0.617
Wilcoxon test value		1.054 (0.292)	-0.504 (0.614)	-1.109 (0.308)	0.496 (0.620)	-0.145 (0.885)	-0.173 (0.863)	-2.087** (0.037)
Economic & environmental	*Yes*	0.519	0.838	**0.725**	**0.688**	**0.790**	**0.826**	**0.656**
	No	*0.520*	*0.845*	0.678	0.680	0.780	0.819	0.615
Wilcoxon test value		0.357 (0.721)	-0.977 (0.328)	-0.464 (0.643)	0.245 (0.807)	-0.373 (0.709)	-0.630 (0.529)	-3.136*** (0.002)
Economic, social & environmental	*Yes*	0.510	0.839	**0.857**	0.660	0.778	**0.832**	**0.685**
	No	*0.520*	*0.906*	0.677	*0.680*	*0.781*	0.819	0.622
Wilcoxon test value		1.256 (0.209)	-0.557 (0.577)	-1.742* (0.082)	0.599 (0.549)	0.093 (0.926)	-0.592 (0.554)	-1.484 (0.138)

Note: nonparametric Wilcoxon rank-sum test is used; values are in italics when median efficiency of unsustainable farms is higher, bold stands for the opposite; ***,**,* stand for significance at 0.01, 0.05 and 0.1, respectively.
Source: author's work based on unpublished FADN data

In most of cases, the median scores for sustainable farms (in different dimensions) are not significantly different from the median for unsustainable farms. The difference is significant for permanent crops farms when economic, social and environmental dimensions of sustainability are simultaneously taken into account as well as for mixed farms when environmental or economic and environmental dimensions are considered. Interestingly, in all of these cases, the median value of efficiency was higher for farms classified as sustainable. In the rest of the cases, the differences were not significant but the general rule is that for crop farms the median efficiency scores were usually slightly lower for sustainable farms while for livestock farming it differs, depending on a particular type and sustainability dimension. However, taking all these results into account, we can say that we did not identify a trade-off effect between technical efficiency and sustainability of polish market-oriented farms. In the case of mixed farms, which constitute the largest share of the sample, we can even argue for the presence of a synergy effect.

Our results are in line with the findings of Adenuga et al. (2019; 2020), Peña et al. (2018), Urdiales et al. (2016), Wetteman and Latacz-Lohmann (2017), Guesmi and Serra (2015), or Hai and Speelman (2020). All these researchers advocate that it is possible to improve environmental aspects of farm functioning without deteriorating efficiency. For example, Wettemann and Latacz-Lohmann (2017) found that dairy farms in Germany can decrease their cost and GHG emission without depleting production level. Peña et al. (2018) found on the example of South America that economic effects can be improved by 20% with a simultaneous reduction of inputs and bad outputs by 20%. Based on the Irish example, Adenuga et al. (2019; 2020) concluded that analysed farms could increase production and reduce the nitrogen surplus at the same time. However, there are also contradictory findings in the literature. For example, Soteriades et al. (2015) have noted a negative correlation between dairy production efficiency and environmentally-friendly farm practices. According to Ullah et al. (2019) it is hard to achieve high economic efficiency and eco-efficiency at the same time. Huang et al. (2016) found, in turn, that relation between technical and environmental efficiency of farms depends on their size.

To answer the second research question we deal with the sources of farms` inefficiency for the farms with technical efficiency below one. More specifically, we analyse the average level of slacks on inputs and outputs to identify the most problematic areas of inefficient farms belonging to different farm types (Table 4). Elimination (or at least the decrease) of these slacks would increase farms` technical efficiency.

Table 4. The average level of slacks [in % of initial values] – an average of DMUs 2004-2019 means for studied farms

Variable/ Type of farming	Field-crops	Horticul-ture	Permanent crops	Dairy	Grazing live-stock	Grani-vores	Mixed
Production	70	15	38				
Crop production				110	80	27	36
Livestock production				8	10	12	62
Labour	-8	-10	-12	-11	-8	-10	-10
Land	-23	-24	-10	-8	-9	-9	-21
LSU				-9	-6	-7	-27
Fertilisers	-43	-24	-41				
Pesticides	-27	-24	-26				
Fertilisers & pesticides							-20
Feed				-8	-7	-3	-16
Energy	-18	-15	-19	-14	-11	-12	-16
Depreciation	-22	-13	-15	-14	-12	-15	-20
External costs			-24			-7	
Other costs	-13	-3	-13	-8	-4	-7	-8

The key source of inefficiency among crop farms was fertiliser and pesticides use. Slack on fertilisers was particularly high for field crops and permanent crop farms. The values in Table 4 mean that, for example, inefficient field crop farms should decrease spending on fertilisers by 43%, on average. If we assume that all sample farms have access to the technological frontier (which seems to be a reliable assumption for FADN farms from a given type), then we can say that inefficient field crop farms have a large room for fertiliser decrease. The European Green Deal assumes reducing fertilisers use by 20% and pesticides by 50% by 2030 on the EU level. If we compare the results in Table 4 with these general objectives, then we can conclude that improving efficiency through the elimination of slacks would help significantly in the fulfilment of these goals.

For permanent crops farms, another important field of potential improvement is external costs which comprise hired labour, rents and interest paid. This type of farming is usually more dependent on external production factors (labour input, in particular) than others, but our results suggest that a decrease in spending for this type of cost is possible. Interestingly, among field crop and horticulture farms a relatively large slack on land input was observed. At the same time, the production level for all three crop farm types should be increased. It indicates an important problem with technical efficiency since slacks values suggest that inefficient farms could, on average, decrease their acreage but increase production simultaneously. In other words, many farms achieve too low production in relation to the current inputs used.

When it comes to livestock farming, the relative values of slacks are lower, meaning that the room for improvement is smaller in comparison to crop farming. However, the largest slacks are found concerning energy input and depreciation, while the latter represents the use of fixed capital. It shows that a transition to more energy-saving technologies is needed. The high value of slack on depreciation indicates that the use of fixed capital is too high for production. Therefore, it can be said that some livestock farms deal with the problem of overinvestment (Pawłowski et al., 2021).

Interestingly, there are some slacks on typical inputs for livestock production, such as feed costs, but they are relatively small. It is especially striking when compared with slacks on fertilisers and pesticides for crop farms. This result suggests that the use of main inputs is closer to optimal when it comes to livestock farms. Large slack in crop output for livestock farms results from the fact that many of them have very little crop production. Therefore, the relative slack values may be exaggerated.

Regarding inefficient mixed farms, it can be said that they struggle with the relatively large slacks on land and the number of livestock units and even larger slacks on production, especially livestock output. This suggests that the main problem of these farms is that their production level does not correspond to the degree of involvement of basic production factors, such as land or livestock units. It shows that there is significant room for improvement in terms of revenue, even without increasing the scale of operation.

Conclusions and recommendations

In this paper, we have used data from 2,299 commercial polish farms representing all seven main farm types for the 2004-2019 period to deal with two research questions, namely: whether there is a synergy or trade-off effect between technical efficiency and farm sustainability and what are the sources of farm inefficiency. To answer these questions, we have classified farms according to sustainability definitions and calculated median technical efficiencies for different groups of farms. Finally, we have performed the slack analysis to investigate the sources of farms` inefficiency.

Among the limitations of the research, one can mention the fact that sustainability and efficiency measurement employed in this paper is somehow subjective. However, the problem is that there is no consensus on how to measure these phenomena. A systematic approach proposed in this paper could add to the existing knowledge. The use of competitive approaches, such as stochastic frontier analysis, can be seen as a fruitful line for further research. Moreover, more environmental indicators should be gathered at the FADN level system in the European Union countries (Borychowski et al., 2022). This would allow an even more precise examination of farm development, taking into account the relationship between efficiency and environmental issues.

In the course of the analysis, we did not identify the substitution (trade-off) effect between farms` sustainability and efficiency. For mixed farms, there is some evidence of a synergy effect since sustainable farms exhibit a higher level of technical efficiency and these differences were statistically significant. The main policy recommendation that can be derived from these results is that agricultural policy should support both efficiency improvements and progress toward higher sustainability. These two policy objectives can be treated as complementary rather than opposite to each other.

The results also indirectly indicate that greater digressive of decoupled payments should take place, depending on the UAA (Grzelak, 2022a). The idea is to limit the impact of the rent-seeking phenomenon on-farm efficiency. The slack analysis has shown that major sources of inefficiency for crop farms are the excessive use of fertilisers and pesticides. For livestock farming, these were excessive energy consumption and inadequate level of fixed assets. Agricultural policy should stimulate a reduction in the use of fertil-

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isers and pesticides on crop farms, e.g. by promoting precision agriculture. In the case of livestock farms, it is necessary to take measures aimed at reducing the energy intensity of production and limiting the phenomenon of farm overinvestment. Among the most important problems of mixed farms is that they achieve a too low level of production with respect to their size. Production diversification, typical for mixed farms, provides some environmental benefits but it impedes the improvement of production results. The policy could provide some incentives for mixed farms to specialise in crop or livestock production. Alternatively, if higher diversity is seen as a public good, the policy should top-up incomes of mixed farms with specific subsidies. This postulate will be partially fulfilled through eco-schemes in the new common agricultural policy.

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The contribution of the authors

Conceptualization, A.G. and Ł.K.; methodology, A.G. and Ł.K.; obtaining data, A.G.; literature review, A.G.; estimation of models, Ł.K.; analysis and interpretation of data, Ł.K.; writing–original draft preparation, A.G. and Ł.K.; project administration, A.G.; funding acquisition, A.G. All authors have read and agreed to the published version of the manuscript.

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GENERAL ENVIRONMENTAL AND SOCIAL PROBLEMS

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ENERGY LITERACY IN CZECHIA AND ITS INFLUENCE ON CITIZENS' PERCEPTION OF ENERGY CONSUMPTION BEHAVIOUR

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ABSTRACT: The analysis is based on a sample of 1015 citizens from Czechia. The cognitive energy literacy index (CELI), based on the knowledge of the energy mix in electricity production and the knowledge of the import/export of electricity in Czechia, is constructed in this article. The research aims to answer the following questions: What is the level of CELI within the population of Czechia? To what extent do the selected socio-demographic indicators affect the CELI? To what extent does CELI influence respondents' perceptions? The medium level of CELI is widespread across the population, while high and low levels of CELI are roughly equally shared. People with a high CELI are more likely to be older men with a university education. CELI also significantly affects the perception of behaviour on an individual, collective, and systemic level. Higher CELI is also associated with higher support for innovative solutions and renewable energy resources.

KEYWORDS: Czechia, energy literacy, energy consumption, household survey, human perception

Introduction

The utilisation of non-renewable fossil energy resources boosted economies and improved standards of living yet resulted in unsustainable growth accompanied by various problems, including pollution and climate change (Chevalier, 2009). Fossil fuels remain the primary energy sources that provide economic growth and industrialisation. However, the current global energy crisis motivates efforts to employ green technologies and alternative energy sources (Ng et al., 2021). This energy crisis arose at the beginning of 2022 after the coronavirus (Covid-19) pandemic and became more serious with the war in Ukraine. Apart from this fact, UN member states are committed to meeting the energy challenges of adopting a sustainable development paradigm defined in the late 1980s (WCED, 1987). One of the practical outputs is the 17 Sustainable Development Goals (SDGs), some of which are related to the energy sector. In Goal 7 – Affordable and Clean Energy, the community of states aims to ensure access to affordable, reliable, and modern energy for all. Energy production and consumption are also crucial from the perspective of Goal 13 – Climate Action (United Nations, 2015). Although the SDGs do not formulate specific policies to be implemented by the nations, the governments react to its agenda (Vávra et al., 2022).

To cope with the current challenges, the EU has adopted the "2030 Climate and Energy Policy Framework" with its main goals to be achieved by 2030 – at least a 40% reduction of greenhouse gas emissions, at least a 27% share of renewable energy in gross final energy demand with an indicative target of at least a 27% improvement in energy efficiency (European Council, 2014). These targets are not binding for each member state, but the governance framework should provide incentives to increase renewable energy sources (RES) deployment (Veum & Bauknecht, 2019). Although there were significant reductions in greenhouse gas emissions and improvements in the power sector, some political barriers to effective climate policy persisted as fossil fuels remain the main sources of energy, such as in Central and Eastern European countries that want to sustain coal-based energy carriers. Climate policies may be affected by increasing Euro-scepticism and climate scepticism (Oberthür, 2016). In this context, it is interesting to examine the level of energy knowledge of people using the concept of energy literacy.

Hence, energy literacy can be perceived as essential knowledge for understanding the energy nature in relation to its use and impacts on production and consumption, which encourages sustainable energy consumption habits as well as better decision-making on energy (Martins et al., 2020). Energy literacy and the awareness of households are also important for the evaluation of investment decisions in energy equipment and directly affect

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behaviour regarding energy consumption (Brounen et al., 2013). If energy literacy is such a powerful tool for behavioural change and energy savings and transition (Cotton et al., 2021), it could provide a basis for achieving the energy pledges and their acceptance by the public as the energy crisis still prevails.

Currently, there are disparities among EU countries when it comes to renewable energy resources (RES) deployment, which is not only a result of economic and financial factors but also geography and other natural factors. The highest shares of RES are evidenced in Sweden, Finland and Latvia, with the lowest shares in Luxembourg, Malta and the Netherlands. Demand for energy is increasing, but EU countries continue to set ambitious targets followed by investments (Anton & Nucu, 2020). Some of the member states, including Czechia, Slovakia, and Bulgaria, were not eager to fast-track energetical changes (Marinaș et al., 2018). Nevertheless, the EU is a global leader in the decarbonisation of the energy system (Bastida et al., 2019). Germany and France are included in the top ten energy-consuming countries (Shahbaz et al., 2018). However, Germany and France, but also Spain, Italy, Sweden, Denmark, Poland, Portugal, and the current EU exited the United Kingdom belong to the top 15 renewable energy-consuming countries (Saidi & Omri, 2020). However, many European countries are still dependent on fossil fuel sources. According to the indicator of fossil fuel energy consumption, its use is over 60% in most of them. For Czechia, the value of this indicator is approaching 80% (Martins et al., 2018). Although Czechia is Europe’s 3rd largest exporter of electricity (Liu & Wu, 2021), 16% of Czech households are affected by energy poverty, and there is a probability that household expenditures on energy in Czechia are increasing. Such households cannot afford to heat or cool their houses adequately in the different seasons (Karásek & Pojar, 2018). Energy literacy and adequate knowledge can enable a just energy transition, build resilient power systems, improve household energy use practices, and therefore reduce energy use and the risk of energy poverty (Chodkowska-Miszczuk et al., 2021). The threat of energy poverty is also increasing due to the general increase in energy prices, especially electricity and gas (Eurostat, 2022).

As part of the National Energy and Climate Plan of the Czech Republic, it is planned to increase awareness and enlighten and educate consumers. E.g. the so-called EFEKT Program was introduced as a political measure aimed at increasing energy efficiency and supporting energy savings. As part of this program, actions focused on the active dissemination of information and education in the field of energy savings are planned (MPO, 2019).

This paper contributes to the discourse on energy literacy at the level of a Member State of the European Union, especially in the context of Central Europe at a time when the energy mix is moving towards renewables and

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more environmentally friendly forms. At the same time, however, nuclear energy remains of great importance. This paper's approach of linking energy literacy to perceptions of individual behaviour, collective behaviour and system level can be considered novel and innovative. The research will show what the level of cognitive energy literacy within the Czech population is, but also how the Cognitive Energy Literacy Index (CELI) is affected by socio-demographic variables. Of particular interest may be the observed effect of education level across the population.

The paper is structured as follows. The literature review section briefly presents the concept of energy literacy. The methods and survey design sections consist of the description of Czechia, the research questions and hypotheses, and the survey. The results section starts with the description of the specifics and construction of CELI, followed by the results within the perception of individual behaviour, collective behaviour and system perspective, and the interference of the individual behaviour and the system. In the discussion and conclusion parts, the results are discussed in comparison to other research with respect to the topic.

An overview of the literature

Within this paper, we proceed mainly from the definition by DeWaters and Powers (2008), DeWaters et al. (2013), and DeWaters and Powers (2013). The authors divided energy literacy into three domains – cognitive (knowledge, skills), affective (attitude, values, personal responsibility) and behavioural (intention to preserve energy, energy-saving habits). Understanding the basic energy concepts falls within the cognitive domain. The energy-literate person in the affective domain is characterised by trying to reduce their consumption and environmental impact. Such a person understands the steps that can prevent a negative environmental impact and understands energy consumption in the context of economic responsibility for the transformation towards renewables. The energy-literate person in the domain of behaviour has such patterns of behaviour that are manifested in the fact that, as the authors describe, there is an "intention to preserve" (DeWaters & Powers, 2008). DeWaters and Powers (2013) established measurement criteria for energy literacy questionnaires concerning and covering all three dimensions.

Energy literacy defined in this way was later the subject of a paper from Martins et al. (2020), and the authors proposed a partial modification. The originally defined cognitive domain contained energy knowledge. However, it has been newly designed to include energy and financial knowledge. This extension to financial knowledge is also supported by the other concepts of

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energy literacy mentioned above (e.g., Brounen et al., 2013; Blasch et al., 2021).

Within our paper, we use primarily the definition of DeWaters and Powers (2008), DeWaters et al. (2013), DeWaters and Powers (2013), Martins et al. (2020) with a cognitive domain of energy literacy. From our point of view, the cognitive domain can be understood as indirect energy literacy and the other domains as direct energy literacy. For this reason, we call our key variable the cognitive energy literacy index (CELI). The index construction will be described in more detail in the section on material and methods.

Brounen et al. (2013) consider energy literacy as the ability of households to find a compromise between savings from energy efficiency investments and the upfront investments which are necessary to achieve improvements in energy efficiency in the long term. Blasch et al. (2021) work with a different concept and call it energy-related financial literacy. The essence is a combination of energy cost-specific knowledge and the skills needed to process this information. Energy literacy is often the subject of empirical research. Authors like Öykün and Abbasoğlu (2017), Yeh et al. (2017) conducted research among high school students. Other research measures energy literacy at universities (Cotton et al., 2021), but there is also research with a more complex sample that covers multiple levels of the education system (Dwyer, 2011). Cotton et al. (2021) pointed out relatively high energy literacy among students, but cultural differences were found. Students from the United Kingdom, as representatives of Europeans, had a more positive attitude towards energy savings. While students from China had a better knowledge of the facts about the energy sector and also had more confidence in the state and businesses in terms of energy regulations. The results among European students can also be supported by research from Öykün and Abbasoğlu (2017). In this case, most students also support energy efficiency, although energy knowledge about the facts is not so high. Misconceptions about energy and why students hold these have been the subject of research by Yeh et al. (2017).

Another group of researchers is those that focus on households in the context of energy literacy. These authors (e.g. van den Broek, 2019; Martins et al., 2020) deal with the energy literacy of households in general. The output is a description of the structure of this literacy and a useful tip on how to look at this issue and how to improve the research results. Martins et al. (2020) propose implementing the financial dimension together with knowledge, affective and behaviour to gain a more comprehensive assessment of energy literacy. Van den Broek (2019) recognises four types of household energy literacy states as device energy literacy, action energy literacy, financial energy literacy and multifaceted energy literacy, and calls for more com-

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mon principles and measures for direct comparisons within the household energy literacy research.

Brounen et al. (2013), in research across households in the Netherlands, found that "energy literacy" and awareness among respondents and households is low in the context of monthly energy fees. The relationship between limited knowledge in the field of energy and the non-utilization of potential savings was the subject of research across three European countries (Italy, Netherlands, Switzerland) by Blasch et al. (2021). Boogen et al. (2021) confirm that the residential sector in these three European countries could save approximately 20% of its total electricity consumption on average. Sovacool and Blyth (2015) described energy users from Denmark as organic users. However, their results did not support the claim that Danish households would prioritise low energy prices and affordability as key energy concerns and that they are knowledgeable about energy and environmental issues. Gołębiowska (2020) mapped the energy literacy of households in the context of Central and Eastern Europe. Relatively low energy literacy was found among Poles. Energy literacy was, in this case, defined as knowledge of energy prices, environmental effects of consumption, and knowledge about climate change. It also confirmed the relationship between energy literacy and norms associated with the use of energy.

It is also necessary to mention the impact of the energy literacy of households on consumer behaviour. An example is the purchase of electrical appliances, Blasch et al. (2019) confirm that individuals with a higher level of energy literacy are more likely to perform an optimisation rather than relying on a decision-making heuristic. These consumers are more likely to identify the most cost-effective product due to their energy literacy.

Together with Denmark, Bulgaria and Germany, Czechia is one of the European countries with the highest rate of motivation to save electricity for financial reasons (Mills & Schleich, 2012). However, among European countries, Czechia has the lowest financial energy literacy (van den Broek, 2019). The sharp increase in energy prices since January 2022 has worsened the situation of Czech households affecting housing affordability and the risk of poverty (Čermáková & Hromada, 2022).

Research methods

Research questions; a hypothesis

Within the research, based on the definition of the cognitive domain of energy literacy, the CELI was constructed, which is further operated within the data analysis. The research aims to answer these questions: What is the level of CELI within the population of Czechia? To what extent do some selected socio-demographic indicators affect the CELI? To what extent does CELI influence respondents' perceptions?

As regards the leading variables, we take into consideration the following sociodemographic characteristics: gender, age and education. Our construction of energy literacy (high, medium and low energy literacy) is used as an explanatory variable too.

Czechia

Czechia is located in Central Europe, bordered by Poland to the north, Germany to the west, Austria to the south and Slovakia to the east. Its capital and largest city, with 1.3 million inhabitants, is Prague. The aggregate number of inhabitants is over 10 million (Czech Statistical Office, 2022). Most of the country is located between 200 and 500 meters (600 and 1,600 feet) above sea level and has a fairly homogeneous climate (Czech Statistical Office, 2021). Czechia has a temperate climate, situated in the transition zone between the oceanic and continental climate types, with warm summers and cold, cloudy and snowy winters.

The survey, questionnaire and data analysis

The article is based on data obtained in a questionnaire survey developed by the authors, which was entitled Bioeconomy, Environment and Energy. The distribution of the questionnaire and data collection was carried out by the professional market research agency FOCUS – Center for social and marketing analysis in December 2020. It included 1015 respondents using the online (CAWI) method on a representative adult population (18+ years) selected via quotas of gender, age, education, municipality size and region.

Our methodology is based on an empirical operationalisation of energy literacy – the CELI. The questionnaire included questions focused on the various topics of energy, bioeconomy, waste management, forestry and standard socio-demographic questions. The specific set of questions dealing with energy issues is analysed in this paper. These include:

- In your opinion, what is the structure of electricity production in Czechia at present? How do you think electricity should be produced in Czechia in 2040? Please indicate in percentages the total is 100% (Question #1)?
- If we add up the imports and exports of electricity, in your opinion, does Czechia import or export electricity? (Question #2)?
- Are you considering your own energy production in your household (solar panels, water turbines, geothermal energy, biogas plant, etc.)? (Question #3)?

- Would you support your municipality/district / city to have its own joint production of renewable energy (biogas plants, solar panels, wind, etc.)? (Question #4)
- Can alternative energy sources (biomass, wind, sun) exist without subsidies? (Question #5)?
- What effect do you think consumer behaviour has on overall energy consumption? (Question #6)?

A relatively high N and representativeness of the sample above allowed a statistical comparison using IBM SPSS software. This included descriptive statistics, chi-square and ordinal regression. Chi-square is used in the analysis of all questions, while ordinal regression is used in the case of CELI and sociodemographic relationships. If not stated otherwise, the statistical significance level is $p = 0.05$.

Results of the research

CELI index

The construction of the CELI is based on two questions: the knowledge of the energy mix in electricity production and the knowledge of electricity balance. We selected these two questions because they are the most knowledge-based in the part of a survey concerning energy. The other comparative questions are normative, oriented to the future, about the motivation and attitudes about the individual energy plans, and attitudes towards municipal and regional policies. The rest is made up of questions concerning attitudes towards energy.

The first part of the CELI index is knowledge of the structure of energy production (Question #1). Figure 1 compares the average respondents' energy mix estimates with reality (International Energy Agency, 2022). It is clear that respondents tend to overestimate renewable sources. On the other hand, they are not fully aware of the extent of coal and nuclear energy as energy sources.

Due to the great deviations (several times more) in the estimation of small share energy sources in our energy mix, such as wind, water, biogas, solar, and geothermal, we integrated the categories in the following way: renewable energy sources (RES), coal, nuclear energy, and other (mostly natural gas).

Indirect indicators of energy literacy are based on a contingency table looking for homogenous characteristics; for electricity production, the deviation of the estimation from reality (International Energy Agency, 2022) was calculated for each of the three types of electricity sources (renewables

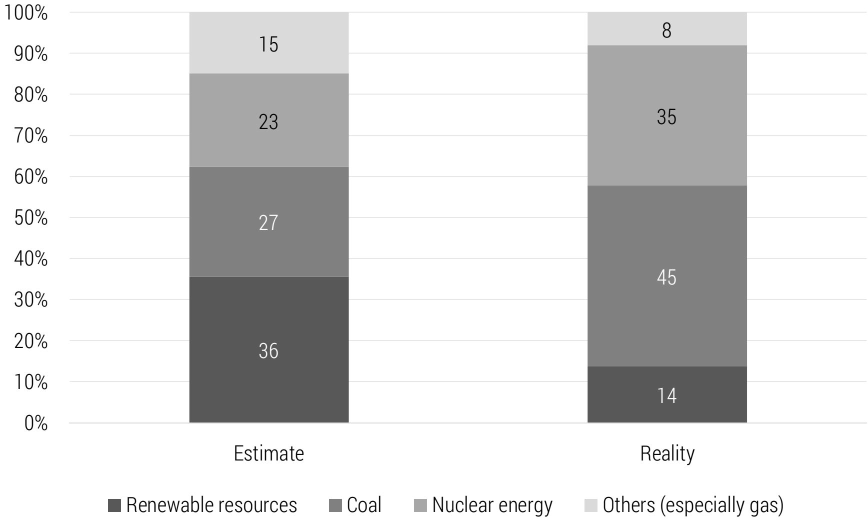

Figure 1. Electricity generation estimate and reality [%, rounded]
Source: authors' work based on International Energy Agency (2022).

together, coal, nuclear) and transformed into its absolute value. Then, the mean of the three absolute values of deviations was created. The sample of respondents was then categorised into the terciles according to their mean deviation of the assessment of electricity production from reality. First tercile with a mean deviation <16%, second 16-25%, third >25%. A total of 34% of respondents had the lowest deviation, less than 16%. Furthermore, a total of 33.3% of respondents had the middle category, a deviation between 16% and 25%, and 32.7% of respondents had the highest deviation, i.e., greater than 25% (see Table 1).

The second part of the CELI index is knowledge of the export/import of electricity (Question #2). It was categorised as "more export/more import/roughly the same/don't know", with the correct answer being "more export" and the incorrect ones being "more import" and "roughly the same". Czechia exported more electricity than it imported in 2019. Exports amounted to 24.1 TWh, and imports to 11 TWh (Energy Regulatory Office, 2019). Thus, net exports amounted to 13.1 TWh. A total number of 49% of respondents correctly answered that Czechia exports more electricity, while 22% believe that it imports more than it exports. Even 13% of respondents who believe that imports and exports are the same did not answer correctly. The remaining 16% of respondents chose the answer "I don't know, I don't think about it".

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Answers to these two questions were combined to create the CELI, as shown in Table 1. Based on this distribution, three categories of CELI were prepared. First, respondents with a high CELI answered the export/import question correctly and were in the first tercile of deviation (23.6% of respondents, light grey in Table 1). Second, those with a medium CELI who either answered export/import incorrectly or didn't know and were in the first or second tercile of deviation, plus those in the second and third tercile but with the correct answer to the export/import question (53.3%, grey in Table 1). Third, respondents with a low CELI were in the third deviation decile as well as replying incorrectly or didn't know the answer to the export/import question (23.1%, dark grey in Table 1).

Table 1. Energy Literacy Index distribution among respondents

		Export/import knowledge			Total
		Correct answer	Incorrect answer	Don't know	
Deviation of electricity production estimation	<16%	23.6%	7.9%	2.5%	34%
	16-25%	15.4%	12.5%	5.4%	33.3%
	>25%	9.7%	14.4 %	8.7 %	32.7%
Total		48.7%	34.8	16.6%	100%

Note: Percent of all respondents; light grey = high CELI, grey = medium CELI, dark grey = low CELI

Chi-square was used to test the relationship between the surveyed factors ($p = 0.05$). The abbreviation "ar" below indicates adjusted residuals (absolute value ≥ 1.96 as threshold of significance). We started with the relationship of CELI and sociodemographics. For this purpose, the age was categorised into 6 groups (see Annex for details). The chi-square tests revealed a significant relationship between CELI and all three characteristics: gender ($\chi^2 = 109.901$; df = 2; $p < .001$), age ($\chi^2 = 87.465$; df = 10; $p < .001$) and education ($\chi^2 = 130.994$; df = 6; $p < .001$). A total number of 23.6% of our respondents have high energy literacy measured by the energy literacy index (CELI) introduced above. These respondents are more often men (ar +8.3), in the age categories 55–64 and 65+ (ar +2.8, ar +4.6) and respondents with a university degree (ar +6.0). Women (ar -8.3), younger respondents in the age categories 18–24, 25–34 and 45–54 (ar -3, ar -3.4, ar -2.7) and respondents with basic and apprenticeship education[1] are less likely to have high a CELI (ar -2.2, ar -5.4).

1 Apprenticeship education indicates a lower, more practical form of high school (vocational).

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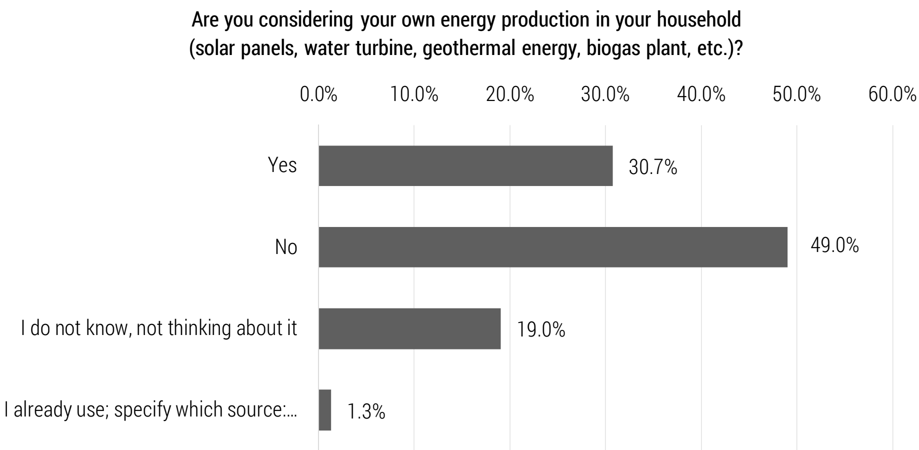
A total number of 53.3% of respondents reach the medium level of CELI. These are more often respondents with a high school education (ar +2.5). On the other hand, respondents with an apprenticeship education reach the middle level of CELI less often (ar -3.5).

A total number of 23.1% of respondents have low energy literacy, as measured by CELI. These are more often women (ar +8.6), respondents in the age categories 25–34 and 35–44 (ar +5.1, ar +2.8) and respondents with an apprenticeship certificate (ar +9.6). On the other hand, these respondents are less often men (ar -8.6), older respondents in the age categories 55–64 and 65+ (ar -3.2, ar -5.8) and respondents with high school and university education (ar -4.8, ar -6.4).

Ordinal regression with CELI as a dependent variable and gender, age groups and education as independent variables confirms that even when the effect of other sociodemographic characteristics is controlled, each of them significantly influences CELI in line as Chi-square shows (in both cases of main effect only as well as an interaction; Nagelkerke Pseudo $R^2 = 0.282$, respectively 0.296).

In further research, we focused on whether the energy literacy of our respondents measured by CELI has an impact on their attitudes, behaviour, and relationship to the energy policy of the state. The following four questions from the questionnaire were used for this analysis.



Own energy production in households (solar panels, water turbine, geothermal energy, biogas plant, etc.) (Question #3)

Figure 2. Own energy production in the households

Note: Percent of all respondents.

The largest group is 49% of respondents who do not consider producing their own future energy. Further responses are detailed in Figure 2. The relation between CELI and own energy production is statistically significant (χ^2 =38.101; df = 6; p < .001). Respondents with a high CELI are more often among those who have already produced energy in their own household (ar +2.6), those who think about it (ar +2.4). On the contrary, this answer was more often chosen by respondents with the low CELI (ar +5).

Support of the municipalities/ district / city to have its own joint production of renewable energy (biogas plants, solar panels, wind, etc.) (Question #4)

A total of 64.8% of respondents, almost two thirds, support the production of joint energy in their place of residence. Further responses are detailed in Figure 3. Overall significance of chi-square is relatively lower than in case of other questions (χ^2 = 10.908; df = 6; p = .091), yet there are some significant adjusted residuals: respondents with a low CELI more often chose the answer I don't know/I don't think about it (ar + 3.1) and less often the support of joint energy production (ar -2.6).

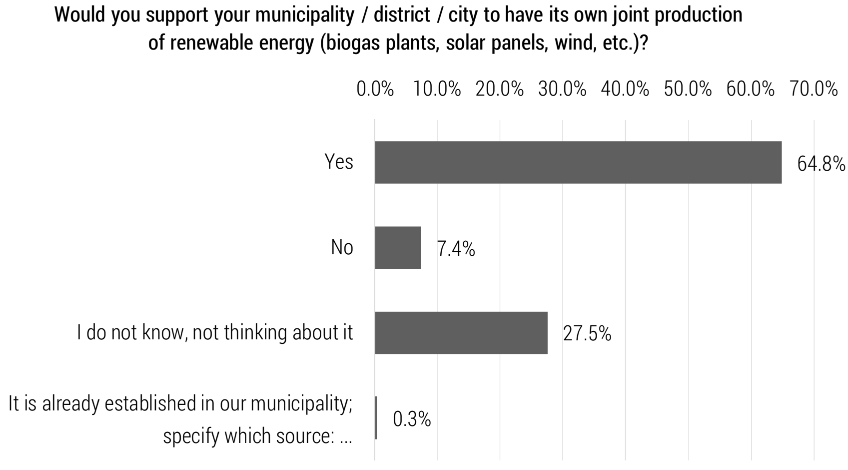


Figure 3. Support of the municipalities/ district/ city to have its own joint production of renewable energy

Note: Percent of all respondents.

Existence of alternative energy sources (biomass, wind, sun) without subsidies (Question #5)

The 45% of respondents answered that RES cannot exist without subsidies (see Figure 4 bellow). Unlike the previous question, the relation of CELI

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and RES was highly significant ($\chi^2 = 57.064$; df = 4; $p < .001$). Respondents with a high CELI more often answered that RES can exist without subsidies (ar +3.9), and respondents with a low CELI do not know or do not consider it (ar +6.4). On the other hand, the last-mentioned answer was less often given by respondents with a high CELI (ar -5.1). Respondents with a low CELI less often chose the answer that RES can exist without subsidies (ar -2.8), but also the answer that RES cannot exist without subsidies (ar -3).

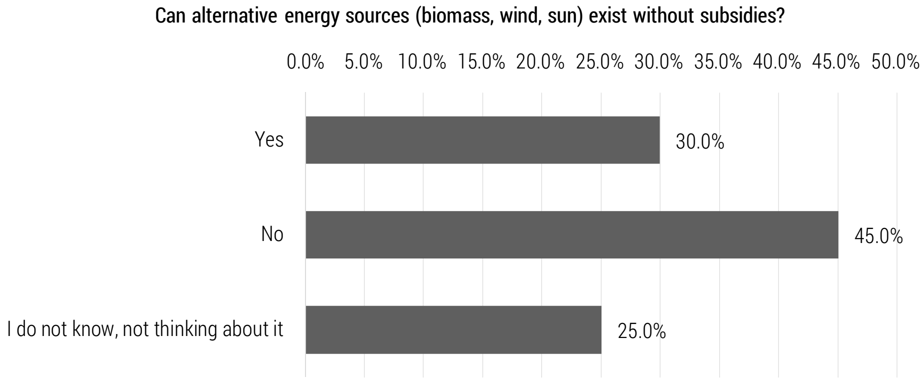

Figure 4. Existence of alternative energy sources without subsidies

Note: Percent of all respondents.

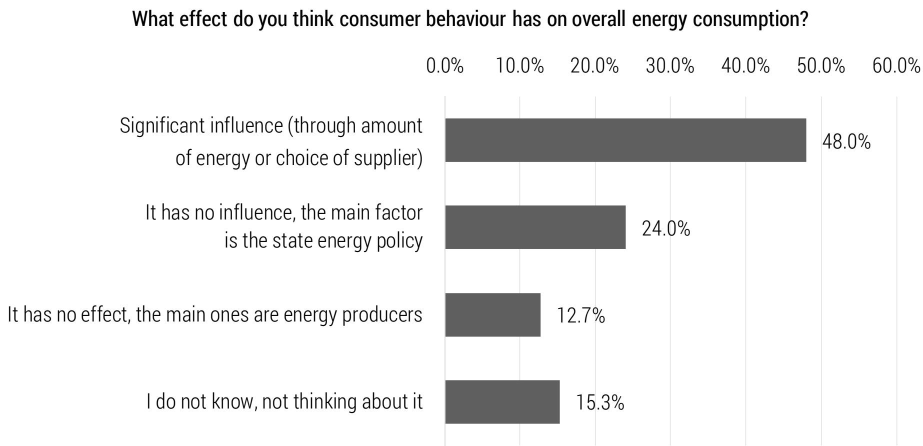

Figure 5. Influence of consumer behaviour on overall energy consumption

Note: Percent of all respondents.

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Influence of consumer behaviour on overall energy consumption (Question #6)

A total of 48% of respondents think that consumer behaviour has an impact (through the amount of energy or the choice of supplier) on overall energy consumption. Further responses are detailed in Figure 5. CELI is, again, variable with significant effect on the answers to the question ($\chi^2 = 74.789$; df = 6; $p < .001$). Respondents with a medium CELI more often answered that the main role is played by the state energy policy, not consumers (ar +2.2), and this answer was less often chosen by respondents with a low CELI (ar -4.4). The answer I don't know/I don't think about it was chosen less often by respondents with a high or medium CELI (ar -3.8, ar -3.6), and conversely, respondents with a low CELI chose it more often (ar +8.1).

Discusion and conclusions

This research article answered the researcher's several questions. The CELI within the Czech population can be divided into three groups, where the largest is the part of the population with a medium CELI score. People with a higher CELI or lower CELI represent approximately one-quarter of the population. However, this is affected by our construction of the three categories according to the CELI score. Socio-demographic indicators significantly influence the CELI score across populations. An interesting finding is that older men with a university degree achieve the highest score. The CELI also significantly affects the perception of behavior on an individual, collective, and systemic level. In general, people with a higher CELI score are more pro-environmentally minded, in our case it is the promotion of renewable energy sources and innovative solutions in terms of their own energy situation or the situation in their place of residence (region).

Instead of the energy literacy mentioned in the literature review, we cannot use this direct literacy, i.e., a comparison with literacy and the real-world behavior of individual respondents. So, instead we used a modification, indirect literacy, which is based on the knowledge of the energy mix in electricity production and the energy balance in the production of electricity in Czechia – and the reality of the mix and balance. Energy literacy is more about the respondents' perception of behaviour to energy production than about their own behavior. Knowing this fact, we avoid statements about behavior-based greening of Czech society and similar interpretations. It is more about general expectations and a picture of the mind in terms of energy production.

Many authors (e.g., Öykün & Abbasoğlu, 2017; Yeh et al., 2017; Cotton et al., 2021; Dwyer, 2011) focus on energy literacy in the context of students. We also have this population group in our research, and due to the CELI, it can be

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stated that younger respondents with basic and apprenticeship education are less likely to have a high CELI. However, it must be emphasized that people with a university degree, on the other hand, achieve a high CELI score.

Young people at age 18-24 are commonly seen as a sensitive group in the context of environmental expectations. This can be confirmed, for example, by the results where young EU citizens aged between 15-29 believe that climate change has an impact on everyday life (European Investment Bank, 2021).

The construction of the CELI was based on two knowledge questions. There are great differences in the estimation and reality in the case of knowledge of the energy mix in electricity production (not so much in the energy balance). Even looking at a normative question about the horizon 2040 and energy mix, optimistic expectations in the sense of increasing renewable energy resources exceed all expert's government concepts up to 2038. The main Czech energy company ČEZ group confirms our results in terms of the great overestimating of RES with its own experience with visitors in ČEZ visitors' centers (Votruba, 2021). The question is about the causes of these expectations.

The first, easy explanation shows weak interest in the energy mix and then weak estimations of reality. Undoubtably, this is the case. On the other hand, in a case like this, we can also expect the opposite estimation in terms of a higher estimation of coal in the energy mix. However, it does not occur.

One possible explanation is related to the fact of the relatively widespread discussion about RES, both positive and negative, in Czech mass media during the last ten years. It is connected with global climate change and social problems, the problematic subsidy scheme of solar energy (Vávra, 2014), CO_2 emissions, and the EU and its low carbon strategy. The impact of this discussion on Czech citizens inflates the share of RES in mass media rather than show the correct picture and real share of RES in the energy mix. Citizens also tend to underestimate the contribution of nuclear and coal power. In this case, slightly less than half of the respondents correctly state that electricity exports are greater than imports within Czechia.

Another part of the data analysis focused on whether the energy literacy of our respondents measured by the CELI has an impact on their perception of behavior, and its relationship to the energy policy of the state. At the level of perception of individual behaviour, it can be confirmed that overall, a smaller part of the population considers their own energy production in their households, but it is the part of the population with a higher CELI. The perception of collective behaviour was related to the support of the municipalities/district/city to have its own joint production/renewable energy. In this case, a larger proportion of the population expressed agreement, but the effect of the CELI was not statistically significant. The system level repre-

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sented the possibility of alternative energy sources (biomass, wind, solar) without subsidies. It was found that the part of the population with a higher CELI is aware of the possibility of RES without a noticeable influence of subsidies. The effect of the CELI on the consumption behaviour on total energy consumption was also found. In this case, as the CELI score decreases, the belief in consumer influence also decreases. These questions completed the picture of the Czech population and their energy literacy. The results thus contribute to already published European research (e.g., Brounen et al., 2013; Blasch et al., 2021; Boogen et al., 2021; Sovacool & Blyth, 2015) especially in the context of central Europe (e.g. Gołębiowska, 2020).

The CELI has revealed a gap between the thinking of energy experts, politicians and economists and the rest of the population in Czechia. We are witnessing a missing framework for the idea of an energy mix in the general population. Nevertheless, political and economic decisions are being made, as well as long-term strategies in the name of modernising the economy. From the point of view of the social situation, this mostly missing information is not an objective attitude comparable to that of experts. There is a lack of interest in the composition of the energy mix in the majority of the population. However, there is no lack of an interpretive framework for the attitude, which is significantly pro-environmental. We are witnessing two interpretive frameworks: energetically "real" held by experts and politicians and economists, and energetically "green" with a clear inclination towards RES for the majority of the population of Czechia. We believe that these frameworks cannot be simply explained as knowledge versus ignorance or expert versus non-expert. On the part of the majority population is the impact of the pro-environmental narrative, as presented in the media, on energy savings, CO_2 reduction, carbon switching, renewable energy, waste minimisation, modern energy-saving biotechnology, the circular economy and bioeconomy. This narrative is, in essence, a defence of energy restructuring and the high costs of this modernisation. On the other hand, it raises high expectations of a highly ecological energy mix that does not correspond to government strategies at all and far exceeds them. The question is to what extent these expectations will be reflected in the strategies in the future through the appropriate political representation holding the views of this segment of voters. This is one of the reasons why we believe that these two frameworks cannot be set in isolation but must be considered in a complementary way.

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Question	Answers	Frequency of answers	Gender		Age						Education				Cognitive energy literacy index		
			Man	Woman	18-24	25-34	35-44	45-54	55-64	65 +	Elementary School	Secondary vocational school	High School	University	High	Medium	Low
Knowledge of the structure of energy production (deviation).	<= 15	34%	8.2	-8.2		-3.2	-2.8		2.2	3.0		-6.8		6.6	24.7	-10.5	-12.5
	16-25	33%								3.1		-3.1	3.4		-12.5	21.1	-12.3
	26+	33%	-8.1	8.1	2.0	5.0	2.9		-3.4	-6.1	2.0	10.0	-5.3	-7.2	-12.4	-10.6	25
If we add up the imports and exports of electricity, in your opinion, does Czechia import or export electricity?	More imports	22.%	-4.3	4.3	4.6	5.3			-2.3	-5.1					-9.4		8.5
	More exports	48.7%	8.4	-8.4	-3.2	-4.7	-2.3		4.2	5.3		-4.5	2.3	3.8	18.2		-17
	Imports and exports are the same	12.7%							-2.9						-6.8	2.5	3.9
	I do not know, not thinking about it	16.6%	-6.8	6.8								4.3		-3.7	-7.9		9.9
Cognitive energy literacy index	High	23.6%	8.3	-8.3	-3	-3.4	-2.7		2.8	4.6	-2.2	-5.4		6			
	Medium	53.3%										-3.5	2.5				
	Low	23.1%	-8.6	8.6		5.1	2.8		-3.2	-5.8		9.6	-4.8	-6.4			
Are you considering your own energy production in your household (solar panels, water turbine, geothermal energy, biogas plant, etc.)?	Yes	30.7%	2.5	-2.5	3.6	2.9				-4.8		-2.7		2.7	2.4		
	No	49.0%											1.9				
	I do not know, not thinking about it	19.0%	-3.0	3.0			3.4			-3.3		3.9		-3.4	-3.5		5
	I already use; specify which source:...	1.3%											-2.7	5.3	2.6		
Would you support your municipality / district / city to have its own joint production of renewable energy (biogas plants, solar panels, wind, etc.)?	Yes	64.8%								-3.6							-2.6
	No	7.4%	2.2	-2.2	2.0						2.0						
	I do not know, not thinking about it	27.5%			-2.3	-2.9				4.5			2.1	-2.4			3.1
	It is already established in our municipality; specify which source: ...	0.3%				2.4											

Question	Answers	Frequency of answers	Gender		Age						Education				Cognitive energy literacy index		
			Man	Woman	18-24	25-34	35-44	45-54	55-64	65 +	Elementary School	Secondary vocational school	High School	University	High	Medium	Low
Can alternative energy sources (biomass, wind, sun) exist without subsidies?	Yes	30.0%	4.7	-4.7	2.4										3.9		-2.8
	No	45.0%						-2.1									-3
	I do not know, not thinking about it	25.0%	-5.1	5.1								3.4		-3.2	-5.1		6.4
What effect do you think consumer behavior has on overall energy consumption?	Significant influence (through amount of energy or choice of supplier)	48.0%										-2.8		2,9			
	It has no influence, the main factor is the state energy policy	24.0%														2.2	-4.4
	It has no effect, the main ones are energy producers	12.7%															
	I do not know, not thinking about it	15.3%	-3.1	3.1			2.0	2.2		-2.0		4.4		-4.8	-3.8	-3.6	8.1

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The contribution of the authors

Roman Buchtele: conception – 30%, literature review – 45%, acquisition of data – 30%, analysis and interpretation of data – 35%.

Eva Cudlínová: conception – 25%, literature review – 5%, acquisition of data – 10%, analysis and interpretation of data – 20%.

Miloslav Lapka: conception – 20%, literature review – 10%, acquisition of data – 10%, analysis and interpretation of data – 15%.

Nikola Sagapova: conception – 5%, literature review – 10%, acquisition of data – 10%, analysis and interpretation of data – 5%.

Martina Krásnická: conception – 5%, literature review – 10%, acquisition of data – 10%, analysis and interpretation of data – 5%.

Jan Vávra: conception – 10%, literature review – 5%, acquisition of data – 20%, analysis and interpretation of data – 15%.

Zuzana Dvořáková Líšková: conception – 5%, literature review – 10%, acquisition of data – 10%, analysis and interpretation of data – 5%.

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Sylwia **FRYDRYCH**

THE ROLE OF CREDIT RATING OF THE ESG DEBT INSTRUMENTS ISSUERS

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ABSTRACT: The aim of this article is to assess whether having a creditworthiness assessment from more than one credit rating agency by issuers of ESG debt instruments affects the number of issues and the average amount issued. The empirical research was carried out using the observation method and the analysis of source documents. In the analysed period, 53.38% of issuers received ratings at least from one CRAs as S&P, Moody's, and Fitch. The results of the conducted research indicate that the number of ESG debt instruments and the average issue amount were affected by the number of ratings given to the issuer. A database collected from Refinitiv Eikon for the period between 2012 and 2021 allows us to conclude that it is enough to have two credit ratings. The conclusions of this study can be used in the process of obtaining financing for ESG projects.

KEYWORDS: ESG, credit rating, bonds

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JEL: G12, G15, G24

Introduction

There is an increase in interest in sustainable, socially, environmental and climate-stable development of the economy. However, the level of investment is insufficient to prevent adverse climate change, such as limiting global warming.

Increased awareness of investments focused on environmental and social factors contributes to the increase in the supply of debt instruments, the purpose of which is to finance projects related to the establishment of ESG criteria (environmental, social, and management).

A question therefore arises – does the issuer's fulfilment of criteria related to the environment, management or social relations affect the assessment of its creditworthiness?

Credit ratings are used when investors make investment decisions to estimate the credit and default risks. Thus the knowledge about the impact of the ESG measures on credit ratings is very important. Using credit ratings given by external credit rating agencies will help to assess the mentioned phenomenon. It is still noticed a small number of studies about the impact of ESG policies on the probability of default.

Accordingly, there is a research gap relating to the role of ESG information in the granting of credit ratings to issuers by credit rating agencies. Therefore, the number of ratings held by issuers of ESG instruments was examined.

The aim of the article is to assess whether the fact that issuers of ESG debt instruments have a credit rating from more than one agency has an impact on the number and average amount of issues. This goal was achieved through the process of analysing the ratings assigned by the selected largest rating agencies. The results of the study will allow the credit rating to considered in the process of raising debt capital for purposes related to meeting the ESG criteria, including counteracting the negative effects of climate change.

As regards the structure of this study, its first section presents an overview of the literature on the subject, with particular emphasis on the analysis of credit ratings by the three largest agencies. In the empirical part, the differences in the given credit ratings between the agencies were analysed. Moreover, the paper captures the impact of having the ratings assigned by the rating agencies on the number of issues and the average amount of the issued ESG instrument. The article ends with conclusions regarding the role of credit rating of the ESG instrument issuers in raising capital.

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An overview of the literature

As ESG is weighted in terms of environmental, social and management factors, the company engages in these activities at different levels (Duque-Grisales & Aguilera-Caracuel, 2021). The environmental criterion covers climate change and issues such as energy consumption, waste management, and pollutant emissions. Social criteria include respect for human rights and the promotion of diversity and equality among employees, irrespective of gender, origin or sexual orientation. An important element of the social criterion is also paying attention to the needs of customers and taking care of relations with the local community. The management aspect concerns issues such as respecting the rights of shareholders. Companies having different stakeholders (employees, local communities and societies) have an ethical responsibility to respond to their diverse environmental, social and governance expectations to maximise value for stakeholders. Attention should also be paid to the needs of shareholders (Yamahaki & Frynas, 2016).

A growing number of investors focus on the profitability of investment strategies and look for their social value. ESG investing fulfils this goal. These are non-financial factors that investors use to evaluate an investment as well as the issuer. ESG looks at the company's environmental, social, and governance practices, as well as traditional ones. ESG investors believe that investments in companies employing ESG practices may have a material impact on their investments' profitability and risk. Lo and Sheu (2007) indicate that companies with sustainable development strategies are more likely to be rewarded by investors with a higher valuation of their assets.

Due to Friede et al. (2015), in order to use the ESG criteria, it is necessary to integrate them with investments. There are several ESG factors that are helpful in assessing the performance of an investment. Investments with high ESG performance may increase the rate of return, while those with low ESG performance may inhibit them. ESG ratings can be viewed as „company ratings based on a comparative assessment of its quality, standards and performance in environmental, social and governance issues" (Wong, 2018).

The ESG assessments objectively and effectively evaluate a company's ESG efforts through its competitive advantage, social reputation, and operational performance. The ESG risk assessment measures are provided by RobecoSAM, Sustainalytics, CDP (Carbon Disclosure Project), ISS (Institutional Shareholder Services), MSCI ESG Research, FTSE Russell, Bloomberg, Standard & Poor's Global and Moody's. The agencies provide ESG assessment services for investors (Avetisyan & Ferrary, 2013). The ratings are similar to those issued by credit rating agencies but with an emphasis on meeting ESG criteria. They measure the issuer's exposure to industry-specific ESG risks

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and the way it manages them. As the number of ESG rating providers increases, there are differences in methodologies and final ratings (Avetisyan & Hockerts, 2017). However, all rating providers refer to the company's ESG practices. Therefore, the ESG rating agencies influence the behaviour of companies and investors (Galbreath, 2013).

Zerib (2019) and Pedersen et al. (2021) examined the impact of ESG investing on asset prices, assuming that some investors derive utility from investing in assets with high ESG performance. Goldstein et al. (2022) analysed how information about these results reaches asset prices through investors. Uncertainty about ESG payouts has been described by Avramov et al. (2021). A comprehensive analysis of the implications of sustainable investment equilibrium and an analysis of welfare and social impact was the work of Pastor et al. (2021).

Theories of legitimacy and stakeholders provide a solid theoretical basis for the relationship between environmental, social and governance (ESG) disclosures and financial performance (Qureshi et al., 2020). Transparent ESG information proves that companies are actively taking environmental and social responsibility, thereby improving their reputation with consumers and investors, gaining access to capital at a lower cost and increasing competitive advantage (Bofinger et al., 2022; Gillan et al., 2021). While rating agencies assign different ESG ratings to the same company due to different ESG keywords and weights selected, which can lead to different conclusions (Clementino & Perkins, 2021).

Zeidan et al. (2015) suggest that the ESG objectives are not clearly defined and do not apply to the lending policy. According to Friede et al. (2015), ESG ratings are not used by financial institutions, even if they are relevant to investment decisions. At the same time, Jang et al. (2020) suggest that ESG activity, apart from its impact on moral capital, may also generate financial benefits, in particular for bond issuers. Thus, ESG, being an important pillar of corporate social responsibility in the development of sustainable strategies, has an impact on the financial results of enterprises (Eccles & Serafeim, 2013). On the other hand, activities related to the fulfilment of ESG criteria may improve the financial value of some entities but weaken it in the case of others (Humphrey et al., 2012). Meeting the ESG criteria also generates additional costs for the enterprise (Derwall et al., 2005; Semenova & Hassel, 2008), which has an impact on the financial results.

The relationship of ESG with the financial performance of enterprises in developed markets was the subject of many studies (Waddock & Graves, 1997; McWilliams & Siegel, 2000; Lee et al., 2016). The results of the linear model developed by Nollet et al. (2016), using Bloomberg's assessment of the Environmental Social Governance Disclosure for S & P500 companies in 2007-2011, suggest that there is a significant negative relationship between return on capital and corporate social performance. While Van Beurden and Gössling (2008) received empirical evidence for a positive correlation between the social and financial performance of enterprises.

Credit Rating Agencies (CRAs) have different probabilities of default. However, studies comparing Moody's, Fitch, and Standard & Poor's ratings have found strong similarities in credit ratings (Ammer & Packer, 2000). CRA's use different symbols to denote the rating given to issuers of debt instruments. However, the differences are slight, and it is easy to see the relationship between the symbols. CRA's products are similar (Candelon et al., 2014). The ratings are divided into two categories: investment rating and speculative rating. Credit ratings are used to assess the probability of default (Kang & Qiao, 2007; Matthies, 2013). Choy et al. (2006) showed that there is a strong correlation between credit ratings and the probability of default. However, the higher the credit rating, the lower the risk of default. From the issuer's perspective, credit ratings affect the cost of debt and access to financing (Gray et al., 2006). It is very important to know the factors that influence a company's credit ratings (Birindelli et al., 2015). Attig et al. (2013) state that credit rating agencies tend to give relatively high ratings to companies fulfilling environmental and social criteria. The transparency of reporting environmental, social and governance performance and their relationship to the credit ratings of listed companies also play an intermediate role (Li et al., 2022). ESG actions benefit society by increasing transparency and can also benefit companies by reducing their financing costs by reducing investors' perception of default risk. How the number of creditworthiness ratings of issuers of green debt instruments affects the number of issues and the average amount issued was the subject of the Frydrych study (2021). The results indicate that the number of green debt instruments and the average amount of the issue were influenced by the number of ratings assigned to the issuer. The largest number of green debt instruments and the highest average issue amount were held by issuers of green bonds with three ratings.

In view of the above, the author hypothesises that having a credit rating by issuers from at least one of the selected agencies (Moody's Investors Service, Standard & Poor's (S&P) and Fitch Group) has an impact on the number and average amount of ESG debt instruments issued.

Research methods

The analysis covers the credit rating of the issuers of ESG debt instruments issued in the years 2012-2021. The dataset provides information on all types of ESG debt issuers. Their geographical spread covers the whole world, all sectors of activity. The study includes only the instruments which were in the circulation on 31st of December 2021.

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The research material in this paper includes – apart from the analysis of literature – a method of observation, analysis of source materials, and deduction. The paper utilises the data from Refinitiv Eikon.

The study assessed whether having a rating from more than one agency and from which of the analysed CRAs, has an impact on the number of issues and the average number issued. In order to allow the data to be compared with each other and for further analysis, the ratings were converted to numeric and then compared. Thereafter, the author has examined which agencies (among S&P, Moody's, and Fitch) most often gave the ratings to issuers of the ESG debt instruments. Therefore, only credit rating given by those agencies were analysed. Moreover, it has been checked whether the issuers were rated by one or more agencies and which agency awarded the highest and lowest credit rating. Furthermore, the differences in ratings between the agencies and what rating was given most frequently have been examined.

For this purpose, issues of 916 issuers of ESG debt instruments have been analysed. The analysis included bonds as well as notes and others ESG instruments. Moreover, the average amount of issued papers were given in USD.

Results of the research

In the years 2012-2021, ESG instruments were issued by 2086 issuers. Only 17.74% of issuers have no credit ratings. Moreover, credit rating assigned by others CRA's than S&P, Moody's and Fitch had 800 issuers (Figure 1). While 43.91% issuers had credit ratings at least 1 rating from S&P, Moody's, or Fitch.

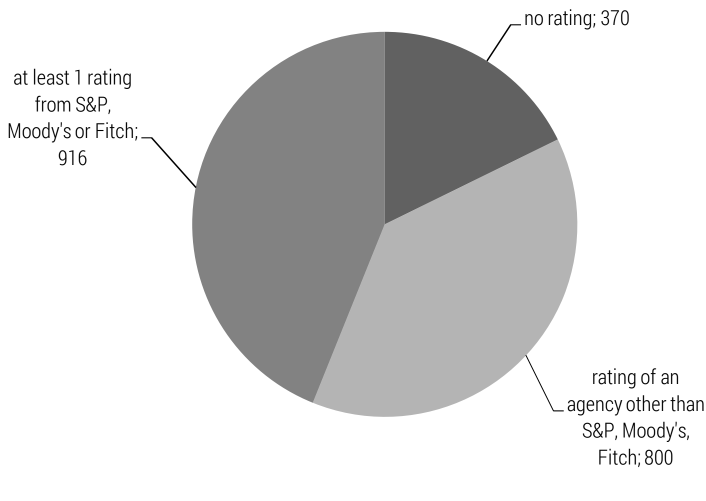

Figure 1. The number of credit ratings of the ESG instruments issuers

Source: author's work based on Refinitiv Eikon [01-01-2022].

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As can be seen in Table 1, one agency gave a credit rating to 41.92% of the issuers; two agencies gave a credit rating to 38.21% of the issuers, while three agencies gave a credit rating to 19.87% of the ESG instruments issuers. The highest average amount of issue applied to issuers with three credit ratings. However, the largest average number of instruments were issued by issuers with two credit ratings (Moody's and Fitch). On the other hand, issuers with a rating only from Moody's issued the lowest average value of a ESG instrument, while the rating given to an issuer only by Fitch determined only nearly two issues per issuer.

Table 1. The number of ratings assigned by selected CRAs vs. number of issues and average amount issued [USD]

S&P	Moody's	Fitch	Issuers	Number of issues	Average Amount Issued [USD]
x			214	532	278 084 183
	x		73	407	121 243 354
		x	97	189	383 715 842
x	x		119	483	419 593 989
x		x	177	565	628 643 767
	x	x	54	480	287 005 000
x	x	x	182	1181	768 603 470

Source: author's work based on Refinitiv Eikon [01-01-2022].

The S&P awarded the highest number of ratings – 42.58%. Moody's, on the other hand, assigned 26.34% and Fitch 31.08% of ratings. Since 532 issuers of ESG instruments have two or more credit ratings, the second stage of the research focused on the comparison of the highest and lowest credit ratings awarded by selected CRAs and the difference in the credit ratings between the agencies. For this purpose, the issuers who received the ratings from two or three agencies were analysed. The issuers who received the rating only from one agency were excluded from this sample.

The comparison of the highest and lowest credit rating awarded by S&P, Moody's and Fitch led to some conclusions. S&P gave the highest rating to 25.94% of the issuers. Whereas Fitch only to 17.92% of the issuers. When analysing the lowest grade received by the issuers, the situation looks similar. S&P gave the lowest rating to 26.78% of the issuers while Moody's to 16.34% of the issuers of the ESG instruments (Figure 2). Moody's gave similar credit ratings as others CRA's to 65.35% of the ESG instruments issuers.

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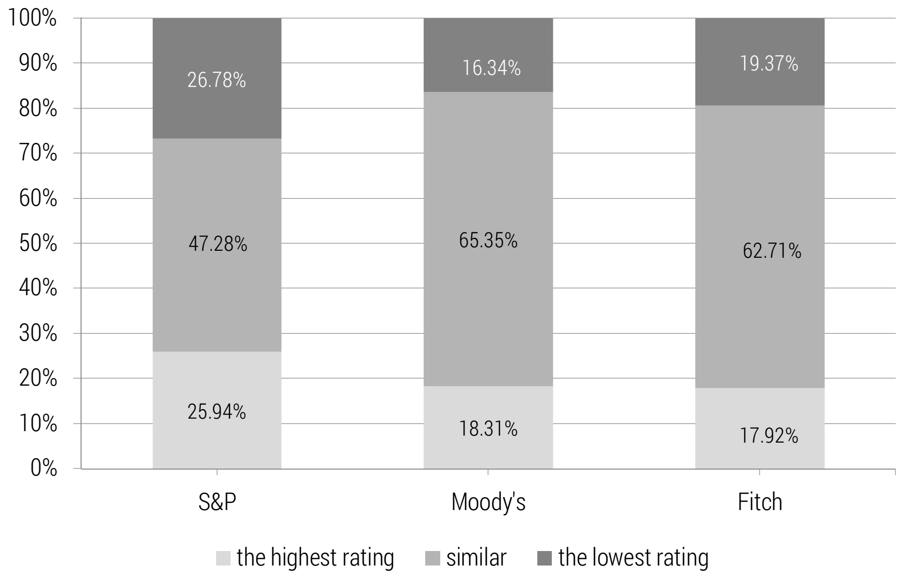

Figure 2. The highest, the lowest ratings of CRA

Source: author's work based on Refinitiv Eikon [01-01-2022].

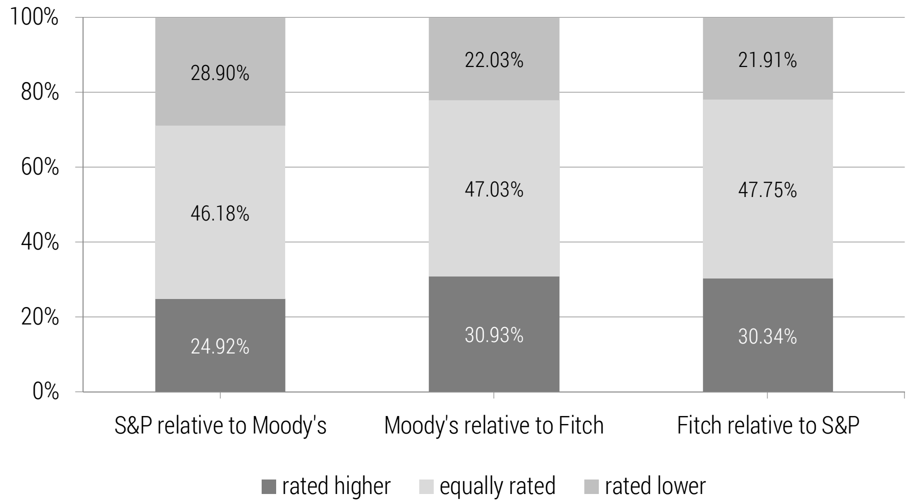

Figure 3. Ratings differences between agencies

Source: author's work based on Refinitiv Eikon [01-01-2022].

Furthermore, there are some differences in the ratings given to issuers between agencies (Figure 3). Moody's rated higher than Fitch in 30.93% of the cases and the S&P ratings were lower than Moody's in 28.90% of the cases, whereas Fitch gave similar ratings to S&P in 47.75% of the cases and similar ratings to Moody's in 47.03% of the cases. When comparing the Moody's with the S&P ratings, 46.18% of the issuers received the same rating. The Fitch ratings were higher than S&P ratings only in about 30.34% of the cases and lower than the S&P's ratings in 21.91% of the cases.

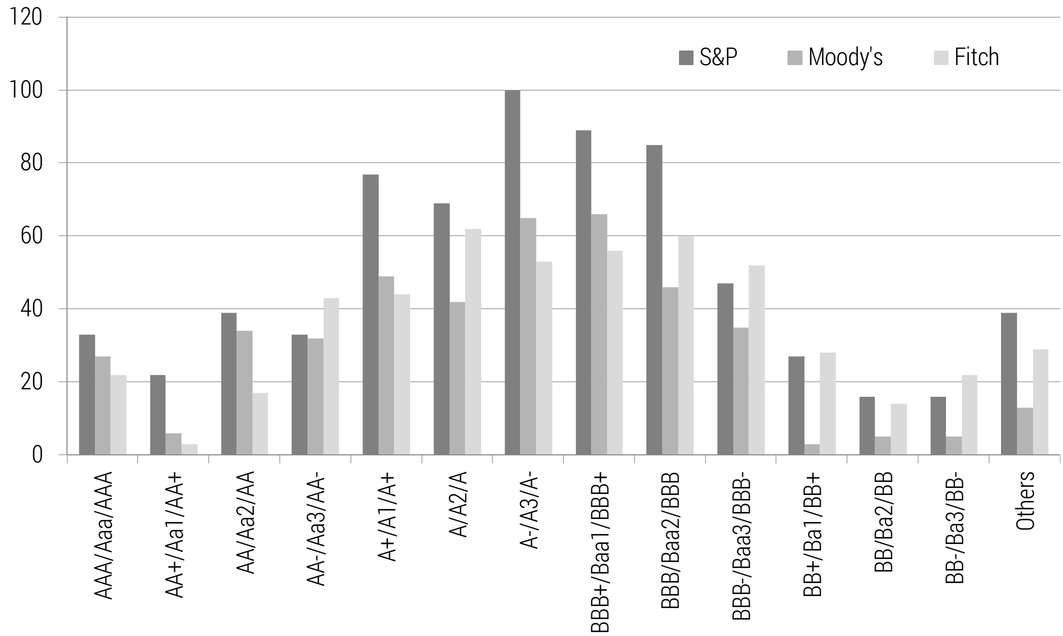

Figure 4. Ratings assigned by Moody's, Standard and Poor's and Fitch
Source: author's work based on Refinitiv Eikon [01-01-2022].

The Figure 4 shows that A-/A3/A- and BBB+/Baa1/BBB+ ratings prevail among the ratings given to the issuers. The low credit risk was awarded 218 times, with 100 issuers receiving such ratings from Standard & Poor's, 65 from Moody's and 53 issuers receiving such rating from Fitch The moderate credit risk was awarded 211 times, with 89 issuers receiving such ratings from S&P, 66 from Moody's and 56 issuers receiving such rating from Fitch. Whereas the highest quality credit rating (AAA/Aaa/AAA) was given 82 times. In default, credit rating was not assigned at any time by CRA'a among the ESG instruments which were in the circulation on 31st of December 2021. Whereas others contain the credit ratings from B to CCC awarded to the ESG instruments issuers.

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Conclusions

The purpose of this article was to analyse the impact of the number of credit ratings of an issuer of the ESG instruments on the number of issues and average amount issued. This basically means proving whether a higher number of ratings for an issuer that incurs additional costs result in more issues and average amount of the ESG instruments issued.

During the period under analysis, 82.26% of issuers had credit ratings, while 370 issuers were not rated. Taking into account the number of credit ratings assigned by CRAs to issuers of ESG instruments, the 53.38% rated issuers received ratings from one CRAs as S&P, Moody's and Fitch. Therefore, the research based on data collected from the Refinitiv Eikon Database for the period between 2012 and 2021 allows us to conclude that the higher number of issuer's ratings results in the higher number of issues. It is enough to have two credit ratings issued by replaced agencies. However, it is worth to add that the ratings should be given by Moody's and Fitch. In contrast, issuers with three ratings issued the highest average value of ESG bonds. The issuers with only one rating, assigned by Moody's, had the lowest average value of issues. On the other hand, the lowest average number of issues was recorded by issuers with only one Fitch rating. Research conducted by Frydrych (2021) on green bonds confirms the required number of ratings for the average value of the issue. While for green instruments it is sufficient for the issuer to have two credit risk assessments also for the highest average value of the issue.

In addition, credit ratings assigned to issuers by Standard & Poor's were 28.90% below Moody's and those assigned by Moody's were 22.03% below Fitch. In addition, Moody's gave higher ratings than Fitch to 30.93% issuers of ESG instruments and Fitch gave higher ratings than Standard & Poor's to 30.34% gave lower ratings than 30.34% of entities and a similar credit rating to over 47.75% of entities. The most common credit ratings assigned by CRAs were A-/A3/A- and BBB+/Baa1/BBB+. On the other hand, among the ratings assigned to issuers of Eurobonds from Central and Eastern European countries, the Baa/BBB/BBB rating prevails (Frydrych, 2020). This means that issuers of debt instruments ESG, which stands for environmental, social, and governance have a higher creditworthiness rating.

On the grounds that there are also considerations other than the issuer's credit rating that affect the average value and number of debt instruments issued, this study has numerous limitations which render it difficult to make decisions about the number of credit ratings and from which CRAs.

The source literature does not include many studies comparing the credit ratings of ESG bond issuers. The conclusions of this study can be used in the

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process of obtaining debt financing for purposes such as climate improvement. The similar analyses may be conducted also for issuers of other debt instruments. The further research should also explain the impact of a changing credit rating of the issuer during the ESG bonds term.

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WHAT EXPERIENCES DO TOURISTS SEEK IN NATIONAL PARKS? ANALYSIS OF TRIPADVISOR REVIEWS

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ABSTRACT: The article aims to analyse and compare experiences gained by tourists visiting three national parks in Poland. The authors focused on the following questions: What are people's experiences visiting national parks in Poland? Do the natural assets of the national parks affect visitors' unique experiences, or are environmentally valuable areas not crucial for their experiences? The authors used mixed quantitative (text mining, correspondence analysis) and qualitative (content analysis) methods. The data for analysis were opinions written by TripAdvisor users. Reviews on TripAdvisor indicate that the most important experiences for tourists in the National Parks studied were Nature appreciation and Physical activity. The other groups of experiences reflected in the reviews were: Aesthetic, Connection, Tension and Excitement. This confirms that nature is the most important feature of national parks for tourists, but it also indicates a trend to maintain good health and the desire to regenerate physical strength in areas of natural beauty.

KEYWORDS: content analysis, coding experiences, text mining, Poland's national parks, sustainable tourism

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Introduction

National parks are natural attractions with the highest frequency, both in Poland and in the world (Liszewski, 2009; Wearing et al., 2009; Kruczek, 2017; Stoleriu et al., 2019). These attractions are on the list of places in Poland that, according to Poles, should be seen by a foreigner to recognise Poland as a fascinating country, i.e. places that Poles can boast of to others (Herrmann, 2010). Paradoxically, the decision to include protection carries a threat from tourism in the bud (Eagles et al., 2002; Butler, 2018; Niezgoda & Markiewicz, 2021). Granting the status of a national park to an area is generally perceived as ennobling (Stasiak, 1997) and causes a desire to visit this place (Giergiczny & Zwijacz-Kozica, 2018). Tourist use of national parks is systematically increasing, dictated not only by the desire to contact nature or seek aesthetic impressions but also by the need to rest and practise outdoor sports (Davenport & Borrie, 2005; Niezgoda & Nowacki, 2020).

It is worth considering whether tourists visiting parks want to experience a place's unique qualities or whether these values are of secondary importance.

The article aims to analyse and compare experiences gained by tourists visiting three of the most interesting protected areas in Poland: Tatra National Park (UNESCO M&B), Białowieża National Park (UNESCO WHL) and Wolin National Park. The authors focused on the following questions:

1. What are the experiences of people visiting national parks in Poland?
2. Do the natural assets of the national parks affect visitors' unique experiences, or are environmentally valuable areas not crucial for their experiences?

An original method of identifying tourist experiences was used to answer these questions. The text mining method consisted of coding words characteristic of selected dimensions of tourist experiences. Thanks to this, it was possible to identify and compare the experiences of tourists in three different national parks with a diverse (contrasting) nature of the ecosystem and tourism development.

As Lindberg et al. (2007) pointed out, to coherently combine the protective function with the tourist function of parks, apart from the number of visitors, the following should be analysed: visitor behaviour, duration of stay, tourist concentration, and type of tourism. In addition, the experiences tourists are looking for are an essential issue. Therefore, the authors analysed the perception of these national parks by contemporary tourists, for whom different experiences may be important.

Moreover, the concept of experiences presented in the works of Packer and Ballantyne (2016) and Packer et al. (2018) was supplemented by the

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authors with "nature appreciation", which is of exceptional importance for tourists visiting environmentally valuable areas. In addition, thanks to the correspondence analysis, associations of experiences dimensions and different types of national parks were identified.

Tourist experiences in national parks

National parks came into being with a noble and inspiring purpose, to protect areas of wildlands for a nation rather than for a privileged few, and at the same time, encourage access to those areas by all those who could travel there (Butler, 2018). People choose the destination they believe will best meet their needs. Tourism marketers tend to talk about the new traveller (Hudson, 2000; Doswell, 2002; Mehmetoglu, 2007; Niezgoda, 2013), who is better educated and more culturally aware but also more environmentally sensitive. An important trend characteristic of modern tourists is the "return to nature". This includes the desire to experience tranquillity, view the scenery, and be physically surrounded by soothing nature (Mehmetoglu, 2007; Luo & Deng, 2008; Kim et al., 2015; Rossi et al., 2015; Davenport & Borrie, 2005).

Experiences are the main issue in tourism (Aho, 2001) and outdoor recreation (Hassell et al., 2015). Tourists want to give their travels meaning and are looking for elite forms of recreation in which experience can play a distinctive role (Wearing et al., 2009). On the other hand, as Doswell (2002) noted, people who travel for pleasure choose to go somewhere, for example: for rest, adventure, escape, discovery, excitement, sport or romance, or any other pleasure-seeking motivations.

The needs of the tourist are characterised by the oft-quoted escapism – the flight from the boredom of everyday life, the need for a change of environment, and the search for something different. The scenic attractions of the holiday destinations stand at the central focus of tourist needs and are the most important tourist motivation. The landscape's structure, beauty and mood – its whole „experience value" – are crucial for the contrast of real life. From the tourist's point of view, the attraction of nature-protected areas lies in the dissimilarity. As Canavan (2017) notes, despite growing environmental awareness, leisure is still a hedonistic experience for many tourists, far from being responsible. Krippendorf (1997) also notes that tourism has undoubtedly contributed to mass awareness of the importance and difficulties of nature conservation, but only in the sense of therapeutic reparation.

That there would be no paradox that tourism destroys the object of its desire (Tucker, 2001; Lubbe et al., 2019), the condition is ecological awareness of tourists, which takes into account not only the process of "raising

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awareness" but also the effects of this process. In line with the principles of sustainable development, tourism develops a flow of traffic to beauty spots while putting pressure on them. No tourist area can compete without carefully considering who its visitors are or whom it wants its visitors to be (Haywood, 1997; Rossi et al., 2015; Davenport & Borrie, 2005). Whatever the situation, a tourist area must offer and be able to deliver a tourist experience that is unique and intensely satisfying for visitors (Wearing et al., 2009). The experiences of visitors may also explain how and why some users express affinity for, or a sense of place towards, some parks but not others. In the longer term, this has potential repercussions for political commitment to establishing and maintaining protected areas such as national parks (Stedman, 2002; Rossi et al., 2015). However, Fennel (2015) noted that not all types of nature tourists are necessarily compatible with the environment. As stated by Davenport et al. (2016), understanding recreation experiences within a particular setting are essential in evaluating that specific activity's appropriateness in a national park.

Therefore, one should first consider the experience preferences under which tourists come to protected areas and, secondly, whether tourists' behaviour is related to environmental awareness. The answer to these questions can be found by analysing the experiences of tourists visiting national parks.

The role of traveller-generated content (TGC) and TripAdvisor reviews in communicating experiences

During the analysis of the tourists' experiences, the role of traveller-generated content (TGC) should be taken into consideration. Nowadays, the evolution of the Internet has become a major factor of change both in the tourism and travel industries and in how tourists purchase and experience travel products (Munar & Jacobsen, 2013). Most authors agree on the importance of the Internet as a travel information source (Llodrà-Riera et al., 2015; Xiang et al., 2015). The opinions of other users and consumers can be transmitted both via word-of-mouth (WOM) and by electronic communication (eWOM). TGC, which includes travel blogs, online travel reviews (OTR), travel-related forums, tweets, Facebook posts, etc., has become the main source of secondary information (in addition to the primary source of own experience) in the process of procuring goods or contracting services online (Marine-Roig, 2019). TGC, such as travel blogs and online travel reviews, influences the decision-making process of other tourists (Munar & Jacobsen, 2013; Marine-Roig & Ferrer-Rosell, 2018). Over the last few years, TGC and social media have reversed in priority as sources of information (Marine-Roig, 2019). One of the sources generated by travellers is TripAdvisor, which has a more or

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less global reach, even if some language barriers do exist (Munar & Jacobsen, 2013).

TripAdvisor is still the world's most popular travel destination review platform in recent times (Gan et al., 2017; Kim et al., 2016; Filieri et al., 2020; Niezgoda & Nowacki, 2020;), although Mathayomchan and Taecharungroj (2020) report that in the USA the fastest-growing review platform is Google Maps' Local Guide. Online reviews are considered credible and trustworthy by tourists as they are based on the previous experiences of real customers. Ease of use and suitability are also important (Filieri et al., 2020). Research by Drozdowska and Duda-Seifert (2016) proves that this type of data is also reliable, complete and valuable from the point of view of marketing research.

Methods

The authors used mixed quantitative (text mining, correspondence analysis) and qualitative (content analysis) methods. The data for analysis were opinions written by TripAdvisor users. Trip Advisor allows users to interpret and share experiences, as well as influence other visitors. When communicated online, experiences gain greater significance and shape destinations' images and future visitors' decisions and expectations (Zhang & Cole, 2016; Stoleriu et al., 2019). A similar method was used by Stoleriu et al. (2019), who identified four groups of nature experiences: sensory experiences, awe and wonder or emotional experiences, cognitive (reflective) experiences and spatiotemporal experiences. The research by these authors was based on earlier groups of experiences distinguished by Packer and Ballantyne (2016). Thus, one can notice the simultaneous occurrence of a trend among modern tourists of seeking solace in nature and a search for experiences.

In this study, all reviews from the 'Things to do' category were collected regarding attractions (category 'Things to do' in TripAdvisor) located in three of Poland's national parks: Tatra NP (624), Białowieża NP (273) and Wolin NP (157). In total, 1,054 reviews were downloaded (5,291 sentences and 98,170 words) from 27 attractions or areas (Table 1).

To identify reviews in which words related to experiences appeared, a procedure of coding reviews was carried out. Packer and Ballantyne (2016) and Packer et al. (2018) distinguished 15 dimensions of experiences such as physical activity, excitement, aesthetic appreciation, peacefulness, togetherness, spiritual engagement, attention, fascination, privilege, compassion, reflective engagement, connection, autonomy, personal growth, and tension.

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Table 1. Types of attractions reviewed (N = 27)

Things to do	Białowieża	Wolin	Tatry	No of attractions
Beaches		7		1
Bodies of Water			396	2
Forests	105			1
Historic Areas		5		1
Lookouts		32		2
Mountains			165	3
Museums	40	38		6
National Parks	44	38		2
Points of interest	10	37		2
Reserves	74			1
Valleys			38	3
Waterfalls			25	2
No of reviews	273	157	624	
No. of attractions				27

Each experience dimension was characterised using various words. Words characteristic of particular dimensions of experience were identified based on the content analysis of articles by Packer and Ballantyne (2016), and Packer et al. (2018) looked for the characteristics of the dimensions of experience and their synonyms. For example, physical activity was characterised using: active, mobil, vigor, energet, physical, climb, visit, walk, and hike (Table 2). Also, these 15 dimensions were developed based on results from "museums, art galleries, science centres, zoos, and aquariums" (Packer et al., 2018). They may include physical activity as an experience (such as hiking, walking etc.), but do not cover any terms relating to nature as an experience. Therefore, in this work, a 16th experience of nature appreciation has been added, which included terms relating to nature such as forest, bison, animal, nature, beach, park, reserve, lake, mountain and horse.

The authors of the article used these words to identify the experiences described in the reviews. The words appearing in the reviews were coded into dimensions using KH Coder software (khcoder.net). The KH Coder software searched for the appropriate words (visitor experiences) and then assigned them to specific dimensions of visitor experiences. Statistical differences in the frequency of the occurrence of words between parks were verified using Pearson's Chi-squared test. NVivo 11 (qsrinternational.com) was

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used in the qualitative analysis. The content analysis consisted of searching for reviews containing words related to experiences and analysing their meaning. Finally, correspondence analysis was made to visualize the associations between experience dimensions and national parks. Correspondence analysis is a descriptive and exploratory technique that provides information on the structure of relations between columns (variables) and rows (cases) in a multidimensional table (Greenacre & Blasius, 1994).

Table 2. Dimensions of visitor experiences and words

Dimensions of visitor experiences	Words – the content of visitor experiences
*Physical activity	activ | mobil | vigor | energet | physical | climb | visit | walk | hike | fitness | sport | exercising | training | motion
*Excitement	excit | exhilarat | enthusias | enjoy | elat | enjoy | stun | fun | amuse | indulge | breathtak | passion | thrill | emotion | stimulat | elation | joy
*Aesthetic	aesthetic | appreciation | beauty | grandeur | senses | beauti | beautus | nice | great | elegant | pleasing | charming | groovy | splendid | gorgeus | tastefull | lovely | esthetic | cute | attractive | fantastic | marvelous | bonny | fabulous | incredible | extraordinary | fine | picturesque | stunning | breathaking | pretty
*Peacefulness	peace | seren | relax | refresh | restore | quiet | calm | tranquility | stillness | placid | rest | repose | quietude | hush | silence | lull | equanimity | inactivity | harmony | patience | noiseless | nirvana
*Togetherness	sociable | togetherness | fellowship | companionship | community | camarade | comrade | unity | friendship | closeness | amity | proximity | alliance | intimacy | friendliness
*Spiritual	spirit | reverent | worship | sacred | holy | religious | ghostly | mental | intellectual | metaphysic | psychical | saintly | transcendent | psychological
*Attention	attentive | alert | observant | concentration | mental | focus | emphasis | awareness | careful | caution | consciousness
*Fascination	fascinat | amaz | intrigue | wonder | imagin | charisma | charm | desire | allure | captiv | attractive | obsessi | glamour | desire | temptation | awe | craze | fixation | wonder | enthusiasm | marvel
*Privilege	privilege | honour | fortunat | grateful | respect | authority | honor | pride | entitled
*Engagement	reflective | thoughtful | introspective | thought | ponder | involv | engag | participat | commit | struggle | attendan
*Connection	connect | attachment | nostalgia | love | relat | associat | join | link | tie | connex | relevan | union | interconnect | bound
*Autonomy	independen | confident | choice | control | deciding | freedom | sefl-govern | selfsyfficienc | self-determinat | autonom | sovereign | selfdeterminat | independan
*Personal growth	accomplish | fulfill | growth | self-discovery | self-actualiz | self-develop | self-realisat | self-fulfill | self-enrich | self-improve
*Tension	tens | frustrate | stress | overload | uncomfortabl | crowd | pressure | friction | conflict | anxiety | worry | strain | stretch | effort | intens | enmity
*Nature appreciation	forest | bison | animal | nature | beach | park | reserve | lake | mountain | horse

Source: authors' work based on Packer and Ballantyne (2016); Packer et al. (2018).

Results

First, the most common words in reviews about the three national parks were counted (Table 3). Most popular words in reviews for Białowieża NP was: forest, see, guid, bison and visit, for Wolin NP was: walk, visit, place, view, park, and for Tatra NP was: walk, lake, mountain, place and oko (the name of a pound).

Table 3. Most common words for Białowieża, Tatry and Wolin found in reviews

Białowieża NP		Wolin NP		Tatra NP	
Word	Frequency	Word	Frequency	Word	Frequency
forest	106	walk	39	walk	202
see	76	visit	36	lake	182
guid	72	place	29	mountain	133
bison	55	view	28	place	109
visit	55	park	26	oko	106
place	51	nice	25	beauty	105
animal	48	beach	22	zakopan	104
park	42	great	22	view	101
bialowieza	40	interest	20	morski	98
nature	39	polish	20	take	87
tour	36	beauty	18	hike	84
walk	31	people	16	visit	67
area	29	sea	16	get	64
museum	27	see	15	park	64
nice	26	time	14	tatra	62
reserve	24	good	13	hour	61
good	22	lot	13	great	58
great	22	enjoy	12	trip	58
time	22	famous	12	horse	57
beauty	21	lighthouse	12	bus	56

Next, words related to experiences were sought. The coding procedure was started. Based on the terms used in the reviews, the most common experience in the three parks was Nature appreciation (73.1%), but more so for

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Białowieża (82.2%) than Tatra (79.1%) and least in Wolin (38.2%) (Table 4). Reviewers were delighted with the main natural features and the landscape: “Absolutely unique experience for all nature lovers” (BNP, travel0shoes, Spain), wild animals, flora and fauna: “If you are looking for a wild forest, wild mushrooms and wild animals you should get to Bialowieza” (BNP, Urszula C, Sankt Ibb, Sweden).

Table 4. The results of automatic coding of experiences vs national parks

Experiences	Białowieża	Tatra	Wolin	Total reviews	chi-square
*Physical activity	*114 (41.7%)*	**500 (80.1%)**	*78 (49.6%)*	692 (65.6%)	144.8**
*Excitement	*20 (7.3%)*	**92 (14.7%)**	20 (12.7%)	132 (12.5%)	9.5**
*Aesthetic	*74 (27.1%)*	**320 (51.2%)**	63 (40.1%)	457 (43.3%)	45.9**
*Peacefulness	18 (6.5%)	**66 (10.5%)**	*8 (5.1%)*	92 (8.7%)	6.8*
*Togetherness	0 (0.0%)	2 (0.3%)	0 (0.0%)	2 (0.1%)	n.a.
*Spiritual	1 (0.3%)	7 (1.1%)	0 (0.0%)	8 (0.7%)	n.a.
*Attention	3 (1.1%)	12 (1.9%)	2 (1.2%)	17 (1.6%)	n.a.
*Fascination	3 (1.1%)	15 (2.4%)	1 (0.6%)	19 (1.8%)	n.a.
*Privilege	1 (0.3%)	4 (0.6%)	1 (0.6%)	6 (0.5%)	n.a.
*Engagement	0 (0.0%)	12 (1.9%)	0 (0.0%)	12 (1.1%)	n.a.
*Connection	**53 (19.4%)**	76 (12.1%)	*15 (9.5%)*	144 (13.6%)	11.1**
*Autonomy	2 (0.7%)	12 (1.9%)	0 (0.0%)	14 (1.3%)	n.a.
*Personal growth	1 (0.3%)	0 (0.0%)	0 (0.0%)	1 (0.1%)	n.a.
*Tension	*6 (2.2%)*	**122 (19.5%)**	*10 (6.3%)*	138 (13.1%)	57.6**
*Nature appreciation	**219 (80.2%)**	**494 (79.1%)**	*60 (38.2%)*	773 (73.1%)	116.5**
N of Documents	273	624	157	1054	

Note: * – $p < 0.05$, ** – $p < 0.01$; bold – above mean, italics – below mean; n.a. – Chi-square values can only be calculated for values more than 5 counts per cell.

The next topic in order of significance (65.6%) contained words related to the experiences of *Physical activity: most in Tatra (80.1%) and least in Białowieża (41.7%). These are both descriptions of trips around the valleys “easy road, you are just walking, looking around” (TPN, Nastya_Lampy, St. Petersburg, Russia) as well as mountain climbing on the demanding trails “some parts were very steep. Climbing up took 30 min” (TPN. Specas), “Białowieża National Park is a very pleasant place for a long walk or bike trip, but not expect seeing something more than trees” (BPN, Jakub G, Bielsk Podlaski, Poland).

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Another group of experiences was *Aesthetics (43.3%): again, most in Tatra (51.2%) and least in Białowieża (27.1%). For example: "large stones completely around the beautiful lake surrounded by mountain peaks" (TPN, Michael S, Boston, Massachusetts), "Still some magnificent views along the way" (TPN, CM9493, Scotland) or "wow you with their natural grandeur" (TPN, Mekydro, Chertsey, United Kingdom).

The following most frequently reported experiences belonged to the dimension of *Connection (13.6%): „A beautiful place to visit and make an encounter with nature and soul" (BPN, Alda Ferro, Lisbon, Portugal), "Look out over the nature reserves and enjoy the ships that pass" (WPN, Clogsin-France, Hambye, France) or "What a perfect place to visit if you like being close to nature and enjoy doing some trekking" (TPN, Beta-J, Malta).

Subsequent experiences were associated with *Tension (13.1%) – again most in Tatra (19.5%): „When you reach the lake, the first impression will be the crowd, not the wonderful lake if you depart around 9 am and more" (TPN, Ruaidol, Cassino, Italy), "But if you have travelled to other mountain ranges in the world, and seen their lakes, then Morskie Oko isn't worth the effort" (TPN, dacky2, Tromso, Norway). Many reviews about the Tatra National Park concerned overcrowding, tension and overloaded horse-drawn carriages. Many cases of horses falling from exhaustion were described.

The next group of experiences belonged to *Excitement (12.5%): "If you would like to enjoy a retreat in the green and serene environment, Bialowieza has that to offer with the feel of mystique of the forest" (BPN, Malmercy, Sentosa Island, Singapore) or "You will need an entire day to fully enjoy the beauty of Morskie Oko, and it's best to start early in the day" (TPN, carl_and_janelle, Queensland, Australia) and *Peacefulness (8.73%): "Is a place that is full of peace and quiet" (BPN, Nelva G) or "For me, the lake is beautiful, if you are looking for a bit of quiet time, I recommend that you walk around the lake, not all tourist willing to walk around the lake when they get there" (TPN, HanselL_12, Jakarta, Indonesia).

Then a correspondence analysis was made to visualise associations of experiences dimensions and national parks. Experiences which were occurred in less than 1% of reviews (*Togetherness, *Spiritual, *Privilege and *Personal growth) were removed from the analysis so that they did not unnecessarily affect the analysis with their presence. The Chi-square test proved a statistically significant relationship at the level of $p<0.001$ between experience dimensions and parks. Then, an analysis of the correspondence was performed, which resulted in obtaining two dimensions that reproduced 100% of the total inertia (Figure 1). Hence it is seen that Tatra experiences are characterised mainly by *Peacefulness and *Physical activity, Wolin by *Excitement and Aesthetic and Białowieża mainly by *Nature appreciation and *Connection.

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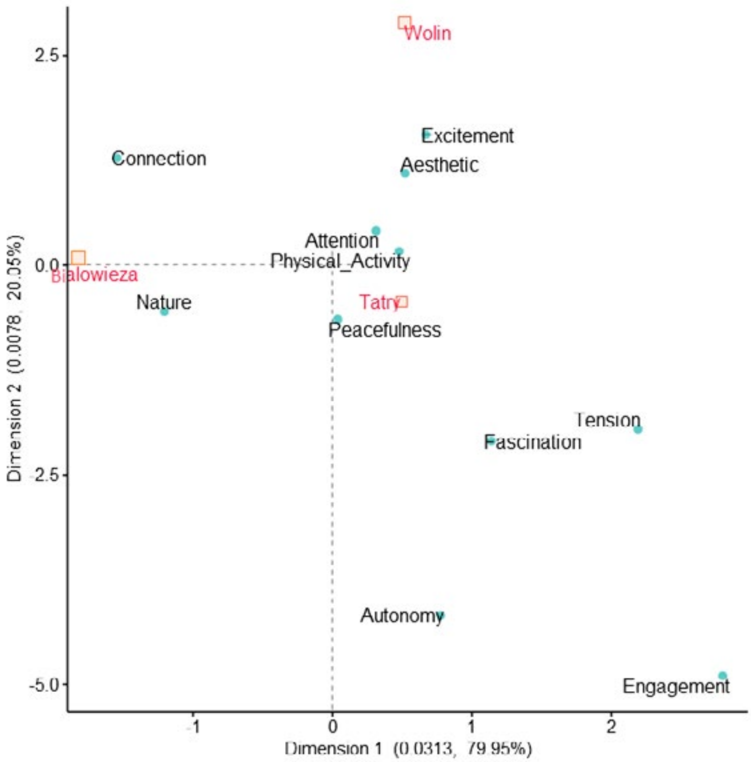

Figure 1. Correspondence analysis between cases (experiences) and variables (national parks)

Discussion

Reviews on TripAdvisor indicate that Nature appreciation is the experience most often described by reviewers, which confirms the findings of other authors (Rossi et al., 2015; Wearing et al., 2009; Davenport & Borrie, 2005; Lubbe et al., 2019; Breiby et al., 2022). This research mainly concerns Białowieża and the Tatra Mountains. The lesser importance of nature in Wolin may result from the seaside and the summer character of this park, which adjoins famous seaside resorts and is more a destination for patients and relaxing on the beach than for ecotourists.

The second most important experience for the reviewers was physical activity. These results differ from the findings of other authors who noted that experiencing nature was an important factor in visitors' experiences (Hassell et al., 2015; Davenport & Borrie, 2005; Breiby et al., 2022). This confirms the trend to maintain health and the desire to regenerate physical strength in areas with valuable natural values. Staying in green areas, including national parks, increases the level of general satisfaction with life. Additionally, in the case of national parks, this result is even several times higher, which means that the positive impact on health does not weaken with subsequent visits but even accumulates (Buckley et al., 2019). Simultaneously, movement is an essential part of life (Holder, 1997). Previous studies have shown the importance of physical activity for people visiting national parks (Niezgoda & Nowacki, 2020). This can be a starting point for deeper analysis and further action by national park authorities. There is a doubt whether tourists who want to engage in physical activity must necessarily visit the area with the highest degree of nature protection. The diversified motives and aspirations of tourists in National Parks may cause a recreational conflict. It occurs when the area is crowded or when the behaviour of one group is considered inappropriate or unacceptable by another group (Eagles et al., 2002; López-Mosquera & Sánchez, 2014; Nowacki, 2015; Rossi et al., 2015; Davenport & Borrie, 2005). A recreational conflict can also occur due to different levels of tourists' skills or experiences. For example, amateurs can upset seasoned nature photographers, and cyclists can obstruct the movement of hikers.

The third and most commonly described experience is Aesthetic, appearing most often in opinions about the Tatra Mountains and Wolin and much less frequently in Białowieża. Such indications prove that the landscapes of the Tatra Mountains and Wolin are more spectacular: mountain and seaside landscapes characterised by a greater variation in altitude and the presence of bodies of water may be more attractive to tourists from the perspective of vantage points.

The next most frequently mentioned elements of experience are Connection, Tension, and Excitement. Connection is an experience described most often in conjunction with close encounters with nature, which occurred very often in opinions about Białowieża. Some tourists feel tension, which indicates that the carrying capacity especially in Tatra NP is exceeded. The Excitement category may reflect impressions of both communing with nature and practising physical activity in a national park.

As demonstrated by Klenosky et al. (2000), people with a high level of experience (or involvement) may have more complex and better-established means-end knowledge structures relative to those with low levels of experience or involvement. Therefore, the fact that tourists looking for experiences come to national parks could contribute to pro-ecological behaviour, provided that the previous experiences of these tourists would raise their environmental awareness.

Therefore, in naturally valuable areas, one should strive to attract tourists not only with high environmental awareness but also rich experiences. This group of visitors can help promote awareness of protected areas by pro-

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viding information to the world about the park as they visit it (Eagles et al., 2002). For the co-creation experience to run well, it needs to be supported by active consumer participation (Grissemann & Stokburger-Sauer, 2012). The level of success in the co-creation experience is highly affected by driving factors-antecedents, which are from the consumer side as co-creator actors and co-creation environment (Verleye, 2015).

The use of Information and Communication Technologies (ICTs) is very important and can play a positive role in the development of tourist experiences (De La Fuente-Robles et al., 2020; Buonincontri & Micera, 2016). The value created by consuming tourism experiences depends not only upon the objective experience but also upon the tourist and the tourist's state of mind at that particular moment (Andersson, 2007).

The new and updated problem relates to unexpected changes caused by the COVID-19 pandemic. Due to limitations in Polish national parks, groups of tourists appeared who were not always interested in nature treated their stay in the national park as a substitute for another trip (abroad, to large resorts, etc.) and even other activities (social events, shopping in a shopping mall, exercises in the gym) (Niezgoda & Markiewicz, 2021). The feeling of individual and social security, which translates into an improvement in the quality of physical and mental health, may lead to a permanent increase in the popularity of national parks also for those tourists who did not visit them before the pandemic.

Conclusions

In our study, the six most frequently mentioned groups of experiences in the analysed national parks indicate that for tourists, the unique values of nature are the most important. These opinions reflect an interest in nature, the unique qualities of the landscape, and the possibilities of contemplation and connection with nature. An in-depth study of opinions on Tension experiences could allow for verification of whether, when assessing congestion, tourists notice a deterioration in their perception of impressions in places of natural value and whether they also see the harmfulness of tourism on nature. Finally, the category that came second – Physical activity – indicates that tourists visiting national parks are not always guided by pro-ecological motives (Niezgoda & Nowacki, 2020). Analysis of the opinions confirms that tourists visiting national parks are guided by various motivations for their visit, which may cause recreational conflict and increase tension. This not only lowers the assessment of tourists staying in the national park but, above all, threatens the natural environment.

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Increasing the number of visits (tourists) is risky as it may negatively affect the natural environment. More possibilities are offered by increasing the length of stay and attracting consumers who are willing to pay higher average expenses per day of stay. The condition is an appropriate level and ecological quality of land development. In tourism capacity, an even balance has to be maintained, both in the physical environment and the quality of the experience of the host country to the visitor (O'Reilly, 1997).

An opportunity to relieve the areas of National Parks is the creation of attractive tourist infrastructure, especially recreational ones, in their foreground and the preparation of new tourist products based on natural, cultural and historical attractions of entire regions (Skawiński, 2010; Niezgoda, 2006; Eagles et al., 2002).

Research confirms an important trend characteristic of modern tourists, which is the "return to nature". This includes the desire to experience tranquillity, view the scenery as well as be physically surrounded by soothing nature (Mehmetoglu, 2007; Luo & Deng, 2008; Kim et al., 2015). Tourists want to give their travels meaning and are looking for elite forms of recreation in which experience can play a distinctive role. On the other hand, as Doswell (2002) noted, people who travel for pleasure choose to go somewhere, for example: for rest, adventure, escape, discovery, excitement, sport or romance, or any other pleasure-seeking motivations. The motivations for travel are many and various, although recreation is a major factor (Holder, 1997).

In summary, tourism in the protected area depends on the maintenance of a high-quality environment and cultural conditions, which can be the basis for creating a tourism experience. This is essential to maintain the economic and social benefits for the local population. In naturally valuable areas, visitors expect to find an attractive offer (services, routes). However, not all requirements can be met, as some expectations may not be consistent with the objectives and tasks of protected areas. In agreeing with the conclusions of other authors (Wearing et al., 2009; Davenport & Borrie, 2005; Lubbe et al., 2019), it should be remembered that the point of ensuring the attractiveness and competitive advantage of National Parks are the values for which these areas were originally established.

This research also points to management implications. National park managers should be aware of what experiences tourists are looking for. Tourists can seek contact with nature and appreciate the beauty of nature through pro-ecological behaviour, but they can also visit natural areas to participate in physical activity. There is a doubt whether tourists who want to engage in the physical activity must necessarily visit the area with the highest degree of nature protection. Investigating various experiences may allow the sources of conflicts and new solutions to be found, for example, by directing tourist

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traffic to areas where tourists can practise sports without using natural resources in the most sensitive areas. On the other hand, managers of national parks and local destinations can use the opinions and experiences of tourists to create a tourist product compatible with sustainable tourism while at the same time providing information on raising environmental awareness.

Limitations of the study

Finally, it is worth noting that the limitations of the method used should be indicated. Firstly, the research sample – although exceptionally large – cannot be treated as representative because the analysed reviews come from an online source, so they do not represent the opinions of people who are inactive on the Internet and social media. It can be assumed that these are mainly older people. So in the study, we are probably dealing with an over-representation of young and middle-aged reviewers (e-WOM generation). Secondly, it takes time, commitment and determination to post a review on TripAdvisor. It can be assumed that making this effort results from vivid emotions (positive or negative) and an overwhelming desire to share one's opinions with others. Thirdly, only reviews in English were analysed. For the vast majority of reviewers, it was not their native language.

The contribution of the authors

Conceptualisation: M.N., A.N.; literature review: M.N., A.N.; methodology: M.N, A.N.; analysis: M.N.; data collection: M.N.; writing: M.N., A.N.; conclusions and discussion: M.N., A.N. Both authors have read and agreed to the published version of the manuscript.

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SUMMARIES IN POLISH

Dorota MICHALAK, Paulina SZYJA

DETERMINANTY BEZPIECZEŃSTWA KLIMATYCZNEGO – PRÓBA ANALIZY WSKAŹNIKOWEJ

STRESZCZENIE: W artykule podjęto zagadnienie bezpieczeństwa klimatycznego – zagadnienie niewystarczająco zbadane w literaturze przedmiotu. Celem opracowania jest uzupełnienie luki w literaturze dotyczącej wyjaśnienia powiązania zmian klimatu i bezpieczeństwa, zdefiniowania terminu bezpieczeństwa klimatycznego oraz próba doboru wskaźników (w oparciu o selekcję spośród już istniejących) na potrzeby zdiagnozowania poziomu bezpieczeństwa klimatycznego. Przeprowadzone badania pozwoliły ustalić, iż brakuje opracowań, które precyzyjnie wyjaśniałyby termin bezpieczeństwo klimatyczne, stąd też przyjęto autorską definicję. Z kolei przegląd istniejących wskaźników wskazał ich ograniczenia. Mimo to pozwolił na odpowiedź na pytanie, czy mamy do czynienia z zagrożeniem dla zapewnienia bezpieczeństwa klimatycznego.

SŁOWA KLUCZOWE: bezpieczeństwo klimatyczne, wskaźniki bezpieczeństwa klimatycznego, bezpieczeństwo narodowe

Krzysztof Adam FIRLEJ, Marcin STANUCH

PROGNOZOWANIE ROZWOJU ENERGII ELEKTRYCZNEJ Z ODNAWIALNYCH ŹRÓDEŁ ENERGII W POLSCE NA TLE KRAJÓW UNII EUROPEJSKIEJ

STRESZCZENIE: Jednym z kluczowych elementów rozwoju krajów jest stabilność energetyczna szczególnie związana z zapewnieniem ciągłości zasilania, m.in. w energię elektryczną. Komisja Europejska próbuje uchronić bezpieczeństwo dostaw energii wprowadzając wewnętrzne uwarunkowania dotyczące udziału OZE w życiu codziennym. Celem artykułu była prognoza udziału OZE w produkcji energii elektrycznej dla wszystkich krajów członkowskich Unii Europejskiej. Badanie przeprowadzono analizując lata 1985-2021, gdzie badania oparto o dwa modele: autoregresyjny (AR) oraz model Holta-Wintersa, a wartości predykcji zostały wyznaczone dla okresu 2022-2030. Wartości prognoz wykazały, że Dania jako jedyny z krajów wspólnoty już na przełomie 2026-2027 może okazać się państwem samowystarczalnym pod względem produkcji energii elektrycznej z OZE. W przypadku Polski istnieje duże prawdopodobieństwo niespełnienia oczekiwań udziału OZE w planowanym udziale na rok 2030. Potencjalnie, dla większości krajów UE energia produkowana z OZE dla 2030 r. będzie zaspokajać przynajmniej 50% zapotrzebowania na energię elektryczną. Prognoza dotycząca szans realizacji przedstawionych w krajowych planach na rzecz energii i klimatu zobowiązań dotyczących udziału odnawialnych źródeł energii w produkcji energii elektrycznej w krajach członkowskich Unii Europejskiej w 2030 roku wskazuje, że nie zostaną one spełnione w większości gospodarek unijnych.

SŁOWA KLUCZOWE: energia elektryczna, prognozowanie, OZE w Unii Europejskiej, model Holta-Wintersa, model autoregresyjny

Andrzej GRACZYK, Alicja Małgorzata GRACZYK, Adam WĘGRZYN

ZMIANA KONCEPCJI WYKORZYSTANIA GAZU ZIEMNEGO W KONTEKŚCIE ZRÓWNOWAŻONEGO GOSPODAROWANIA ENERGIĄ W POLSCE

STRESZCZENIE: Transformacja energetyczna wymaga zmiany w strukturze wykorzystywanych nośników energii. Celem artykułu jest określenie roli gazu ziemnego w polityce energetycznej Unii Europejskiej i Polski jako paliwa przejściowego w kontekście promowanej polityki zrównoważonego rozwoju. W analizowanych dokumentach przedstawiających wizje polityki energetycznej obserwuje się zróżnicowane podejście do efektów zastosowania gazu ziemnego. Przeprowadzono analizę i ocenę możliwych efektów wykorzystania gazu ziemnego w miksie energetycznym Polski. W badaniach zastosowano metodę analizy dokumentów. Uwzględniono sześć atrybutów zrównoważonego gospodarowania energią i relacje między nimi. W rezultacie stwierdzono: 1. gaz ziemny jako nośnik energii nie spełnia warunków zrównoważonego gospodarowania energią, 2. z punktu widzenia skutków zastosowania energetyczne wykorzystanie gazu ziemnego jest lepsze od wykorzystania innych paliw kopalnych, 3. w warunkach rozwoju technologii OZE i energetyki jądrowej energetyczne wykorzystanie gazu będzie się zmniejszać, co powinno przynosić pozytywne skutki dla zrównoważonego gospodarowania energią. Wniosek ogólny – transformacja energetyczna napędzana jest głównie czynnikami o charakterze politycznym. Konieczne jest zatem traktowanie problemu zrównoważonego gospodarowania nośnikami energii w sposób kompleksowy.

SŁOWA KLUCZOWE: gaz ziemny, zrównoważenie, transformacja, polityka

Przemysław BIELECKI

RELACJA CEN UPRAWNIEŃ DO EMISJI CO_2 I CEN ENERGII ELEKTRYCZNEJ W POLSCE W LATACH 2013-2020

STRESZCZENIE: W artykule zbadano zależność pomiędzy cenami uprawnień do emisji gazów cieplarnianych w systemie EU ETS (unijny system handlu uprawnieniami do emisji), a hurtowymi cenami energii elektrycznej w Polsce. Wykorzystano modele regresji liniowej do oszacowania parametru transmisji cen uprawnień do emisji na hurtowe ceny energii elektrycznej podczas III fazy EU ETS (2013-2020). Wyniki modelowania wykazały, że cały koszt uprawnień do emisji CO_2 był uwzględniany w hurtowej cenie energii elektrycznej. Zgodnie z oczekiwaniami szczytowy parametr transmisji okazał się wyższy niż pozaszczytowy, niemniej jednak różnica jest niewielka i statystycznie nieistotna, model nie pozwala więc na wyciąganie daleko idących wniosków w tym zakresie. Wyniki pokazują, że producenci energii elektrycznej byli w stanie przerzucić całość kosztów związanych z emisjami na odbiorców, co może rodzić pytanie, czy EU ETS jest skutecznym narzędziem dającym wystarczające zachęty do dekarbonizacji produkcji energii elektrycznej.

SŁOWA KLUCZOWE: transmisja cen uprawnień do emisji gazów cieplarnianych na ceny energii, ceny energii elektrycznej, ceny uprawnień do emisji do emisji gazów cieplarnianych, system handlu uprawnieniami do emisji

Ewa JASTRZĘBSKA

RAPORTOWANIE INFORMACJI ZWIĄZANYCH Z KLIMATEM PRZEZ LIDERÓW CSR W POLSCE: INDEKS UJAWNIEŃ KLIMATYCZNYCH

STRESZCZENIE: Celem artykułu jest ocena zakresu raportowania informacji związanych z klimatem przez przedsiębiorstwa uznawane za liderów CSR w Polsce, dokonana za pomocą autorskiego indeksu ujawnień klimatycznych. Najpierw przeprowadzono krytyczną analizę porównawczą treści inicjatyw ujawnień klimatycznych (regulacji, wytycznych i standardów) w celu zidentyfikowania kluczowych i najczęściej wymaganych ujawnień klimatycznych. Na tej podstawie zbudowano autorski indeks ujawnień klimatycznych, w oparciu o który policzono indeks dla 20 firm uznawanych za liderów CSR w Polsce (w oparciu o analizę treści publicznie dostępnych w Internecie raportów niefinansowych firm). Badania pozwoliły stwierdzić, że praktycznie wszystkie inicjatywy ujawnień klimatycznych w większym bądź mniejszym stopniu implementują wytyczne TCFD, które stały się podstawą autorskiego indeksu ujawnień klimatycznych, obejmującego 18 wskaźników. Całkowita wartość indeksu (przyjmującego wartości od 0 do 1) dla analizowanych firm wyniosła 0.51 przy medianie równej 0.42. Indeks pokazuje, że firmy zaliczane do liderów CSR w Polsce nie charakteryzują się wysoką świadomością w zakresie zmian klimatu.

SŁOWA KLUCZOWE: ujawnienia klimatyczne, przedsiębiorstwa, indeks, raportowanie niefinansowe

Elżbieta LOREK, Agnieszka LOREK, Wiesław KOCZUR

EDUKACJA DLA ZRÓWNOWAŻONEGO ROZWOJU W POLSKICH SZKOŁACH WYŻSZYCH – TERAŹNIEJSZOŚĆ I PRZYSZŁOŚĆ

STRESZCZENIE: Edukacja na rzecz zrównoważonego rozwoju wciąż rozwija się jako szeroka i kompleksowa koncepcja zawierająca powiązane treści dotyczące środowiska, gospodarki i społeczeństwa. Do kluczowych zagadnień zrównoważonego rozwoju należą, m.in. kwestie ekonomiczne, modele produkcji i konsumpcji, zarządzanie zasobami naturalnymi, ochrona środowiska, modele rozwoju, ograniczanie ubóstwa, prawa obywatelskie, demokracja, sprawowanie rządów itp. Zagadnienia te są zatem bardzo zróżnicowane i wymagają podejścia holistycznego w nauczaniu. Celem artykułu jest diagnoza i ocena aktualnego stanu edukacji dla zrównoważonego rozwoju w polskich szkołach wyższych ze szczególnym uwzględnieniem Uniwersytetu Ekonomicznego w Katowicach oraz wskazanie kierunków zmian. Niniejszy artykuł został napisany w oparciu o wieloletnie doświadczenie naukowe i dydaktyczne Autorów, a także w roku 2020/2021 przeprowadzono badania ankietowe wśród studentów UE w Katowicach, które pozwoliły zidentyfikować kierunki przyszłych działań edukacyjnych.

SŁOWA KLUCZOWE: zrównoważony rozwój, szkolnictwo wyższe, edukacja dla zrównoważonego rozwoju

Adam KUCHARSKI, Paulina SZTERLIK-GRZYBEK

OCENA MOŻLIWOŚCI LOKALIZACJI STACJI ŁADOWANIA SAMOCHODÓW ELEKTRYCZNYCH WYKORZYSTUJĄCA ROZMYTĄ METODĘ AHP ORAZ GIS – PRZYPADEK ŁODZI

STRESZCZENIE: W artykule zbadano możliwość lokalizacji stacji ładowania pojazdów elektrycznych pod kątem wykorzystania wielokryterialnej analizy decyzyjnej (ang. *Multicriteria Decision Analysis - MCDA*) oraz GIS (ang. *Geographic Information Systems* – systemy informacji geograficznej). W ostatnich latach obserwuje się wzrost zainteresowania wykorzystaniem alternatywnych źródeł napędu pojazdów mechanicznych. Stymulują go zarówno czynniki odgórne jak przepisy wprowadzane przez Komisję Europejską czy wprowadzanie tzw. stref czystego transportu przez niektóre samorządy, ale i oddolne. Te ostatnie obejmują wzrost kosztów utrzymania samochodów napędzanych paliwami ropopochodnymi, co skłania właścicieli samochodów do poszukiwania sposobów ich ograniczenia. Tego typu badania mogą być dalej wykorzystywane przez samorządy w celu znalezienia spójnej strategii rozwoju wykorzystania aut elektrycznych w miastach. W pracy weryfikowana jest hipoteza mówiąca, że obszar miasta Łodzi jest zróżnicowany pod względem przydatności do lokalizacji stacji ładowania samochodów elektrycznych, z przewagą obszarów niekorzystnych dla tego typu inwestycji. Ponadto badania mają na celu znalezienie metodyki umożliwiającej przeprowadzenie analizy przydatności pod kątem lokalizacji nowych elementów infrastruktury w przestrzeni miejskiej.

SŁOWA KLUCZOWE: AHP, FAHP, GIS, elektromobilność, problem lokalizacji

Izabela DZIADUCH

BADANIE SATYSFAKCJI PASAŻERÓW KOMUNIKACJI MIEJSKIEJ WE WROCŁAWIU ZA POMOCĄ CSI I IPA

STRESZCZENIE: Celem artykułu jest ocena poziomu satysfakcji pasażerów korzystających z usług komunikacji miejskiej we Wrocławiu oraz wskazanie cech jakości, które usługodawca musi poprawić, jeśli chce zwiększyć ogólną jakość świadczonych przez siebie usług. Badanie satysfakcji pasażerów zostało przeprowadzone zgodnie z przedstawionymi w artykule etapami procedury. Dążąc do realizacji przyjętego celu, zastosowano - CSI i IPA. Głównym narzędziem pomiarowym, który zastosowano, był kwestionariusz ankietowy. Badania przeprowadzono na próbie 500 respondentów, co pozwala ufać wynikom na 95% przy założeniu błędu oszacowania na poziomie ± 5%. Ogółem do oceny poziomu satysfakcji pasażerów korzystających z usług świadczonych przez MPK Wrocław wybrano 14 postulatów przewozowych. Respondenci oceniali następujące cechy jakości usług komunikacji miejskiej: dostępność przestrzenna, częstotliwość połączeń, regularność odjazdów, bezpośredniość podróży, prędkość podróży, punktualność odjazdów, niezawodność podróży, czas podróży, bezpieczeństwo, dostępność informacji, koszt podróży, komfort podróży, integracja oraz koszt inwestycji. Statystyczną analizę danych przeprowadzono za pomocą oprogramowania Statistica 13.3 oraz przy użyciu funkcji i poleceń dostępnych w programie Microsoft Excel. Otrzymane wyniki pozwoliły na przeprowadzenie szczegółowej analizy związanej z poziomem jakości usługi. Wyniki te powinny być wykorzystane przez

organizatorów i operatorów transportu miejskiego do kształtowania oferty przewozowej, przede wszystkim w aspekcie zwiększenia jakości usług przewozowych. Jest to bardzo istotne, gdyż to właśnie między innymi jakość systemu transportowego decyduje o jakości życia mieszkańców, a także o warunkach rozwoju gospodarczego obszaru objętego planem transportowym.

SŁOWA KLUCZOWE: zrównoważony rozwój, publiczny transport zbiorowy, jakość usług, wskaźnik satysfakcji klienta (CSI), analiza ważności-realizacji (IPA)

Joanna GÓRNIAK, Agnieszka BUKOWSKA-PIESTRZYŃSKA

OPAKOWANIA ZWROTNE NA RYNKU E-COMMERCE W UJĘCIU SPOŁECZNO-EKONOMICZNYM – WYNIKI BADAŃ

STRESZCZENIE: Rosnąca sprzedaż on-line, wpływa na wzrost ilości opakowań będących w obiegu gospodarczym, wywołując tak efekty ekonomiczne (wzrost kosztów wytworzenia opakowań, przechowywania i utylizacji), jak i środowiskowe. Sposobem na zmniejszenie skali problemu mogłoby stać się opakowanie wielokrotnego użytku, które byłoby stosowane przez przedsiębiorstwa w ramach e-commerce. Pytanie: czy klienci są na to gotowi? Jaka jest ich opinia na temat wdrożenia takiego rozwiązania? Czy byliby skłonni płacić kaucje za korzystanie z takiego opakowania? Celem artykułu jest wskazanie jednostkowego opakowania zwrotnego możliwego do zastosowania w e-commerce jako przejawu społecznej odpowiedzialności przedsiębiorstwa oraz postaw klientów wobec tego rozwiązania. Artykuł ma charakter empiryczny – część empiryczna przedstawia wyniki badań własnych.

SŁOWA KLUCZOWE: e-commerce, społeczna odpowiedzialność przedsiębiorstw, opakowania zwrotne

Izabela KRUSZELNICKA, Dobrochna GINTER-KRAMARCZYK, Michał MICHAŁKIEWICZ, Przemysław MUSZYŃSKI, Marianna CIŚLAK, Wojciech GÓRA

JAKOŚĆ WODY STUDZIENNEJ W POLSCE – STUDIUM PRZYPADKU

STRESZCZENIE: Celem pracy była analiza jakości i porównanie wartości użytkowej wód z tradycyjnie kopanych i wiertniczych studni zlokalizowanych w zachodniej Polsce. Określono podstawowe parametry fizykochemiczne i mikrobiologiczne (Escherichia coli w 100 ml, bakterie z grupy coli w 100 ml, enterokoki w 100 ml, łączna liczba bakterii w 1 ml hodowanych w 22°C, całkowita liczba bakterii w 1 ml hodowanych w 36°C) dla próbek wody. Dodatkowo w niektórych próbkach wód analizowano obecność metali ciężkich, TN (całkowity azot), TOC (całkowity węgiel organiczny) i NPOC (rozpuszczony węgiel organiczny). Przeprowadzone badania wykazały, że w wodach pobieranych ze studni występuje skażenie mineralne i mikrobiologiczne. Potwierdza to niedostateczną ochronę studni oraz przenikanie zanieczyszczeń do wód z ich bezpośredniego otoczenia, warstw geologicznych, z którymi stykają się zasoby wód podziemnych.

SŁOWA KLUCZOWE: studnie wiercone, studnie kopane, jakosć wody, zanieczyszczenia wody, jakość wody

Konrad TURKOWSKI, Michał DUBROWSKI

POSTRZEGANIE USŁUG EKOSYSTEMÓW DOSTARCZANYCH PRZEZ STAWY KARPIOWE W PASŁĘKU, POLSKA

STRESZCZENIE: Ocenę postrzegania usług ekosystemowych stawów rybnych przeprowadzono w miejscowości Pasłęk, położonej w północno-wschodniej Polsce. Przeprowadzono 94 wywiady eksperckie z osobami niezwiązanymi zawodowo z rybactwem. Ankieta zawierała listę 28 potencjalnych usług ekosystemowych dostarczanych przez stawy rybne. Za najważniejsze uznano usługi środowiskowe, następnie usługi społeczne i usługi produkcyjne. Najwyżej respondenci ocenili funkcję stawów jako miejsca tarła i rozrodu ryb, następnie ich rolę jako zbiorników przeciwpożarowych oraz miejsca wypoczynku i rekreacji. Porównanie z innymi badaniami wykazało, że na postrzeganie usług ekosystemów w badaniach lokalnych może wywierać wpływ szereg uwarunkowań, w tym takich jak charakter i lokalizacja stawów rybnych. Badania wykazały, że osoby niezwiązane z rybactwem i hodowlą ryb są świadome szerokiego zakresu usług ekosystemowych świadczonych przez stawy rybne. Stanowi to pozytywną rekomendację społeczną dla europejskiej polityki rybackiej, której celem jest rozwój akwakultury bez pogarszania stanu środowiska, tworzenie zrównoważonych relacji między producentami, a konsumentami produkcyjnych i pozaprodukcyjnych produktów akwakultury.

SŁOWA KLUCZOWE: usługi ekosystemowe, wielofunkcyjność, stawy rybne

Anna KRYSZTOPIK, Izabela Anna TAŁAŁAJ, Paweł BIEDKA

UDZIAŁ INSTALACJI DO MECHANICZNO-BIOLOGICZNEGO PRZETWARZANIA ODPADÓW KOMUNALNYCH (MBP) W POZIOMIE RECYKLINGU I PRZYGOTOWANIA DO PONOWNEGO UŻYCIA PAPIERU, METALI, TWORZYW SZTUCZNYCH I SZKŁA OSIĄGNIĘTYM PRZEZ GMINY

STRESZCZENIE: Celem artykułu jest określenie udziału instalacji do mechaniczno-biologicznego przetwarzania odpadów komunalnych (MBP) w wysokości osiąganych poziomów recyklingu i przygotowania do ponownego użycia papieru, metali, tworzyw sztucznych i szkła (PMPG) przez gminy w województwie podlaskim (Polska) w 2019 r. Analizie poddano samorządy gminne kierujące zmieszane odpady komunalne do instalacji MBP o największym i najmniejszym udziale gmin, które osiągnęły wymagany poziom recyklingu. Otrzymane wyniki dotyczące udziału masy odpadów PMPG wysegregowanych ze zmieszanych odpadów komunalnych w dwóch analizowanych instalacjach MBP zestawiono z osiągniętymi przez gminy poziomami recyklingu oraz łączną masą odpadów poddanych recyklingowi. Wysoki udział MBP w masie odpadów poddanych recyklingowi nie determinował osiągnięcia przez wszystkie gminy wymaganego poziomu recyklingu, natomiast niski udział nie przesądzał o nieosiągnięciu przez gminę poziomu recyklingu.

SŁOWA KLUCZOWE: odpady, poziom recyklingu, zakład przetwarzania odpadów

Anita BEDNAREK, Anna M. KLEPACKA, Aleksandra SIUDEK

BARIERY ROZWOJU BIOGAZOWNI ROLNICZYCH W POLSCE

STRESZCZENIE: Celem artykułu jest rozpoznanie barier jakie związane są z rozwojem biogazowi rolniczych. Uzupełnienie danych wtórnych stanowiły dane pierwotne pozyskane na podstawie kwestionariusza, przeprowadzonego wśród pracowników przedsiębiorstwa, którego produkcja biogazu jest jednym z elementów gospodarki obiegu zamkniętego. Wyniki badań wskazały, iż respondenci w zdecydowanej większości wskazali na przeszkody zewnętrzne, systemowe i rozwojowe. Największy procentowy udział odpowiedzi dotyczył braku stabilnych przepisów prawa w zakresie odnawialnych źródeł energii, w tym biogazowni oraz braku programów finansujących budowę biogazowni rolniczych. Ponadto, respondenci wskazywali na propozycje, które mogłyby w przyszłości usprawnić rozwój biogazowni rolniczych. Respondenci za bardzo ważny motywator uznali aktualizację i zagwarantowanie opłacalności inwestycji w sytuacji znacznie wyższych nakładów, rosnących kosztów działalności i obsługi zadłużenia poprzez cenę referencyjną, a także uwzględnienie w systemie wsparcia taryf gwarantujących stabilny dochód przez co najmniej 15 lat. Bariery rozwoju biogazowni rolniczych w Polsce pozostają niezmienne, a świadomość pozytywnego oddziaływania biogazowni rolniczych na wielu płaszczyznach wciąż jest bardzo mała.

SŁOWA KLUCZOWE: bariery, rozwój, biogazownie rolnicze, Polska

Karol KOCISZEWSKI, Magdalena SOBOCIŃSKA, Joanna KRUPOWICZ,
Andrzej GRACZYK, Krystyna MAZUREK-ŁOPACIŃSKA

ZMIANY NA RYNKU POLSKICH PRODUKTÓW EKOLOGICZNYCH POCHODZENIA ROLNICZEGO

STRESZCZENIE: Celem artykułu jest określenie zmian czynników wpływających na funkcjonowanie polskiego rynku ekologicznych produktów pochodzenia rolniczego oraz czynników wpływających na przyszły rozwój tego rynku. Zawiera on syntezę wyników badań ankietowych przeprowadzonych wśród rolników (z lat 2011, 2019, 2021), dystrybutorów (z lat 2019 i 2021) i konsumentów (z lat 2009 i 2021). Wyniki badań z 2011 i 2019 wykazały, że według rolników największe szanse rozwoju rynku wiążą się z czynnikami popytowymi, w tym zwłaszcza świadomością ekologiczną konsumentów. W 2021 r. opinie te pogorszyły się, co wskazuje, że rolnicy napotykają trudności w dotarciu ze swoją ofertą do konsumentów. Dotacje unijne również straciły na znaczeniu, co wiąże się z utrudnieniami administracyjnymi i biurokratycznymi. Obok wysokich kosztów produkcji i słabości powiązań rolników z dystrybutorami stanowią one największe bariery rozwoju rynku. Podobne wnioski wynikają z wyników badań dystrybutorów. Według konsumentów największymi szansami rozwoju rynku są rosnąca świadomość ekologiczna, zwiększenie różnorodności oferty i lepsza promocja. Ograniczeniami są wysoka cena, znikoma edukacja ekologiczna, brak odpowiedniego wsparcia ze strony państwa oraz zbyt mało informacji o ofercie.

SŁOWA KLUCZOWE: rolnictwo zrównoważone, rolnictwo ekologiczne, rynki produktów ekologicznych, szanse i ograniczenia rozwoju

Aleksander GRZELAK, Łukasz KRYSZAK

ROZWÓJ VS EFEKTYWNOŚĆ POLSKICH GOSPODARSTW ROLNYCH - EFEKTY SUBSTYTUCJI CZY SYNERGII?

STRESZCZENIE: Celem artykułu jest określenie charakteru zależności pomiędzy rozwojem gospodarstwa rolnego a jego techniczną efektywnością rozumianą z perspektywy analizy obwiedni danych (DEA). Zakres czasowy analizy odnosi się do okresu 2004-2019. Część empiryczna artykułu opiera się na indywidualnych niepublikowanych danych dla polskich gospodarstw prowadzących rachunkowość rolną według systemu Farm Accountancy Data Network (FADN). Zasosowany został nieradialny model DEA oparty na luzach (SBM-DEA) z nadefektywnością przy założeniu zmiennych efektów skali, co umożliwia porównanie i uszeregowanie efektywnych gospodarstw, a także szczegółową analizę źródeł (nie)efektywności badanych jednostek. Nie odnotowaliśmy efektu substytucji (trade-off) pomiędzy zrównoważonym rozwojem gospodarstw a ich efektywnością. W przypadku gospodarstw mieszanych istnieją pewne dowody na efekt synergii, ponieważ gospodarstwa zrównoważone wykazują wyższy poziom efektywności technicznej, a jednocześnie różnice były statystycznie istotne. Główna rekomendacja, po przeanalizowaniu wyników badań jest taka, że polityka rolna powinna wspierać zarówno poprawę efektywności, jak i postęp w kierunku wyższego poziomu zrównoważenia.

SŁOWA KLUCZOWE: gospodarstwa rolne, model efektywności oparty na „luzach", efektywność techniczna, zrównoważenie, FADN

Roman BUCHTELE, Eva CUDLÍNOVÁ, Miloslav LAPKA, Nikola SAGAPOVA,
Martina KRÁSNICKÁ, Jan VÁVRA, Zuzana DVOŘÁKOVÁ LÍŠKOVÁ

KOMPETENCJA ENERGETYCZNA W CZECHACH I JEJ WPŁYW NA POSTRZEGANIE ZACHOWAŃ W ZAKRESIE ZUŻYCIA ENERGII PRZEZ OBYWATELI

STRESZCZENIE: Analiza oparta jest na próbie 1015 obywateli z Czech. W artykule skonstruowano indeks kognitywnych umiejętności energetycznych (CELI), oparty na wiedzy o miksie energetycznym w produkcji energii elektrycznej oraz wiedzy o imporcie/eksporcie energii elektrycznej w Czechach. Badania mają na celu udzielenie odpowiedzi na następujące pytania: Jaki jest poziom CELI w populacji Czech? W jakim stopniu wybrane wskaźniki społeczno-demograficzne wpływają na CELI? W jakim stopniu CELI wpływa na postrzeganie przez respondentów? Średni poziom CELI jest rozpowszechniony w całej populacji, natomiast wysokie i niskie poziomy CELI są mniej więcej równo podzielone. Osoby o wysokim CELI to częściej starsi mężczyźni z wyższym wykształceniem. CELI istotnie wpływa również na postrzeganie zachowań na poziomie indywidualnym, zbiorowym i systemowym. Wyższe CELI wiąże się również z wyższym poparciem dla innowacyjnych rozwiązań i odnawialnych źródeł energii.

SŁOWA KLUCZOWE: Czechy, wiedza o energii, zużycie energii, badanie gospodarstw domowych, percepcja człowieka

Sylwia FRYDRYCH

ROLA RATINGU KREDYTOWEGO EMITENTÓW INSTRUMENTÓW DŁUŻNYCH ESG

STRESZCZENIE: Celem artykułu jest ocena, czy posiadanie przez emitentów instrumentów dłużnych ESG oceny zdolności kredytowej wydanej przez więcej niż jedną agencję ratingową wpływa na liczbę i średnią kwotę emisji. Badania empiryczne przeprowadzono metodą obserwacji oraz analizy dokumentów źródłowych. W analizowanym okresie 53,38% emitentów otrzymało oceny wiarygodności kredytowej przynajmniej od jednej agencji ratingowej, jak S&P, Moody's i Fitch. Wyniki przeprowadzonych badań wskazują, że na liczbę instrumentów dłużnych ESG oraz średnią kwotę emisji miała wpływ liczba ratingów nadanych emitentowi. Baza danych zebrana z Refinitiv Eikon za okres od 2012 do 2021 roku pozwala stwierdzić, że wystarczą dwie oceny zdolności kredytowej. Wnioski z tego badania można wykorzystać w procesie pozyskiwania finansowania na projekty ESG.

SŁOWA KLUCZOWE: ESG, rating kredytowy, obligacje

Marek NOWACKI, Agnieszka NIEZGODA

JAKICH DOŚWIADCZEŃ POSZUKUJĄ TURYŚCI W PARKACH NARODOWYCH? ANALIZA OPINII W SERWISIE TRIPADVISOR

STRESZCZENIE: Celem artykułu jest analiza i porównanie doświadczeń turystów odwiedzających trzy parki narodowe w Polsce. Autorzy skupili się na następujących pytaniach: Jakie są doświadczenia osób odwiedzających parki narodowe w Polsce? Czy walory przyrodnicze parków narodowych mają wpływ na ich unikalne doświadczenia, czy też obszary cenne przyrodniczo nie są dla nich ważne? Autorzy zastosowali mieszane metody: ilościowe (text mining, analiza korespondencji) i jakościowe (analiza treści). Dane do analizy stanowiły opinie użytkowników serwisu TripAdvisor. Analiza recenzji z TripAdvisora wskazała, że najważniejszymi doświadczeniami turystów uzyskanymi w badanych parkach narodowych było: docenianie przyrody i aktywność fizyczna. Pozostałe grupy doświadczeń odzwierciedlone w recenzjach to: estetyczne, kontaktów, napięcia i ekscytacji. Stwierdzono, że przyroda jest dla turystów najważniejszym walorem parków narodowych. Badania wskazały także na tendencję wśród turystów do dbania o zdrowie i chęć regeneracji sił fizycznych na terenach o wybitnych walorach przyrodniczych.

SŁOWA KLUCZOWE: analiza treści, kodowanie doświadczeń, eksploracja tekstu, polskie parki narodowe, zrównoważona turystyka

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